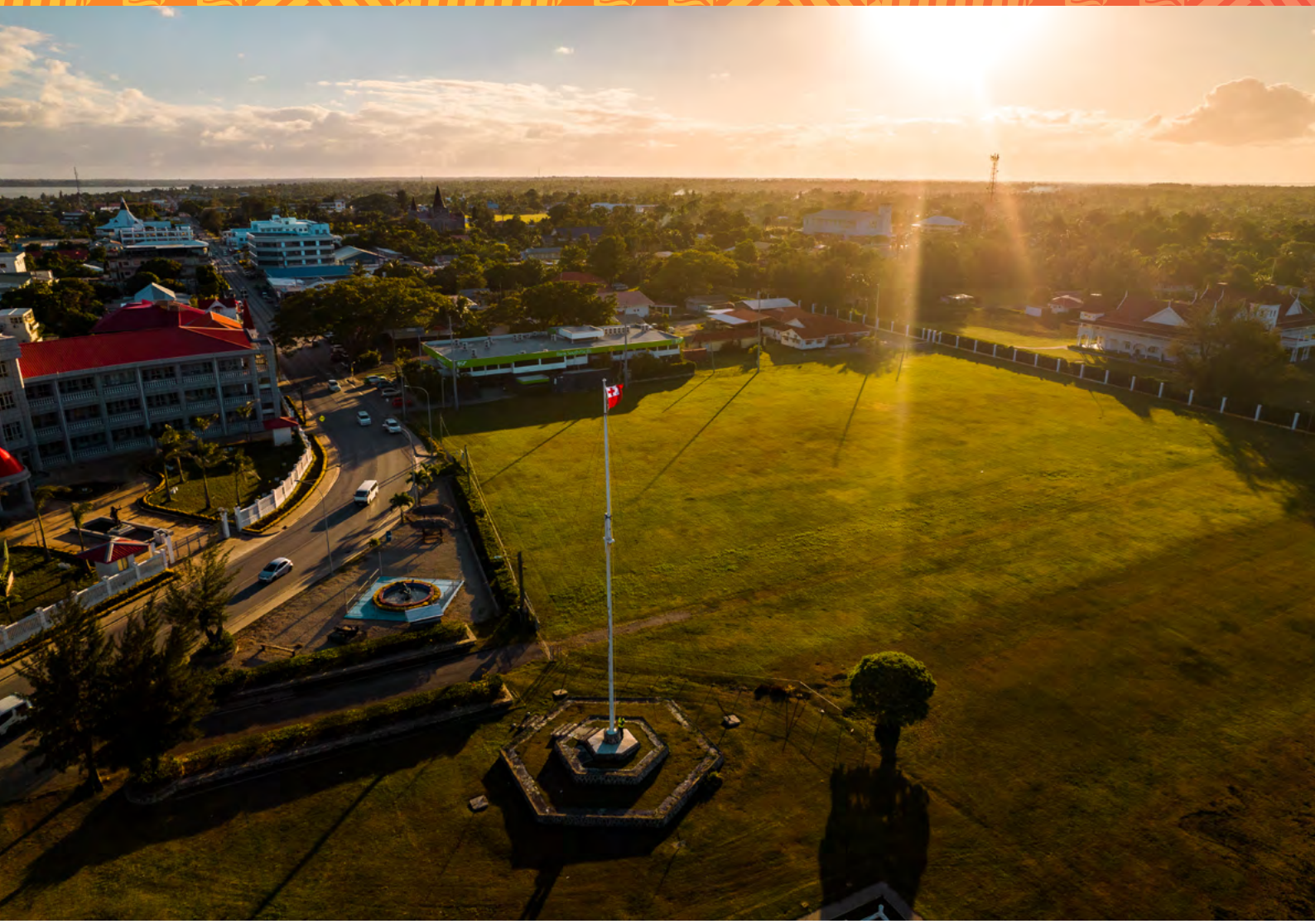
Government of Tonga

Tonga Second Nationally Determined Contributions Review Report



Review of the 2020 Second Nationally Determined Contributions and Recommendations for the 2020 for the 2025 Nationally Determined Contributions

Government of Tonga

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The funding supported the provision of expert consultancy and consultation activities to review the progress towards the targets in the 2020 NDC and deliver an enhanced 2025 NDC.

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Executive Summary

As a Party to the Paris Agreement, Tonga submitted its Second Nationally Determined Contribution (NDC 2.0) in 2020, outlining sectoral mitigation and adaptation commitments to advance national climate resilience and contribute to global climate goals. The NDC 2.0 reflected Tonga's priorities at the time, particularly in renewable energy, forestry, waste management and marine protection, supported by cross-cutting measures such as financing, institutional strengthening, and capacity building. The 2025 NDC review process provides an important opportunity to assess the progress made, identify achievements, and highlight gaps and challenges that require greater attention in the next cycle of NDC enhancement. While the review has confirmed encouraging progress in areas such as tree planting, renewable energy generation, and waste collection coverage, it also highlights where action has lagged—most notably in transport energy efficiency, residential electricity demand management, and systematic monitoring for AFOLU and coastal protection. Table 1 below presents a consolidated overview of the NDC 2.0 sectoral targets, the progress made, and the status of the associated means of implementation across mitigation and adaptation sectors

Table 1: Overview of NDC-2.0 Targets and Means

Mitigation				
Sector	**NDC-2 Target**	**Target Progress Assessment**	**Means**	**Means Progress Assessment**
Energy	13% (16 Gg) reduction in GHG emissions from energy by 2030 compared to 2006	9.89 Gg of the targeted 16 Gg achieved	**Means 1:** 70% of electricity generation from renewable sources	16.66% of RE electricity generation share in 2023. Means in progress but at risk
			Means 2: 2% annual fuel-efficiency gain in newly purchased light-duty vehicles	No direct performance data available to assess fuel-efficiency gains
			Means 3: Limit growth in grid-connected residential electricity demand to 1% per year	No direct performance data available to assess residential electricity demand gains

AFOLU	Identification of a GHG emission target for agriculture, forestry and other land use for the 2025 NDC	AFOLU component of the Fourth National GHG Inventory is 75% complete	**Means 4:** Establishment of a forest inventory	25% complete, with only initial preparatory work complete. Means is on track to be completed by 2030
AFOLU	Planting one million trees by 2023	Completed	**Means 5:** To be determined: kind of trees to be planted, land on which trees to be planted, and who will be responsible for planting the trees	Complete
Waste	Identification of a GHG emission target for waste for the 2025 NDC	Completed	**Means 6:** Expansion of formal waste collection system	Completed. Household waste collection coverage increased from 70% in 2020 to 93% in 2023. Expansion of recycling, infrastructure, and monitoring systems as well.
Adaptation				
Sector	**NDC-2 Target**	**Target Progress Assessment**	**Means**	**Means Progress Assessment**
AFOLU	There is a lack of data to accurately determine the land-cover percentage changes. Land-cover mapping by the Tongan Government has not been updated from the 2006 assessment.	Planting of 1 million trees by 2023	**Means 1:** One million tree planting achieved,	There is a lack of data to accurately determine the land-cover percentage changes. Land-cover mapping by the Tongan Government has not been updated from the 2006 assessment.

Coastal protection	Prevent any permanent loss of land to rising sea levels on Tonga's four main islands	In progress but at risk. A sea level rise of 0.22m was recorded on the Nuku'alofa tidal gauge over the period 1993-2024, and a further 0.18m rise is expected in the following 30 years. Data on loss of land is unavailable.	**Means 2:** Expansion of MPAs and SMAs to 30% of Tonga's EEZ	The number of SMAs has increased from 46 in 2019 to 64 in 2025. The combined area for MPAs/SMAs is small at an estimated size of 385.71 km^2 or only 0.06% Protected. Means in progress
Coastal protection	Maintenance of the existing stocks of fish and other marine species	In progress but at risk.		

Progress of mitigation interventions

Energy: Tonga set a 13% reduction target (≈16 Gg CO_2e) in energy-sector emissions by 2030 (relative to 2006). As of 2023, 9.89 Gg of the targeted 16 Gg have been achieved – roughly 62% of the goal. This progress is primarily due to increased renewable electricity generation, which reached 16.7% of total generation in 2023 (on track toward the 70% renewable power goal by 2030). However, no measurable progress has been made on improving vehicle fuel efficiency or limiting residential electricity demand (original "Means 2" and "Means 3" targets), as no initiatives or data collection systems were put in place for these measures. The lack of action on transport and efficiency means Tonga risks falling short of its overall 2030 energy emissions target.

IPPU: Tonga's Second NDC did not include a GHG reduction target for IPPU, reflecting the sector's negligible emissions and limited industrial activity. With no heavy industry and minimal use of industrial gases, IPPU emissions are very low.

AFOLU: No quantitative GHG target was set for AFOLU in NDC 2020 due to incomplete data, but Tonga pursued enabling measures. Notably, the "1 Million Trees by 2023" planting campaign was successfully completed, enhancing carbon sinks and engaging communities. Work to establish a national forest inventory is about 25% complete and

on track for full completion by 2030. Completing the forest and GHG inventory (now ~75% done for AFOLU data) is expected to inform a concrete emissions target for AFOLU in the 2030 NDC.

Waste: Tonga has completed the groundwork to set a waste-sector GHG target: the 2025 NDC will include a waste emissions goal now that baseline data have been gathered. The formal waste collection system was expanded to 93% in 2023, alongside new recycling infrastructure and monitoring improvements. This expansion met the NDC 2 waste objective and provides a solid foundation (comprehensive 2023 waste audit and improved MRV capacity) to introduce an emissions reduction target for waste going forward.

Progress of adaptation interventions

AFOLU: Tonga aimed to have 30% of its land area under agro-forestry or forestry by 2025, a first-time land-use adaptation target. While the country did plant one million trees (achieving the tree-planting milestone), it has been difficult to assess progress toward the 30% land cover goal. Conflicting and outdated land cover data (the last full mapping was in 2006) means the current percentage of land under agro-forestry/forestry is uncertain. Given that forest cover was only ~12% in recent estimates, the 30% target appears overly ambitious and likely unmet to date. In summary, Tonga's nature-based adaptation efforts (e.g. community agro-forestry initiatives) are underway, but lack of monitoring data obscures the actual percentage of land achieved.

Coastal protection: Tonga's adaptation goal to prevent any permanent loss of land on its four main islands is "in progress but at risk". Sea levels have risen 0.22 m from 1993 to 2024 (with a further ~0.18 m rise projected in the next 30 years), intensifying coastal erosion threats. Data on actual land lost to the sea are not available, making it hard to gauge success. Efforts to protect marine resources have seen mixed progress: the number of community Special Management Areas (SMAs) grew from 46 in 2019 to 64 in 2025, yet the combined area under protection remains only 0.06% of Tonga's EEZ (far below the 30% marine protection target). Initiatives to maintain fish stocks and marine biodiversity are therefore ongoing but currently insufficient in scale. Overall, while Tonga has elevated adaptation as a national priority, many adaptation targets lack quantitative evidence of progress, highlighting the need for better data and more attainable indicators.

Recommendations for NDC 3.0 – Mitigation

To enhance Tonga's climate mitigation impact, the following evidence-based recommendations are proposed for NDC 3.0:

Energy: Reformulate the energy-sector target with clear sub-sector goals. Instead of a single aggregate percentage reduction, set separate absolute GHG reduction targets (in Gg CO_2e) for the power and transport sub-sectors. The overall energy mitigation ambition should increase to reflect new opportunities: analysis suggests updating the 2030 energy target from a 16 Gg reduction to approximately 46.7 Gg (cumulating ~20.9 Gg from electricity sector actions and ~25.7 Gg from transport measures). Achieving the 70% renewable electricity goal will require fast-tracking grid reinforcements and project roll-out, backed by substantial climate finance. On the transport side, NDC 3.0 should replace the unrealized "2% annual efficiency gain" target with a comprehensive package of measures – for example, adoption of vehicle fuel efficiency standards, incentives for newer and electric vehicles, improved public transport, and promotion of active mobility and maritime efficiency. This package (modeled as TERM-PLUS Scenario B) could yield an estimated 25.7 Gg in transport emission reductions by 2030. Regularly tracking fuel imports, power generation stats, and project impacts will improve transparency and accountability.

IPPU: Given the small role of IPPU emissions in Tonga, NDC 3.0 should maintain transparency about this sector while building capacity for future action. The recommendation is to start integrating IPPU-related measures in the next NDC in a qualitative or preparatory way. For example, include a commitment to implement the Montreal Protocol's Kigali Amendment by phasing down HFC refrigerants, and improve data collection on refrigerant usage and other product-related emissions. As the Fourth National Communication will provide better estimates for these gases, Tonga can set the groundwork for a future IPPU target.

AFOLU: NDC 3.0 should explicitly bring AFOLU into the mitigation framework with clear, measurable targets and aligned actions. First, Tonga is advised to establish a quantified GHG emissions or removals target for the AFOLU sector. This will fill the gap from NDC 2020, which lacked specific AFOLU mitigation numbers. To enable this, completing the national GHG inventory for AFOLU (and the full forest inventory) must be a top priority – accurate data on land use emissions and sinks will underpin realistic target-setting. Investments in data collection and management capacity are recommended so that agricultural emissions, forest cover, and soil carbon can be monitored on an ongoing basis. Equally important, sharpen the definitions and scope of "forestry" vs. "agro-forestry" in policy – NDC 3.0 should clarify these terms to avoid the ambiguity that hindered the 30% land-cover goal. With clear definitions, Tonga can set a more realistic land-use goal (perhaps a lower percentage or a different metric, like

hectares of new agro-forestry systems established) that can actually be measured with current capabilities. Building on the success of the one-million-trees initiative, Tonga could introduce a new tree-planting or forest cover target for 2030 – for instance, a target focused on terrestrial reforestation (planting trees on degraded inland and agricultural lands) in addition to ongoing coastal mangrove restoration. Such a target might be expressed in the number of trees or hectares added, and should emphasize species that maximize carbon sequestration and co-benefits for communities. Finally, it's recommended to integrate agro-forestry and sustainable agriculture into the climate strategy, leveraging the traditional Tongan practices of mixed cropping and tree planting.

Waste: The NDC 3.0 should reaffirm its commitment to establishing a GHG target for the waste sector. Tonga could introduce a waste sector MRV system for better data collection and monitoring of the emissions along with infrastructure related actions such as upgrading landfills with weighbridges that would support the estimation of emissions from the sector. In addition, the waste sector action should align with the Tonga Single-Use Plastic Roadmap, in order to accelerate the implementation of the roadmap. Setting a measurable target like a 10% reduction in per capita generation or a goal of recycling 25% of post-consumer single-use plastics by 2030 is recommended and is well aligned with the roadmap.

Recommendations for NDC 3.0 – Adaptation

Recognizing that adaptation is Tonga's top priority, NDC 3.0 should refine its adaptation commitments to be more measurable, realistic, and effective in building resilience:

General Adaptation Targets: Shift to quantifiable and monitorable adaptation indicators. The experience with the 30% land cover target showed that overly broad or data-heavy metrics are impractical. It is recommended that Tonga replace or complement qualitative goals with indicators that can be tracked with available data. For example, instead of "30% of land under agro-forestry," the next NDC could target a specific number of hectares reforested or a percentage increase in tree cover on agricultural lands, based on updated land-use surveys. Likewise, the target of "no land loss" could be reframed as "*X kilometers of vulnerable shoreline protected*" or "*Y communities equipped with coastal defenses by 2030*." Additionally, improving baseline data (e.g. conducting a new land cover assessment and coastal erosion mapping) should be part of the adaptation strategy so that future targets are grounded in up-to-date evidence.

Coastal Protection and Resilience: Scale up nature-based and hybrid coastal defense initiatives, and set measurable goals for shoreline protection. To prevent permanent land loss, Tonga should invest in a blend of ecosystem restoration and engineered protections. NDC 3.0 can commit to an expanded program of mangrove

restoration, coral reef conservation, and strategic seawalls/revetments in high-risk areas. A recommended target is to protect a certain length of coastline by 2030 – for instance, “reinforce X km of coastline with nature-based or hybrid defenses by 2030”. This provides a quantifiable outcome directly supporting the no-land-loss objective. The approach would pair “soft” solutions (mangrove planting, wetland rehabilitation, coral gardening) with “hard” structures where needed (improved seawalls in densely populated waterfronts), thereby dissipating wave energy and reducing erosion. Implementing this recommendation will require mapping of erosion hotspots, community involvement in ecosystem-based measures, and securing funding for coastal engineering projects.

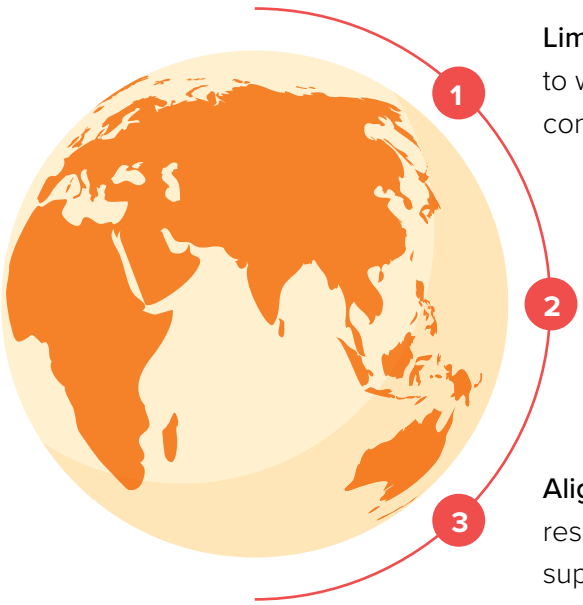
Marine and Fisheries Adaptation: While not explicitly highlighted in NDC 2020’s recommendations, sustaining fisheries is crucial for Tonga’s adaptation. NDC 3.0 should reinforce the commitment to expand Marine Protected Areas/Special Management Areas beyond the current 0.06% coverage. For instance, Tonga could aim for a more attainable interim target (e.g. protect 10% of its EEZ by 2030) and pair this with strengthened community-based fisheries management. This would help maintain fish stocks and marine ecosystem services. Ensuring that the marine adaptation goal is quantitative (area protected, number of SMAs with effective management, etc.) will again improve clarity. Additionally, investing in coastal and ocean monitoring (tide gauges, coral reef health surveys, fish population assessments) is an enabling action to support these targets, and can be mentioned as part of the transparency measures in NDC 3.0.

1. Introduction

Tonga submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC in 2015 and ratified the Paris Agreement on 21 September 2016. Upon the Agreement's entry into force on 4 November 2016, the INDC became Tonga's First NDC. Tonga's second NDC followed in 2020. Tonga's Second NDC (2020) outlines both mitigation and adaptation targets. Mitigation efforts aim to reduce GHG emissions in the energy sector, with additional non-GHG targets for AFOLU and waste. Adaptation measures address climate impacts in the AFOLU and marine sectors. All targets are conditional on external support for finance, capacity building, and technology. The accompanying Implementation Roadmap and Investment Plan identifies priority projects and outlines steps to achieve the NDC goals.

1.1 Paris Agreement and Nationally Determined Contributions

The Paris Agreement, adopted in 2015 and entering into force in 2016, represents a landmark international treaty aimed at uniting global efforts to tackle climate change. Central to this agreement are three key objectives:



Limiting the increase in the global average temperature to well below 2˚c above pre-industrial levels, with concerted efforts to further constrain warming to 1.5˚c;

Enhancing adaptive capacity and resilience to climate change, particularly in ways that protect food security and promote sustainable development pathways with low greenhouse gas (GHG) emissions;

Aligning financial flows towards sustainable, climate-resilient development, ensuring economic activities support rather than undermine climate objectives.

At the heart of achieving these ambitious goals are the Nationally Determined Contributions (NDCs), which are country-specific climate action plans. Each Party to the Paris Agreement develops, communicates, and periodically updates its NDC to reflect the highest achievable ambition, tailored to its national circumstances and capacities. Initially, countries submitted Intended Nationally Determined

Contributions (INDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) secretariat in 2015, which were then formalized into official NDCs upon ratification of the Agreement.

Parties are required to update and communicate their NDCs every five years, reflecting progressive ambition and improvements informed by evolving science, technology, and global efforts. The first Global Stocktake (GST), completed at COP28 in 2023, underscored a collective shortfall in achieving the Paris Agreement targets and emphasized the urgent necessity for substantial, immediate, and enduring emissions reductions. The outcomes of the GST provide critical guidance for upcoming NDC submissions, urging Parties to present new or enhanced NDCs by 2025, informed by the GST findings, and to align their national planning horizons with the global pathway towards net-zero by considering 2035 as a common target year.

1.2 Tonga's Nationally Determined Contributions

Tonga has been proactively engaged in the global effort to combat climate change, beginning with the submission of its Intended Nationally Determined Contribution (INDC) to the UNFCCC in 2015. The nation solidified its international commitment by ratifying the Paris Agreement on 21 September 2016, formally transitioning its INDC into Tonga's First NDC upon the Agreement's entry into force on 4 November 2016. Following this foundational step, Tonga demonstrated ongoing commitment by updating and enhancing its climate ambitions through the submission of its second NDC in 2020.

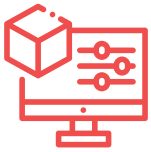
Tonga's climate action framework strategically integrates both mitigation and adaptation priorities tailored to its national circumstances. Mitigation strategies primarily focus on reducing greenhouse gas (GHG) emissions within the energy sector, complemented by robust actions addressing non-GHG targets in Agriculture, Forestry and Other Land Use (AFOLU), and the waste management sectors. Concurrently, recognizing its vulnerability to climate-induced risks, Tonga's adaptation measures strategically target resilience building within critical sectors such as agriculture, forestry, fisheries, and marine ecosystems.

Acknowledging the constraints posed by limited national resources, Tonga's NDC emphasizes the essential role of international cooperation, clearly stipulating that achieving its ambitious climate targets relies on external support encompassing financial assistance, technological transfer, and capacity-building initiatives. To operationalize its commitments, Tonga developed a comprehensive Implementation Roadmap and Investment Plan, which details priority projects, actionable measures, and strategic guidance to steer national efforts effectively toward meeting its NDC objectives.

2. Methodology

The methodology underpinning this progress report is designed to comprehensively evaluate Tonga's 2020 NDC implementation and to provide evidence-based recommendations for the formulation of the forthcoming 2025 NDC. This robust approach ensures the findings are accurate, relevant, and actionable, supporting Tonga's ongoing climate ambition in alignment with international best practices.

The report employs a mixed-method approach, drawing from:



A detailed review and analysis of publicly available datasets, official reports, and policy documents related to Tonga's climate mitigation and adaptation activities.

Targeted stakeholder consultations conducted through structured interviews, facilitated by Tonga's Department of Climate Change. Interviews engaged representatives across various sectors from both public institutions and private entities, ensuring comprehensive sectoral insights.

Identification and critical analysis of progress toward the stated targets, effectiveness of implementation measures, prevailing data gaps, and issues concerning data quality, availability, and dissemination.

To provide structured insights, the report specifically examines:

- Achievement levels of mitigation and adaptation targets outlined in the 2020 NDC
- Implementation measures, including the identification of strengths and existing gaps
- Assessment of data availability, quality, transparency, and effectiveness of communication mechanisms
- Formulation of strategic recommendations informed by international standards, specifically following guidance outlined by the *Quality Assurance Checklist for NDC 3.0 by UNDP*.

The draft findings of this report were validated through a dedicated stakeholder validation workshop held on 15th August 2025. During this workshop, government stakeholders and sectoral leads engaged in structured discussions addressing four key areas:

- Agreement and additional insights on the review results of the 2020 NDC implementation.

- Agreement and additional recommendations for enhancing sector-specific targets and strategies for the 2025 NDC.
- Identification of barriers, opportunities, and enabling actions required to achieve the proposed 2025 NDC targets.
- Recommendations for effective integration of gender equality into the planning, implementation, and monitoring of NDC activities.

Stakeholder feedback gathered on questions 1 and 2 was incorporated directly into the final analysis and recommendations presented in this report. Insights from discussions on question 3 regarding barriers, opportunities, and enabling actions will inform the drafting of Tonga's 2025 NDC and are documented in the Annex.

3. Mitigation

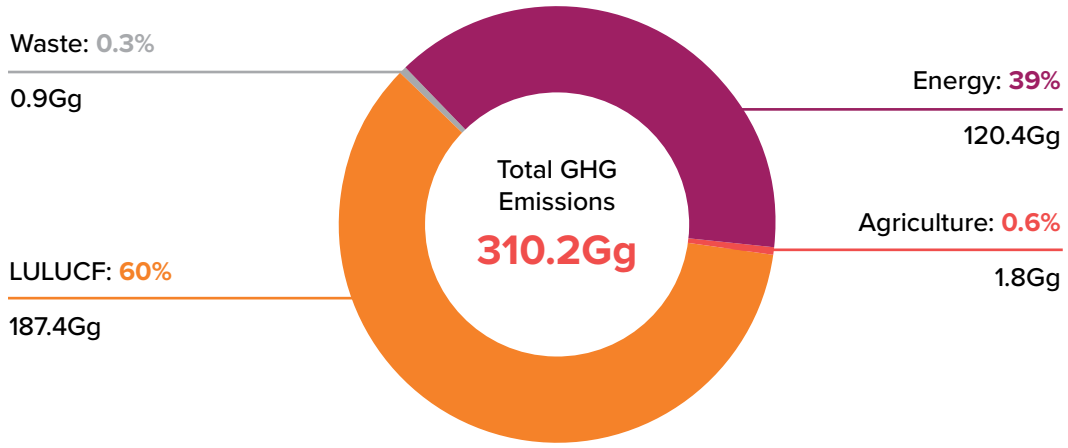
Mitigation refers to efforts to reduce greenhouse gas (GHG) emissions or enhance their removal from the atmosphere (UNFCCC, 2009). This includes: Reducing emissions through actions such as transitioning from fossil fuels to renewable energy; and/or enhancing removals via carbon sinks like forests and soils. The 2019 refinement of the IPCC guidelines, classifies the key GHG-emitting sectors into four groups:

Energy (e.g., electricity, transport, residential and commercial use)	Industrial Processes and Product Use (IPPU)	Agriculture, Forestry, and Other Land Use (AFOLU)	Waste

The 2020 NDC identified the primary sources of GHG emissions in Tonga were:

- Fossil fuel combustion
- Land-use change, particularly deforestation and grassland conversion (Government of Tonga, 2019)

Figure 1: GHG Emissions by Sector



Tonga's 2020 NDC targets sought to quantify for the first time a GHG emissions target starting with energy with the ambition to build capacity and gather data to enable targets to be established for the other sectors, the three targets for mitigation were as follows:

Energy: 13% (16 Gg) reductions in GHG emissions by 2030 compared to 2006 through a transition to 70% renewable electricity as well as energy efficiency measures

AFOLU: establishment of a forest inventory as prerequisite to identify a GHG emission target for the 2025 NDC and planting one million trees by 2023

Waste: expansion of the formal waste collection system as prerequisite to identify a GHG emission target for the 2025 NDC

3.1 Energy

As of 2023, **Tonga has achieved 9.89 Gg of the targeted 16 Gg GHG emissions reduction under NDC 2020's Energy target.** This was driven primarily by progress toward *Means 1—70% renewable energy generation by 2030*. In contrast, *Means 2 - 2% annual fuel-efficiency improvement in new light-duty vehicles* and *Means 3 -limiting grid-connected residential electricity demand growth to 1% per year* show no measurable progress (See Table 2 below). This is due to a lack of clear initiatives and progress to establish key parameters, define measurable indicators, or implement clear data-collection systems to track and monitor any progress. Even with TERMPLUS and TEEMP outlining clear initiatives, the absence of coordinated execution and integration into national energy sector planning left these targets without monitoring and tracking. Without robust baselines, monitoring and evaluation frameworks, and urgent implementation pathways, progress toward Means 2 and 3 falls short, posing a significant risk to achieving the full 2030 energy-sector GHG reduction goal and future NDCs.

Table 2: Mitigation Targets and Means for the Energy Sector

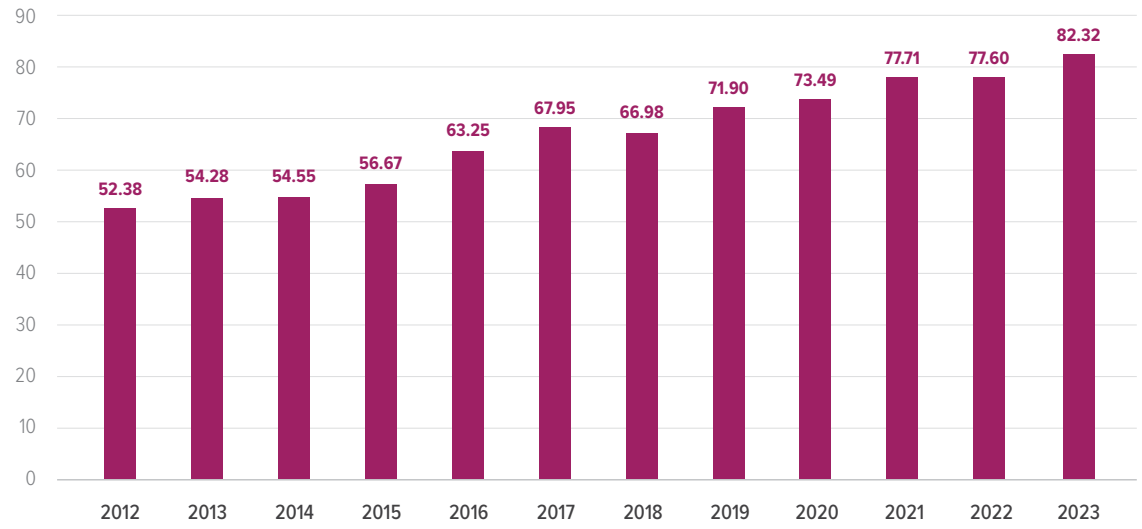
NDC 2020 Target	Target Progress Assessment	Means	Means Progress Assessment
13% (16 Gg) reduction in GHG emissions from energy by 2030 compared to 2006	9.89 Gg of the targeted 16 Gg achieved	**Means 1:** 70% of electricity generation from renewable sources	16.66% of RE electricity generation share in 2023. Means in progress but at risk
		Means 2: 2% annual fuel-efficiency gain in newly purchased light-duty vehicles	No direct performance data available to assess fuel-efficiency gains
		Means 3: Limit growth in grid-connected residential electricity demand to 1% per year	No direct performance data available to assess residential electricity demand gains

3.1.1 Implementation Status

Means 1: 70% of Electricity Generated from Renewable Sources by 2030

During the period of the NDC-2, there has been a notable increase in the Tonga Power Limited's (TPL) installed capacity since 2019. TPL increased its installed capacity from 25 MW in 2019 (Tonga Power Limited, 2019) to 26 MW in 2021, reaching 31.56 MW in 2022[1] and about 35.9 MW in 2024 (Tonga Power Limited, 2024). Diesel generators accounted for 62.6% of the total installed capacity. This increase was achieved by overhauling aging diesel units and through Australian-funded Cummins generators, 1.6 MW unit for Popua and two 0.6 MW QSK23 machines for ‘Eua and Ha‘apai (Tonga Power Limited, 2024). These additions increased the total installed capacity to 35.9 MW in 2024. In 2024, renewables make up 37.4% of the installed capacity, mainly from solar (12 MW) and wind (1.3 MW) (Tonga Power Limited, 2024). Despite such a significant share in the installed capacity, renewable systems only produced 16.66% by the end of 2023 (TPL reported 18.9% in the financial year 2023/24).[2] This was mainly due to grid stability limits that restrict TPL’s grid to only achieve a limited renewable energy penetration (Tonga Power Limited, 2024; Tonga Power Limited, 2025). This indicates that further storage and grid-forming upgrades are urgently required in Tonga.

Figure 2: Annual Electricity Generation (GWh)



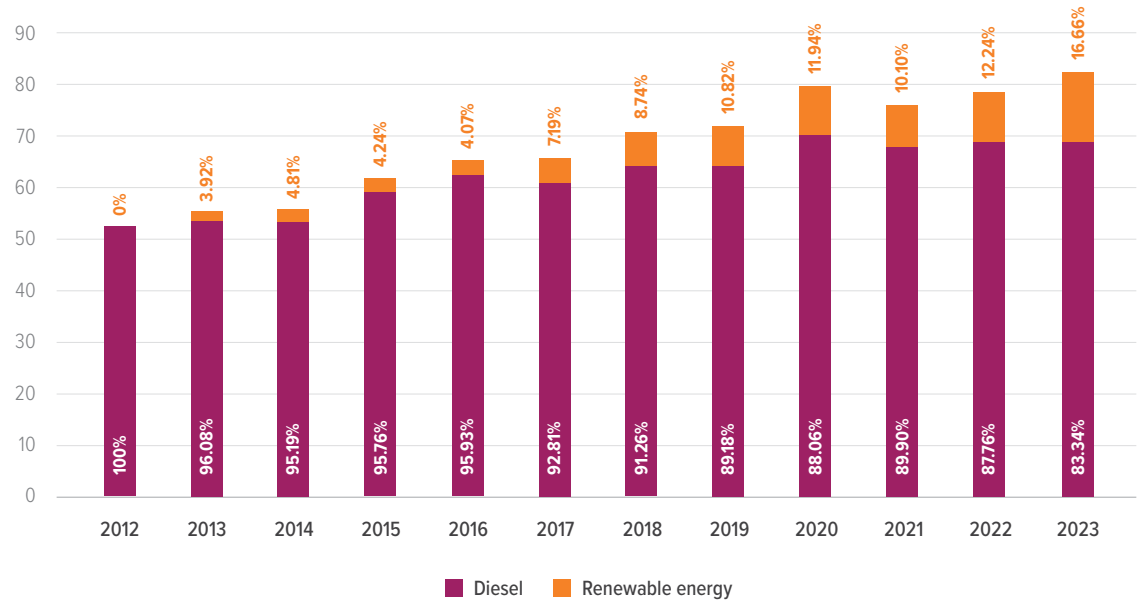
TPL annual generation increased from 52.38 GWh in 2012 to 82.32 GWh in 2023[3] due to increase in demand from a growing population, modernisation of services and increase in ownership of electrical appliances (see Figure 2). As demand tend to increase, the need for stable grid becomes vital, hence, TPL moved from their usual reactive repairs to systematic enhancements of their grid. In Tongatapu,

1. 31.51 in 2022 (Genset #8 of 2.8 MW was decommissioned in 2022).
2. TPL reported 18.9% because they report on a financial year period rather than calendar year period as NDC.
3. TPL report 70.6 GWh in FY18/19 to 86.1 GWh in FY23/24.

the Nuku'alofa Network-Upgrade Project (NNUP) rebuilt LV/HV feeders in Areas 1 through 3, lowering urban line losses to below 9.94% in 2022 and increasing annual power generation by 7 GWh. The NNUP Area 5 which is nearly complete, maintaining a line losses of 9.97% in 20233. However, NNUP Area 4, which includes power-intensive zones like the port and manufacturing areas are currently seeking funding. The Department of Energy states that upgrading Area 4 is essential to keep line losses below 8% especially with new renewable energy projects in the pipeline.

There has been a significant upgrade to the grid in the outer islands. Under the OIREP, Vava'u's HV backbone renewal has been complete, resulting in approximately a 30% reduction in power outages in Vava'u3. Targeted improvements to transformers and HV on Ha'apai and 'Eua have minimized voltage deviations to less than 5%. The smart meter rollout of 19,221 units, has provide the foundation for realtime GIS and outage analytics for TPL, thereby providing real-time load visibility for uninterrupted solar dispatch (Tonga Power Limited, 2024). In 2024, given the rise in renewable energy systems planned to meet the 70% renewable energy target, TPL planned to upgrade its network from 11kV to 33 kV, integrating fail-over fibre, and unifying all diesel generators, renewable energy systems, and BESS controls with a SCADA system (Tonga Power Limited, 2025). Such grid upgrade is still currently under discussion by TPL and the government of Tonga.

Figure 3: Power Generations Share by Fuel Type



Electricity generation in Tonga has steadily increased over the past decade, with renewable energy making an increasingly important contribution. Tongatapu continues to supply approximately 86% of the nation's electricity demand, but ongoing grid upgrades and the integration of solar farms with BESS in Vava'u, 'Eua, and Ha'apai have enabled these outer islands to cover up to 40% of their monthly electricity loads3. Since the commissioning of several solar and wind farms in Tonga between 2013 and 2023, renewable energy penetration has risen from 3.92% in 2013 to 16.66% in 2023, while the share of diesel in total annual generation has declined from 100% in 2012 to 83.34% in 2023 (see Figure 3). This trend highlights a gradual but cleaner shift in Tonga's energy mix, signaling progress

toward reducing fossil fuel dependency and advancing the country's renewable energy transition.

Diesel remains the backbone, yet its dominance is steadily eroding. Diesel remains a central part of Tonga's energy grid, but its dominance is slowly declining. In 2008, diesel consumption stood at 14.1 million litres, dropping to 12.8 million litres in 2015 (Tonga Power Limited, 2019). However, consumption has since risen again, reaching 17.9 million litres in 2023, reflecting both growing electricity demand and continued reliance on diesel generation (Tonga Power Limited, 2025). Despite this rise in diesel consumption, the share of electricity generated from diesel has fallen significantly as renewable energy expands. In 2012, Tonga's grid was powered 100% by diesel, but by 2023 diesel's share had declined to about 83%, with renewable energy providing the remaining share (see Figure 4). This shift shows a positive trend: while overall fuel use has increased in line with rising demand, renewable energy has steadily displaced diesel's share of generation, improving Tonga's pathway toward its renewable energy target.

Figure 4: Share of RE and Diesel in Power Generation

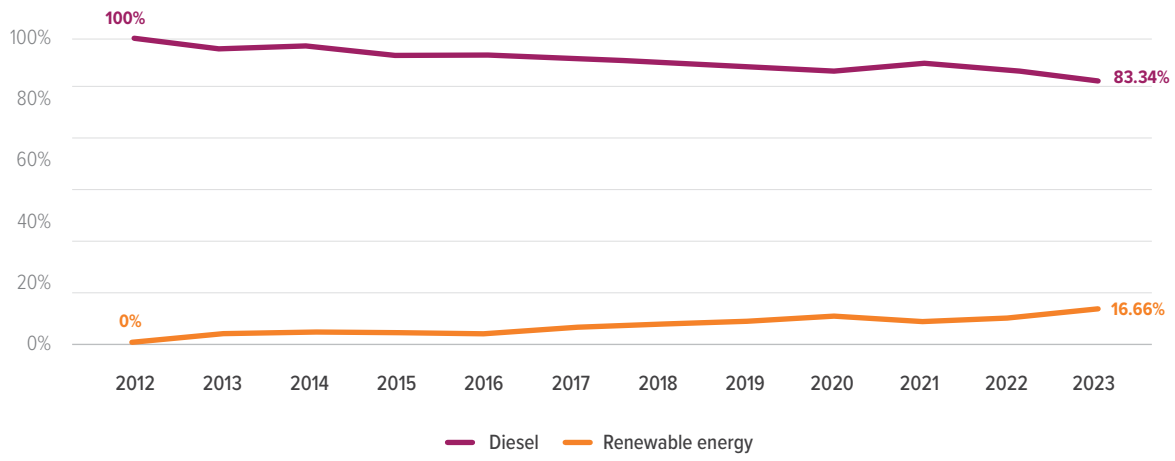
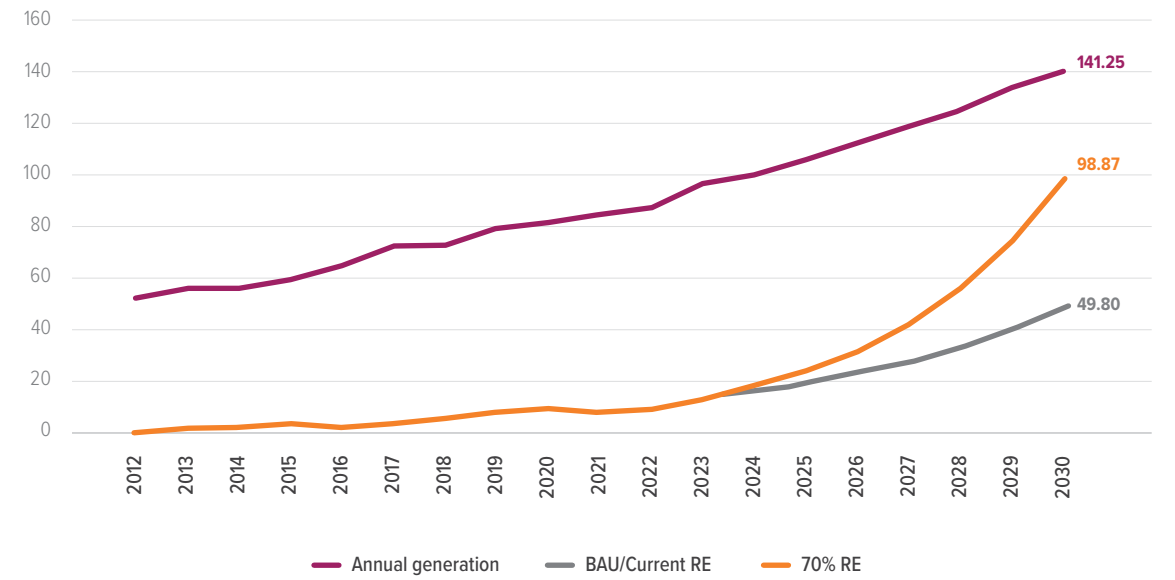


Figure 5: Annual Electricity Generation Forecast (GWH)



Battery energy storage has transitioned from a conceptual idea to a fundamental component of Tonga's power sector. TPL now operates four gridscale battery systems across its main grids. On Tongatapu, the Popua grid stabilising BESS was commissioned at the end of 2021 and is rated 7.2 MW/3.8 MWh (exportlimited to ≈6 MW) (Tonga Power Limited, 2023). A second Tongatapu unit—the 6 MW/20.8 MWh Matatoa load shifting BESS—was commissioned and in operation in 2023 (Tonga Power Limited, 2025). Outer island hybrid plants combine smaller batteries with new PV: Vava'u's project pairs a 1 MW/2MWh BESS with 0.3 MW of solar, while 'Eua's system couples a 1 MW/1.85 MWh BESS to 0.35 MW of solar (Tonga Statistics Department, 2020) . Earlier OIREP microgrids on Ha'apai's islets also include modest battery banks (Tonga Power Limited, 2019). The Popua BESS now provides fast freq uency response, enabling diesel sets to stand by when it is needed, and Matatoa is designed to shift midday PV and cut curtailment (Tonga Power Limited, 2025). These storage assets are already lifting renewable penetration: Ha'apai reached 23.3 % RE in November 2022, and allisland average rose to 16.66 % in 2023 (Tonga Power Limited, 2024). BESS therefore remains central to raising Tonga's renewable share toward the 70 % 2030 target.

Table 3: Renewable Energy Mitigation Target for the Energy Sector

Energy Target	Achieved RE Share (2023)	Progress Assessment	Notes
70% of electricity generated from renewable sources by 2030	16.66%	Not on Track	RE share at the end of December 2023 was 16.66%. China-funded wind farm, expected in 2022 to lift share above 50%, was delayed and commissioned in 2025. RAPID project, expected to reach 70%, faces major land approval delays. Without substantial grid upgrades—including NNUP completion, SCADA/EMS integration, and 33 kV backbone reinforcement, the target is unlikely to be achieved. Grid improvements alone could increase RE share and reduce GHG emissions, even without new generation, but may not deliver 70% by 2030. Significant financing is required for both generation and grid-readiness.

Means 2: 2% Annual Fuel-Efficiency Gain in Newly Purchased Light-Duty Vehicles

According to the IMTS data of import vehicles from the Tonga Statistic Department, passenger car imports declined from 1,086 units in 2019 to 912 in 2020 due to COVID-19-related shipping disruptions (Tonga Statistics Department, 2020). Volumes rebounded to 1,604 units in 2021 as back-orders were cleared (Tonga Statistics Department, 2021), but rising freight costs and tighter credit conditions contributed to a moderate decline—down to 1,537 units in 2022 (Tonga Statistics Department, 2022) and 1,405 units in 2023 (Tonga Statistics Department, 2023).

Despite the decline in imports, used vehicles dominate the market, with approximately 97% of imports, with median vehicle build year of 2010. Japan and New Zealand remain the primary sources of second-hand import for these vehicles, accounting for about 63% of arrivals in 2024. However, China's share has grown significantly—from 8% in 2019 (Tonga Statistics Department, 2021) to 37% in 2024 (Tonga Power Limited, 2019; Tonga Power Limited, 2024). According to the stakeholder consultations, this is due to affordable cars but also the increase of Chinese business in Tonga. These second-hand imports are for personal purposes which was about 96% and the rest was for governments and other purposes, highlighting strong household-driven demand (Tonga Power Limited, 2019; Tonga Power Limited, 2024). The influx of second-hand vehicles—many of which are old and fuel-inefficient—not only contributes to growing waste and rising vehicle ownership in Tonga, but also undermines the country's target of achieving a 2% annual improvement in light-duty vehicle efficiency.

Since 2019, Tonga's import tariff has applied a 0% customs duty on all passenger cars and a 3% duty on trucks and buses (Ministry of Revenue and Customs, 2020). However, this is accompanied by an engine-size-based excise tax: 50 seniti per cc for engines up to 1500 cc, 75 seniti per cc for engines between 1500–3000 cc, and TOP 1 per cc for engines over 3000 cc. Vehicles that are 10 years or older receive a 50% reduction on this excise rate (Excise Tax Act Schedule 1, 2007). In addition, all vehicles are subject to the standard 15% Consumption Tax under the Ministry of Revenue and Customs fee schedule. While smaller-engine cars have become increasingly attractive to Tongans due to their lower fuel consumption, the number of such vehicles in the country has continued to rise. However, because most are more than 15 years old and second-hand, their fuel efficiency has significantly declined, undermining the NDC-2 target of achieving annual improvements in light-duty vehicle efficiency.

Tonga's demand for used cars remained strong under a stable zero-duty regime. In 2021, Customs cleared 2,674 passenger vehicles, with volumes easing to approximately 2,300 units in 2022 due to rising freight costs (Ministry of Revenue and Customs, 2022). In 2023, a new regulation imposing a <10-year age limit on vehicle imports was gazetted, taking effect in 2024 (Ministry of Revenue and Customs, 2024). In anticipation of the new law, importers accelerated shipments, driving vehicle clearances up by 15% to 3,307 units in 2024. As a result, over 97% of imported passenger vehicles continue to be second-hand petrol models, undermining Tonga's target of achieving a 2% annual improvement in the fuel efficiency of new light-duty vehicle imports.

According to the Department of Energy, Tonga has slow shift toward electric vehicles (EVs). The TEEMP sets a target for 10% of all new light-duty vehicle registrations to be electric and hybrid by 2030 (Climate Technology Centre and Network, 2020), with TERMPLUS increasing this target to 30%

by 2035. In 2022, MEIDECC and PCREEE established an EV Working Group to begin discussions and planning around electric vehicle (EV) adoption. However, progress has been limited by low stakeholder engagement, the absence of supporting infrastructure, and limited local capacity for EV maintenance. Although PCREEE has drafted EV charging standards aligned with Australian and New Zealand protocols, government participation in advancing these standards has remained minimal. These barriers are among several factors that have slowed momentum and delayed the widespread adoption of EVs in Tonga.

To achieve the transport targets, a stronger policy and investment push is needed—prioritising EVs and fuel-efficient vehicles over the continued influx of cheap, second-hand petrol cars. At the same time, a rapid shift to full electrification will take years due to the lack of infrastructure, limited technical expertise, and the high cost of investment. In the near term, more practical and achievable measures should be prioritised, such as introducing fuel-efficiency standards, promoting public transport, and encouraging shared mobility and cycling. While these approaches also require investment in infrastructure, finance, and planning, they represent cost-effective and scalable solutions that can deliver immediate progress, while EV adoption and broader transport electrification are planned in parallel.

Table 4: Fuel Efficiency Mitigation Target for the Energy Sector

Energy Target	Achieved Progress	Progress Assessment	Key Issues
2% annual fuel-efficiency gain in newly purchased light-duty vehicles (LDVs)	0% – No measurable progress	No Progress – Insufficient Data	• No official definition of LDV in Tonga's transport or energy policies. • No fuel-efficiency standard to benchmark improvements. • Data collected limited to total fuel consumed, number of vehicles, and engine size (cc), which is insufficient to determine annual efficiency gains. • No records on vehicle make, model, year, fuel type, or manufacturer-rated fuel consumption (L/100 km) / CO_2 emissions (g/km). • No tracking of odometer readings or distance travelled. • No MRV (Monitoring, Reporting, Verification) framework to link imports, usage, and efficiency trends.

Means 3: Limit Growth in Grid-Connected Residential Electricity End-Use to 1% per Year

Household cooling appliance imports in Tonga have surged at a pace far exceeding population growth. According to the IMTS annual reports, imports of refrigerators and freezers rose from 737 units in 2019 (Tonga Statistics Department, 2021) to 1,157 in 2020 (Tonga Statistics Department, 2022), and 1,409 in 2021 (Tonga Statistics Department, 2022). Volumes nearly doubled to 2,233 in 2022, with China overtaking New Zealand to supply 52% of all appliances (Tonga Statistics Department, 2023). A significant buying surge followed with 2,493 units imported in the fourth quarter of 2023 alone (Ministry of Revenue and Customs, 2020), and a further 2,330 units recorded in the first three quarters of 2024 (Ministry of Revenue and Customs, 2024). More than 98% of these imports are for personal use and are dominated by second-hand appliances. Since Tonga has not implemented MEPSL at the border, the presence of efficiency labels on these appliances is neither verified nor recorded. This makes it difficult for the Department of Energy to monitor and track the efficiency standards of electrical appliances entering the country. Tonga's MEPSL regulations were only endorsed in March 2025, with codes of practice and enforcement processes still under development and expected to take effect later in 2025. In the meantime, a window remains open for the continued influx of old, inefficient appliances, undermining progress toward the target of limiting annual growth in grid-connected household electricity demand to 1%.

Lamp import data confirms Tonga's rapid transition to LED lighting. In 2020, IMTS recorded 98,452 imported lamps—primarily compact fluorescent lamps (CFLs) alongside a mix of incandescent bulbs (Tonga Statistics Department, 2021). Anticipating the TERMPLUS ban on incandescent bulbs, retailers began shifting to LED stock in 2021 (Ministry of MEIDECC, 2021), with imports reaching 14,481 units and most incandescent lines phased out (Tonga Statistics Department, 2021). Import volumes dipped slightly to 11,765 units in 2022 (Tonga Statistics Department, 2022) before rebounding to around 12,000 LED lamps in 2023 (Tonga Statistics Department, 2023). China consistently accounts for around 75% of lamp imports, followed by New Zealand, Australia, and others at roughly 15%. However, IMTS annual reports note that MEPSL information was not recorded for lamp entries, reflecting the absence of MEPSL regulation at the time. Despite this regulatory gap, Tonga's transition to LED lighting has been driven primarily by retailer preference—valuing the longer lifespan and higher efficiency of LEDs—rather than by enforcement.

IMTS data shows that 5,291 washing machines were imported in 2019 (Tonga Statistics Department, 2020) but the volumes rose sharply to 8,424 units in 2021—77% of which originated from China—and remained steady at 8,437 units in 2022 (Tonga Statistics Department, 2022). In 2023, imports surged again to 9,307 units (Tonga Statistics Department, 2023). More than 90% of these imports were for personal use and were predominantly second-hand units shipped from Australia and New Zealand, with only a small share being new (Tonga Statistics Department, 2023). According to the Department of Energy, surveys indicate many of these second-hand washing machines are gifts or donations from overseas family members. Most are already several years old, in some cases up to 15 years, raising serious concerns about both energy and water efficiency. This trend underscores the dominance of used, energy-intensive machines in Tonga's market.

Table 5: Residential Electricity End-Use Mitigation Target for the Energy Sector

Energy Target	Achieved Progress	Progress Assessment	Key Issues
Limit growth in grid-connected residential electricity end-use to 1% per year	0% – No measurable progress	No Progress – Insufficient Data	• No DOE-defined "residential sector" classification; TPL categories too broad for accurate tracking. • No established baseline year or demand level for residential consumption. - Few smart meters; majority of households lack real-time demand data. • Appliance import data exists but lacks MEPSL compliance tracking; MEPSL implemented March 2025 but not fully operationalised. • No regular household appliance ownership/usage surveys. • No MRV framework linking residential consumption trends with appliance efficiency improvements.

Mata 'oe La'a solar farm at Vaini contributing to increasing the supply of renewable energy.
© Department of Climate Change, MEIDECC 2021

3.1.2 Communication

Renewable Electricity Generation

For the 70% renewable electricity target, Tonga Power Ltd. (TPL) compiles annual operational reports covering total generation (GWh), renewable generation by source, and diesel consumption. These are validated by the Ministry of Public Enterprises (MPE) but are not consistently shared with the Department of Energy (DOE), despite DOE's mandate under the Tonga Energy Act 2021 as the lead energy authority. Formal submission to DOE would strengthen compliance, data flow, and coordination.

DOE consolidates this information for the MEIDECC Annual Report, TERMPLUS, TEEMP, other national strategies, and UNFCCC reporting. Progress is discussed through DOE-led stakeholder consultations. When discrepancies arise—such as gaps between installed renewable capacity and actual output—DOE provides technical explanations, typically involving curtailment or grid stability constraints. Looking ahead, the establishment of new regulatory bodies under the Energy Act, supported by EU technical assistance, is expected to improve monitoring, reporting, and sector-wide data transparency.

For the 70% renewable electricity target, TPL prepares annual reports on generation, renewable output, and diesel use, which are validated by MPE but not consistently shared with DOE, despite DOE's legal mandate as lead energy authority under the Tonga Energy Act 2021. Formal submission to DOE would improve compliance, coordination, and data integrity. DOE consolidates this information for national strategies, MEIDECC reporting, and UNFCCC submissions, while also providing technical explanations when discrepancies—such as curtailment or grid stability limits—arise. The forthcoming establishment of regulatory bodies under the Energy Act, supported by EU assistance, is expected to enhance monitoring, reporting, and transparency across the sector.

Fuel Efficiency in Light-Duty Vehicles

For the commitment on fuel-efficiency improvement in newly imported light-duty vehicles (LDVs), monitoring relies on IMTS vehicle import data, which records make, model, year, and engine capacity. However, critical technical details—such as drivetrain type, rated fuel consumption, and certified CO_2 emissions—are missing, and publications are infrequent. The Ministry of Infrastructure's registration database also omits these fields, further limiting data quality.

In the absence of direct performance data, DOE uses proxy indicators like engine size and vehicle age for the Annual Energy Balance, NDC reporting, and TERMPLUS/TEEMP monitoring. This weakens the accuracy of measurement, reporting, and verification (MRV) under the UNFCCC Enhanced Transparency Framework (ETF). Strengthening MRV requires:

- centralised data-sharing between agencies,
- mandatory fuel economy certification at import,
- expanded registration fields and codes, and
- more frequent, detailed reporting.

Monitoring of the NDC-2 target to limit residential electricity demand growth to 1% annually relies on TPL metered consumption data and IMTS appliance imports as indirect indicators. While DOE receives monthly consumption data from TPL, analytical capacity is limited, with no assessment of peak loads or appliance-level usage. IMTS data and the DOE database also lacks efficiency classifications or MEPSL labels for appliances. Strengthened MRV systems, appliance-level tracking, and enforcement protocols are needed to ensure timely monitoring and corrective action.

Residential Electricity Demand Growth

For the NDC-2 target of limiting grid-connected residential electricity demand growth to 1% annually, monitoring draws on TPL metered residential consumption and IMTS appliance import data. TPL provides DOE with monthly household consumption data, which is cross-checked against meter counts, while IMTS tracks appliance imports as indirect demand indicators.

However, significant gaps remain. TPL lacks real-time analytical capacity, and data is not processed to assess peak loads or appliance-level usage. IMTS data also cannot support Minimum Energy Performance Standards and Labelling (MEPSL) enforcement, since Customs has no efficiency classification codes or compliance checks in place. To ensure effective monitoring and timely corrective action, Tonga needs strengthened MRV systems, appliance-level tracking, and enforcement protocols.

Monitoring of fuel-efficiency is lacking. The Department of Statistic IMTS data are limited to import numbers. The Ministry of Infrastructure's registration database lacks critical information such as drivetrain type, certified fuel economy, and CO_2 emissions. DOE relies on proxy indicators like engine size and vehicle age for NDC and TERMPLUS/TEEMP reporting. Strengthening MRV requires centralised data-sharing, mandatory fuel economy certification at import, expanded registration fields, and more frequent detailed reporting.

3.1.3 Recommendations for NDC3.0

The following section sets out the revised "means" proposed for NDC-3, presenting absolute GHG reduction targets for electricity generation and transport, linking these to concrete initiatives, and embedding mechanisms for transparent annual monitoring.

Reduction in the emissions of the electricity sector

Initiatives 1: 70% of Electricity Generated from Renewable Energy by 2030

The initiative to achieve 70% renewable electricity by 2030 remains Tonga's most critical supply-side measure, as outlined in TERMPLUS, the LT-LEDS, and the SDG7 Roadmap. However, based on demand forecasts and the pipeline of planned projects, renewable generation is projected to deliver only 49.8 GWh—equivalent to 35.3% of demand—by 2030. This shortfall reflects the current emphasis on large-scale solar and wind projects without corresponding grid upgrades. With limited investments in grid infrastructure to enhance absorption capacity, much of the potential renewable generation is constrained, resulting in curtailed output and wasted resources.

Achieving the 70% renewable energy target will require 98.9 GWh of generation. However, with current projections delivering only 49.8 GWh by 2030, Tonga faces a 49.1 GWh shortfall. Applying Tonga's reported grid emission factor of 0.127 Gg/GWh (DOE/UNFCCC submissions), bridging this gap would avoid approximately 6.2 Gg of GHG emissions. This estimate is consistent with UNFCCC-aligned accounting methodologies and provides a transparent benchmark for tracking progress toward the target.

To close the gap and ensure the 70% renewable energy target is achieved, a three-phase strategic approach is proposed. Each phase allocates specific GHG reduction contributions to identified initiatives, enabling effective monitoring, transparent tracking, and measurable delivery of the NDC-3 energy sector commitments.

Phase 1 (2024–2027) Grid-first catch-up	Phase 2 (2026–2028) Tranche A and gap cover	Phase 3 (2028–2030) Optimisation and resilience

TERMPLUS emphasises that the first priority is to clear Tonga's backlog of grid and control upgrades so that existing and in-train renewable generation can operate at their intended performance levels. This phase includes NNUP Areas 4 and 5, 33 kV grid strengthening, SCADA/EMS integration with DERMS activation, and the completion of the nationwide smart meter rollout. These firm TERMPLUS measures (pp. 32–45) directly address bottlenecks in hosting capacity, transmission limits, and demand visibility.

When combined with the full operation of Tonga's 4 × BESS fleet (Popua, Matatoa, and outer-island units) and the enforcement of siting rules (≤2 MW per PV site with dispersed wind), these upgrades will unlock "in-train" projects and lift the renewable share from the 2023 baseline of 16.6% to around 35–40% by 2026. By 2027, renewable penetration is expected to reach 50–58%, representing approximately 31 GWh of additional usable renewable generation.

Applying Tonga's grid emission factor of 0.127 Gg/GWh, this equates to ~4.0 Gg of avoided GHG emissions by 2030 (see Table 6). This result is consistent with the cumulative contribution of all Phase 1 initiatives, each of which individually delivers between 0.4 and 0.9 Gg of annual emission reductions. Together, these measures strategically prioritise grid readiness, ensuring that the system can absorb higher levels of renewable generation before major new capacity is added.

Table 6: GHG Emissions Reduction for Phase 1

Phase	Initiative	Purpose	Contribution logic	Anticipated RE/ efficiency gain by 2030 (GWh)	Avoided GHG by 2030 (Gg)
1.1	NNUP Area 4 & 5	Loss reduction, hosting capacity	Clears feeder bottlenecks; TERMPLUS indicates >5 GWh additional RE acceptance	7	0.9

1.2	33 kV grid strengthening	Enable RE transfer	Provides backbone for high-volume PV/ wind injection across Tongatapu	6	0.8
1.3	SCADA/EMS/ DERMS	Real-time coordination	Reduces curtailment; optimises dispatch of PV and BESS	5	0.6
1.4	Smart meter rollout	Demand management, load visibility	Enables 1% demand cap by improving household load tracking and visibility	3	0.4
1.5	Operate 4×BESS to spec	Stability and load shifting	Provides fast frequency response and evening peak cover, preventing RE curtailment	6	0.8
1.6	Enforce siting rules	Manage variability	Avoids ramping risks; supports dispersed PV/ wind integration	4	0.5
Total Phase 1 impact			**Unlocks existing "in-train" RE projects; moves system to 50–58% RE share by 2027**	**31**	**4.0**

Phase 1 (2024–2027) Grid-first catch-up	**Phase 2 (2026–2028) Tranche A and gap cover**	Phase 3 (2028–2030) Optimisation and resilience

With Phase 1 addressing backbone upgrades and control bottlenecks, Phase 2 introduces the bulk of new renewable energy supply. The anchor is the TPL's RFT Tranche A (nominal +34 GWh/yr)[4], which TERMPLUS identifies as the key bridge toward the 70% target. This tranche consists of a mix of solar PV and wind projects with integrated BESS, including the RAPID projects and other IPP developments currently under negotiation[5]. Although TERMMPLUS does not provide a consolidated figure for these projects, securing Tranche A is essential for Tonga to advance beyond 60% and approach the 70% renewable target.

Once operational and integrated into the strengthened feeders, Tranche A is expected to increase renewable penetration to roughly 65–68% by 2028. However, TERMPLUS modelling indicates that a residual shortfall of about 8 GWh/yr will remain against the ~98.9 GWh requirement for a 70% share in 2030. To close this gap and provide resilience under demand or performance uncertainties, a dedicated "gap closer" project is proposed. A solar or wind facility of approximately 8 MW (≈ 12.9

4. See TERMPLUS for the project proposed under Tranche A.
5. Based on the discussion with the Department of Energy and TPL on project pipelines that have been approved but under negotiations to secure funding, land approvals etc.

GWh/yr potential) would serve this purpose. Given Tonga's solar resource (≈ 1,600 kWh/kWp/yr), this is technically feasible, though in practice only part of the output (≈ 8.5 GWh of the 12.9GWh) is expected to be effectively utilised by 2030 due to curtailment limits near the 70% penetration ceiling.

To further reduce curtailment and extend renewable contribution into evening peaks as diesel use declines, a ~30 MWh BESS is staged in parallel with new RE additions. This storage enables recovery of around 4 GWh by 2030 that would otherwise be curtailed. In addition, fast-acting capacitors and a synchronous condenser may be required as system stability measures at high shares of PV and wind. While these do not add new energy, they are essential enablers for secure grid operation, ensuring voltage, inertia, and fault ride-through requirements are met. Overall, the effective marginal renewable energy contribution from Phase 2 initiatives, beyond Phase 1, is estimated at 30.5 GWh/yr, translating into approximately 3.87 Gg of avoided CO_2e annually by 2030.

Table 7: GHG Emissions Reduction for Phase 2

Initiative	Specification	Purpose	Contribution logic (marginal to Phase 1)	Added RE effectively utilised by 2030 (GWh)	Avoided GHG 2030 (Gg)
TPL RFT Tranche A	+34 GWh/yr	Major RE addition; backbone of the step to ~65–68% by 2028	After Phase 1 (~50–58%), Tranche A raises usable RE toward ~65%	18	2.29
Storage add on (BESS)	~30 MWh	Reduce curtailment; extend evening peaks	Recaptures energy that would otherwise be spilled once Tranche A is on line; ~4 GWh by 2030	4	0.51
"Gap closer" PV/wind	≈ 12.9 GWh/yr	Cover projected residual shortfall	Used only to close the remaining gap to 70% after Tranche A+BESS.	8.5	1.08
Fast acting capacitors	As engineered	Reactive power / voltage support	No direct GWh; enables secure operation at high PV	0	0
Synchronous condenser (if needed)	1 unit	Inertia / fault ride through	No direct GWh; only if stability studies confirm need	0	0
Total Phase 2				**30.5**	**3.87**

Phase 1 (2024–2027) Grid-first catch-up	Phase 2 (2026–2028) Tranche A and gap cover	**Phase 3 (2028–2030) Optimisation and resilience**

By the late 2020s, Tonga's grid will be operating close to the 70% renewable energy target. Phase 3 is therefore less about adding large new supply and more about optimising system performance, strengthening resilience, and preparing for uncertainties.

The key optional supply measure is TPL's RFT Tranche B (+16.5 GWh/yr). TERMPLUS identifies this as "headroom capacity," not strictly required for meeting the 70% target by 2030. However, it provides a safeguard if electricity demand grows faster than expected or if Tranche A and the gap-closer underperform. In such cases, around 6 GWh of Tranche B is assumed to be effectively used by 2030, rising to its full 16.5 GWh potential by 2035.

Alongside this, additional battery storage (BESS) in the 20–30 MWh range supports seasonal balancing and contingencies, unlocking roughly 3 GWh by 2030 and up to 5 GWh by 2035. Smart-grid features—such as demand response and managed EV charging—build on the smart meters introduced in Phase 1. These enable load shifting and peak shaving, avoiding around 2 GWh of diesel use by 2030, doubling as EV adoption expands by 2035.

Loss-reduction programmes, targeting below 8% network losses, are a firm TERMPLUS commitment. They sustain around 1 GWh of annual savings by 2030, increasing with load growth. Finally, firm-renewable pilots (biofuel, biogas, waste-to-energy) are introduced at small scale to test dispatchable renewable options. Their impact is modest—about 1 GWh by 2030, potentially 2 GWh by 2035—but they strengthen resilience during shocks or outages.

In total, Phase 3 initiatives deliver ~13 GWh of effective displacement of diesel generation by 2030, equivalent to 1.65 Gg of avoided GHG emissions, marginal to Phases 1 and 2. By 2035, their contribution rises to nearly 30 GWh (~3.8 Gg), consolidating Tonga's transition toward a more reliable and resilient renewable system.

Table 8: GHG Emissions Reduction for Phase 3

Initiative	Specification	Purpose	Contribution logic (marginal to Phase 2)	Added RE/ efficiency effectively utilised by 2030 (GWh)	Avoided GHG 2030 (Gg)
TPL RFT Tranche B (if required)	+16.5 GWh/yr	Provide headroom for demand growth	Only triggered if load rises faster; ~6 GWh by 2030	6	0.76
Additional BESS	~20–30 MWh	Seasonal balancing, contingency cover	Unlocks ~3 GWh by 2030	3	0.38

Full smart-grid features	DR, EV charging	Flexibility, peak shaving	~2 GWh avoided diesel use by 2030	2	0.25
Loss-reduction programmes	Maintain <8% losses	Efficiency, tariff stability	Sustains ~1 GWh by 2030	1	0.13
Firm-renewable pilots	Small biofuel/ biogas/WtE	Dispatchable backup	Pilot scale: ~1 GWh by 2030	1	0.13
Total Phase 3				**13**	**1.65**

Initiative 2: Limit growth in residential electricity end-use to 1% per year on average

Demand-side management is a critical complement to Tonga's renewable expansion. Without intervention, household demand would grow by 5–6% annually, driven by inefficient appliances and non-LED lighting. This unchecked growth would undermine TERMPLUS supply-side gains by forcing continued reliance on diesel generation.

To prevent this, Initiative 2 sets a cap of 1% annual growth in residential electricity demand between 2025 and 2030. Holding growth to this level avoids ~12 GWh of diesel generation (≈1.5 Gg of CO_2e) by 2030, rising to ~16 GWh (~2.0 Gg) by 2035 as efficiency standards and solar water heating continue to scale.

The initiative is implemented in three sequenced phases, aligned with the TERMPLUS supply-side rollout:

Phase 1 (2025–2026) Foundations

Minimum Energy Performance Standards (MEPS) enforcement at the border prevents inefficient appliances from entering Tonga. A ban on non-LED lamp imports, supported by nationwide distribution and awareness campaigns, reduces lighting loads. Together, these measures save ~0.8 Gg (≈6–7 GWh) by 2030.

Phase 2 (2026–2028) Technology rollout

Solar water heating systems for households and hotels reduce electricity use for water heating. Building energy audits establish efficiency baselines for future retrofits. These contribute ~0.5 Gg of avoided emissions by 2030, while audits act as an enabler for later efficiency codes.

Phase 3 (2028–2030) Consolidation and codes

Mandatory building efficiency standards for new construction, combined with appliance replacement schemes, lock in cumulative demand savings. These measures add ~0.45 Gg of avoided emissions by 2030.

By 2030, Initiative 2 achieves ~1.5 Gg of avoided emissions annually. While smaller in scale than supply-side measures, demand restraint is strategically vital: without it, Tonga would need larger, more costly renewable projects to sustain the 70% target. Initiative 2 therefore secures the technical, financial, and social feasibility of Tonga's energy transition.

Table 9: GHG Emissions Reduction for Phase Initiative 2

Phase	Initiative	Purpose	Contribution logic	Anticipated RE/ efficiency gain by 2030 (GWh)
Phase 1 (2025–2026)	MEPS enforcement at borders	Enforce standards for refrigerators, freezers, ACs, washing machines; restrict inefficient imports	Prevent lock-in of high-consumption appliances	0.6
	Lighting efficiency upgrade	Ban non-LED lamps; nationwide LED rollout	Reduce baseline lighting load	0.2
Phase 2 (2026–2028)	Solar water heating deployment	Subsidise/install household & hotel solar heaters	Displace electric water heating; cut peak demand	0.5
	Building audits	Conduct audits in government & commercial buildings	Identify savings; prepare for codes	Enabler (no direct GHG in 2030)
Phase 3 (2028–2030)	Building efficiency codes	Mandatory standards for new buildings	Reduce long-term load growth	0.25
	Appliance replacement & demand cap	MEPS + retrofit programmes	Lock in cumulative demand savings	0.2
Total				1.5

Overall Assessments of both Initiatives

Tonga's electricity sector has already made substantial progress toward decarbonisation, achieving a 16.6% renewable electricity share in 2023. This displaced diesel generation equivalent to ~78 GWh and avoided 9.89 Gg of emissions annually. Building on this foundation, two complementary initiatives under NDC-3 chart a pathway to 2030.

Initiative 1 targets 70% renewable electricity by 2030 through a three-phase TERMPLUS programme.

- **Phase 1 (2024–2026)** focuses on clearing grid bottlenecks through NNUP upgrades, 33 kV backbone reinforcement, SCADA/EMS integration, smart meter rollout, and full BESS operation. These measures enable ~31 GWh of new renewable uptake, equal to **4.0 Gg avoided emissions**.

- **Phase 2 (2026–2028)** brings bulk renewable supply: Tranche A (+18 GWh effective), a 30 MWh BESS (+4 GWh), and an 8 MW "gap closer" (+8.5 GWh). Together these contribute **30.5 GWh and 3.87 Gg avoided**.
- **Phase 3 (2028–2030)** secures resilience through partial utilisation of Tranche B, additional BESS, smart-grid features, loss-reduction programmes, and firm-renewable pilots. By 2030, these will deliver **13 GWh and 1.65 Gg avoided**.

In total, Initiative 1 accounts for ~74.5 GWh of additional renewable generation and 9.52 Gg avoided emissions by 2030. Initiative 2 complements this by capping residential electricity demand growth at 1% per year (2025–2030). Measures include enforcing MEPS at the border, banning non-LED lamp imports, scaling solar water heating, conducting building audits, enforcing new building codes, and implementing appliance replacement schemes. Collectively, these measures reduce residential demand by ~12 GWh, equivalent to 1.5 Gg avoided emissions by 2030. Together, Initiatives 1 and 2 deliver ~20.91 Gg of avoided emissions annually by 2030, ensuring Tonga reaches its 70% renewable electricity target in a technically and financially sustainable way.

Table 10: Proposed GHG Saved from BAU RE vs. 70% RE Target

Category	Phase / Initiative	Key Measures	Added RE / Demand Reduction by 2030 (GWh)	Avoided GHG by 2030 (Gg)
Baseline (already achieved)	2023 RE share (16.6%)	Existing solar, wind, and BESS	78	9.89
Initiative 1 – Supply-side (70% RE by 2030)	Phase 1 (2024–2026: Grid-first catch-up)	NNUP Areas 4 & 5, 33 kV strengthening, SCADA/EMS+DERMS, smart meters, siting rules, full BESS operation	+31	4.00
	Phase 2 (2026–2028: Bulk RE rollout)	Tranche A (+18 GWh effective), 30 MWh BESS (+4 GWh), Gap-closer PV/wind (+8.5 GWh), stability devices (no GHG)	+30.5	3.87
	Phase 3 (2028–2030: Optimisation & resilience)	Tranche B (partial 6 GWh), additional BESS (+3 GWh), smart-grid features (+2 GWh), loss-reduction (+1 GWh), firm-renewable pilots (+1 GWh)	+13	1.65
Subtotal Initiative 1			+74.5	9.52

Category	Phase / Initiative	Key Measures	Added RE / Demand Reduction by 2030 (GWh)	Avoided GHG by 2030 (Gg)
Initiative 2 – Demand-side (1% growth cap)	Phase 1 (2025–2026: Foundations)	MEPS enforcement at borders, LED transition	+6–7 avoided demand	0.8
	Phase 2 (2026–2028: Rollout)	Solar water heating, building audits (enabler)	+4 avoided demand	0.5
	Phase 3 (2028–2030: Consolidation)	Building codes, appliance replacement, demand cap	+3 avoided demand	0.2
Subtotal Initiative 2			**+12**	**1.5**
Total Electricity Sector (2030)			**≈ 164 GWh RE & avoided demand (70% penetration + efficiency)**	**20.91**

Note: See Annex for Methodology to calculating these emissions

Reduction in the Energy Subsector- Transport by 4 Gg by 2030

The transport sector is Tonga's largest energy consumer and one of the fastest-growing sources of greenhouse gas (GHG) emissions, relying almost entirely on imported fuels. In 2021, transport accounted for over 62% of total national energy use and nearly 90% of petroleum demand. Land transport dominates, with an estimated 16,000 vehicles in operation—about 85% on Tongatapu. The motorisation rate of 160–170 vehicles per 1,000 people is high by Pacific standards, with private ownership making up 95% of registrations. Passenger cars and light pick-ups represent about three-quarters of the fleet, while public transport is virtually absent, with buses accounting for less than 1%.

Maritime transport, while smaller in fleet size, is vital for inter-island mobility, trade, and fisheries. Tonga operates 129 vessels (under 15 metres), most powered by diesel outboards or inboards, with very limited uptake of efficiency upgrades or alternative technologies. Aviation is included in national GHG inventories but is not modelled under TERMPLUS due to its negligible domestic role.

TERMPLUS projects transport-related emissions to rise from 130.45 Gg in 2021 to 170.18 Gg in 2035—a 30% increase. Trucks and light pick-ups are the contributors (over 70% of emissions), with private cars adding a further 15%. This reflects average growth of ~2% per year, while per-capita transport emissions are projected to climb nearly 3% annually, driven by rapid vehicle growth against modest population expansion.

Progress under NDC-2 has fallen short. The target of 2% annual efficiency gains in new light-duty vehicle imports was not achieved. Around 97% of imports remain second-hand, with a median build year of 2010. Fiscal policies have worsened the problem: excise duties are halved for imports over 10

years old, encouraging older, inefficient vehicles. The new <10-year import age restriction, gazetted in 2023 and effective mid-2024, has been undermined by a pre-implementation surge in imports.

These shortcomings highlight deep structural weaknesses: a dependence on fossil fuels, dominance of inefficient vehicles, and the absence of viable public transport. To align with NDC-3, Tonga must prioritise reforms in vehicle efficiency, fiscal policy, electrification, and public transport development.

Four initiatives are recommended, drawn from TERMPLUS, TEEMP, and the National Ship Emissions Reduction Strategy. Their delivery depends on two implementation pathways:

Scenario A

On-time TERMPLUS/TEEMP rollout
Measures start in 2025 and are fully scaled by 2030, contingent on financing and enabling reforms.

Scenario B

Delayed rollout
Given current slow progress, implementation begins around 2027, achieving only partial delivery by 2030, with full impact postponed to 2033–2035.

Initiatives 1: Structural and Regulatory Measures

The TERMPLUS confirms that the transport sector is Tonga's largest energy consumer and its fastest-growing source of greenhouse gas (GHG) emissions. In 2021, emissions were estimated at 130.45 Gg, dominated by road transport: trucks (medium and heavy) contributed 37%, light pick-ups 36%, private cars 15%, taxis and government fleets 7.2%, and maritime small vessels (<15 m) 2.7%. If left unchecked, transport emissions are projected to rise to 170.18 Gg by 2035, a 30% increase over 15 years (≈2% per year). Progress under NDC-2 was limited due to weak enforcement, unreliable data, and minimal action by key stakeholders. For NDC-3, the Department of Energy must assume a stronger coordinating role to ensure transport-sector mitigation is effectively implemented.

Per-capita transport emissions are expected to grow even faster, at nearly 3% per year (2021–2035), driven by steady increases in vehicle imports (>1% annually) and very low population growth (~0.2%). To address this, TERMPLUS sets a target of limiting road transport oil consumption growth to 25% between 2019 and 2035 (≈1.4% per year). Achieving this depends on two key structural and regulatory measures with quantified mitigation potential:

1. **Motor Industry Quality Assurance Programme (MIQAP)**: This programme embeds fuel-efficiency and emissions standards into imported vehicles. It encourages modern technologies such as variable valve timing, turbocharging, and smaller-displacement engines. TERMPLUS targets a 2.4% annual efficiency improvement through MIQAP.
2. **Stricter Vehicle and Fuel Standards**: These include phasing in Euro V standards by 2035, supported by inspection and maintenance regimes, tighter age restrictions on imports, and the adoption of lower sulphur fuels. These measures prevent lock-in of inefficient vehicles and improve long-term fleet performance.

As shown in Table 11, the combined mitigation potential of these measures is significant. Under Scenario A (on-time rollout from 2025), Tonga could achieve 14.77 Gg of reductions by 2030, rising to

19.88 Gg by 2035. Under Scenario B (delayed rollout beginning ~2027), mitigation would be lower by 2030 at 11.08 Gg, but could still reach 19.88 Gg by 2035 if full implementation occurs. Given Tonga's limited preparatory progress, Scenario B is more realistic, though it still requires strong institutional leadership, regulatory enforcement, and financing to deliver the projected benefits.

Table 11: GHG Emissions Reduction for Structural and Regulatory Measures

Measure	TERMPLUS Target	Scenario A (On-time) Mitigation by 2030 (Gg)	Scenario A Mitigation by 2035 (Gg)	Scenario B (Delayed Start) Mitigation by 2030 (Gg)	Scenario B Mitigation by 2035 (Gg)
Motor Industry Quality Assurance Programme	2.4% annual efficiency gain	**8.86**	**11.93**	**6.65**	**11.93**
Stricter Vehicle & Fuel Standards	Euro V adoption by 2035	**5.91**	**7.95**	**4.43**	**7.95**
Total Phase 2		**14.77**	**19.88**	**11.08**	**19.88**

Initiative 2: Demand-Side and Behavioural Measures (from TEEMP)

The Tonga Energy Efficiency Master Plan (TEEMP) identifies demand-side and behavioural measures as cost-effective and immediately actionable tools for reducing transport-related GHG emissions. Unlike fuel-switching or heavy-technology options, these measures target how vehicles are used, managed, and regulated. They directly reduce inefficiencies in driving behaviour, distance travelled, and fuel consumption. TEEMP highlights three priority measures: reducing vehicle kilometres travelled (VKT), improving fuel economy of new light-duty vehicles (LDVs), and cutting idle time in both heavy- and light-duty vehicles.

VKT Reduction is the most important behavioural lever. TEEMP targets a 20% reduction in LDV travel below the 2030 BAU projection, achieved by shifting mobility toward walking, cycling, carpooling, public transport, and telecommuting. Since LDVs account for most new imports and rising emissions, this is the top priority group. By 2030, VKT reduction could avoid 3.9 Gg of emissions under Scenario A (on-time rollout), or 2.9 Gg under Scenario B (delayed start). By 2035, the benefit rises to between 4.5–5.5 Gg depending on rollout pace.

Fuel Economy Improvements in New LDVs build on the NDC-2 efficiency target. TEEMP raises ambition to a 30% efficiency gain by 2030, lowering average fuel use from 10.1 L/100 km in 2016 to 7 L/100 km. Achieving this requires a package of stricter import standards, differentiated tariffs, and registration fees favouring high-efficiency vehicles. By 2030, this measure could deliver 5.9 Gg savings under Scenario A or 4.4 Gg under Scenario B, rising to 6–7 Gg by 2035.

Idle Time Reduction addresses diesel wasted by unnecessary idling. In Tonga, HDVs consume ~3.5 L/hour idling, while LDVs consume ~1.5 L/hour. TEEMP proposes cutting idling by 1 hour/day through

bans, operator training, and auxiliary technologies such as automatic shut-off and electrified parking spaces. Warm conditions in Tonga make this feasible, since cold-start concerns do not apply. This measure could save 1.4 Gg under Scenario A or 1.0 Gg under Scenario B by 2030, rising to 1.5–2.0 Gg by 2035.

Taken together, these three measures yield 11.2 Gg of avoided emissions by 2030 under Scenario A and 8.3 Gg under Scenario B, increasing to 14.5 Gg and 12.0 Gg respectively by 2035 (see Table 12). While Scenario A is technically feasible, Tonga lacks the current regulatory frameworks and enforcement capacity to deliver it on time. Scenario B is more realistic for NDC-3, giving the Department of Energy and stakeholders time to establish enabling conditions from 2025–2027 before full-scale interventions begin. This staged approach ensures feasibility while laying the foundation for long-term behavioural change and cumulative emissions savings.

Table 12: GHG Emissions Reduction for Demand-Side and Behavioural Measures

Measure	Target	Scenario A (On-time) Mitigation by 2030 (Gg)	Scenario A Mitigation by 2035 (Gg)	Scenario B (Delayed Start) Mitigation by 2030 (Gg)	Scenario B Mitigation by 2035 (Gg)
VKT Reduction (LDVs)	20% below 2030 BAU	3.9	5.5	2.9	4.5
Fuel Economy (New LDVs)	30% efficiency improvement	5.9	7.0	4.4	6.0
Idle Time Reduction	1 hr/day less idling (HDVs/ LDVs)	1.4	2.0	1.0	1.5
Total		**11.2**	**14.5**	**8.3**	**12.0**

Initiative 3: Technology and Fuel Switching (TEEMP + TERMPLUS)

Technology and fuel switching are structural levers for decarbonising Tonga's transport sector, complementing demand-side measures by directly lowering the carbon intensity of fuels and vehicles. Both TERMPLUS and TEEMP identify two priority pathways: Biodiesel Blending and Electric Vehicle (EV) Uptake. Together, they diversify energy sources, reduce fossil fuel dependency, and align the transport sector with Tonga's broader energy transition.

Biodiesel Blending sets a target of introducing a 10% biodiesel mix in all road diesel by 2030. Feedstock would come primarily from waste oil and grease (covering up to 77% of demand), with coconut oil filling the balance. Beyond reducing fossil diesel imports, this creates co-benefits in waste management and local agriculture. Regional precedents, such as the Philippines achieving a 5% coconut biodiesel blend, demonstrate feasibility with the right policies. If implementation begins on time (Scenario A), blending could displace 5.5 Gg by 2030 and 7.0 Gg by 2035. A delayed rollout from 2027 (Scenario B) reduces benefits to 4.1 Gg by 2030 and 6.0 Gg by 2035.

Electric Vehicle (EV) Uptake targets 10% of new LDV sales as EVs or hybrid electric vehicles (HEVs) by 2030. This requires supporting measures such as charging infrastructure, fiscal incentives, and mechanic training. While the 10% target is conservative given global trends and declining battery costs, Tonga's renewable share and grid readiness are essential for maximising climate gains. Under Scenario A, EV uptake could save 2.5 Gg by 2030 and 4.5 Gg by 2035. With a delayed start (Scenario B), savings fall to 1.5 Gg by 2030 and 3.0 Gg by 2035.

Combined, biodiesel blending and EV uptake could reduce emissions by 8.0 Gg by 2030 under Scenario A, or 5.6 Gg under Scenario B. By 2035, reductions rise to 11.5 Gg (Scenario A) and 9.0 Gg (Scenario B) (see Table 13). While Scenario A is technically achievable, Tonga has not yet established the necessary regulatory frameworks, financing, or infrastructure. Scenario B is therefore the more realistic pathway under NDC-3, allowing time to build enabling conditions before full-scale rollout.

Table 13: GHG Emissions Reduction for Technology and Fuel Switching

Measure	Target	Scenario A (On-time) Mitigation by 2030 (Gg)	Scenario A Mitigation by 2035 (Gg)	Scenario B (Delayed Start) Mitigation by 2030 (Gg)	Scenario B Mitigation by 2035 (Gg)
Biodiesel Blending	10% biodiesel in road diesel	5.5	7.0	4.1	6.0
EV Uptake	10% of new LDV sales as EV/HEV by 2030	2.5	4.5	1.5	3.0
Total		**8.0**	**11.5**	**5.6**	**9.0**

Initiative 4: Maritime Transport Efficiency through Low-Carbon Technologies

Although small compared to land transport, maritime transport is vital for Tonga's inter-island connectivity, fisheries, and tourism. It accounts for less than 2% of the national vehicle stock but remains a meaningful contributor to emissions. The Marine & Ports Division reports 129 vessels under 15 metres: about 90 outboard-powered (tourism) and 39 inboard diesel-powered (fisheries). These vessels are almost entirely diesel-reliant, with little uptake of efficiency technologies or alternative fuels. TERMPLUS estimates that small vessels emitted ≈3.5 Gg in 2021 (≈2.7% of transport emissions), underscoring their importance in Tonga's decarbonisation pathway.

The **National Ship Emissions Reduction Strategy** prioritises efficiency-first measures such as hull maintenance, optimised routing, solar/wind-assist retrofits, and slow steaming. These can deliver moderate but dependable savings. Under Scenario A (on-time rollout from 2025), efficiency measures would reduce emissions by 1.2 Gg by 2030, rising to 2.0 Gg by 2035. With a Scenario B delayed rollout (from 2027), savings fall to 0.5 Gg by 2030, though they still reach 2.0 Gg by 2035 once fully deployed.

Beyond incremental improvements, maritime electrification of small vessels offers a transformative opportunity. TERMPLUS sets a target for 20% of small vessel sales in tourism and fisheries to be electric by 2035, delivering ≈2.1 Gg in savings by 2035. Even a single electric vessel can avoid ~0.045 Gg annually, far more per unit than replacing a truck or bus. Under Scenario A, electrification could begin by 2025, saving 0.9 Gg by 2030 and 2.1 Gg by 2035. Under Scenario B, with infrastructure and financing only in place by 2027, reductions would be limited to 0.3 Gg by 2030, before also reaching 2.1 Gg by 2035.

In total, maritime measures could achieve 2.1 Gg of avoided emissions by 2030 under Scenario A, or 0.8 Gg under Scenario B, scaling to 4.1 Gg in both scenarios by 2035 (see Table 14). While relatively modest compared to road transport, these reductions are strategically important for Tonga's fisheries and tourism resilience, reducing reliance on imported fuels, and positioning Tonga as a Pacific leader in low-carbon shipping.

Table 14: GHG Emissions Reduction for Maritime Efficiency & Electrification

Measure	Target	Scenario A (On-time) Mitigation by 2030 (Gg)	Scenario A Mitigation by 2035 (Gg)	Scenario B (Delayed Start) Mitigation by 2030 (Gg)	Scenario B Mitigation by 2035 (Gg)
Ships efficiency and operational improvements	n/a	1.2	2.0	0.5	2.0
Maritime Electrification	20% of small vessel sales for tourism and fisheries to be electric by 2035	0.9	2.1	0.3	2.1
Total		**2.1**	**4.1**	**0.8**	**4.1**

Summary of key challenges and recommendations for the energy sector

- The NDC-2 target aggregates the entire energy sector rather than distinguishing between electricity and transport, which together account for the vast majority of emissions, making it difficult to assign responsibilities, monitor progress, and account for future demand growth.
- NDC-2 Means 2 and 3 showed no measurable progress due to the absence of clear initiatives, measurable indicators, and data-collection systems. Even with TERMPLUS and TEEMP outlining strategies, the lack of coordinated execution and integration into national energy planning left these targets without monitoring and tracking.
- The overall energy target of a 13% (≈16 Gg) reduction by 2030 suffered from structural weaknesses: reliance on a contested 2006 baseline, use of a single aggregate sectoral target,

no allocation of reductions by sub-sector, weak planning pathways, unclear stakeholder roles, and significant data limitations.

- TPL is making progress, but at its current rate, it will fall short of the 70% renewable electricity target by 2030. Despite growth in installed capacity and BESS integration, major project delays, unfinished grid upgrades, and insufficient secured funding mean that, on the current trajectory, renewable penetration would reach only 35.3% (≈49.8 GWh) by 2030, far short of the ≈98.9 GWh required. Meeting the target will require timely completion of grid reinforcements and new project rollouts backed by substantial financing.
- Progress under NDC-2 transport measures also fell short. Around 97% of imported vehicles remain second-hand and inefficient, undermining the fuel-efficiency target. Fiscal incentives favor older vehicles, EV uptake has been minimal, and enabling infrastructure is absent. A stronger policy and investment push is needed, prioritizing efficiency standards, public transport, and practical near-term measures such as shared mobility and cycling.
- The DOE manages key energy and transport datasets, but the lack of an integrated MRV platform, dedicated staff, and formalised data-sharing leads to delays, gaps, and inconsistent reporting. Current verification remains ad hoc, limiting reliability and credibility of national reporting.
- Forums like the Donor Roundtable and Energy Steering Committee are often underutilised, with weak accountability and limited inclusivity. DOE's leadership role remains constrained, reducing opportunities for early engagement, especially with vulnerable groups.

Recommendations

Restructure the three NDC-2 Means into two, with a stronger focus on electricity and transport, expressed as absolute GHG reduction targets. Each initiative should include a quantified emissions-reduction contribution to enable transparent monitoring.

- Adopt absolute GHG reduction targets in gigagrams (Gg), disaggregated by sub-sector and aligned with national strategies (TERMPLUS, TEEMP, LT-LEDS, SDG7 Roadmap, National Maritime Strategy)
- Adopt a phased implementation approach, strategically sequencing initiatives and building on existing strategies and documents rather than creating new measures.
- Update the electricity target from 12 Gg to ≈20.91 Gg of annual avoided emissions by 2030, reflecting Tonga's actual progress and the combined potential of Initiative 1 (supply-side) and Initiative 2 (demand-side).
- Accelerating grid reinforcements and ensuring timely rollout of renewable projects are essential to closing the gap. Securing substantial new funding and strengthening implementation capacity will be key to achieving the 70% renewable energy target.
- Shift from percentage-based targets against a historic baseline to absolute sub-sectoral GHG reduction targets (in Gg), directly linked to pipeline projects and measurable through national fuel-import data, Tonga Power Ltd. generation statistics, and sectoral audits. This will enhance

measurability, credibility, and transparency, while aligning ambition with implementation capacity.

- Replace the unachievable 2% annual fuel-efficiency target for light-duty vehicles with a package of TERMPLUS/TEEMP measures: structural and regulatory reforms, demand-side behavioral measures, technology and fuel switching (EVs, biodiesel), and maritime efficiency and electrification. Adopting Scenario B sets reductions at ≈25.7 Gg by 2030 and ≈44.9 Gg by 2035.
- Update the NDC energy target from 16Gg to 46.67 Gg reduction by 2030. This 20.91 Gg from electricity through 70% renewable generation and capped residential demand, and 25.70 Gg from transport via structural, behavioural, technological, and maritime measures.
- Establishing a centralised MRV system and a dedicated unit within DOE, supported by standardised formats and inter-agency protocols, would strengthen data integrity. Further reforms should include staff training in ETF-aligned monitoring and commissioning independent audits to enhance transparency and trust.
- Strengthening NDC-3 requires DOE to enforce clear stakeholder roles under the Tonga Energy Act, broaden participation, and provide technical materials to support informed input. Future improvements should prioritise automated and digitised data flows, real-time demand monitoring, inter-agency agreements, and a centralised MRV system with trained staff.

3.2 Industrial Processes and Product Use (IPPU)

The IPPU sector, though currently a small share of Tonga's total GHG emissions, is gaining importance due to rising demand for refrigeration and air-conditioning. Emissions stem primarily from hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), substances with high global warming potentials (GWPs), making their management a national priority for mitigation and compliance with the Montreal Protocol and its Kigali Amendment.

Tonga's industrial base is limited, with no heavy manufacturing in sectors such as cement, chemicals, metals, or electronics, and minimal use of industrial products like lubricants, paraffin waxes, and solvents. Historically, national GHG inventories have had limited IPPU data coverage. However, the forthcoming Fourth National Communication (expected 2026) will introduce improved emissions accounting for refrigerants and other controlled gases, supported by strengthened data collection and regulatory reforms.

The LT-LEDS envisions the development of a low-GWP cooling sector, driven by accelerated HFC phase-down, enhanced monitoring, and capacity building for accurate emissions reporting. The strategy further emphasizes capacity building for accurate emissions reporting and enforcement, underpinning Tonga's commitment to sustainable industrial and product use practices aligned with international climate goals.

Tonga's Second NDC does not include a GHG emissions reduction target for the IPPU sector (Kingdom of Tonga, 2020). This is consistent with both the previous NDC and recommendations

from the NDC Review Report (MEIDECC, 2021). The rationale remains unchanged: Tonga lacks significant manufacturing industries in mineral, chemical, metal, or electronics sectors, and uses only limited quantities of lubricants, paraffin waxes, and solvents. The contribution of IPPU emissions to national totals is therefore negligible, and there is a paucity of reliable data to support a quantified and verifiable target. The Second NDC explicitly states that "no target" is set for IPPU due to limited relevance and insufficient data (Kingdom of Tonga, 2020). Moreover, there is no mention of the sector's role in Tonga's emissions profile, nor any reference to relevant sub-sectors such as refrigeration, foam blowing, or the use of hydrofluorocarbons (HFCs). While Tonga's third national GHG inventory (TNC) does include IPPU emissions—mainly from product use—this information was not incorporated into the Second NDC, and the sector remains excluded from the national climate mitigation narrative.

It should be noted that the Government plans to include IPPU emissions in the Fourth National Communication (4NC), offering a pathway to integrate this sector into the NDC 3.0 and/or future NDCs once sufficient data are available.

3.2.1 Implementation Status

While Tonga's Second Nationally Determined Contribution (NDC) did not establish a quantified mitigation target for the IPPU sector due to its currently negligible emissions and limited activity data, significant regulatory momentum is advancing the sector's monitoring and control of synthetic greenhouse gases. This progress is critical for improved future emissions accounting, as reflected in preparations for Tonga's upcoming Fourth National Communication, scheduled for submission in 2026.

Tonga's progress since its Second NDC includes:

- **Regulatory Advances:** Full legislative alignment with the Kigali Amendment via the revised Ozone Layer Protection Act (OLPA, 2016) and its 2021 Amendment (Government of Tonga, 2021), which expanded the controlled substance list to include HFCs, established import prohibitions on bulk HCFCs/HFCs and related equipment from non-Party countries beginning 2024, and set import quotas and permitting requirements.
- **Institutional Strengthening:** The National Ozone Advisory Committee (NOAC) has broadened to include multiple ministries, customs, trade, and private sector representatives, fostering an integrated cross-sector response.
- **Customs Integration:** Enhanced data exchange exists between the Ministry of Environment, Climate Change, Disaster Management, Energy, Environment and Communications (MEIDECC) and Customs, enabling improved tracking of refrigerant imports.
- **Capacity Building:** Ongoing technical training and certification programs for refrigeration and air-conditioning (RAC) technicians have been implemented to ensure best industry practices that minimize emissions.

- **Enforcement:** Ozone officers and customs officials have new powers to inspect, seize illegal imports, and require detailed reporting on controlled substances, supported by strict penalties.
- **MRV Development:** Work is in progress to establish a national MRV system linked with the GHG inventory for accurate monitoring of synthetic gas emissions.
- **Market and Regulatory Incentives:** Introduction of measures to promote low-GWP refrigerant adoption and to facilitate proper end-of-life management and refrigerant recovery.
- **Data Improvement:** Planned economy-wide surveys on controlled substance use aim to refine inventories and better target mitigation efforts.

3.2.2 Communication

Although the IPPU sector has thus far been largely absent from Tonga's climate communications, this is set to change with improved data availability and new MRV systems. The government plans to include IPPU emissions in its Fourth NC due in 2026, reflecting ongoing efforts to capture and report these emissions with greater accuracy. Recent initiatives have delivered sector-specific GHG inventory guidelines covering IPPU and established data-sharing mechanisms (for example, between customs and the environment ministry) to track refrigerant imports. These measures will enable consistent, transparent reporting of IPPU emissions across national communications and future NDC updates, aligning with international best practices. Furthermore, through stakeholder workshops, technician training, and the National Ozone Advisory Committee (MEIDECC, 2022), the government is actively disseminating information on new refrigerant regulations and low-GWP alternatives, raising awareness and fostering broader engagement in IPPU emission management.

3.2.3 Recommendations

The Second NDC is transparent in stating the absence of an IPPU target and provides clear reasoning based on national circumstances and data limitations. There is also no reference to Tonga's obligations or opportunities under the Kigali Amendment, which could be leveraged to support low-GWP refrigerant transitions and industrial efficiency improvements. The NDC also lacks any proposed timeline, data-sharing protocols, or stakeholder engagement processes related to the IPPU sector, thereby limiting future opportunities for monitoring or scaling up mitigation in this area.

For NDC-3.0, it is recommended to:

- Explicitly state that IPPU emissions will be included in the GHG inventory for the 4NC.
- Reference the Ozone Layer Protection Act and its amendment as enabling legislation for refrigerant management.
- Consider capacity building for data collection/monitoring and technical training for handling refrigerants, which could indirectly reduce emissions.

3.3 Agriculture, Forestry and Other Land Use (AFOLU)

The NDC 2020 recognizes the AFOLU sector as crucial for both mitigation and adaptation. However, no specific GHG emissions reduction target was set for AFOLU due to incomplete emissions data in this sector. As a result, comprehensive GHG figures are not available for this review. Nevertheless, the national "1 Million Trees" campaign – a key mitigation initiative – was successfully completed, and an additional tree-planting program led by the Ministry of Agriculture, Food and Forests (MAFF) is ongoing. The sole adaptation target – to have 30% of Tonga's land under agro-forestry or forestry by 2025 – has proven difficult to assess and is likely overly ambitious given conflicting land cover data and limited agro-forestry information. It is recommended that this target be revisited and refined in future NDCs, as it may have been overestimated.

Table 15: Mitigation Targets and Means for AFOLU

NDC 2020 Target	Target Progress Assessment	Means	Means Progress Assessment
Identification of a GHG emission target for agriculture, forestry and other land use for the 2025 NDC	AFOLU component of the Fourth National GHG Inventory for the Fourth National Communication is 75% complete.	**Means 4:** Establishment of a forest inventory	25% complete, with only initial preparatory work complete. Means is on track to be completed by 2030.
Planting one million trees by 2023	Completed	**Means 5:** To be determined: kind of trees to be planted, land on which trees to be planted, and who will be responsible for planting the trees	Completed

3.3.1 Implementation status

AFOLU Target 1: Identification of a GHG Emission Target for Agriculture, Forestry and Other Land Use for the 2025 NDC

This target focuses on developing a complete greenhouse gas (GHG) inventory for the AFOLU sector. Significant progress has been made: the AFOLU component of Tonga's National GHG Inventory is in its final stage of data calculation as of the time of reporting. The Department of Climate Change (within MEIDECC) is leading this effort, as part of the preparation of Tonga's Fourth National Communication, but progress has been slower than expected. A key challenge has been limited access to robust sectoral data – particularly from agriculture and forestry agencies – which caused delays in completing the inventory.

Status: 75% completion and in its final stage of GHG emission data calculations

Despite these challenges, preliminary findings from the agriculture sub-sector suggest a 59% increase in agricultural GHG emissions from 2006 to 2023 (rising from 1.75 Gg to 4.26 Gg of emissions); however, these early estimates may change in the Fourth National Communication.

Means: Establishment of a forest inventory

This target aims to develop a comprehensive national forest inventory to quantify Tonga's forest resources (critical for both carbon stock assessment and adaptive land management). Progress on this target has been limited, with roughly 25% of the work achieved so far. On a positive note, the Forestry Division of MAFF has undertaken significant capacity-building efforts: personnel have been trained and essential inventory tools and methodologies have been acquired. The division's management has expressed confidence that they are prepared to carry out a full forest inventory, thanks to these preparatory steps. However, a complete inventory has not been realized due to funding shortfalls. The lack of dedicated funding meant that, despite readiness in terms of capacity, the actual field assessment and data collection could not be fully implemented.

Status: Off track (approximately 25% achieved). Only initial preparatory activities have been completed; the full national forest inventory remains unfinished.

AFOLU Target 2: Planting of 1 million trees by 2023

This flagship mitigation target – to plant one million trees across Tonga by 2023 – has been achieved in full, and even exceeded. Led by the Department of Climate Change (MEIDECC) in partnership with communities and other agencies, the national tree-planting campaign successfully met its goal, making a significant contribution to carbon sequestration and ecosystem enhancement. By the conclusion of 2023, Tonga had officially planted one million trees (and in fact slightly surpassed the target), demonstrating strong commitment and coordination by the government. All six of Tonga's island groups participated in this effort. The largest contribution came from the main island, Tongatapu, which accounted for about 93% of the total plantings; the Vava'u group contributed

roughly 6%, and the remaining islands (Ha'apai, 'Eua, Niuatoputapu, and Niuafo'ou) collectively contributed around 1%. Notably, about 91% of the trees planted were mangroves, established along the north-western coastal areas of Nuku'alofa to restore and protect coastal ecosystems. The other ~9% of plantings were terrestrial (land-based) tree species on Tonga's land territory.

Table 16: Trees Planted by Island by 2023

Islands	Quantity
TBU	1,148,365
VV	78,606
Hp	1,296
NTT	1,000
NF	1,142
Eua	1,255
Total	**1,231,664**

Table 17: Trees Planted by Tree Type and Island by 2023

Tree Type	Island	Quantity
Mangroves Trees	TBU	1,100,711
	VV	12,074
Coastal Trees	TBU	2,523
	VV	3,431
	Hp	402
	Eua	495
Terrestrial	Tonga	112,028
	Total	**1,231,664**

Monitoring and evaluation of the million-tree initiative is ongoing. Detailed data on species selection, planting locations (with mapping), survival and mortality rates, tree growth, and the extent of community (and gender) involvement are being compiled and analyzed. Early reports indicate that this initiative had broad community engagement, including significant participation by women and youth (in nursery management and planting activities), which is an encouraging sign for inclusive climate action.

Urban agroforestry and landscaping in Tonga is driven by women and youth. The women initiative on promoting edible fruit tree species, home gardening and smart agricultural best practices is transferrable to family farm lands in collaboration with male activities. Women and youth are very proactive on community-based natural resources development and conservation activities including tree nurseries, coastal protection and community beautification activities.

Status: Achieved (100% of target completed). Tonga officially declared that the one million trees goal was reached by 2023.

BOX 1: Additional initiative: MAFF 1 million tree planting target

In parallel with the completed 2023 tree-planting target, the Ministry of Agriculture, Food and Forests (MAFF) launched a complementary initiative to plant another one million trees by 2030. This is not an official NDC2.0 target, but a national effort to sustain momentum in increasing forest cover and to further enhance carbon sinks. The MAFF-led tree planting program is envisioned as a long-term, sustainable forestry effort that continues where the initial campaign left off. However, progress to date under this initiative has been limited. While MAFF has finalized its data collection, management, and monitoring framework for the program, the actual number of trees planted so far is relatively low. As of this review, less than 10% of the target (i.e. fewer than 100,000 trees) have been planted, reflecting a slow start.

Status: 20% completion in MAFF's 1 million tree planting efforts

Tree planting initiative reaches its one million target supporting coastal resilience and GHG reduction goals.
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3.3.2 Communication

The status of emissions tracking and reporting in the AFOLU sector under NDC2.0 revealed several transparency gaps. Tonga's GHG inventory for AFOLU (as part of its Fourth National Communication) was still incomplete, which meant recent emission levels could not be fully compared against the 2000 or 2006 baseline inventories. Only preliminary figures were available for some subsectors; for instance, initial data indicated about a 59% increase in agriculture-related emissions from 2006 to 2023, but this result remains unofficial pending a complete inventory. These data gaps hindered the ability to transparently track AFOLU emission trends and communicate progress during the NDC2.0 period.

Efforts were identified to improve coordination and data consistency across AFOLU subsectors. The NDC2.0 review highlighted that land-use categories were not consistently defined – for example, what counted as "forestry" versus "agroforestry" was unclear – which led to challenge in measuring and reporting mitigation outcomes. To address this, stakeholders emphasized the need to harmonize definitions and better integrate the agriculture and forestry efforts. In particular, integrating agroforestry into farming systems was seen as a way to boost tree cover and unify sectoral contributions, such as planting fast-growing or high-value trees on farmlands to increase carbon sequestration. Clarifying these definitions and improving inter-sector coordination is essential for a more coherent and transparent framework for AFOLU emissions reporting going forward.

3.3.3 Recommendations for NDC 3.0

The next NDC should include clearly defined and measurable mitigation targets for agriculture, forestry and other land use, addressing the absence of such specifics in NDC2.0. Concrete objectives—such as explicit targets for reducing emissions from agriculture or increasing forest carbon sinks—will provide direction and accountability. At the same time, it is critical to bolster the underlying data systems that support these targets. Completing the ongoing GHG inventory work, including a full national forest inventory, should be a top priority to improve the accuracy and transparency of AFOLU emission estimates. Given that the target of initial capacity building and preparations for the field inventory is successfully completed, appeals to complete the implementation of a national forest inventory for Tonga are reinforced.

Investments in data collection and management capacity (for example, establishing consistent procedures to gather and update agriculture and land-use emissions data) are needed so that progress can be monitored and reported reliably. One essential aspect is emphasized is the need for a more proactive strategic planning and awareness to harmonise the forestry and agroforestry definitions as well as its implementation strategies. Such effort is necessary to bind all the AFOLU sub-sectors in planning and actions on NDC3.0.

NDC3.0 should also refine Tonga's land-use mitigation goals and implementation strategies to be more realistic and well-defined. Any targets for expanding forest or agroforestry cover must be grounded in clear terminology and robust baseline data, avoiding the ambiguities that hindered the 30% land-area goal under NDC 2020. In practice, this means explicitly clarifying what constitutes "forestry" versus "agroforestry" and ensuring these categories are consistently measured across agencies. Tonga can then pursue integrated AFOLU interventions that leverage both sub-sectors: for example, promoting agroforestry by introducing fast-growing fallow species and fruit trees into farming systems, which will enhance carbon sequestration on agricultural lands. Building on the momentum of the one-million-tree initiative, the next NDC could set new forest cover or tree-planting targets with greater emphasis on terrestrial reforestation (inland tree planting), not just coastal mangrove restoration. Such refined targets and definitions will enable all AFOLU stakeholders to work toward common, verifiable mitigation outcomes in NDC3.0.

The commitment of the Honourable Minister of Agriculture, Forests and Food, Dr. Siosiua Halavatau, in confirming the MAFF engagement in the enhancement of NDC3.0 is highly acknowledged. Accordingly, MAFF will act upon; confirmation of the definition for "forest" with context that takes into account Tonga's biodiversity, for example county coconut palms and other agroforestry systems as "forests". In order to break into the broader farm lands areas of Tonga, the agroforestry concepts that have a more predominant tree component is promoted. Further, the contribution of Soil Carbon's towards GHG emission management, which will deal directing with the way in which soils are being utilized for agriculture is taken into account. And more urgently, MAFF will improve its basic agriculture and forestry data collections and management. This will be improved by integrating of forestry data such as firewood uses, trees in the agroforestry systems, coconut palms as well as in urban agroforestry systems and coastal forestry.

Last but not the least, urban agroforestry and landscaping in Tonga is driven by women and youth. The women initiative on promoting edible fruit tree species, home gardening and smart agricultural best practices is transferrable to family farmlands in collaboration with male activities. Women and youth are very proactive on community-based natural resources development and conservation activities

Youth lead urban agroforestry in Tonga, promoting sustainable agriculture and contributing to national tree planting and forest inventory goals.
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3.4 Waste

The waste sector in Tonga is a relatively small source of national greenhouse gas (GHG) emissions–accounting for **about 0.3% of total emissions** – but it represents a significant opportunity for targeted mitigation. Emissions are dominated by methane from the anaerobic decomposition of organic waste in landfill sites, with smaller contributions from the open burning of waste and from wastewater handling.

Rapid urbanisation, changes in consumption patterns, and increased waste generation–particularly of plastics and organic material –are intensifying the pressure on existing waste management systems. These trends present both challenges in terms of service delivery and environmental protection, and opportunities for impactful interventions that reduce emissions, promote resource recovery, and create local green jobs.

Tonga's waste sector planning and investment priorities are guided by four key frameworks:

- **Tonga Single-Use Plastic Roadmap** – acts as a guide to navigate the country towards a sustainable plastic economy.
- **NDC Implementation Roadmap (2022)** – defining climate mitigation priorities and investment pipelines for the sector.
- **National Infrastructure Investment Plan (2021–2030)** – identifying critical infrastructure upgrades, such as improved landfills, transfer stations, and organics processing facilities, to build capacity for sustainable waste management.
- **Long-Term Low Emission Development Strategy (LT-LEDS)** – establishing the long-term vision and targets for net-zero methane emissions from waste by 2050, fostering the transition to a sustainable and climate-resilient waste management system

This waste composition underscores the critical mitigation potential in **organic waste diversion**—through composting, anaerobic digestion, and other recovery methods–as well as in scaling up recycling infrastructure and systems.

Waste management services are delivered primarily by **Waste Authority Limited (WAL)** in urban Tongatapu. In other islands, the Ministry of Health and local authorities coordinate collection and disposal services. The private sector also plays a pivotal role, with operators such as Gio Recycling Company and Sustainable Resource Recovery Company engaged in collecting and processing metals, batteries, e-waste, and certain plastics, most of which are prepared for export.

The ADB Integrated Urban Resilience Sector Project in Tonga includes several major initiatives relevant to both municipal solid waste (MSW) and wastewater management. Central to these efforts is the enhancement of the Tapuhia Waste Management Facility on Tongatapu, where a new sanitary landfill cell is being constructed and existing infrastructure is being upgraded, including a new office and maintenance facility. The project also supports the acquisition of new waste collection trucks and equipment, expanding Waste Authority Limited's (WAL) operational ability, with particular

attention to gender inclusion and reaching underserved outer island communities. On the wastewater side, the project is upgrading the septage and leachate treatment plant at Tapuhia, expanding treatment capacity for both solid and liquid waste streams. This is integrated with broader public and environmental health objectives, supporting septage collection and safe disposal from households across Nuku'alofa. Public awareness campaigns on water, sanitation, and hygiene (WASH), including menstrual hygiene, are being rolled out in schools, health centers, and public places, with strong gender and community inclusion.

Further, Tonga's new waste levy reform proposes replacing the uniform $15 monthly waste fee for all residents with a levy system tied to the purchase of recyclable materials from retailers. This approach aims to make waste management fees more equitable by charging higher-waste producers and businesses proportionally more, while reducing the burden on households that generate less waste. The new system seeks to align waste management costs with actual waste generation, foster fairness and accountability, and support community engagement, with ongoing public consultations showing broad support for the change.

Table 18: Mitigation Target and Means for the Waste Sector

NDC 2020 Target	Target Progress Assessment	Means	Means Progress Assessment
Identification of a GHG emission target for waste for the 2025 NDC	Significant progress in data collection and MRV improvement, but the waste-sector GHG target remains under development and is deferred to the 2030 NDC.	**Means 6:** Expansion of formal waste collection system	Collection coverage in Tongatapu now exceeds 90%, and since collection services were introduced in 2020, approximately 99% of general waste in Ha'apai has been collected. Expansion of recycling, infrastructure, and monitoring systems as well.

3.4.1 Implementation status

Target: Identification of a GHG Emission Target for Waste for the 2025 NDC

Since the submission of Tonga's Second NDC in 2020, significant progress has been achieved in advancing the waste sector's mitigation potential through a combination of infrastructure development, policy reforms, institutional strengthening, and enhanced data systems.

- **Legislative and Policy Advances**: The country has rigorously enforced the Waste Management Act (2005), Environmental Management Act (2010), and Litter and Waste Control Regulations (2016). These are complemented by ongoing initiatives to develop and implement a comprehensive National Waste Strategy and targeted measures to reduce plastic pollution, including a recently launched National Single-Use Plastics Roadmap. The National Single-Use

Plastics Roadmap (2024), provides a systematic approach to phasing out problematic single-use plastics by 2030 and promoting a circular plastic economy aligned with national frameworks such as the Tonga Strategic Development Framework II and Joint National Action Plan II. This Roadmap emphasizes institutional strengthening, legislation, behavioral change, financial mechanisms, and stakeholder collaboration to reduce plastic pollution and foster sustainable alternatives.

- **Organic Waste Diversion and Methane Mitigation Pilots:** Community-scale composting programs, school initiatives, and household biogas digester pilots have been established to reduce methane emissions from organic waste, which comprises about 40% of municipal solid waste.
- **Enhanced Monitoring, Reporting, and Verification (MRV):** The introduction of waste data audits, digital record-keeping, and waste facility weighbridge systems has improved the precision and transparency of emissions and waste flow monitoring, a key requirement for compliance with international climate reporting frameworks.
- **Institutional Strengthening:** Enhanced coordination among the Waste Authority Limited (WAL), the Ministry of Environment, Climate Change, Disaster Management, Energy, Environment and Communications (MEIDECC), the Ministry of Health, and local governments has improved policy implementation, planning, and enforcement capacity.

Despite these advances, challenges remain in infrastructure gaps, hazardous waste management, financial sustainability, and equitable service extension to all islands, which require sustained effort and support.

Means: Expansion of Formal Waste Collection System

- **Expansion of Waste Collection Services:** The coverage of the waste collection in Tongatapu currently exceeds 90%, and since the introduction of collection services in 2020, approximately 99% of general waste in the Ha'apai has been collected. Recycling, infrastructure, and monitoring systems are also being expanded.
- **Waste Infrastructure Improvements:** Upgrades have been implemented at Tonga's two classified modern sanitary landfills—Tapuhia on Tongatapu and Kalaka on Vava'u—with weighbridge installations, enhanced leachate management, and landfill cell improvements. Planning and funding mechanisms are in place to modernize facilities in Ha'apai and 'Eua, which currently operate as unregulated open disposal sites lacking environmental safeguards.
- **Recycling and Resource Recovery Expansion:** Recycling rates have almost tripled, growing from under 3% to approximately 8.6%, driven by private sector efforts such as the Moana Taka plastic and metal recovery scheme and community initiatives fostering glass recycling and reuse.
- **Community Engagement and Behavioral Change:** Public education campaigns such as the annual "Clean Up Tonga Day" and school programs have increased community awareness and participation in waste reduction and segregation activities.

3.4.2 Communication

Tonga's Second NDC highlighted the need to improve waste sector data collection to accurately measure waste volumes and emissions. In response, the government and partners have implemented systematic waste audits and data collection initiatives. For example, a national waste characterization survey in 2020/21 (supported by the World Bank and SPREP's PacWaste Plus program) conducted detailed waste audits across Tongatapu and outer island communities (World Bank, 2021). These audits, along with a 2023 "Waste Facility Register" survey, have provided improved data on waste generation, composition, and disposal at each facility. Under the Pacific region's new Waste Data Collection, Monitoring and Reporting (DCMR) framework, Tonga's Department of Environment (within MEIDECC) and WAL now routinely track key waste indicators (e.g. tonnes landfilled, recycled, recovered) across 8 core and 10 supplementary metrics (SPREP, 2023).

Importantly, waste sector MRV improvements extend nationwide. WAL has expanded its services and data collection to the outer island centers of Vava'u, Ha'apai, and 'Eua in recent years (with support from JICA's J-PRISM II project). This expansion means that formal collection and weighing of waste now occur beyond the capital, capturing data that was previously absent (many outer islands had relied on open burning or unmanaged dumps, which went unrecorded). MEIDECC oversees these MRV efforts at the national level, while WAL handles operational monitoring and facility-level reporting. Notably, the Waste Management Act designates WAL as the "approved authority" for the Tongatapu waste service area, and assigns the Ministry of Health as the interim authority for other islands until formal waste service areas are declared.

Tonga is also actively incorporating its waste sector emissions data and mitigation actions into national climate reporting instruments such as NCs and the upcoming Biennial Transparency Reports. In its Third NC to the UNFCCC, Tonga for the first time included a dedicated assessment of waste sector emissions, covering methane from solid waste disposal (landfills) and wastewater treatment, as well as nitrous oxide from human sewage.

3.4.3 Recommendations

The Second NDC is explicit and transparent in its treatment of the Waste sector. It clearly states the reasons for not including a direct GHG target: lack of reliable waste data, minor share of national GHG total (less than 1%), and the priority of building data systems and collection capacity. It is recommended to report on progress in expanding the waste collection system and data collection in subsequent NDCs, with a view to enabling the identification of a waste-sector emissions target in the 2030 NDC. This approach is consistent with UNFCCC guidance on "clarity, transparency, and understanding." The reporting also suggests the methodology (IPCC 2006 Guidelines) to be used for future GHG inventories once sufficient data is available. Furthermore, the NDC 3.0 should clearly outline its linkages with Tonga's LT-LEDS and other national documents such as the Zero Waste Tonga

Roadmap. It should discuss how planned waste management measures align with Tonga's LT-LEDS vision of achieving zero unmanaged waste by 2050. Overall, communication of the Waste sector's mitigation potential is limited and lacks technical or strategic depth.

- Report on progress in expanding waste collection coverage, using the >90% figure as a key achievement.
- Use waste composition data from the audit to establish a baseline and apply the 2006 IPCC Guidelines for GHG estimation.
- Consider introducing a modest, achievable GHG target (e.g. methane reduction through composting or landfill gas capture) alongside continued system expansion.
- Clearly link Waste sector measures to the LT-LEDS and other national frameworks such as the Zero Waste Tonga Roadmap.

Potential targets could include:

- Reducing per capita plastic waste generation by 10% by 2030.
- Recycling 25% of post-consumer single-use plastics by 2030.
- Establishing a centralized MRV system and national waste database by 2030.

Tapuhia landfill highlights Tonga's waste challenge and the need to expand formal waste collection to cut emissions.

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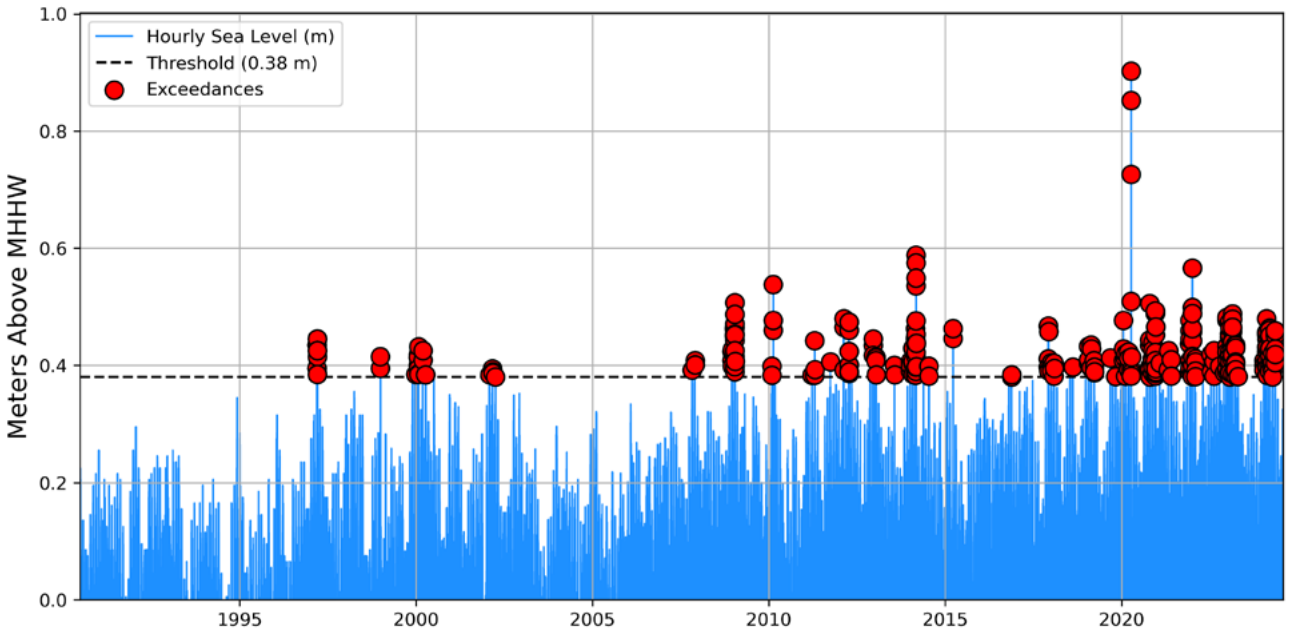
4. Adaptation

In contrast to mitigation (which focuses on reducing greenhouse gas emissions), adaptation is about reducing vulnerability and increasing the capacity to cope with climate impacts that are already happening or anticipated in the future.

As a low-lying Small Island Developing State, Tonga is particularly vulnerable to the impacts of climate change. The country is already experiencing more frequent and intense extreme weather events (such as tropical cyclones), coastal erosion, and flooding. Sea levels around Tonga are rising at roughly *6 millimeters per year*—about twice the global average—leading to saltwater intrusion and loss of land in some areas (Mulhern, 2020). Several coastal communities have even had to relocate due to encroaching seas and severe erosion (with up to 40 meters of shoreline retreat recorded in parts of the Ha'apai islands) (Mulhern, 2020). Moreover, heavy rainfall events and wave-driven inundation are projected to increase, posing long-term threats to Tonga's largest and most populated island, Tongatapu (UNDP, n.d.). These climate pressures threaten the people of Tonga, their livelihoods, and the natural environment, putting development goals at risk. Consequently, adaptation has been elevated as Tonga's top priority in its climate response, recognizing that building resilience is critical for protecting communities and the economy.

Figure 6: Daily Sea Level Relative to the Average High Tide (NASA Sea Level Change Team, 2024)



Reflecting this urgency, Tonga's 2020 included specific adaptation goals for the first time. Tonga's NDC reiterates that adaptation is the nation's priority response to climate change and outlines measurable targets to build resilience. These key adaptation targets (focused on nature-based solutions and protective measures) are as follows:

Land and Forests: 30% of Tonga's land to be utilized for agroforestry or forestry by 2025.

Coastal Areas: Prevent any permanent loss of land on Tonga's four main islands (Tongatapu, Ha'apai, Vava'u, and 'Eua) due to rising sea levels.

Marine Resources: Maintain existing stocks of fish and other marine species by expanding the coverage of MPAs and Special Management Areas (SMAs) to 30% of Tonga's Exclusive Economic Zone (EEZ).

4.1 AFOLU

4.1.1 Implementation status

Target 1: 30% of land in Tonga utilized for agro-forestry or forestry by 2025

Tonga's baseline land use has a relatively small forest cover and a large agricultural footprint. As of 2018, forested area made up about 12.5% of Tonga's land, while 43.1% was classified as agricultural land (including crops and pasture). The remaining ~44% was in settlements, infrastructure, or other uses (CIA, n.d.). Over the past decade, agricultural land has expanded – for example, arable (crop) land increased from roughly 22% in 2011 to 28% in 2022, reflecting conversion of more land to cultivation. In the same period, forest cover has held almost steady (about 12.4% in 2022, only a slight decrease from 12.5%). This indicates that Tonga is still far from the 30% agro-forestry/forestry land target, unless agro-forestry on farms is counted toward that goal.

On the other hand, the Ministry of Survey, Planning and Natural Resource's GIS Division provided a statistical summary of the land cover change for Tonga. Total land area accounts to 706.7 km^2 or 174,628.606 acres. The built-up area in 2006 constituted 9,904 acres 2R 21.6P (approximately 5.70%) as compared to the 10,154A 2R 38.3P (approximately 5.80% of residential area plus built-up area extension) in 2025. It implies that approximately 250 Acres are converted into settlement by 2025. The land covers class (19 classes), based on the 2006 topographic layers is summarized as: total woodland (forest) of 67,041,754.148 m^2 (9.49%), total cropland area of 586,220,531.369 m^2 (82.95%). CIA World Factbook reported 12.5% forest cover (2020) and MSPNR reported a 9.49% (2025) (CIA, n.d.).

Agro-forestry is not a new concept in Tonga. In fact, it has long been a traditional practice. A well-known Tongan proverb, "T*akitaha tauhi hono vaha'a ngatae,*" translates to "each landowner must maintain the erythrina (ngatae) trees on his land boundaries." This reflects how trees are considered an integral part

of farmland. Many Tongan farms include coconut palms, fruit trees, or windbreak trees interspersed with crops and pastures. However, data on the extent of these agroforestry systems are limited. Because such tree-covered farms do not meet the conventional definition of a "forest" (which usually excludes land used primarily for agriculture (Ministry of Agriculture, Food, Forestry, and Fisheries, 2017), they often go uncounted in forest statistics. This traditional abundance of on-farm trees suggests that if agro-forestry areas were recognized in national land-use accounting, Tonga might be closer to its 30% tree-cover goal than raw forest percentages indicate.

Several national plans and reports provide context and support for this target:

- The Fourth National report on the review of **NBSAP** highlighted that the agriculture ecosystem recorded a stunning increase in fruit trees to 61% of the total agricultural species, while root crops dropped off to 20%. This trend is attributed to the introduction of improved varieties of fruit trees from North Queensland, Australia.
- The **Management Plan for the Forests and Tree Resources of Tonga** 2017 highlighted that more than 85% of Tonga is covered in trees. Much of which falls outside of the conventional definition of 'forest' used by FAO, that excludes land predominantly used for agriculture.
- The **National Forest Policy** statement on conservation of biodiversity points to; The National Forest Inventory to categorise species and ecosystem biodiversity and highlight areas of rich biodiversity, areas where biodiversity is threatened and priority areas for protection, and the government to provide incentives to encourage landowners to conserve biodiversity.
- One of **TASP**'s key development options is on Natural Resource Conservation. It acknowledged Tonga being fortunate to have fertile soils, which have sustained diverse agricultural production systems for generations. However, some aspects of the country's agriculture resources are under threat and warrant close and immediate attention, such as declining organic matter in soils and, possibly, some nutrient deficiencies.
- **MAFF CP 2021-2023** aimed to improve MAFF's service delivery to be more responsive, accurate and relevant to the agriculture sector. It supports the 4 main programmes of TASP in SO1: and to develop a climate-resilience environment SO2: To improve enabling environment SO3: To develop diverse, climate-resilience farming systems for the Kingdom's Islands

Means 1: Planting 1 million trees by 2023

The "One Million Trees by 2023" campaign has been effectively implemented, meaning Tonga successfully mobilized the planting of one million seedlings nationwide. This achievement contributes significantly to community resilience, particularly through extensive mangrove restoration that strengthens coastal protection and enhances carbon sequestration. However, the overarching goal of achieving 30% of Tonga's land area under forestry or agro-forestry by 2025 has proven difficult to verify and likely remains unmet. The primary challenge is obtaining up-to-date land use data and forest inventory information, which makes it impossible to confidently measure progress toward the 30% land-cover target.

Preliminary evidence also suggests that the composition of the tree-planting effort limited its impact on broad land cover: approximately 91% of the trees planted were mangroves, focused in intertidal coastal zones. While these mangrove plantings are valuable for adaptation, they do not substantially increase inland forestry or agro-forestry coverage. In short, the means of planting one million trees was achieved (delivering many co-benefits), but it did not translate into a verifiable expansion of terrestrial forest cover toward the 30% target due to data gaps and the nature of trees planted.

Table 19: Adaptation Target and Means for AFOLU

NDC 2020 Target	Target Progress Assessment	Means	Means Progress Assessment
30% of land in Tonga utilized for agro-forestry or forestry by 2025	Land-cover percent changes are difficult to accurately determine because the land-cover mapping by the Tongan Government has not been updated since the 2006 assessment.	Planting of 1 million trees by 2023	One million tree planting achieved,

4.1.2 Recommendations for NDC3.0

In light of the findings, it is recommended that Tonga's Third NDC (NDC 3.0) revise its forestry-related adaptation target to be more measurable and attainable under current conditions. The action should focus on absolute gains instead of percentage of land-cover targets. Until a robust forest inventory and land-cover data are available, frame targets in terms of absolute numbers or clearly definable areas. For example, rather than "30% of land in Tonga under agro-forestry," a target could be "Increase national forest cover by X hectares by 2030" or "Plant an additional Y trees by 2030." Such goals can be tracked with the data and tools currently at hand.

Another option would be to shift the goals toward outcomes like expanding forest cover or conserving existing forests, which are more quantifiable with present capabilities. For instance, Tonga could set a target to rehabilitate or reforest X hectares of degraded land and to legally protect Y% of remaining native forests by a certain date. These targets would highlight tangible improvements, such as areas of new forests established or existing forests put under protection, that can be measured using on-ground surveys.

Emphasize Forest Cover Increase and Conservation: Shift the goal toward outcomes like expanding forest cover or conserving existing forests, which are more quantifiable with present capabilities. For instance, Tonga could set a target to rehabilitate or reforest X hectares of degraded land and to legally protect Y% of remaining native forests by a certain date. These targets would highlight tangible improvements – such as areas of new forests established or existing forests put under protection – that can be measured using satellite imagery or on-ground surveys. By focusing on concrete land area increases or conservation status (e.g., hectares under community forestry programs), Tonga can

better demonstrate progress in the forestry sector without relying on an uncertain percentage-of-land metric.

Future tree-planting efforts should broaden their scope to include a diverse range of species and planting locations. The heavy reliance on mangroves in the initial campaign underscored the importance of coastal ecosystems, but NDC 3.0 targets should also encourage planting of terrestrial trees (native hardwoods, fruit trees, agro-forestry species, etc.) across agricultural lands and communities. This diversity will enhance biodiversity, food security, and ecosystem resilience. Additionally, recognize and incorporate urban and peri-urban forestry as part of the solution – for example, setting targets for tree planting in towns, schools, and along streets. Urban eco-forestry efforts (which have already seen thousands of trees planted in school compounds and town areas) contribute to climate resilience by reducing heat, improving air quality, and engaging local communities.

Mangrove planting in Sopu strengthens coastal ecosystems and builds resilience against climate impacts.

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4.2 Coastal protection

4.2.1 Implementation status

Target 2: Prevent any permanent loss of land to rising sea levels on Tonga's four main islands (i.e., Tongatapu, Ha'apai, Vava'u, and 'Eua)

At Nuku'alofa (Tonga's capital), the relative sea level has risen about 22 cm over the past 30 years, and is projected to rise another 15–18 cm in the next 30 years – even under low-emission scenarios. Under a high-emissions pathway (RCP 8.5), sea level around Tonga is projected to rise ~24 ± 5 cm by 2050 and ~80 ± 25 cm by 2100 (World Bank, n.d.). Because 84% of Tonga's population lives within 1 km of the coast (and essentially all Tongans live within 5 km), even modest sea-level rise can disrupt daily life. For example, a 0.3 m rise could inundate about 1.1% of Tongatapu's land area, and a 1 m rise may claim 3.9% of its land – displacing up to 9,000 people (≈14% of Tongatapu's population) (Australia Pacific Climate Partnership Support Unit, 2021). These projections underline how quickly sea-level rise can translate into permanent land loss and human displacement in Tonga.

Coastal flooding is already a reality in low-lying neighborhoods like Popua and Sopu. In Sopu, coastal wetlands still provide a natural buffer against high tides – attenuating tidal heights by roughly 30 cm – but this protection is weakening as seas rise. By around 2090, many low-lying parts of Nuku'alofa are expected to be permanently inundated at each high tide, which could force the abandonment of entire residential areas (Asian Development Bank, 2019). In short, sea-level rise is no longer a distant threat; it is a present and steadily intensifying reality for Tonga's coastal communities.

Beyond the outright loss of land, rising seas have secondary effects that undermine habitability. Higher sea levels elevate coastal water tables, causing saltwater to intrude into groundwater and soils. This leads to waterlogged septic systems, blocked drainage, and saline contamination of drinking water and farmland. Saltwater infiltration is increasing soil salinity, rendering once-fertile lands unsuitable for staple crops like taro and yams. Experimental data show that even moderate salt levels can sharply reduce crop yields (Myrans et al., 2024). These findings indicate that as salt intrudes farther inland, Tonga's food crops will suffer major losses in productivity.

The eruption of Hunga Tonga–Hunga Ha'apai in January 2022, followed by a tsunami, dramatically worsened soil conditions. A post-eruption soil assessment by CSIRO found that tsunami-affected soils on Tongatapu showed "significant increases in both soil salinity and sodicity," exceeding crop tolerance thresholds, along with spikes in chloride content (International Fund for Agricultural Development, 2022). (Notably, the volcanic ash itself did not cause lasting soil damage; the primary issue was salt water inundation.) In parallel, chronic climate stressors – shifting rainfall patterns, more intense droughts, and higher temperatures – are accelerating soil degradation and acidification across Tonga and other Pacific Islands (e.g. loss of nutrients, organic matter, and increased acidity in topsoils). These trends shrink the area of arable land, put further pressure on the remaining fertile plots, and allow pollutants to leach into freshwater and coastal waters, harming fisheries and coral

reefs as well. Ultimately, declining land productivity due to salinization and erosion directly threatens Tonga's food security and livelihoods, potentially increasing poverty and inequality.

Tonga has already undertaken several initiatives to combat coastal land loss. The "One Million Trees" Initiative (2020–2023) aimed to restore coastal vegetation, and indeed the vast majority of the planted trees were mangroves. Healthy mangrove forests can stabilize shorelines and buffer against waves, so this campaign likely improved resilience to sea-level rise in some areas. However, *the impact is hard to quantify* without updated data on the extent of mangrove cover and on the actual rate of coastal land loss, it is difficult to measure how much land (if any) has been saved by these efforts. In Sopu, for example, the natural wetland buffer is still present but may be shrinking. Establishing robust monitoring of shoreline change and mangrove health is an identified need going forward.

Beyond tree-planting, Tonga is pursuing policy and partnership-based adaptations. Notably, the government set up the Tonga Climate Change Fund, first conceived in 2011 and legally established by the Climate Change Fund Act of 2021. This fund channels international climate finance (from partners such as New Zealand, Japan, Australia, and the UK) directly into local adaptation and resilience projects (Pedro, 2025). The focus is on supporting vulnerable communities – especially in the outer islands – with projects that improve water and food security and protect coastlines. By 2023, Tonga also formulated a National Adaptation Plan aligned with its climate targets, and opened calls for community-led adaptation proposals, signaling a "grassroots" approach to resilience

Target 3: Maintenance of the existing stocks of fish and other marine species (Expansion of MPAs and SMAs to 30% of Tonga's EEZ)

On paper, Tonga has achieved its goal of 30% of the EEZ covered by marine protected areas (MPAs) or special management areas (SMAs). As of 2025, there are 64 SMAs in Tonga, which is up from 46 in 2019.

Sea-level rise, warming ocean temperatures and acidification of surrounding waters further damage coral reefs and nearshore ecosystems. These stressors are projected to reduce productivity of demersal fish by up to 50%, and intertidal invertebrates by 5–10%, by 2100 under current emission scenarios (Green Climate Fund, 2020). In addition, the socioeconomic implications of these trends are profound. Around 85% of Tongans depend directly on agriculture and fishing for their livelihoods, and approximately half of all households depend on fishing as a primary or secondary source of income (Green Climate Fund, 2020).

The degradation of land and soil is also directly linked to the deterioration of coastal ecosystems and fisheries, which are vitally important to Tongan society. Although the fishery sector accounts for only 2.1 % of national GDP (Tonga Statistics Department, n.d.), its social value is far greater. Tonga ranks as the 10th most vulnerable country in the world in terms of climate risks to its fisheries and is the 7th most exposed country to sea-level rise for fishers (Heck et al., 2020). Coastal land loss reduces natural marine buffers such as mangroves, and the destruction of these areas leads to degradation of key fish breeding and nursery habitats (zu Ermgassen et al., 2025).

In short, sea-level rise, land acidification and fisheries decline in Tonga are not isolated phenomena,

but mutually reinforcing processes that threaten national livelihoods, food security and cultural continuity. Land loss accelerates environmental degradation and leads to soil contamination, which then undermines coastal ecosystems and reduces fish quality and quantity. If left unaddressed, these dynamics will continue to increase displacement risks and deepen the social, economic and cultural impacts of climate change across the country.

The Green Climate Fund-backed project "Towards climate change resilient coastal fisheries and aquaculture in Tonga" seeks to strengthen community-based fisheries management and enhance resilience through to 2027 by expanding Special Management Areas (SMAs) and building community capacity for the sustainable management of coastal resources (Green Climate Fund, 2020).

Table 20: Adaptation Targets and Means for Coastal Protection

NDC 2020 Target	Target Progress Assessment	Means	Means Progress Assessment
Prevent any permanent loss of land to rising sea levels on Tonga's four main islands	• In progress but at risk. • A sea level rise of 0.22m was recorded on the Nuku'alofa tidal gauge over the period 1993-2024, and a further 0.18m rise is expected in the following 30 years. • Data on loss of land is unavailable.	Expansion of MPAs and SMAs to 30% of Tonga's EEZ	• The number of SMAs has increased from 46 in 2019 to 64 in 2025. • The combined area for MPAs/SMAs is small at an estimated size of 385.71 km^2 or only 0.06% Protected. Means in progress
Maintenance of the existing stocks of fish and other marine species	In progress but at risk		

4.2.2 Recommendations for NDC 3.0

To strengthen Tonga's next NDC with respect to this adaptation target, we propose the following recommendations:

- **Scale Up Coastal Protection and Nature-Based Solutions:** Commit to an expanded program of mangrove restoration, coral reef conservation, and engineered defenses in critical erosion hotspots. This could include building or upgrading seawalls in population centers alongside restoring mangroves and wetlands in surrounding areas. A hybrid approach can dissipate wave energy (via reefs and mangroves) and shield high-value infrastructure (via seawalls or revetments). NDC 3.0 should set a measurable target for shoreline stabilization, for example:

X kilometers of coast reinforced with nature-based or hybrid defenses by 2030This will help prevent further permanent land loss on the main islands.

- **Promote Climate-Resilient Agriculture and Soil Management:** To combat the creeping salinization of soils, Tonga should pledge support for salt-tolerant crops, improved irrigation, and soil remediation in coastal farmlands. NDC 3.0 can include programs to introduce crop varieties and farming techniques that withstand higher salinity (e.g. salt-resistant taro or cassava strains), rainwater harvesting for irrigation to flush salts, and community training on soil conservation. A concrete target might be to pilot salt-resistant crop cultivation in at least 3 high-salinity districts by 2025, scaling up successful practices nationwide by 2030. This will maintain livelihoods and food security on lands that might otherwise be lost to rising seas. In parallel, water security must be strengthened as a complementary priority. Building on the National Water Tank Program, Tonga should aim for 100% household coverage to ensure access to safe rainwater for drinking and sanitation, particularly in outer islands where stored rainwater is also critical for farming and daily needs.

Seawalls in Manuka shield coastal land from rising seas, supporting Tonga's goal to prevent permanent land loss.
© Department of Climate Change, MEIDECC 2021

5. Retrospective analysis of the overall ambition and gaps in the NDC 2020

To inform the preparation of Tonga's NDC 3.0, this assessment reviews the strengths and areas for improvement within the country's current NDC (Kingdom of Tonga, 2020), with particular attention to the energy and IPPU sectors. Guided by the UNDP Quality Assurance Checklist for NDC 3.0 (United Nations Development Programme, 2025), the analysis considers five core dimensions: national ownership and inclusivity, ambition, just transition and sustainable development, clarity and transparency, and overall feasibility (refer to Figure 7). The review assesses sectoral targets, institutional arrangements, financing mechanisms, stakeholder participation processes, and coherence with international requirements, including the *Paris Agreement*'s Enhanced Transparency Framework (ETF) and outcomes of the Global Stocktake (GST).

Figure 7: Core Dimensions of Quality Assurance for NDC 3.0 (UNDP, 2025)

Enhancing country ownership and inclusivity
Political and societal stakeholders at all levels are meaningfully engaged and the outcomes of these engagements, along with the roles, needs, and priorities of these stakeholders, are fully integrated into NDCs.

Enhancing ambition
NDC aims for the highest possible ambition for mitigation and adaptation, reflect the Global Stocktake outcomes, is aligned with 1.5°C pathways, and reflect countries' common but differentiated responsibilities and respective capabilities.

Including just transition and sustainable development
NDC delivers sustainable development priorities, aligned with the 2030 Agenda on Sustainable Development, and include social justice and equity considerations that leave no one behind.

Enhancing clarity and transparency
The clarity, transparency and understanding of NDC, cross-cutting issues, and enabling actions are informed by robust, credible methodologies using the latest and best available science.

Feasibility
Key enabling conditions and needs for accelerating implementation of NDCs are described, i.e., finance mobilization, technology transfer and institutional capacity-building.

The sections that follow present Tonga's current approaches under each dimension and highlight opportunities for improvement that can strengthen NDC 3.0 in a coherent, inclusive, and actionable way.

5.1 Country Ownership & Inclusivity

Strong NDCs are rooted in broad-based participation across government institutions, civil society, communities, and the private sector. This dimension assesses the extent to which NDC 2.0 reflects a whole-of-government and whole-of-society process, ensuring that perspectives from ministries, subnational authorities, women's groups, youth, vulnerable populations, and private sector actors are transparently integrated into targets and measures. Genuine inclusivity not only reinforces domestic legitimacy but also enhances prospects for effective and equitable implementation.

Current Status

Tonga's NDC 2.0 was developed under the leadership of the Department of Climate Change within MEIDECC, with technical support from the Pacific NDC Hub partners and GGGI, and contributions from the Joint National Action Plan (JNAP) Technical Team. The formulation process of NDC 2.0 involved broad national consultations with government, private sector, and NGO representatives, including a stakeholder validation workshop with approximately 25 women and 20 men, followed by final inter-ministerial agreement and Cabinet approval. The NDC details engagement with civil society representatives and includes a commitment to consider gender, income, and age factors in developing the NDC. These efforts demonstrate clear national ownership, alignment with existing national frameworks, and a foundational level of inclusivity, albeit largely at a high level.

Areas for Enhancement

- **Specify sub-national engagement:** Clarify engagement with subnational authorities (island, municipal, village levels), detailing their participation and influence on the NDC.
- **Address gaps in stakeholder involvement:** Document involvement—or absence—of academia, youth, indigenous groups, local communities, and other vulnerable or marginalized populations (currently unaddressed).
- **Operationalize inclusion:** Translate broad statements on social inclusion into specific, resourced measures and targets, such as gender-transformative initiatives within mitigation and adaptation measures.
- **Define private sector roles:** Detail sector-specific private sector responsibilities and engagement mechanisms beyond workshop attendance.
- **Integrate targeted education/awareness actions:** Include time-bound activities to support NDC uptake, like coastal risk communication campaigns.

5.2 Ambition

Ambition is evaluated in terms of how well NDC 2.0 advances beyond previous commitments, aligns with a 1.5°C trajectory, and incorporates lessons from the first GST. This dimension examines whether the mitigation and adaptation targets are comprehensive, measurable, and science-based, covering key sectors and gases, while strengthening unconditional components. Ambition is defined not only by numerical targets but also by the credibility of underlying policies and long-term consistency with pathways toward decarbonization and resilience.

Mitigation

Tonga's NDC 2.0 advances from intent to quantification within the mitigation pillar by establishing an absolute energy-sector target of a 13% (16 Gg) reduction in GHG emissions by 2030 relative to 2006. It complements this with non-GHG sectoral targets in AFOLU and waste, previously absent from the Intended Nationally Determined Contribution (Kingdom of Tonga, 2015). The NDC broadens its scope to reference IPPU, AFOLU, and waste sectors, and signals new policy directions including minimum energy performance standards, vehicle standards, and pricing incentives. The implementation window is clearly defined as 2021–2030, with energy-sector measures aligning with Tonga's broader long-term decarbonization strategy.

Areas for Enhancement

- **State 1.5 °C alignment and methodology:** Include a concise 1.5 °C compatibility statement, referencing recognized approaches (e.g., IPCC AR6 ranges) to substantiate alignment.
- **Show pathway transparency:** Provide an indicative emissions trajectory and cumulative carbon budget to 2030, distinguishing between unconditional and conditional contributions.
- **Complete gas coverage:** Extend the scope beyond CO_2, CH_4, and N_2O to include a timeline and plan for inventorying and incorporating fluorinated gases (HFCs, PFCs, SF_6, NF_3).
- **Enhance sectoral details:** For transport, buildings, and IPPU, clearly specify source and sink categories addressed, accompanied by indicative mitigation impacts.
- **Prepare policy enforcement:** Translate announced measures (Minimum Energy Performance Standards (MEPS), vehicle standards, pricing incentives) into enforceable policies by adding scope, start dates, compliance mechanisms, and estimated emission reductions to demonstrate implementation readiness.
- **Harmonize transparency framework:** Commit to an ETF-ready monitoring framework detailing indicators, baselines, methodologies, reporting frequency, data sources, and responsible agencies to consistently track sectoral progress.

Adaptation

Tonga's 2020 NDC adaptation section marks a clear progression from the broadly framed INDC to structured, measurable targets with defined actions (Kingdom of Tonga, 2015). It sets quantifiable goals such as 30% of Tonga's landmass utilized for agro-forestry or forestry by 2025, and expanding Marine Protected Areas (MPAs) and Special Management Areas (SMAs) to 30% of the Exclusive Economic Zone (EEZ). Concrete actions include planting one million trees by 2023 and establishing local SMA regimes as support measures. These targets are directly anchored in Tonga's Joint National Action Plan 2 on Climate Change and Disaster Risk Management (JNAP 2), showing policy coherence, while the NDC also incorporates updated, comprehensive climate risk and impact assessments, applicable across the nation's main island groups and the maritime EEZ. Overall, the NDC adaptation component reflects a significant shift to clearer objectives and sectoral focus on forestry, coastal and marine ecosystems, and land use.

Areas for Enhancement

- **Extend adaptation milestones:** Develop and publicly commit to a timeline extending key adaptation milestones from 2025 through 2030 and 2035, incorporating intermediate quantified indicators aligned with Tonga's emerging NDC-3.0 long-term horizon and the Long-Term Low Emission Development Strategy (LT-LEDS).
- **Map adaptation targets to global frameworks:** Prepare a mapping matrix that connects each adaptation target with the dimensions and thematic areas of the framework for the UNFCCC's Global Goal on Adaptation (UNFCCC, 2024)—known as the UAE Framework for Global Climate Resilience (UNFCCC, 2024).
- **Establish adaptation M&E framework:** Design and adopt a comprehensive adaptation Monitoring & Evaluation (M&E) framework that specifies measurable indicators, baseline years and values, data collection methodologies, review frequency, and assigns responsible institutions; include provisions for annual public reporting on adaptation progress to enhance transparency and accountability.
- **Report adaptation progress:** Summarize and publish a result table documenting progress since the INDC, featuring key delivery indicators SMAs.
- **Specify resource requirements:** Explicitly state indicative resource needs per adaptation target, including financial cost ranges, human resource capacities, data and monitoring equipment requirements, to enhance planning feasibility and support effective donor and domestic budgeting.
- **Integrate social inclusion:** Strengthen social inclusion in adaptation targets and actions by specifying approaches to address the needs of vulnerable communities, particularly in interventions related to coastal safety, early warning systems, and ecosystem management.
- **Schedule evidence-based updates:** Define a clear schedule for periodic updates of the climate risk and vulnerability evidence base, such as refreshing vulnerability assessments like those in the NDC 2.0, and describe triggers from new science and the ongoing GST that would prompt adjustments to adaptation targets and measures.

5.3 Just Transition and Sustainable Development

Climate action should create opportunities for inclusive growth while ensuring social equity. Just Transition and Sustainable Development evaluates how effectively NDC 2.0 incorporates the principles of a just transition by linking climate commitments to national development goals, poverty reduction strategies, gender equality, and the Sustainable Development Goals (SDGs). Additionally, it examines whether policies address potential distributional impacts and promote conditions for green jobs, skills development, and the protection of vulnerable groups, ensuring that no one is left behind during the transition.

Current Status

Tonga's 2020 NDC clearly aligns with key national policies, including the Tonga Strategic Development Framework (TSDF II), Tonga Energy Road Map, the Energy Efficiency Master Plan, the National Forestry Policy, and JNAP 2, demonstrating strong policy coherence. The NDC was developed through inclusive multi-stakeholder and cross-ministerial consultations with explicit gender, income, and age considerations integrated into the stakeholder engagement processes. These procedural features reflect a committed intention towards inclusive outcomes. However, the original NDC document contains limited detail on socio-economic, distributional, and gender-specific impacts, which are comprehensively addressed in the 2022 NDC Implementation Roadmap and Investment Plan (NDC IR & IP).

Areas for Enhancement

- **Summarise socio-economic impacts inside the NDC:** Include a concise summary box in the NDC detailing projected jobs, livelihoods, and distributional effects of priority projects drawn from the NDC IR & IP project fiches.
- **Add an SDG alignment table:** Add a table in the NDC mapping targets and measures to corresponding SDG targets consistent with IR & IP tagging.
- **State links to biodiversity and land commitments:** Explicitly integrate forestry and 30% MPA/SMA commitments with the National Biodiversity Strategy and Action Plan (Kingdom of Tonga, 2021) and the voluntary Land Degradation Neutrality Targets under the United Nations Convention to Combat Desertification (UNCCD/LDN) objectives (UNCCD, 2025).
- **Specify measures for vulnerable and underrepresented groups:** Strengthen explicit inclusion and measurable indicators for vulnerable groups.
- **Track what matters:** Incorporate Just Transition and social development indicators such as green jobs created, workers reskilled, women and youth beneficiaries, and SMA co-management participation into the M&E framework with a defined reporting cadence.

5.4 Clarity and Transparency

Clear and transparent communication underpins the credibility and accountability of NDCs. This dimension reviews whether NDC provides sufficient detail on targets, assumptions, methodologies, and institutional arrangements in line with the ETF. It also assesses the presence of monitoring and evaluation systems, data quality assurance, and reporting mechanisms that enable stakeholders to track progress, understand trade-offs, and link climate action to broader development and human rights indicators.

Current Status

Tonga's NDC 2.0 establishes a clear implementation timeframe (2021–2030) and includes structured ICTU elements such as base year, target types, gases, and recognized use of IPCC 2006 guidelines for greenhouse gas estimation. Although the NDC itself does not define a national transparency system, the 2022 NDC IR & IP introduces a foundational M&E framework with designated executors for priority actions, complemented by a brief M&E section within Tonga's LT-LEDS. Together, these constitute a basic platform to progress toward an ETF-compliant transparency infrastructure, notwithstanding that comprehensive system design elements, support-tracking mechanisms for finance, technology, and capacity, data quality assurance and quality control (QA/QC) procedures, and clear NDC emission trajectory presentations remain undeveloped or partial within the current NDC and IR & IP documents.

Areas for Enhancement

- **Provide a concise overview of the national transparency system in the NDC:** Concisely describe the institutional arrangements, data architecture, reporting schedules, and data stewardship roles within the NDC and related documents.
- **Adopt an ETF-compliant master monitoring table across NDC and IR & IP:** Develop a comprehensive monitoring table aligned with ETF guidance, covering indicators, baselines, methodologies, data collection frequency, sources, and agency responsibilities, and replace current executor-centric tables in the IR & IP. This should align templates to ETF Modalities, Procedures, and Guidelines (MPGs) and the BTR schedule.
- **Expand the ICTU annex to full coverage:** Fully disclose fairness and ambition rationales, distinguish conditional versus unconditional NDC components, detail assumptions underpinning targets, and explicitly link to mechanisms for tracing international support.
- **Introduce an adaptation M&E table aligned to the UAE Framework:** Incorporate a dedicated monitoring and evaluation table for adaptation aligned with the UAE Framework standards. This should include robust quantitative and qualitative indicators, defined baselines, and scheduled review cycles, focused on coastal resilience, forestry, and marine targets.

- **Insert a QA/QC plan and technical review provisions:** Define a detailed quality assurance and quality control plan specifying formal processes, responsible institutional units, and validation steps for inventories, sectoral datasets, and modelling tools.
- **Clarify institutional and legal anchors for transparency:** Thoroughly articulate the institutional and legislative foundations for transparency, naming core entities such as the Department of Climate Change (DCC), sectoral focal points, and the Tonga Statistics Department (TSD). Reference relevant enabling laws, including the Climate Change Fund Act, and cement commitment to issuing annual public NDC progress reports.
- **Note intent to pilot voluntary loss-and-damage reporting:** Consider piloting voluntary loss-and-damage reporting linked with national disaster-loss databases, supported by streamlined reporting templates, to enhance transparency around climate impacts.

5.5 Feasibility

Ambitious commitments must be supported by realistic implementation pathways. This dimension evaluates whether NDC 2.0 identifies financing strategies, investment frameworks, and institutional capacities necessary for execution. It considers the mobilization of domestic and international resources, readiness to engage with carbon markets, and measures to reduce investor risks. Additionally, Feasibility entails establishing robust institutional coordination mechanisms and addressing legislative, policy, and technology gaps to ensure that commitments are both actionable and deliverable.

Current Status

The 2020 NDC and the NDC IR & IP collectively provide a comprehensive and workable delivery framework for Tonga's climate ambition. The NDC designates MEIDECC's Department of Climate Change (DCC) as the lead agency, establishes the implementation period (2021–2030), and clarifies the policy stance of non-participation in voluntary cooperation under Article 6 of the Paris Agreement. The IR & IP operationalizes this by providing fully costed mitigation and adaptation project pipelines with indicative investment needs, a detailed financing narrative mapping domestic public, private, and international sources (including the Tonga Climate Change Fund), identification of key fiscal and structural barriers, institutional actors, realistic timelines, and capacity requirements. It further identifies crucial policy and regulatory gaps with proposed reforms and, together with the LT-LEDS, outlines critical technology needs and the relevant legal and governance frameworks. Key implementation roles—NDC M&E Officer, sector focal points, project executors—and their interlinkages with existing disaster risk management and climate bodies are mapped with reporting lines, enabling clear accountability and coordination.

Areas for Enhancement

- **Insert a cost & investment summary in the NDC:** Include total needs for mitigation and adaptation to 2030 with an unconditional/conditional split in the NDC, sourced from the IR & IP.
- **Summarise the financing pathway in the NDC:** Specify how domestic public budgets, domestic private capital (IPP/PPP), international public finance, and international private/FDI will be mobilised, and by whom.
- **Clarify how the Tonga Climate Change Fund will operate and track support:** Describe eligibility and co-finance rules, and state that it will maintain annual finance/technology/capacity-building ledge

Annexure

Methodology for Calculating CAGR

Methodology for Forecasts to 2030

Methodology for Calculating GHG Emissions Reduction – Phase 1

Methodology for Calculating GHG Emissions Reduction – Phase 2

Methodology for Calculating GHG Emissions Reduction – Phase 3

Methodology — Structural & Regulatory Measures

Methodology — Demand-Side and Behavioural Measures

Methodology — Technology and Fuel Switching

Methodology — Maritime Transport Efficiency through Low-Carbon Technologies

Methodology for Calculating CAGR

Objective

The purpose of this method is to project Tonga's electricity generation under a business-as-usual (BAU) pathway and to model the required pathway to reach 70% renewable electricity by 2030. The approach uses the compound annual growth rate (CAGR) to extend historical generation data into the future, a standard technique widely applied in international energy forecasting.

Formula for CAGR

The general formula for CAGR is:

$$CAGR = \left(\frac{\text{Ending Value}}{\text{Starting Value}}\right)^{\frac{1}{\text{Years}}} - 1$$

Where:

- Starting Value = generation in the base year
- Ending Value = generation in the final year of the historical period
- Years = number of years between starting and ending year

Historical CAGR calculations

Variables

- Gt: Total annual generation in year t (kWh)
- RE_t: Renewable generation in year t (kWh)
- t_0: base year of the historical window
- t_1: final year of the historical window
- $n=t_1-t_0$: number of elapsed years
- CAGR: compound annual growth rate over $[t_0,t_1]$

Formula

$$CAGR = \left(\frac{\text{Ending Value}}{\text{Starting Value}}\right)^{\frac{1}{n}} - 1$$

Total (system) CAGR, 2012 to 2023

- Starting value G2012= 52,381,464 kWh
- Ending value G2023= 96,037,927 kWh
- Years n=11

$$\text{CAGR}_{\text{Total}} = \left(\frac{96{,}037{,}927}{52{,}381{,}464}\right)^{\frac{1}{11}} - 1 = (1.8338)^{0.0909} - 1 \approx 0.05665 = \mathbf{5.665\%/yr}$$

Renewable CAGR, 2013 to 2023

- Starting value RE_{2013} =2,174,578 kWh
- Ending value RE_{2023}= 13,718,332 kWh
- Years n=10

$$\mathrm{CAGR_{RE}} = \left(\frac{13{,}718{,}332}{2{,}174{,}578}\right)^{\frac{1}{10}} - 1 = (6.309)^{0.1} - 1 \approx 0.20224 = \mathbf{20.224\%/yr}$$

These CGARs anchor the BAU forward projections.

Methodology for Forecasts to 2030

Objective

To project **business-as-usual (BAU)** electricity generation and renewable energy (RE) share to 2030, using a compound annual growth rate (CAGR) method. This provides a baseline against which the **70% RE by 2030** target can be measured.

A. BAU Projections to 2030

Variables for forecasting

- Base year 2023
- G_{2023}=96,037,927 kWh
- RE_{2023}=13,718,332 kWh
- r_G = $CAGR_{Total}$ =5.665%
- r_{RE}=$CAGR^{RE}$ =20.224%
- Δt=t−2023 (years after 2023)

Standard projection formula

$$G_t = G_{2023}(1 + r_G)^{\Delta t}$$

$$RE_t^{B,AU} = RE_{2023}^{B,AU}(1 + r_{RE})^{\Delta t}$$

Worked example (2030): $\Delta t = 7$

$$G_{2030} = 96,037,927 \times (1.05665)^7 = 96,037,927 \times 1.4705 = \mathbf{141{,}245{,}670\ kWh}\ (\approx 141.25\ \mathrm{GWh})$$

$$RE_{2030}^{B,AU} = 13,718,332 \times (1.20224)^7 = 13,718,332 \times 3.6312 = \mathbf{49{,}802{,}338\ kWh}\ (\approx 49.80\ \mathrm{GWh})$$

$$\mathrm{RE\ Share}_{2030}^{B,AU} = \frac{49{,}802{,}338}{141{,}245{,}670} = \mathbf{35.3\%}$$

B. 70% RE Projections to 2030

We keep total demand equal to the BAU value (comparability), but force RE share to 70% in 2030.

(i) 2030 targets

$$RE_{2030}^{Target} = 0.70 \times G_{2030} = 0.70 \times 141,245,670 = \mathbf{98{,}871{,}969\ kWh}$$

$$Diesel_{2030}^{Target} = 0.30 \times G_{2030} = \mathbf{42{,}373{,}701\ kWh}$$

(ii) Gap to close

$$\Delta RE_{2030} = RE_{2030}^{Target} - RE_{2030}^{B,AU} = 98,871,969 - 49,802,338 = \mathbf{49{,}069{,}631\ kWh}\ (\approx 49.07\ \mathrm{GWh})$$

C. Pathways Projections

(i) Exponential path

We solve for a constant annual factor f that grows RE_{2003} to RE^{Target}_{2003} over 7 years

$$f = \left(\frac{RE_{2030}^{Target}}{RE_{2023}}\right)^{\frac{1}{7}} = \left(\frac{98{,}871{,}969}{13{,}718{,}332}\right)^{\frac{1}{7}} = \mathbf{1.3259857}$$

Yearly target:

$$RE_t^{Target} = RE_{2023} f^{\Delta t}$$

Examples

2024 (Δt=1): 13,718,332 × 1.3259857 = 18,190,31213 kWh

2027(Δt=4): 13,718,332 × 1.32598574 = 42,408,86713 kWh

2030 (Δt=7): 98,871,969 kWh (by construction)

Diesel each year remains:

$$\mathrm{Diesel}_t = G_t - RE_t^{Target}$$

(ii) Linear path

Evenly add the same increment each year:

$$\text{Annual increment} = \frac{RE_{2030}^{Target} - RE_{2023}}{7} = \frac{98{,}871{,}969 - 13{,}718{,}332}{7} = \mathbf{12{,}164{,}805.29\ kWh/yr}$$

$$RE_t^{Target} = RE_{2023} + (\text{increment}) \times \Delta t$$

Methodology for Calculating GHG Emissions Reduction – Phase 1

Objective

Phase 1 focuses on grid reinforcement and system-readiness measures to remove bottlenecks and allow existing "in-train" renewable projects to be absorbed. These do not build new RE plants themselves but unlock the ability to utilise more renewable energy (RE) without curtailment.

The methodology estimates:

1. The **additional renewable generation (GWh)** enabled by each measure by 2030.
2. The **avoided GHG emissions (Gg)** by displacing diesel generation, using Tonga's grid emission factor.

Emission Factor (EF)

The emission factor represents the amount of CO_2-equivalent emissions avoided for each unit of renewable electricity that displaces diesel generation on Tonga's grid.

- Reported by the Department of Energy (DOE) to the UNFCCC:
  EF = 0.127 Gg/GWh (equivalent to 127 tCO_2e per GWh).
- Interpretation: for every 1 GWh of renewable electricity effectively utilised, Tonga avoids 0.127 Gg of CO_2e emissions from diesel combustion.

Conversion Logic

The avoided GHG is derived from the displaced diesel electricity, based on the grid emission factor:

$$\text{Avoided GHG (Gg)} = \text{Additional RE (GWh)} \times \text{Emission Factor (Gg/GWh)}$$

where:

- **Added RE (GWh)** is the incremental renewable energy enabled by the measure, accounting for reduced curtailment, improved hosting capacity, and operational readiness.
- **EF = 0.127 Gg/GWh** (as explained above)

Calculation

Phase	Initiative	Added RE by 2030 (GWh)	Formula	Avoided GHG (Gg)
1.1	NNUP Areas 4 & 5	1,100,711	7 × 0.127	0.9
1.2	33 kV grid strengthening	12,074	6 × 0.127	0.8
1.3	SCADA/EMS/DERMS	2,523	5 × 0.127	0.6
1.4	Smart meter rollout	3,431	3 × 0.127	0.4
1.5	Operate 4×BESS to spec	402	6 × 0.127	0.8
1.6	Enforce siting rules	495	4 × 0.127	0.5
Total Phase 1 impact		**31**	**31 × 0.127**	**4.0**

Methodology for Calculating GHG Emissions Reduction – Phase 2

Objectives

Quantify the additional renewable electricity effectively utilised by 2030 that is marginal to Phase 1 (i.e., extra GWh enabled only after the Phase 1 backbone/controls are in place). Convert those marginal GWh to avoided GHG emissions (Gg) using Tonga's nationally reported grid emission factor.

Emission Factor (EF)

- National reporting (DOE/UNFCCC) uses a diesel-grid emission factor of EF = 0.127 Gg/GWh (i.e., 127 tCO_2e per GWh).
- Interpretation: every 1 GWh of additional, effectively utilised RE that displaces diesel avoids 0.127 Gg CO_2e.

Conversion Logic

$$\text{Avoided GHG (Gg)} = \text{Additional RE (GWh)} \times \text{Emission Factor (Gg/GWh)}$$

where:

- Added RE is the effectively utilised renewable energy by 2030 (after curtailment), over and above what Phase 1 alone would deliver.
- No-energy devices (fast-acting capacitors, synchronous condenser) have 0 GWh and therefore 0 Gg; they are enabling/stability investments.

Calculation

Initiative	Added RE effectively utilised by 2030 (GWh)	Formula	Avoided GHG 2030 (Gg)
TPL RFT Tranche A	18.0	18.0 × 0.127	2.29
Storage add-on (BESS)	4.0	4.0 × 0.127	0.51
"Gap-closer" PV/wind	8.5	8.5 × 0.127	1.08
Fast-acting capacitors	0	0 × 0.127	0.00
Synchronous condenser	0	0 × 0.127	0.00
Total Phase 2 impact	**30.5**	**30.5 × 0.127**	**3.87**

Methodology for Calculating GHG Emissions Reduction – Phase 3

Objective

Quantify the additional, effectively-utilised energy (GWh) delivered by Phase-3 measures beyond Phases 1–2; 2) convert those GWh to avoided GHG (Gg CO_2e) using Tonga's nationally reported grid factor; 3) provide a 2035 check as measures mature.

Emission Factor (EF)

- National reporting (DOE/UNFCCC): EF = 0.127 Gg/GWh (i.e., 127 tCO_2e per GWh of diesel electricity displaced).
- Use: every 1 GWh of additional usable RE/efficiency that substitutes diesel avoids 0.127 Gg

Conversion Logic

$$\text{Avoided GHG (Gg)} = \text{Additional RE (GWh)} \times \text{Emission Factor (Gg/GWh)}$$

where:

- Added RE is the effectively utilised renewable energy by 2030 (after curtailment), over and above what Phase 1 alone would deliver.
- Devices that only provide stability (no net energy) would have 0 GWh → 0 Gg; all entries below have explicit GWh

Calculation

Initiative	Added RE/efficiency effectively utilised by 2030 (GWh)	Formula	Avoided GHG 2030 (Gg)
TPL RFT Tranche B (if required)	6.0	6.0 × 0.127	0.76
Additional BESS	3.0	3.0 × 0.127	0.38
Full smart-grid features (DR, managed EV charging)	2.0	2.0 × 0.127	0.25
Loss-reduction programmes (<8%)	1.0	1.0 × 0.127	0.13
Firm-renewable pilots (biofuel/ biogas/WtE)	1.0	1.0 × 0.127	0.13
Total Phase 3 (2030)	**13.0**	**13.0 × 0.127**	**1.65**

Methodology — Structural & Regulatory Measures

Objective

Quantify annual GHG reductions (Gg CO_2e) in the road-transport sector from:

- **MIQAP** (Motor Industry Quality Assurance Programme): efficiency gains in incoming vehicles.
- **Euro-V + I&M**: cleaner vehicle & fuel standards plus inspection & maintenance.

Compute results for **2030** and **2035** under two implementation pathways:

- **Scenario A** (on-time): measures start 2025.
- **Scenario B** (delayed): measures start 2027.

Variables & Definitions

- E_{2021}: Transport GHG baseline in 2021 (Gg).
- *g*: BAU annual growth rate of transport GHG (fraction/yr).
- *t*: Target year (2030, 2035).
- E_t^{BAU}: BAU transport GHG in year t (Gg).
- ^{r}road: Share of road transport in total transport GHG.
- f_{MI} : Applicability factor for MIQAP—share of road emissions affected (km-weighted).
- f_{Euro} : Applicability factor for Euro-V—share of road emissions under standards.
- ^{n}A,^{n}B: Years of effective implementation by 2030 (A: 2025–2030 = 5; B: 2027–2030 = 3).
- rMI : Annual efficiency improvement rate under MIQAP (= 2.4% = 0.024).
- ^{E}MI(n): Cumulative MIQAP efficiency after n years:
- β_{Euro}(t): Realised Euro-V benefit fraction by year t (ramps to full by 2035).

Establish the BAU Baseline

Use TERMPLUS baseline and BAU growth:

- E_{2021}=130.45 Gg
- g≈ 2% per year

$$E_t^{BAU} = E_{2021} \times (1+g)^{(t-2021)}$$

Assume road share ^{r}road:= 97.3%

- $E_{2030road}$= 155.90 × 0.973 ≈ 151.60 Gg
- $E_{2035road}$= 172.13 × 0.973 ≈ 167.47 Gg

Savings Equations

1. **MIQAP – Scenario A (On time)**

Affected base in year

$$t : E_t^{\mathrm{MI}} = E_t^{\mathrm{road}} \times f_{\mathrm{MI}}$$

Cumulative efficiency (Scenario A/B):

$$\epsilon_{\mathrm{MI}}(n_A) = 1 - (1 - 0.024)^5 = 0.1144, \epsilon_{\mathrm{MI}}(n_B) = 1 - (1 - 0.024)^3 = 0.0703$$

$$E_{2030}^{\mathrm{MI}} = 151.60 \times 0.70 = \mathbf{106.12\ Gg}$$

$$S_{\mathrm{MI}}^{A/B}(t) = E_t^{\mathrm{MI}} \times \epsilon_{\mathrm{MI}}(n_{A/B}) \times c_{\mathrm{MI}}^{A/B}(t)$$

$$S_{\mathrm{MI}}^{A}(2030) = 106.12 \times 0.1144 \times 0.74 \approx \mathbf{8.86\ Gg}$$

2. **Euro-V – Scenario A (on-time)**

$$E_{2030}^{\mathrm{Euro}} = 151.60 \times 0.90 = 136.44\ \mathrm{Gg}$$

$$S_{\mathrm{Euro}}^{A}(2030) = 136.44 \times 0.039 \times 0.285 \approx \mathbf{5.91\ Gg}$$

3. **MIQAP – Scenario B (delayed)**

$$S_{\mathrm{MI}}^{B}(2030) = 106.12 \times 0.0703 \times 0.89 \approx \mathbf{6.65\ Gg}$$

4. **Euro-V – Scenario B (delayed)**

$$S_{\mathrm{Euro}}^{B}(2030) = 136.44 \times 0.039 \times 0.255 \approx \mathbf{4.43\ Gg}$$

Calculation

Measure	TERMPLUS target	Avoided GHG 2030 (A) (Gg)	Avoided GHG 2035 (A) (Gg)	Avoided GHG 2030 (B) (Gg)	Avoided GHG 2035 (B) (Gg)
Motor Industry Quality Assurance Programme (MIQAP)	2.4% annual efficiency gain	8.86	11.93	6.65	11.93
Stricter Vehicle & Fuel Standards (Euro V by 2035, tighter import rules, low-S fuels)	Phased to 2035	5.91	7.95	4.43	7.95
Total		**14.77**	**19.88**	**11.08**	**19.88**

Methodology — Demand-Side and Behavioural Measures

Objective

Quantify the potential GHG emission reductions (in Gg) from three behavioural and demand-side measures proposed under TEEMP:

- **Vehicle Kilometres Travelled (VKT) Reduction** – reducing LDV travel by 20% below 2030 BAU.
- **Fuel Economy (FE) Improvement in New LDVs** – achieving a 30% fuel efficiency gain by 2030.
- **Idle Time Reduction** – cutting one hour of daily idling for HDVs and LDVs.

Scenarios:

- **Scenario A** – On-time start in 2025.
- **Scenario B** – Delayed start in 2027.

Variables & Definitions

- E_{2021} : Baseline transport emissions = 130.45 Gg.
- *g*: BAU annual growth rate = 2%.
- *t*: Year of assessment (2030 or 2035).
- E_t^{BAU}: BAU emissions in year t.
- s_{LDV}, s_{HDV}: Shares of emissions from LDVs and HDVs.
- r_{VKT} : Target fractional reduction in VKT = 20% by 2030.
- r_{FE} : Target fuel economy improvement = 30% by 2030.
- r_{idle}: idle time reduction = 1 hr/day.
- $c_t^{A/B}$ Coverage factor depending on whether Scenario A or B.
- $\Delta E_m^{A/B}(t)$: Savings from measure mmm in scenario A or B.

Establish the BAU Baseline

Use TERMPLUS baseline and BAU growth:

- 2021=130.45 Gg
- g≈ 2% per year

$$E_t^{BAU} = E_{2021} \times (1+g)^{(t-2021)}$$

Assume road share r_{road}:= 97.3%

- $E_{2030road}$= 155.90 × 0.973 ≈ 151.60 Gg
- $E_{2035road}$= 172.13 × 0.973 ≈ 167.47 Gg

Savings Equations

1. **Initiative 1: VKT Reduction**

Targets/assumptions

- Fuel-economy gain: r_{VKT}= 20% by 2030 (sustained).
- LDV emissions share addressed by this measure: $s_{LDV,HDV}$ = 0.17
- Coverage factors (policy + market uptake):
  - Scenario A: c_{2030}^{A} = 0.75, c_{2035}^{A} = 0.97
  - Scenario B: c_{2030}^{B} = 0.56, c_{2035}^{B} = 0.79

Equation

$$\Delta E_{VKT}^{A/B}(t) = E_t^{road} \times s_{LDV} \times r_{VKT} \times c_t^{A/B}$$

2030 calculations

- **A:** 151.60 × 0.17 × 0.20 × 0.72 = 3.9 Gg
- **B:** 151.60 × 0.17 × 0.20 × 0.54 = 2.9 Gg

2035 calculations

- **A:** 167.50 × 0.17 × 0.20 × 0.97 = 5.5 Gg
- **B:** 167.50 × 0.17 × 0.20 × 0.79 = 4.5 Gg

Assumption (taken due to lack of data)

TERMPLUS transport baseline (2021, 130.45 Gg):

  - Trucks (M/H) = 37%
  - Light pickups = 36%
  - Private cars = 15%
  - Taxi/government = 7.2%
  - Maritime small vessels = 2.7%
- Together, LDVs (private cars + taxis/gov) ≈ 22% of emissions.
- TEEMP, however, focuses the VKT-reduction goal on passenger-oriented LDVs, not all vehicles. Trucks and pickups are not included in the behavioural VKT measure.
- So for modelling, I set LDV VKT base share ≈ 17% of total road emissions by weighting down the 22% figure slightly, since some of the "taxis/gov" are commercial duty vehicles and partly overlap with fleet/road projects.

Why 0.17? *It's a conservative proxy for the portion of road emissions actually influenced by individual passenger mobility demand (walking, cycling, rideshare, telecommuting).*

2. **Initiative 2: Fuel Economy (New LDVs)**

Targets

- Fuel-economy gain: r_{FE}= 30% by 2030 (sustained).
- Emissions base affected (new LDV cohort share): $s_{LDV,FE}$ = 0.18
- Coverage factors (policy + market uptake):
  - Scenario A: c_{2030}^{A} = 0.72, c_{2035}^{A} = 0.77
  - Scenario B: c_{2030}^{B} = 0.54, c_{2035}^{B} = 0.66

Equation

$$\Delta E_{FE}^{A/B}(t) = E_t^{road} \times s_{LDV} \times r_{FE} \times c_t^{A/B}$$

2030 calculations

- **A:** 151.60 × 0.18 × 0.30 × 0.72 =5.9 Gg
- **B:** 151.60 × 0.18 × 0.30 × 0.54 = 4.4 Gg

2035 calculations

- **A:** 167.50 × 0.18 × 0.30 × 0.77 = 7.0 Gg
- **B:** 167.50 × 0.18 × 0.30 × 0.66 = 6.0 Gg

Assumption (taken due to lack of data)

- The 30% FE improvement applies only to new LDVs imported after 2025/2027.
- TEEMP assumes gradual uptake, not immediate fleet-wide.
- So I didn't apply this to the whole 22% LDV baseline. Instead:
  - About 80% of LDV emissions will still come from the older stock in 2030.
  - Only ~20% (≈0.18 of road emissions) will be from "new LDVs" affected by import regulations and tariffs by 2030.

Why 0.18? *It approximates the share of total road emissions that new, compliant LDVs would represent in 2030–2035. This increases gradually, but for simplicity I fixed it at ~18%.*

3. **Initiative 3: Idle Time Reduction**

Targets

- Operational target: reduce idling by 1 hour/day (fleet-wide HDVs + LDVs).
- Translate to an effective idle fuel fraction of total on-road emissions: Φidle=1.5%=0.015
- ·Coverage factors (compliance + auxiliary tech)
  - Scenario A: c_{2030}^{A} = 0.62, c_{2035}^{A} = 0.80
  - Scenario B: c_{2030}^{B} = 0.44, c_{2035}^{B} = 0.60

Equation

$$\Delta E_{idle}^{A/B}(t) = E_t^{road} \times s_{HDV} \times r_{idle} \times c_t^{A/B}$$

2030 calculations

- **A:** 151.60 × 0.015 × 0.62 =1.4 Gg
- **B:** 151.60 × 0.015 × 0.44 = 1.0 Gg

2035 calculations

- **A:** 167.50 × 0.015 × 0.80 = 2.0 Gg
- **B:** 167.50 × 0.015 × 0.60 = 1.5 Gg

Assumption (taken due to lack of data)

Idle fuel use per vehicle (TEEMP and international data):

  - HDV: ~3.5 L diesel/hr
  - LDV: ~1.5 L petrol/hr
- Assume average daily idling ≈ 1 hour/day (the target reduction).
- Fleet weighted across Tonga's ~16,000 vehicles:
  - Only a portion are HDVs, most are LDVs, so idling is not the dominant consumption mode.
- When scaled against Tonga's total road emissions (≈150 Gg in 2030), the total "idle" consumption represents about 1.5% of annual road fuel burn.

Why 0.015? *It's the ratio of avoidable idle fuel use compared to total road emissions if 1 hour/day is cut, based on fuel consumption rates and vehicle stock structure.*

Measure	Target	Scenario A (On-time) Mitigation by 2030 (Gg)	Scenario A Mitigation by 2035 (Gg)	Scenario B (Delayed Start) Mitigation by 2030 (Gg)	Scenario B Mitigation by 2035 (Gg)
VKT Reduction (LDVs)	20% below 2030 BAU	**3.9**	**5.5**	**2.9**	**4.5**
Fuel Economy (New LDVs)	30% efficiency improvement	**5.9**	**7.0**	**4.4**	**6.0**
Idle Time Reduction	1 hr/day less idling (HDVs/ LDVs)	**1.4**	**2.0**	**1.0**	**1.5**
Total		**11.2**	**14.5**	**8.3**	**12.0**

Methodology — Technology and Fuel Switching

Objective

To assess the mitigation potential of Biodiesel Blending and Electric Vehicle (EV) Uptake, two structural measures highlighted by TERMPLUS and TEEMP, which reduce the carbon intensity of fuels and vehicles in Tonga's transport sector.

Targets

1. Biodiesel Blending

- Target: 10% blend in all road diesel by 2030.
- Feedstock: 77% from waste oil/grease, remainder from coconut oil (TEEMP).
- Emission Factor Adjustment: 10% blending assumed to reduce diesel CO_2 intensity by ≈ 10%.

2. Electric Vehicle Uptake

- Target: 10% of new light-duty vehicle (LDV) sales to be EVs or HEVs by 2030.
- Enablers: Charging infrastructure, fiscal incentives, training.
- Climate Link: Benefits increase if Tonga achieves higher renewable penetration in electricity supply.

Establish the Baseline

- Transport baseline 2021: E2021=130.45E_{2021}=130.45E2021=130.45 Gg
- BAU growth g = 2%➔ road emissions (97.3% of transport):
- E_{2030}road = 130.45 × 1.029 × 0.973 = 151.60 Gg
- E_{2035}road = 130.45 × 1.0214 × 0.973 = 167.50 Gg

Calculation Methodology

Formula:

$$\text{Mitigation}_m(t) = E_t^{road} \times \text{EligibleShare}_m \times \text{EffectSize}_m \times \text{Coverage}_m(t)$$

Where:

- E_t^{road} = Road transport emissions in year t.
- EligibleShare = proportion of the fleet/fuel affected.
- EffectSize = GHG reduction potential (e.g. 10% for biodiesel, ~100% displacement for EVs of their fuel share).
- Coverage = Share of BAU achieved by 2030/2035, depending on scenario.

1. Biodiesel blending (10% blend in all road diesel)

- Assumptions (from TEEMP): diesel share of road fuel ≈ 43% ➔ EligibleSharebio = 0.43
- A 10% blend reduces diesel CO_2 intensity ≈ 10% ➔ EffectSizebio = 0.10

So

$$\text{Mitigation}_{\text{bio}}(t) = E_t^{\text{road}} \times 0.43 \times 0.10 \times \text{Coverage}_{\text{bio}}(t)$$

Scenario A (on-time, policy starts 2025): 2030

Base = 151.60 × 0.43 × 0.10 = 6.5188 Gg

Apply coverage = 6.5188 × 0.843 = 5.50 Gg

Scenario A (on-time, policy starts 2025): 2035

Base = 167.50 × 0.43 × 0.10 = 7.20 Gg

Apply coverage = 7.20 × 0.971 = 7.00 Gg

Scenario B (delay-start, policy starts 2027)

2030 : 6.5188 × 0.629 = 4.10 Gg

·2035 : 7.2025 × 0.833 = 6.00 Gg

2. **EV uptake (10% of new LDV sales are EV/HEV by 2030)**

We model EV savings as: the share of road emissions represented by the "new LDV cohort that becomes EV/HEV" times the emissions displacement of EVs vs. ICE (which improves as the grid gets cleaner).

Assumptions (consistent with TEEMP framing):

- New LDV cohort share of road emissions in 2030–2035 ≈ 6–7% as the affected slice of activity. Use EligibleShareEV = 0.06 (2030) and 0.07 (2035).
- EV displacement (EV vs. ICE tailpipe & fuel cycle):
  - 2030: grid not fully decarbonised ➜ 50% reduction ➜ EffectSizeEV,2030 = 0.50
  - 2035: cleaner grid ➜ 60% reduction ➜ $\text{EffectSize}_{\text{EV}}$,2035 = 0.60

So

$$\text{Mitigation}_{\text{EV}}(t) = E_t^{road} \times \text{EligibleShare}_{\text{EV}}(t) \times \text{EffectSize}_{\text{EV}}(t) \times \text{Coverage}_{\text{EV}}(t)$$

Scenario A (on-time, policy starts 2025): 2030

Base = 151.60 × 0.06 × 0.50 = 4.548 Gg

Apply coverage = 4.548 × 0.55 = 2.50 Gg

Scenario A (on-time, policy starts 2025):2035:

Base = 167.50 × 0.07 × 0.60 = 7.035 Gg

Apply coverage = 7.035 × 0.64 = 4.50 Gg

Scenario B (delay-start, policy starts 2027)

- 2030 : 4.548 × 0.33 = 1.50 Gg
- 2035 : 7.035 × 0.43 = 3.00 Gg

Measure	Target	Scenario A (On-time) Mitigation by 2030 (Gg)	Scenario A Mitigation by 2035 (Gg)	Scenario B (Delayed Start) Mitigation by 2030 (Gg)	Scenario B Mitigation by 2035 (Gg)
Biodiesel Blending	10% biodiesel in road diesel	**5.5 Gg**	**7.0 Gg**	**4.1 Gg**	**6.0 Gg**
EV Uptake	10% of new LDV sales as EV/HEV by 2030	**2.5 Gg**	**4.5 Gg**	**1.5 Gg**	**3.0 Gg**
Total		**8.0 Gg**	**11.5 Gg**	**5.6 Gg**	**9.0 Gg**

Methodology — Maritime Transport Efficiency through Low-Carbon Technologies

Objective

Quantify annual GHG emission reductions (Gg) from Tonga's small-vessel fleet (<15 m) under two initiatives and two rollout scenarios for 2030 and 2035.

Baselines

- Transport baseline (2021): E_{2021} = 130.45 Gg
- BAU growth g = 2% ➜ total transport emissions:
  - E2030tr = 130.45 × 1.029 = 155.90 Gg
  - E2035tr = 130.45 × 1.0214 = 172.13 Gg
- Maritime small vessels share (TERMPLUS): s_{mar} = 2.7%

$$E_t^{\text{mar}} = E_t^{\text{tr}} \times s_{\text{mar}} \Rightarrow \begin{cases} E_{2030}^{\text{mar}} = 155.90 \times 0.027 = \mathbf{4.21\ Gg} \\ E_{2035}^{\text{mar}} = 172.13 \times 0.027 = \mathbf{4.65\ Gg} \end{cases}$$

Formula

Initiative 1: Efficiency & operations

$$\Delta E_{\text{eff}}(t) = E_t^{\text{mar}} \times r_{\text{eff}} \times D_t^{\text{eff}}$$

Initiative 2: Electrification

$$\Delta E_{\text{elec}}(t) = N_{\text{EV}}(t) \times a_{\text{ship}}$$

Where

- E_t^{tr}: total transport BAU in year t (Gg).

- s_{mar}: maritime small-vessel share (=0.027).
- $E_t^{mar} = Et^{t\ rs}_{mar}$: maritime BAU (Gg).
- R_{eff} : fractional reduction from efficiency & operations (0.43 = 43%).
- D_t^{eff}: deployment fraction of efficiency package by year t (dimensionless).
- a_{ship}: per-vessel abatement from electrification (0.045 Gg yr^{-1}).
- $N_{EV}(t)$ number of electrified small vessels operating in year t.

Calculations

Initiative 1: Efficiency & Operational Improvements

Scenario A:

2030: 4.21 × 0.43 × 0.66 = 1.19 ≈ 1.2 Gg

2035: 4.65 × 0.43 × 1.00 = 2.00 Gg

Scenario B:

2030: 4.21 × 0.43 × 0.27 = 0.49 ≈ 0.5 Gg

2035: 4.65 × 0.43 × 1.00 = 2.00 Gg

Initiative 2: Maritime Electrification (Small Vessels)

Scenario A

2030: N_{EV} = 20 ➔ 20 × 0.045 = 0.90 Gg

2035: N_{EV} = 47 ➔ 47 × 0.045 = 2.12 ≈ 2.1 Gg

Scenario B

2030: N_{EV} = 7 ➔ 7× 0.045 = 0.315 ≈ 0.3 Gg

2035: N_{EV} = 47 ➔ 2.1 Gg

Measure	Target	Scenario A (On-time) Mitigation by 2030 (Gg)	Scenario A Mitigation by 2035 (Gg)	Scenario B (Delayed Start) Mitigation by 2030 (Gg)	Scenario B Mitigation by 2035 (Gg)
Ships efficiency and operational improvements	n/a	**1.2**	**2.0**	**0.5**	**2.0**
Maritime Electrification	20% of small vessel sales for tourism and fisheries to be electric by 2035	**0.9**	**2.1**	**0.3**	**2.1**
Total		**2.1**	**4.1**	**0.8**	**4.1**

TERMPLUS gives an indicative per-vessel abatement of 0.045 Gg/yr for a diesel small vessel replaced with electric power (reflecting high annual hours and poor specific fuel efficiency in the baseline).

Formula (stock-additive):

$$\Delta E^{\text{EV-ship}}(t) = N_{\text{EV}}(t) \times 0.045 \text{ Gg}$$

Solve for the number of electrified vessels $N_{EV}(t)$ that yields the targets:

Scenario A

2030 target 0.9 Gg: N_{EV} = 0.9/0.045 = 20 vessels

2035 target 2.1 Gg: N_{EV} = 2.1/0.045 = 47 vessels

Scenario B

2030 target 0.3 Gg: N_{EV} = 0.3/0.045 = 7 vessels

2035 target 2.1 Gg: N_{EV} = 2.1/0.045 = 47 vessels

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Department of Climate Change

Ministry of Meteorology, Energy, Information,Disaster Management, Environment, Climate Change and Communications (MEIDECC)

Level 3, O.G Sanft Building Taufa'ahau Road, Nuku'alofa, Tonga

Tel +676 20 100 | www.climatechange.gov.to