

Blue Halo S – Blue Ecosystem Adaptation Mechanism (BEAM)

ANNEX 22: GHG Emissions Reductions

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EXECUTIVE SUMMARY

This report focuses on assessing the carbon sequestration potential in the WPP 572 region, including current rates of deforestation / degradation, and determining the potential GHG impact of the proposed Blue Halo S – BEAM Project.

Blue carbon ecosystems store significant amounts of carbon in their soils in addition to biomass, making them crucial for climate change mitigation. Blue carbon ecosystems provide an unparalleled combination of carbon density, long-term sequestration permanence, and localized climate adaptation. The protection and restoration of these ecosystems in Indonesia, especially given its extensive mangroves and seagrass beds, are key to enhancing their resilience against physical disturbances and improving carbon sequestration. However, these ecosystems are under significant pressure from climate change, anthropogenic factors, and natural disasters. The Blue Halo S BEAM project, focusing on the WPP 572 region, aims to maintain and enhance the health of blue carbon ecosystems over a 6-year period (2027-2032) with a projected 20-year lifespan impact. This initiative is designed to implement low-emission and climate-resilient management practices to significantly reduce blue carbon emissions resulting from ecosystem loss.

This report aims to translate the impact of BEAM's activities and sub-activities to measurable GHG outcomes. An effectiveness index was used to be conservative. The level to which ecosystem loss will actually be reduced in the project case depends on the effectiveness of the proposed activities, which will be estimated ex-ante for the purposes of this section. A wide variety of activities and sub-activities within the BEAM project will potentially reduce blue carbon emissions in WPP 572, including intervention in policy and regulatory framework to improve MPA management effectiveness (Activity 1.1.1; Sub-Activity 1.1.1.2), grant-facility supports for collaborative MPA management, ecotourism development, and sustainable and diversified fishing livelihoods (Activity 2.1.1; Sub-Activities 2.1.1.1, 2.1.1.2, 2.1.1.3), and through direct restoration of the blue carbon ecosystems (Activity 2.2.1; Sub-Activity 2.2.1.1).

Together, Project interventions are projected to achieve a total emission reduction of **483,322 tonnes of CO₂e by the end of the 6 year Project implementation period**, and **1,298,901 tonnes of CO₂e by the end of the Project's 20-year lifespan**. The BEAM project is set to play a significant role in reducing GHG emissions through the protection and restoration of blue carbon ecosystems in WPP 572, thereby contributing to Indonesia's ambitious climate goals.

INTRODUCTION

This report details a carbon assessment undertaken in the WPP 572 region, focusing on blue carbon ecosystems. Blue carbon refers to the carbon found in coastal systems, especially in mangroves and seagrass beds, often called blue carbon ecosystems (Siikamäki et al. 2013). Blue carbon ecosystems are distinctive from terrestrial forest ecosystems because much of the carbon is stored in their soils instead of their biomass. Organic carbon in these ecosystems, unlike terrestrial ecosystems, remain locked in the sediment for centuries or even millennia if left undisturbed, minimizing the risk of non-permanence. Moreover, blue carbon ecosystems also protect coastal infrastructure and climate adaptation benefits through wave energy reduction as climate change increases erratic weather, storm surge, sea water intrusion and other disasters. Blue carbon ecosystems are particularly vulnerable to degradation, mainly through anthropogenic activities that disturb or degrade the ecosystem (Lovelock et al. 2017). Given the extensive mangroves and seagrass in Indonesia, protecting blue carbon ecosystems' soil and restoring the ecosystems' condition to improve their resilience toward physical disturbance is one of the keys to successful climate mitigation.

We do not consider blue carbon emissions from coral reefs due to the debates whether it is considered as a blue carbon ecosystem or not. Blue carbon ecosystems and coral reefs provide provisioning benefits, such as fuelwood, timber, and fodder (Dali, Aheto, and Blay 2023; Yudha et al. 2021; Basyuni et al. 2023; Mugi et al. 2022), nursery grounds (Robertson and Duke 1987; Chong 2007; Hussain and Badola 2010; Jänes et al. 2020), coastal protection (Menéndez et al. 2020; Beck et al. 2018; Asari et al. 2021), nutrient regulation (Gao and Lee 2022; Sarker et al. 2021; Wang et al. 2022), and cultural services (Spalding and Parrett 2019; Moore et al. 2022). Thus, protecting blue carbon ecosystems and coral reefs is key to improve the climate resilience of the communities in coastal areas.

The BEAM project will provide the necessary maintenance and restoration assistance that these WPP 572 ecosystems need to help Indonesia reach their carbon emission sequestration targets. Additionally, it aims to support delivering crucial ecosystem services to coastal communities in WPP 572, which will serve as one of the pillars of the region's blue economy sector. This analysis provides an assessment of carbon emissions that will occur under a business-as-usual (BAU) scenario and compares these emissions to the carbon emissions scenario following the implementation of Component 2 activities that will restore and protect these ecosystems.

SPATIAL AND OPERATIONAL BOUNDARIES

The spatial boundary of this assessment is WPP 572, covering 94.3 million hectares across six provinces (Aceh, North Sumatra, West Sumatra, Bengkulu, Lampung, and Banten). Within this boundary, three nested spatial boundaries are defined for the mitigation assessment:

- (i) Activity 1.1.1 (Enhance Ecosystem Protection and Fisheries Sustainability through Policy Reform and creation of Innovative Financing Mechanisms): Existing and expanded MPAs within WPP 572. The baseline extent for existing MPAs is 1,319,058 ha, which includes designated and reserved MPAs. The intervention boundary includes management effectiveness improvements within these areas.
- (ii) Activity 2.1.1 (Deploy grants for sustainable climate change adaptation in coastal communities): MPA areas and a 10 km buffer zone outside MPAs where community-led conservation and livelihood activities are expected to reduce pressure on blue carbon ecosystems. The 10 km buffer represents the typical fishing range of small-scale fishers and includes coastal villages adjacent to MPAs.
- (iii) Activity 2.2.1 (Deploy grants to improve ecosystems and achieve sustainable climate change mitigation impacts): Selected restoration sites within WPP 572 where degraded mangrove and

seagrass areas are targeted for active restoration. These sites are identified based on ecological suitability, community interest, and feasibility.

The operational boundary for each intervention includes the direct activities funded by BEAM (e.g., policy reforms, training, patrols, restoration activities) and the indirect effects on ecosystem extent and condition. Emissions reductions are calculated as the difference between baseline (without BEAM) and project (with BEAM) scenarios within these spatial and operational boundaries.

Emissions reductions are aggregated across the three intervention pathways using a conservative approach that avoids double counting: (i) Activity 1.1.1: Reductions are calculated based on improved management effectiveness within MPAs, quantified using the MPA Management Effectiveness (EVIKA by MMAF) tool and applied to the extent of mangrove and seagrass within MPAs. (ii) Activity 2.1.1: Reductions are calculated for MPA areas and a 10 km buffer. For MPA areas, the calculations are additive to Activity 1.1.1, recognizing that community grants complement but are distinct from policy reforms. For the 10 km buffer, reductions are calculated separately as these areas are outside the MPA boundary; (iii) Activity 2.2.1: Sequestration from restoration is calculated separately and is not double-counted with avoided loss from management improvements.

BASELINE SCENARIO AND ADDITIONALITY

Without the multi-layered interventions introduced by Blue Halo S - BEAM Project, the critical blue carbon stocks across WPP 572 will continue to face rapid biogenic and anthropogenic degradation.

Below are the expanded baseline scenario definitions and structural additionality justifications across three core intervention pathways:

(i) Activity 1.1.1 (Enhance Ecosystem Protection and Fisheries Sustainability through Policy Reform and creation of Innovative Financing Mechanisms)

- **Baseline Scenario (Business-As-Usual):** Under the status quo, the legal and operational landscape across WPP 572 remains structurally constrained, with less than 2% of the marine management area legally designated as a Marine Protected Area (MPA). Existing designated zones suffer from a systemic deficit in operational funding, creating a reliance on inadequate public budgets. This financial bottleneck manifests as weak institutional enforcement, near-zero surveillance infrastructure, and non-existent community co-management frameworks. Consequently, the baseline assumes that current management ineffectiveness and historical environmental loss rates will continue unabated. Specifically, localized annual degradation rates for mangroves (derived from historical Global Mangrove Watch data; the average annual loss across WPP572 is 0.2%) and a global annual decline rate of 2.82% for seagrass meadows are applied to the 2027 project-start ecosystem extent.
- **Additionality Justification:** This pathway is additional because it introduces target-driven technical assistance and specialized regulatory support that neither subnational budgets nor standard market forces can provide. GCF concessional resources and project co-financing will directly unlock the gazettement and establishment of 3 million hectares of a new national MPA alongside expanding 713,000 hectares of key provincial MPAs. Furthermore, this activity is additional as it operationalizes innovative financing mechanisms, specifically the Regional Public Service Agency (BLUD) and Public-Private Partnership (PPP) models. These institutional tools

alter the baseline paradigm by allowing site-level management units to capture, retain, and reinvest localized user revenues, systematically transitioning the target geography into a self-sustaining conservation network that would otherwise remain frozen in a state of administrative under-funding.

(ii) Activity 2.1.1 (Deploy grants for sustainable climate change adaptation in coastal communities)

- **Baseline Scenario (Business-As-Usual):** Coastal populations and artisanal fishing communities within WPP 572 are trapped in a cycle of direct resource dependency, leaving their food security highly exposed to climate-induced declines in fish stocks resulting from rising sea levels, rising sea surface temperatures, and more regular extreme weather events. Local communities face compounding micro-level barriers, including a structural lack of collateral, a total deficiency in localized market intelligence, and geographic isolation from regional markets. While state-subsidized microcredit channels (such as BLU LPMUKP) exist on paper, complex paper-based application procedures, long processing timelines, and limited field staff prevent uptake among remote communities, forcing them to rely on predatory informal loan sharks. The baseline scenario therefore dictates that communities will maintain open-access, destructive extraction practices—including illegal near-shore trawling and mangrove harvesting for fuel and timber—to sustain baseline household survival, directly perpetuating the historical ecosystem loss rates within local marine zones and their adjacent 10 km spatial buffers.
- **Additionality Justification:** The adaptation grant windows overcome these socio-economic barriers by providing non-debt financial resources directly to local civil society organizations, cooperatives, and small-scale community enterprises that are fundamentally un-bankable under common commercial banking parameters. These grants absorb the high early-stage operational risks of establishing climate-resilient alternatives, such as eco-tourism ventures and sustainable post-harvest supply chains. This pathway is structurally additional because it creates a direct economic bridge, allowing communities to build operational track records and capacity. This early grant phase systematically prepares local actors to transition into formal financial structures and utilize modernized, digitized microcredit pipelines, removing their long-term reliance on destructive extractive practices. To maintain strict accounting conservatism, an incremental Effectiveness Index (EI) is layered onto the baseline loss trends to reflect the staggered, realistic rollout of community sub-grants over the 6-year execution period.

(iii) Activity 2.2.1 (Deploy grants to improve ecosystems and achieve sustainable climate change mitigation impacts)

- **Baseline Scenario (Business-As-Usual):** High degradation, coastal erosion from severe storms, and untreated agricultural and aquaculture wastewater discharge continue to degrade local mangrove mudflats and scar sub-tidal seagrass beds across WPP 572. Compounding this environmental stress, fishing communities across these same WPP 572 priority zones lack reliable, affordable energy for post-harvest handling and fish processing. Current practices rely heavily on costly, polluting diesel generators to power ice production units, cold storage, and basic processing equipment. These diesel-dependent systems incur exorbitant operational expenses, frequent fuel-supply disruptions, and high maintenance burdens. Consequently, an estimated 20–

30% of daily catches are lost to spoilage before reaching markets, severely depressing fishers' incomes and perpetuating food insecurity. Because ecosystem restoration delivers wide-ranging environmental public goods—such as wave attenuation, biodiversity enhancement, and localized shoreline stabilization—it offers zero short-term direct cash flows. Consequently, commercial private sector actors have no financial incentive to deploy private equity or corporate debt into these landscapes, particularly given the high investment risks and long, uncertain payback horizons associated with coastal carbon markets. Operating with heavily restricted capital envelopes, provincial environmental offices cannot finance high-cost, specialized marine restoration protocols. The baseline scenario therefore assumes a zero-restoration status quo, where degraded coastal clearings remain un-vegetated, progressively lose their underlying sediment organic carbon pools, and experience long-term erosion and continuous biogenic emissions.

- **Additionality Justification:** This pathway is additional because it covers the immense upfront capital costs of localized ecological restoration projects and renewable energy infrastructure deployment that cannot be commercialized or covered under public spending. GCF grant capital acts as the sole enabling mechanism to execute active replanting, specialized seed-sowing, thin-layer sediment deposition, and community-led waste removal across 285 hectares of degraded mangroves and 6 hectares of seagrass. The resulting mitigation impact is mathematically additional, as all calculated carbon stock accumulation and long-term soil carbon burial rates are measured exclusively as net gains achieved directly above a stagnant, zero-restoration baseline. The grant's additionality extends to the renewable energy component by financing the otherwise unattainable upfront capital for procuring, deploying, and commissioning solar photovoltaic systems, renewable-energy-powered ice production machinery, cold-storage hardware, and complementary processing equipment across these same remote coastal sites. This hardware package is accompanied by structured, hands-on training for local operators to ensure sustained use, routine maintenance, and long-term system reliability—a comprehensive capacity-building bundle that is entirely beyond the reach of household savings, microfinance institutions, or provincial agency budgets.

ADDITIONALITY AND BASELINE SCENARIOS BY BEAM INTERVENTION PATHWAY

Element	Activity 1.1.1: Enhance Ecosystem Protection and Fisheries Sustainability through Policy Reform and creation of Innovative Financing Mechanisms	Activity 2.1.1: Deploy grants for sustainable climate change adaptation in coastal communities	Activity 2.2.1: Deploy grants to improve ecosystems and achieve sustainable climate change mitigation impacts
Baseline Scenario	Continued operational ineffectiveness of local marine sanctuaries; historical biogenic and anthropogenic loss rates	Direct resource-dependency forces communities to maintain open-access, destructive extraction patterns, extending baseline	A zero-restoration, business-as-usual landscape; historically degraded and cleared mudflats remain barren, experiencing chronic soil

Element	Activity 1.1.1: Enhance Ecosystem Protection and Fisheries Sustainability through Policy Reform and creation of Innovative Financing Mechanisms	Activity 2.1.1: Deploy grants for sustainable climate change adaptation in coastal communities	Activity 2.2.1: Deploy grants to improve ecosystems and achieve sustainable climate change mitigation impacts
	continue across baseline coastal boundaries.	degradation trends into adjacent spatial buffers.	erosion and lost carbon sequestration potential.
Barriers Overcome	Fragmented governance, inadequate subnational budget allocations, weak spatial enforcement mechanisms, absent community patrolling, and zero long-term revenue retention tools.	Pervasive poverty, isolation from mainland markets, lack of viable credit access, complex and prohibitive lending workflows, and localized exploitation by predatory informal lenders.	Subnational fiscal deficits, high financial risk profiles for coastal investments, severe baseline ecological degradation, and complete private sector market avoidance of non-revenue conservation.
Additionality	Regulatory, structural, and public fiscal barriers completely paralyze site-level management; multi-level policy co-financing and technical assistance are strictly essential to enable enforcement.	Target populations completely lack baseline capital, collateral, and technical capacity; direct, accessible grants are essential to absorb risk and catalyze community solutions.	Public goods deliver zero immediate commercial cash flows; high upfront capital requirements and long payback periods mean interventions cannot occur without non-repayable grant capital.
Key Assumptions	Targeted legal policy reforms, specialized training, and localized BLUD/PPP frameworks turn "paper parks" into high-performing, self-funding conservation zones.	Staggered deployment of direct-access community grants builds alternative livelihood paths, systematically lowering human extraction pressure on nearby blue carbon pools.	Replanted mangrove seedlings and sowed seagrass stocks survive under localized protection, generating additional biomass and long-term sediment soil carbon capture.

METHODOLOGY FOR EMISSION CALCULATIONS

This study uses the methods published as the “2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands” to estimate the baseline blue carbon emissions due to the ecosystem loss in the project area. In general, the basic components to measure carbon emissions or removals for a given area are activity data (A) and emissions factor (EF), which form an equation below.

$$CO_{2,t} = \sum_{n=1}^k d_n A_{n,t-1} EF$$

The total carbon emissions for a given region, in this case within the WPP 572, and time (t) is a summation of carbon emissions in n sub-regions within the given area and time which occurs due to land cover change ($d_n A_{n,t-1}$). In this study, the activity data (A) refers to the blue carbon ecosystem extent, specifically the mangroves and seagrass beds within the entire WPP 572. The activity data, both for mangroves and seagrass, will be estimated at the district (*regency/municipality*) level. Data from the Global Mangrove Watch (Bunting et al. 2022) was used for the mangrove extent and Allen Coral Atlas (Allen Coral Atlas, 2022) for the seagrass beds.

To calculate the impact of the Project on GHG emission reductions, an average yearly loss rate (d_n) was used to estimate the yearly land cover change baseline. Utilizing the annual average loss rate is appropriate for estimating the expected ecosystem extent in the future as it signifies the business-as-usual scenario without the presence of the Blue Halo S project. With the Global Mangrove Watch dataset, the loss rate data for mangroves was obtained at the district level, precisely the average yearly loss rate between 1996 and 2020. On the other hand, Allen Coral Atlas dataset is not historical, thus the seagrass loss rate is not estimatable from available datasets. Instead, the global rate of decline of 2.82% (Stankovic et al. 2021) was used for the GHG estimates. This loss rate is similar to the 2.8% loss rate mentioned in the Seagrass status report released by Indonesia’s National Research and Innovation Agency (Rahmawati & Hernawan 2022).

For the emission factor, carbon emissions and the loss in sequestration potential from land cover change were treated separately. Carbon emission refers to the emission that occurs directly from the loss; meanwhile, loss in sequestration potential is the amount of carbon that can be sequestered if the ecosystem is intact. Few studies have attempted to synthesize the volume of carbon sink contained in blue carbon ecosystems as well as carbon sequestration, usually known as burial rates for blue carbon ecosystems, from available studies, as shown in

Table 1. This study refers to Alongi et al. (2016) for the carbon sink emission factor. Through meta-analysis, they estimated the carbon sink of mangroves and seagrass beds in Indonesia, which cover above and below-ground biomass and soil pools with a standardized 1 m depth. The carbon sequestration rate for mangrove vegetation was based on values recorded by Suprayogi et al (2022). As blue carbon burial rates in Indonesia could not be found, this study uses the global burial rates published by Mcleod et al. (2011). To convert C_{org} to CO_2 , this study follows IPCC's Good Practice Guidance for Land Use, Land-use Change, and Forestry (IPCC 2003) with a conversion rate of 44/12.

TABLE 1 BLUE CARBON ECOSYSTEM CARBON SINK AND SEQUESTRATION POTENTIAL RATES

Ecosystem	Sink			Sequestration/Burial	
	Pendleton et al. 2012*	Siikamäki et al. 2013**	Alongi et al. 2016)***	Lovelock et al. 2017****	Mcleod et al. (2012)*****
Mangroves	933 [373 – 1,492]	467.5	950.5	1.5 – 2.0	226 ± 39
Seagrass	326 [131 – 522]	71.5	119.52	0.25	138 ± 38

Notes: * in Mg CO₂/ha; ** ton CO₂/ha; *** Mg C/ha, mean value; ****in metric tons C_{org}/ha/year; ***** g C/m2/year

Table 2 summarizes the activity data and emission factors according to the tier classification for carbon inventories by the IPCC. The study combines tiers 1 and 2, as the study utilizes country- and global-level data from secondary sources.

TABLE 2 DATA SOURCES FOR CARBON INVENTORIES

Variable		Tier	Source
Activity data	Mangrove area	2	Global Mangrove Watch
	Mangrove loss rate	2	Global Mangrove Watch
	Seagrass area	2	Allen Coral Atlas
	Seagrass loss rate	1	Stankovic et al. (2021)
Emission factors	Mangrove – carbon stocks	2	Alongi et al. (2016)
	Seagrass – carbon stocks	2	Alongi et al. (2016)
	Mangrove - Sequestration	2	Suprayogi et al (2022)
	Mangrove – burial rates	1	Mcleod et al. (2011)
	Seagrass – burial rates	1	Mcleod et al. (2011)

The ecosystem maps are provided in Appendix 1.

Methodology for Non-Blue Carbon Mitigation Components

Under the mitigation grant window (Activity 2.2.1), the mitigation impact of the solar-powered chiller deployment will be targeted (Sub-Activity 2.2.1.2). This subactivity is primarily intended to support the small-scale fishing sector (i.e. it complements the adaptation activities). The methodology for decentralized, off-grid solar-powered fridge installations borrows parameters from methodologies like AM0123: Renewable energy generation for captive use, or requires registering the project under VCS Sectoral Scope 1 (Energy) by following standardized emission reduction calculations. This is also consistent with Indonesia's Directorate General Letter (Perdirjen) PPI P5/PPI/SET/KUM I/12/2017 concerning Guidelines for Calculating GHG Emissions for Community-Based Climate Change Mitigation Actions.

The methodology calculates the greenhouse gas (GHG) emission reductions (ER) by substituting grid electricity with zero-emission solar energy.

The formula for emission reductions is:

$$ER_y = E_{PJ,y} \times EF_{grid,y}$$

Where:

- ER_y : Emission reductions in year y (in tCO₂e).
- $E_{PJ,y}$: Energy from project in year y = Total net renewable electricity generated by the solar PV system powering the fridge in year y (in MWh).
- $EF_{grid,y}$: Emission factor for the displaced electricity grid baseline (in tCO₂ / MWh).]

The baseline emissions are calculated using the following parameters:

- Emission factor for the Sumatra Interconnection system (0.748 kg CO₂/kWh, sourced from the Indonesian EFDB, 2017)
- Assumed daily energy consumption of one freezer (1 kWh/day)
- Number of solar freezers deployed (250 units)

The rationale for using this approach is that solar-powered freezers produce no emissions during operation, making the mitigation emissions factor zero. The baseline assumes that without BEAM intervention, fishers would rely on grid-powered ice production for fish preservation. This is a conservative assumption as it does not account for the full life-cycle emissions of the baseline scenario (e.g., ice production and transport emissions).

In summary, Table below presents the consolidated emission factors and key assumptions used in the quantification of greenhouse gas emissions reductions across all mitigation intervention pathways. The values in this table represent the foundational parameters for all calculations presented in this annex and in the Funding Proposal's logical framework.

CONSOLIDATED EMISSION FACTORS AND KEY ASSUMPTIONS FOR MITIGATION CALCULATIONS

Parameter	Ecosystem/Component	Value	Unit	Source
Carbon stock (mangrove)	Mangrove	950.5	tC/ha	Alongi et al. 2016
Carbon stock (seagrass)	Seagrass	119.5	tC/ha	Alongi et al. 2016
Conversion factor C to CO ₂	All	44/12	-	IPCC 2003
Mangrove loss rate	Mangrove	0.2%	Annual	Global Mangrove Watch
Seagrass loss rate	Seagrass	2.82%	Annual	Stankovic et al. 2021
Electricity emission factor	Renewable Energy	0.748	kg CO ₂ /kWh	Indonesian EFDB 2017
Daily freezer consumption	Renewable Energy	1	kWh/day	Assumption

Parameter	Ecosystem/ Component	Value	Unit	Source
Number of solar freezers	Renewable Energy	250	Units	Project budget
Sequestration rate (mangrove)	Mangrove	1.5–2.0	tC/ha/yr	Mcleod et al. 2011; Suprayogi et al. 2022
Sequestration rate (seagrass)	Seagrass	0.25	tC/ha/yr	Mcleod et al. 2011
Mangrove restoration cost	Mangrove	4,730–4,825	USD/ha	World Bank 2023; MMAF 2023
Seagrass restoration cost	Seagrass	66,944	USD/ha	Consultation with Indonesian research agency (BRIN)

BASELINE BLUE CARBON EMISSIONS AT PROJECT START (2027)

This baseline assessment will follow the blue carbon ecosystem identified within WPP 572 which has been described in Annex 2. Figure 1. Land use and land cover changes in WPP 572 (2000–2024), showing areas of deforestation (pink) and remaining forest cover (green). This spatial analysis illustrates the scale and distribution of historical land-based emissions within the project area, particularly along the coastlines where blue carbon ecosystems are concentrated. Source: Ministry of Environment and Forestry. Land Cover Map, 2025; Tree cover loss (Hansen et al., 2025).

Table 3 describes the estimates of blue carbon extent at project start in 2027.

Deforestation in WPP 572 has resulted in significant historical emissions, particularly from mangrove loss and conversion of coastal ecosystems. The project area has experienced high rates of land cover change between 2000 and 2024, driven by agriculture, aquaculture, and infrastructure development.

map image removed

Figure 1. Land use and land cover changes in WPP 572 (2000–2024), showing areas of deforestation (pink) and remaining forest cover (green). This spatial analysis illustrates the scale and distribution of historical land-based emissions within the project area, particularly along the coastlines where blue carbon ecosystems are concentrated. Source: Ministry of Environment and Forestry. Land Cover Map, 2025; Tree cover loss (Hansen et al., 2025).

TABLE 3 ESTIMATES OF BLUE CARBON ECOSYSTEM (MANGROVE AND SEAGRASS) EXTENT AT PROJECT START (2027) DETAILED BY PROVINCE

MANGROVES

Province	Area extent baseline 2027 (ha)	Loss Rate
Outside of provincial boundaries	935.27	1.09%
Aceh	2,133.07	0.21% - 1.39%
Banten	2,270.76	0
Bengkulu	1,565.77	0
Lampung	1,639.79	0.07% - 1.29%
Sumatera Barat	15,383.48	0
Sumatera Utara	11,877.77	0
Total	35,805.89	

SEAGRASS

Province	Area extent baseline 2025 (ha)	Loss Rate
Outside of provincial boundaries	512.56	2.82%
Aceh	2,379.83	
Banten	1,293.66	
Bengkulu	1,497.68	
Lampung	2,698.26	
Sumatera Barat	6,451.97	
Sumatera Utara	6,708.17	
Total	21,542.13	

The loss rates above denote the business-as-usual emissions without the BEAM Project scenario.

IMPACT OF PROJECT ACTIVITIES

The Project's target area is WPP 572. Ecosystem maps of the target area can be found in Appendix 1, and in more detail in Annex 16 of the Funding Proposal Package.

The BEAM Project, with an implementation period of 6 years (anticipated between 2027 and 2032) and a lifespan of 20 years, aims to maintain and improve the health of the existing stock of ecosystems in the area with a series of activities of improved low-emission and/or climate-resilient management practices. These activities are designed to reduce the loss of blue carbon ecosystems and the emissions associated with that loss.

This part of Annex 22 aims to translate the impact of the different BEAM activities and sub-activities to measurable GHG outcomes. An effectiveness index was used to be conservative. The level to which

ecosystem loss will actually be reduced in the project case depends on the effectiveness of the proposed activities, which will be estimated ex-ante for the purposes of this section. This is done by developing an Effectiveness Index (EI) (cf. Appendix 2) ranging from 0 (no effectiveness) to 1 (full effectiveness). The projected baseline emissions are multiplied by EI to give the estimated GHG emission reductions. Full effectiveness cannot be reached immediately and subsequent to the 6 year funding period, effectiveness is likely to drop without additional funding through fiscal support or other sustainable finance mechanisms like carbon crediting.

Activity 1.1.1. Enhance Ecosystem Protection and Fisheries Sustainability through Policy Reform and Creation of Innovative Financing Mechanisms

Sub-Activity 1.1.1.2. Support the development, gazettement, and management of new and existing Marine Protected Areas (MPAs) and Other Area-based Conservation Measures (OECMs).

This sub-activity will support national and subnational agencies (MMAF and provincial governments) in designating new and expanded MPAs, resulting in more robust marine protection and support fishery management plans with a stronger evidence base and data collection system that will help protect vulnerable ecosystems and fisheries and improve existing regulations to improve the effective management of WPP 572. This is expected to be achieved through the development of working groups at national and provincial levels, conducting technical meetings and workshops for MPA initiation and zoning plans, and updating policy recommendations for MPA establishment and expansion. Additionally, evaluations of MPA management effectiveness using the EVIKA tool will be facilitated. Surveillance practices will be strengthened through awareness-raising activities, training sessions for local government agencies and community surveillance groups (POKMASWAS), and developing collaborative mechanisms for co-management and improved patrolling/surveillance efforts. These approaches will play a key role not only in protecting existing marine blue carbon stocks, but also in expanding their reach to increase the region's potential as a blue carbon sink for Indonesia.

Additionally, it is also important to note that mangrove and seagrass, while different geographically, are still interconnected functionally. Given mangrove habitats are located in estuaries between land and sea, terrestrial conservation areas are critical to protect some mangrove ecosystems. However, seagrass beds, despite being marine ecosystems within coastal waters, are also affected by activities in terrestrial areas, thus requiring both marine and terrestrial conservation areas. Since most terrestrial conservation areas are within the jurisdiction of the Ministry of Forestry, OECM presents an alternative to the formal terrestrial conservation areas.

Based on the proposed Project workplan and discussion with the GoI, it is expected that the targeted improved ecosystems are divided into mid-term and final targets as follows.

TABLE 4 TARGET IMPROVED ECOSYSTEM MANAGEMENT PRACTICE UNDER BLUE HALO S PROJECT

		Target in hectares	
		Mid-term	Final term
Sub-Activity 1.1.1.2. Support the development, gazettement, and management of new and existing Marine Protected Areas (MPAs) and Other Area-based Conservation Measures (OECMs)	a. Improve management effectiveness of the 2 existing provincial MPAs in North Sumatra (MPA Sawo Lahewa) and West Sumatra (MPA Selat Bunga Laut) b. Expansion of 2 existing provincial MPAs in North Sumatra (MPA Muara Batang Toru) and West Sumatra (MPA Pulau Pagai Utara and Pulau Pagai Selatan)	a. Improve management effectiveness of the 2 existing MPAs - MPA Sawo Lahewa 29,230 ha (mangrove: 40 ha; seagrass: 100 ha) - MPA Selat Bunga Laut 129,231 ha (mangrove: 149 ha; seagrass: 1084.75 ha)	b. Expansion of the 2 existing MPAs: - MPA Muara Batang Toru 70,000 ha (mangrove 0 ha; seagrass 255 ha) - MPA Pulau Pagai Utara and Pulau Pagai Selatan 643,000 ha (mangrove 70 ha; seagrass 1344 ha)

Table 5 provides information on climate mitigation benefits from the sub-activity 1.1.1.2. As noted below, in the business-as-usual condition (BaU), there will be emissions and no additional sequestration due to the ecosystem loss. The detailed calculations and assumptions are included in the accompanying excel file, and utilize the effectiveness rates summarized in Appendix 2 below.

TABLE 5 CLIMATE TARGET OF IMPROVED MPA AND OECM MANAGEMENT (ACTIVITY 1.1.1 - SUB-ACTIVITY 1.1.1.2) – IN TONNES CO₂

		Ecosystem extent in hectares (Activity Data)						Total emission benefit (in ton CO ₂)		
		Mid-term		Final term		End of 20-year period				
		Baseline	Intervened	Baseline	Intervened	Baseline	Intervened	Mid-term	Final-term	End of 20-year period
Existing MPA	Mangrove	187.15	187.36	186.62	187.25	182.45	185.75	1,434.98	3,858.64	11,796.54
	Seagrass	998.59	1,021.74	943.06	1,009.96	596.72	859.50	19,711.97	51,178.46	131,145.44
Expansion MPA	Mangrove	69.25	69.35	69.00	69.30	67.04	68.59	674.43	1,813.54	5,544.32
	Seagrass	1,346.82	1,346.82	1,271.93	1,302.94	804.81	1,108.82	0.00	41,829.32	149,541.28
Total								21,821.38	98,679.97	298,027.58

It is expected that the Project's Sub-activity 1.1.1.2 will reduce mangrove loss in the existing MPAs by around 1.1 hectares and seagrass loss by 112.8 hectares by the end of the Project's implementation period, resulting in a total emission benefit by 55,037 tonnes of CO₂. Meanwhile, the estimated benefit from MPA expansion is the reduction in mangrove and seagrass loss by 0.5 hectares and 93.3 hectares respectively, resulting in a total emission benefit of 43,642.9 tonnes of CO₂ by the end of the Project's implementation period.

Activity 2.1.1. Deploy grants for sustainable climate change adaptation in coastal communities

Under Component 2, Activity 2.1.1, grants will be disbursed in a competitive process to local and regional organisations to undertake demand-led projects that deliver sustainable climate change adaptation benefits across the target area of WPP 572. The adaptation grant window (Activity 2.1.1.) seeks to finance projects dedicated to supporting adaptation measures and enhancing resilience to climate change,

primarily targeting vulnerabilities faced by coastal communities in WPP 572. The adaptation grant window is designed to intervene in areas both within and outside of MPAs. While emphasising community-led adaptation, capacity-building, technical assistance, research, and monitoring, activities under this window will also deliver certain climate change mitigation co-benefits by improving the effectiveness of MPA management and reducing pressure on mangrove and seagrass ecosystems. There are three sub-activities within the adaptation grant window that are counted to have these climate change mitigation co-benefits, including the Sub-Activity 2.1.1.1. (Manage grants for ecotourism enterprises for community development), Sub-activity 2.1.1.2 (Manage grants for collaborative MPA management), and Sub-Activity 2.1.1.3 (Manage grants for sustainable and diversified fishing livelihoods).

Sub-Activity 2.1.1.1 Manage grants for ecotourism enterprises for community development

The Sub-activity 2.1.1.1 has a budget of US\$1.8 million which is divided into 3 types of grants: small/unsolicited grant, off-cycle grant, and large grants. A small and an off-cycle grants provide US\$ 40,000 per grant cycle, while a large grant provides US\$ 400,000 per grant cycle. In total, an estimated 9 grants will be issued to local projects that propose activities targeting local communities on ecotourism industries that consist of operator, logistics, transportation, and accommodation. The activities also include providing alternative income for coastal communities that are reliant on fishing during non-viable fishing seasons. Anticipated examples of supported activities including training to local communities in various eco-tourism activities, such as tour management to marine ecosystems (e.g, mangrove, coral reefs, seagrass), and practices that ensure responsible travel to natural areas (e.g,. reef-safe tourism). It is estimated that there are about 6,300 local communities as the beneficiary target for this sub-activity who work in the ecotourism industries (see Annex 24). This sub-activity is expected to provide incentives to local communities through support in ecotourism activities, which in turn reduce pressure on mangrove and seagrass ecosystems.

Sub-Activity 2.1.1.2 Manage grants for collaborative MPA management

Similar to the Sub-Activity 2.1.1.1, the Sub-activity 2.1.1.2 has 3 types of grants: small/unsolicited grant, off-cycle grant, and large grants, with a total budget of US\$ 1.88 million. A small and an off-cycle grants provide US\$ 40,000 per grant cycle, while a large grant provides US\$ 400,000 per grant cycle. In total, an estimated 11 grants will be issued to local projects that propose activities towards improving the management of MPAs. Anticipated examples of supported activities based on the Feasibility Assessment include, among others, community and MPA staff receive education, awareness, and technical training to actively participate in preserving the protected marine areas. This includes conducting monitoring, facilitating dialogues, or mediating conflicts that may arise in the MPA region. The funds for this sub-activity will also be used for collaborative research necessary to support better and sustainable MPA management, involving research institutions, universities, and other stakeholders. While the adaptation grant window is not restrictive in area within the entire WPP 572, the Feasibility Study (Annex 2) anticipates the likely priority provinces for this sub-activity: Aceh, Lampung, and Bengkulu. These three provinces, while having less ecosystems than West and North Sumatra as noted in Table 3, are experiencing a relatively high ecosystem loss due to various drivers mentioned in Annex 2.

Sub-Activity 2.1.1.3 Manage grants for sustainable and diversified fishing livelihoods (community-based economic activities)

As for Sub-Activity 2.1.1.1, the Sub-Activity 2.1.1.3 has 3 types of grants: small/unsolicited grant, off-cycle grant, and large grants, with a total budget of US\$ 1.4 million. A small and an off-cycle grants provide US\$ 40,000 per grant cycle, while a large grant provides US\$ 400,000 per grant cycle. In total, an estimated 8 grants will be issued to local projects that propose activities towards enhancement of

community-based economic activities targeting community groups to support sustainable and diversified fishing livelihoods. Anticipated examples of supported activities include support to improve fish processing and to prevent fish spoilage. This includes the establishment of infrastructure for solar-powered cold storage rooms and ice production units which represents a pivotal approach to optimizing processing methods and combating fish spoilage. It is estimated that there are about 225 community groups targeted for this sub-activity (see Annex 24). By providing support in sustainable and diversified fishing livelihood the pressure on marine ecosystems is expected to be less, thus reducing the loss of blue carbon ecosystems.

When calculating the impact of the above interventions within the 3 sub-activities with regards to GHG, it is expected that there is no overlap in the intervention areas and targeted improved ecosystems with those that are within MPAs which are part of the Activity 1.1.1.

Table 6 provides information on climate mitigation benefits from the Activity 2.1.1 (Sub-activities 2.1.1.1, 2.1.1.2, and 2.2.2.3). The table provides the impact of interventions within MPA areas, as well as additional impact to adjacent areas due to leakage effects (around 10 km outside of MPAs). For detailed calculations, please see accompanying excel file.

TABLE 6 CLIMATE TARGET OF COLLABORATIVE MPA MANAGEMENT (ACTIVITY 2.1.1 – SUB-ACTIVITIES 2.1.1.1, 2.1.1.2, 2.1.1.3) – IN TONNES CO2

Province	Ecosystem extent in hectares (Activity Data)						Total emission benefit (in tonnes CO2)		
	Mid-term		Final term		End of 20-year period				
	Baseline	Intervened	Baseline	Intervened	Baseline	Intervened	Mid-term	Final-term	End of 20-year period
Mangroves (Within MPA)									
Aceh	59.49	59.67	59.12	59.59	57.40	58.74	635.83	1,660.56	4,772.91
Banten	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bengkulu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lampung	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Outside provincial boundaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sumatera Barat	0.63	0.63	0.63	0.63	0.63	0.63	0.00	0.00	0.00
Sumatera Utara	88.81	88.90	88.63	88.86	87.76	88.44	315.76	826.83	2,410.91
Subtotal	148.93	149.20	148.37	149.08	145.79	147.80	951.59	2,487.39	7,183.82
Seagrass (Within MPA)									
Aceh	1,043.94	1,088.44	958.09	1,068.31	641.92	879.22	19,885.90	50,031.29	118,876.51
Banten	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bengkulu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lampung	3.22	3.36	2.96	3.30	1.98	2.71	61.39	154.46	367.01
Outside provincial boundaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sumatera Barat	526.78	549.23	483.46	539.08	323.92	443.66	10,034.55	25,246.12	59,985.86
Sumatera Utara	907.14	945.81	832.54	928.32	557.81	764.00	17,280.05	43,475.20	103,298.95
Subtotal	2,481.09	2,586.85	2,277.05	2,539.00	1,525.63	2,089.59	47,261.89	118,907.07	282,528.33
Subtotal (within MPA)							48,213.48	121,394.46	289,712.16

Mangroves (Extension 10 km)

Aceh	491.46	492.52	488.37	491.09	474.21	481.08	3,694.01	9,546.42	24,596.47
Lampung	125.09	126.45	121.20	124.63	104.55	112.40	4,754.05	12,056.83	28,146.08
Sumatera Barat	4,274.32	4,281.97	4,251.92	4,271.64	4,148.97	4,198.98	26,762.34	69,208.23	178,944.02
Sumatera Utara	4,572.55	4,574.94	4,565.53	4,571.71	4,532.93	4,548.82	8,372.22	21,704.07	56,845.73
Subtotal	9,463.43	9,475.89	9,427.02	9,459.07	9,260.67	9,341.28	43,582.62	112,515.55	288,532.30

Seagrass (Extension 10 km)

Aceh	908.63	935.77	833.90	899.82	558.72	680.67	12,132.21	29,935.66	61,573.32
Lampung	225.97	232.72	207.38	223.78	138.95	169.28	3,017.17	7,444.73	15,312.73
Sumatera Barat	1,090.14	1,122.70	1,000.49	1,079.58	670.33	816.64	14,555.78	35,915.71	73,873.42
Sumatera Utara	1,770.39	1,823.28	1,624.80	1,753.24	1,088.62	1,326.23	23,638.71	58,327.43	119,971.08
Subtotal	3,995.13	4,114.47	3,666.58	3,956.42	2,456.62	2,992.82	53,343.86	131,623.53	270,730.55

Subtotal (Extension 10 km)	96,926.48	244,139.08	559,262.86
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Total	145,139.96	365,533.54	848,975.01
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Activity 2.1.1 is expected to reduce mangrove and seagrass loss within the MPAs by 149.08 hectares and 2,539.00 hectares, respectively, by the end of project's implementation. This avoided ecosystem loss will result in total emission reduction benefits of 121,394.46 and 289,712.16 tonnes of CO₂ by the final-term and at the end of 20 years respectively. Meanwhile, the additional climate benefit of the project interventions within the 10km buffer outside of the MPA is estimated to be 244,139.08 and 559,262.86 tonnes of CO₂ by the final-term and at the end of 20 years, respectively. Over a 20-year period, the project has a potential to realize around 848,975.01 tonnes of CO₂ benefit from avoided ecosystem loss through better collaborative MPA management.

Activity 2.2.1. Deploy grants to improve ecosystems and achieve sustainable climate change mitigation impacts

Sub-Activity 2.2.1.1. Manage grants for high carbon ecosystem restoration

Sub-Activity 2.2.1.1 consists of grants issued through the mitigation grant window to focus on promoting low-carbon, resilient development pathways, aiming to strengthen the climate change mitigation capacity of marine ecosystems in WPP 572. The primary focus of this grant window will be on projects aligned with the project's mitigation objectives, involving the restoration of mangroves and seagrass beds. This activity may be proposed by NGOs focusing on marine biodiversity, coastal conservation, ecosystem restoration, as well as marine research institutions, universities, community-based organizations and environmental consultants, such as CTC, YKAN, WWF, YAPEKA, Wetlands Indonesia, PILI Foundation, WALHI, and Yayasan Rekam Indonesia. The nature restoration initiative focuses on three critical ecosystems that strengthen its ocean economy in WPP 572: the restoration of seagrass and mangrove ecosystems, including the assessment of blue carbon stocks. Ecologically, these ecosystems are highly rich carbon storage sources with significant potential to contribute to Indonesia's GHG mitigation targets. Different to the previous two interventions, Sub-activity 2.2.1.1 focuses on nature restoration, attempting to not only protect the existing ecosystem, but also to improve the extent of ecosystem through various projects, such as replanting and seed sowing, nursery development, layer sediment deposition and waste removal.

The Sub-activity 2.2.1.1 has an estimated allocated budget of US\$ 1.96 million which is divided into 3 types of grants: small/unsolicited grant, off-cycle grant, and large grants. A small and an off-cycle grants provide US\$ 40,000 per grant cycle, while a large grant provides US\$ 400,000 per grant cycle. Based on the Feasibility Study, an estimated 13 grants will be issued. Similar to the Sub-activity 2.1.1.2 (grants for collaborative MPA management), there are no geographical restrictions for the grants within the WPP 572. There are a total of 285 ha and 6 ha of mangrove and seagrass ecosystems, respectively, that are targeted during the project implementation period. The breakdown of the interventions per year by hectares is summarized in Table 7.

TABLE 7 TARGET OF ECOSYSTEM RESTORATION (ACTIVITY 2.2.1 - SUB-ACTIVITY 2.2.1.1)

Ecosystem	Grant type	Target ha per year						Total for the project
		Y1	Y2	Y3	Y4	Y5	Y6	
Mangrove	Small		14.9	14.9	14.9	22.3		67
	Large			72.7			145.3	218
	Total	0	14.9	87.6	14.9	22.3	145.3	285
Seagrass	Small							
	Large				6			6
	Total	0	0	0	6	0	0	6

The climate benefit from the Activity 2.1.1. - sub-activity 2.2.1.1 focuses on the restoration and ecosystem enhancement with the aim to sequester carbon in Mangrove and Seagrass ecosystems. Table 8A provides the estimates on climate mitigation benefits from restoring around 291 hectares including 285 ha of Mangroves and around 6 ha of seagrass. This ecosystem restoration initiative through seed sowing and replanting will result in an additional sequestration of 14,006 tonnes and 137,444 tonnes of CO₂ by the final-term and at the end of 20 years, respectively.

TABLE 8A CLIMATE TARGET OF ECOSYSTEM RESTORATION (ACTIVITY 2.2.1 - SUB-ACTIVITY 2.2.1.1) – IN TONNES CO2

Thematic focus	Thematic sectors	Province	Ecosystem extent in hectares (Activity Data)				Total sequestration in tonnes CO2*			
			Baseline	Mid-term	Final term	End of 20-year period	Baseline	Mid-term	Final term	End of 20-year period
2.2.1.1 Nature Restoration (planting)	a. Mangrove re-planting	West Sumatra	0.00	72.67	72.67	72.67	0.00	1,095.09	7,897.41	3,7430.41
		North Sumatra	0.00	0.00	80.11	80.11	0.00	0,00	1,207.27	3,6918.64
		Aceh	0.00	0.00	80.11	80.11	0.00	0,00	1,207.27	3,6918.64
		Lampung	0.00	0.00	7.44	7.44	0.00	0,00	112.19	3,430.72
		Banten	0.00	0.00	7.44	7.44	0.00	0,00	112.19	3,430.72
		Bengkulu	0.00	0.00	7.44	7.44	0.00	0,00	112.19	3,430.72
	b. Mangrove nursery development	Aceh	0.00	7.44	7.44	7.44	0.00	112.19	809.06	3,834.61
		Lampung	0.00	7.44	7.44	7.44	0.00	112.19	809.06	3,834.61
		West Sumatra	0.00	7.44	7.44	7.44	0.00	112.19	809.06	3,834.61
		North Sumatra	0.00	7.44	7.44	7.44	0.00	112.19	809.06	3,834.61
		Banten	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Bengkulu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	e. Seagrass seed-sowing	West Sumatra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		North Sumatra	0.00	6.00	6.00	6.00	0.00	30.36	121.44	546.48
Total			-	108.44	291.00	291.00	-	1,574.20	14,006.21	137,444.79

The ecosystem rehabilitation (through waste removal and sediment deposition interventions) under this sub-activity will improve the quality of existing ecosystems (247.93 ha of Mangroves and 5.58 ha of seagrass) and also provide additional sequestration and avoided emission benefits, as calculated in Table 8B.

TABLE 8B CLIMATE TARGET OF ECOSYSTEM REHABILITATION (ACTIVITY 2.2.1 - SUB-ACTIVITY 2.2.1.1) – IN TONNES CO2

	Ecosystem extent in hectares (Activity Data)						Total emission benefit (in ton CO2)		
	Mid-term		Final term		End of 20-year period				
Province	Baseline	Intervened	Baseline	Intervened	Baseline	Intervened	Mid-term	Final-term	End of 20-year period
Thin layer sediment deposition (mangroves)									
West Sumatra	49.81	49.85	49.63	49.73	48.15	48.65	237.66	617.68	1,780.91
Aceh	48.92	49.13	47.87	48.46	40.23	42.70	1,345.48	3,420.96	8,852.80
Lampung	49.93	49.94	49.86	49.90	49.30	49.49	88.68	231.15	676.00
North Sumatra	49.93	49.94	49.86	49.90	49.30	49.49	88.68	231.15	676.00
Bengkulu	-	-	24.99	24.99	24.75	24.80	-	47.05	196.95
Banten	-	-	24.94	24.96	23.92	24.15	-	203.19	829.62
Subtotal							1,760.50	4,751.17	13,012.29
Waste removal from seagrass beds									
West Sumatra	0.00	2.95	2.75	2.84	1.74	1.98	28.9	53.1	119.2
North Sumatra	0.00	2.80	2.72	2.74	1.72	1.91	0.0	25.3	93.6
Subtotal							28.9	78.4	212.9
Total							1,789.44	4,829.55	13,225.14

Meanwhile, the benefit from the rehabilitation activities will be 4,829.55 and 13,225.14 tonnes CO₂ by the mid term and final-term, respectively.

Renewable Energy

Under the mitigation window of the grants program to be administered by KI, a budget allocation has been made to support equipping fishing vessels with solar-powered chillers (see Output 2.2, subactivity 2.2.1.2). The solar chillers are expected to reduce fish waste, save fishers money on the cost of ice, and reduce the GHG emissions involved with ice production. This subactivity is primarily intended to support the small-scale fishing sector (i.e. it complements the adaptation activities) and the mitigation impact is relatively small. Nevertheless, the following calculations provide estimates and therefore the project targets for GHG emissions reductions related to this subactivity.

For the GHG emissions reductions calculations it is assumed that the energy used by the chillers replaces or avoids the use of ice production from refrigeration machines powered by the PLN grid (state electricity company), which is assumed to be the Baseline Emissions. Since solar panels produce no emissions during their use (emission factor = 0), the calculation uses the following approach:

$$\text{Emission Reduction} = \text{Baseline Emissions} - \text{Mitigation Emissions (0)}$$

Annual baseline emissions from 1 freezer = 0.748kg CO₂e/kWh x 1KWh/day x 365 days
= 273.02 kg = 0.27302 tonnes CO₂e/year

Therefore,

Baseline Emissions = 0.273 tCO₂e/year x 250 freezers to be replaced with solar freezers
= 68.25 tCO₂e/year

Therefore,

Emission Reductions = 68.25 tCO₂e/year of operation of solar freezers.

Assuming installation in Year 2, there are 2 years of operations to Project Mid-term, 4 years during the implementation period of the Project and 18 years during the life of the Project (assuming replacement by the fishers).

Summary of Emissions Reductions from Renewable Energy grants

Baseline Emissions from a single freezer	0.27	tCO ₂ e/year
Baseline Emissions from 250 freezers	68.26	tCO ₂ e/year
Emissions reductions by mid-term	136.51	tCO ₂ e
Emissions reductions during implementation period	273.02	tCO ₂ e
Emissions reductions during Project lifetime	1,228.59	tCO ₂ e

Calculation Clarifications:

The emission factor of 0.748 kg of CO₂/kWh uses the 2013 Sumatra Interconnection system figure, sourced from the Indonesian EFDB (Emission Factor Database) published in 2017.

The Global Warming Potential (GWP) for CO₂ is 1 (CO₂e) and is not included in the calculation, as it does not change the result. It is only necessary for gases like CH₄ and N₂O. In Indonesia, we still use the GWP from the IPCC's Second Assessment Report, even though newer ones exist.

The basis for assumptions and calculation logic comes from Directorate General Letter (Perdirjen) PPI P5/PPI/SET/KUM I/12/2017 concerning Guidelines for Calculating GHG Emissions for Community-Based Climate Change Mitigation Actions.

Total Emissions Reductions Across Project Activities

Aggregating the estimated emissions reduction (ER) across the 3 covered Activities (1.1.1, 2.1.1, and 2.2.1), the BEAM Project is estimated to achieve a total of 483,322 tonnes of CO₂e by the end of the implementation period (final-term), and 1,298,901 tonnes of CO₂e by the end of the project's lifespan (20 years).

MONITORING, REPORTING, AND VERIFICATION (MRV) ARRANGEMENTS

To establish a transparent, replicable, and third-party auditable framework that aligns directly with international carbon project standard practices, the MRV architecture for the BEAM project is divided into three distinct, structured components: Measurement, Reporting, and Verification.

1. Measurement (Quantification)

This component details the scientific, technical, and spatial protocols used to quantify biogenic and technological carbon pools under the BEAM framework.

Baseline Scenarios

The counterfactual "business as usual" (BAU) baseline establishes the emissions that would occur in the absence of project interventions.

- For **Activity 1.1.1** and **Activity 2.1.1**, the biogenic baseline relies on historical degradation trends across WPP 572, applying a localized annual loss rate for mangroves (district level rates are applied but the average is 0.2% across WPP572) and a global decline rate of 2.82% for seagrass meadows to the 2027 project-start extent.
- For **Activity 2.2.1/Sub-Activity 2.2.1.1 (Nature Restoration)**, the baseline assumes a zero-restoration state where degraded mudflats and cleared scars continue to erode and lose soil organic carbon.
- For **Activity 2.2.1/Sub-Activity 2.2.1.2 (Renewable Energy)**, the baseline assumes small-scale fishers continuously rely on grid-powered ice production for fish preservation.

Data Parameters

Quantification variables are divided into fixed baseline parameters and monitored project variables:

- **Fixed Parameters (Ex-Ante Constants):**
 - Mangrove organic carbon stock: 950.5 tC/ha (covering above/below-ground biomass and a 1 m soil depth), sourced from Alongi et al. (2016).
 - Seagrass organic carbon stock: 119.5 tC/ha (1m soil depth), sourced from Alongi et al. (2016).
 - Global blue carbon burial/sequestration default rates, sourced from Mcleod et al. (2011).
 - Sumatra Interconnection grid emission factor: 0.748kg CO₂/kWh, sourced from the Indonesian EFDB (2017).
 - Standard molecular conversion factor (C to CO₂): 44/12, sourced from the IPCC (2003).
- **Monitored Parameters (Ex-Post Variables):**
 - $A_{\text{intact},y}$: Extent of intact mangrove and seagrass ecosystems under active MPA management or community co-management.
 - $A_{\text{rest},y}$: Surface area (hectares) of successfully restored mangrove and seagrass ecosystems.
 - $E_{\text{solar},y}$: Total kilowatt-hours (kWh) of renewable electricity utilized by the deployed solar-powered freezers.

Sampling, Frequency, and Spatial Boundaries

The project operates within nested spatial boundaries mapped inside the 94.3 million hectare macro-boundary of WPP 572.

- **Policy and Community Protection Zones (Activities 1.1.1 & 2.1.1):** Bounded by legal MPA polygon coordinates and a 10 km functional fishing buffer zone. Ecosystem extent is measured using high-resolution maps and annual changes are mapped using satellite remote sensing.
- **Active Nature Restoration Zones (Activity 2.2.1):** Confined to the micro-polygons of the designated 285 hectares of mangroves and 6 hectares of seagrass beds. Restoration area extent is mapped annually, and vegetative condition is assessed using a random stratified sampling design.
- **Renewable Energy Tracking (Activity 2.2.1):** Bounded by the placement of the 250 solar freezer units. System deployment, usage logs, and energy offsets are monitored **annually**.

2. Reporting

This component details how raw monitoring data is structured, standardized, and uploaded to the centralized data platform.

Standardization

All monitored parameters and spatial datasets are normalized to maintain strict compliance with the GCF's Integrated Results Management Framework (IRMF), the 2013 IPCC Wetlands Supplement, and national carbon accounting rules. Remote sensing models align with domestic standards, specifically **SNI 7717:2020** for mangrove mapping and **SNI 7716:2012** for shallow-sea seagrass habitat validation.

Roles and Responsibilities

The project operates a clear reporting hierarchy to ensure full data traceability:

Sub-Grantees / Field Teams → Record field data and uploads to local tracking logs

Central KI M&E Team & GIS Unit → Develops sampling design, Aggregates data, runs QA/QC, maintains the Project DBMS

Accredited Entity (CI) → Compiles data into the Annual Performance Report (APR) for GCF

Digital MRV (D-MRV) Architecture

To maximize transparency, decrease processing lag, and eliminate human entry error, the project introduces a Project Database Management System (DBMS) during the startup period. This D-MRV infrastructure integrates automated validation checks for incoming field files. Personally Identifiable Information (PII) is encoded automatically to protect community privacy. For mitigation activities related to renewable energy technologies, solar freezer operation times and system usage logs are cross-referenced digitally against BLU LPMUKP transaction pipelines, preventing data manipulation at the source.

3. Verification

This component establishes the independent auditing schedule and quality control boundaries required to validate and verify the calculated emission reductions.

Validation vs. Verification Schedule

The project distinguishes between the baseline validation phase and subsequent ex-post performance verifications.

- **Validation:** Core project baselines, target allocations, and the Effectiveness Index (EI) are validated and if localized data gaps emerge during Year 1, baseline data is collected via field studies and cross verified with latest available data at that time.
- **Verification Audits:** Performance verifications are conducted as per sampling schedule and frequency linked to the project's milestones. Independent, accredited external contractors are engaged via service contracts to perform the **Interim Evaluation in Year 3** and the **Final Summative Evaluation in Year 6**. These independent auditors conduct site visits, review DBMS ledgers, and confirm net climate achievements before project closure.

QA/QC and Double-Counting Safeguards

To guarantee absolute data integrity, the external verification body tracks parameters along a clear chain of custody. Independent third-party contractors perform field observation visits to replicate a sample of grantee-reported calculations. To completely eliminate the risk of double-counting between policy-driven protection (Activity 1.1.1) and community-driven field grants (Activity 2.1.1), the calculations apply a sequential, year-by-year **Effectiveness Index (EI)**. This index isolates overlapping spatial polygons, scaling down respective mitigation claims to reflect realistic co-management thresholds rather than summing identical biogenic pools twice.

Non-Permanence and Risk Management

Because coastal blue carbon ecosystems are exposed to reversals from natural hazards—such as extreme precipitation runoff, sedimentation, sea-level rise, and tectonic events (e.g., the historical destruction of coastal vegetation during tsunamis)—risk management is integrated into the MRV logic.

- **Ecosystem Resilience Tracking:** The environmental co-benefit framework continuously tracks structural quality, including live coral cover and mangrove density metrics, to spot early structural degradation before it triggers carbon losses.

Risk Mitigation: To buffer against localized reversals, all sub-grantee restoration models under Activity 2.2.1 are screened against the project's Environmental and Social Management Framework (ESMF) and Disaster Risk Management Plan. Applicants must formally document a localized exit and maintenance strategy, detailing how community

enforcement and local surveillance networks (POKMASWAS) will safeguard restored habitats from degradation, ensuring carbon permanence far beyond the 6-year implementation lifecycle.

4. Uncertainty Assessment and Key Assumptions

The ex-ante emission reduction estimates were developed using a combination of Tier 1 and Tier 2 methodologies consistent with the 2013 IPCC Wetlands Supplement and Indonesia's national GHG accounting approaches. Estimates rely on the best available national and global datasets; therefore, uncertainties arise from ecosystem mapping accuracy, baseline degradation rates, emission factors, intervention effectiveness, and long-term restoration success. To avoid overestimation, conservative assumptions have been applied throughout the analysis.

The underlying parameters, specific error margins, and risk-mitigation safeguards applied to this project are listed in the matrix below:

- Structural Inventory Parameter Uncertainty and Safeguards

Inventory Variable	Central Value Used	Parameter Uncertainty ($\pm$ %)	Primary Data Source & Scientific Justification	GCF Conservatism Safeguard & D-MRV Alignment
Mangrove Area Extent	35,805.89 ha	$\pm 10\%$	Global Mangrove Watch (Version 3.0, 2022 dataset)	Validated annually via cloud-masked satellite remote sensing; aligned with Indonesian domestic mapping standard SNI 7717:2020
Seagrass Area Extent	21,542.13 ha	$\pm 25\%$	Allen Coral Atlas (2022 baseline assessment)	High penalty factor applied for cloud cover/turbidity; subject to site field validation via SNI 7716:2012 during Year 1
Mangrove Baseline Loss	0.20% annual	$\pm 15\%$	Historical time-series data analysis from Global Mangrove Watch (1996–2020) .	Derived exclusively from localized district-level data to reflect historical realities
Seagrass Baseline Loss	2.82% annual	$\pm 10\%$	Global decline proxy rate from Stankovic et al. (2021)	Highly conservative baseline; similar to the 2.8% decline rate cited in the National Seagrass Status Report by Indonesia's National Research and Innovation Agency (BRIN) that was based on the average decline in seven seagrass bed areas .
Mangrove Soil/Biomass Stock	950.5 tC/ha	$\pm 15\%$	Country-specific empirical synthesis from Alongi et al. (2016)	Standardized to a strict 1-metre soil depth; all deep sub-surface carbon pools are excluded to remain conservative

Inventory Variable	Central Value Used	Parameter Uncertainty ($\pm$ %)	Primary Data Source & Scientific Justification	GCF Conservatism Safeguard & D-MRV Alignment
Seagrass Soil Stock	119.5 tC/ha	$\pm 30\%$	Country-specific empirical synthesis from Alongi et al. (2016) .	Broad standard deviation applied to protect against regional micro-habitat variance across the provinces
Sumatra Grid Emission Factor	0.748 kg CO ₂ /kWh	$\pm 5\%$	Indonesian Emission Factor Database (EFDB, 2017)	Applicable to local-scale renewable-energy based Climate Change Mitigation Actions as per Decree (Perdirjen) of the Directorate General of Climate Change Control (PPI) P.5/PPI/SET/KUM.I/12/2017
Effectiveness Index (EI)	Dynamic %	$\pm 20\%$	Project design logic and phased field-rollout models.	Accounts for staggered field deployment risks; verified ex-post against actual Ministry EVKA performance evaluations.

Quantification of Uncertainty

For the BEAM Project, uncertainty was evaluated based on the above principal parameters that drive emission reduction outcomes, including ecosystem extent estimates, ecosystem loss rates, carbon stock factors, sequestration rates, restoration performance, and intervention effectiveness assumptions. Several of the underlying source datasets and parameters contain substantial variability. For example, mangrove sequestration rates applied in this assessment are reported in the literature as a range of 1.5-2.0 tC ha⁻¹ yr⁻¹, while seagrass burial rates are reported as 138 $\pm$ 38 gC m⁻² yr⁻¹. Similarly, carbon stock estimates and ecosystem extent datasets vary spatially across Indonesia and are derived from a combination of Tier 1 and Tier 2 information sources. These sources of variability are further compounded by uncertainties associated with future management effectiveness, restoration success, and long-term ecosystem response to project interventions.

Compounding these parameter-specific variances through the Root-Sum-of-Squares equation yields a weighted project-level uncertainty range of $\pm 30\%$. This interval is mathematically justified by the higher variance penalties placed on seagrass sediment carbon pools ($\pm 30\%$) and static satellite imagery baseline assumptions ($\pm 25\%$). This value lies within the range commonly reported for ex-ante greenhouse gas estimates that rely on a combination of remotely sensed activity data, literature-derived emission factors, and future effectiveness assumptions. The selected uncertainty range is considered conservative because the assessment already applies precautionary assumptions, including conservative ecosystem loss rates, phased management effectiveness improvements, exclusion of non-quantifiable mitigation benefits, and strict avoidance of double counting across intervention pathways. The $\pm 30\%$ range should therefore be interpreted as an indicative sensitivity interval around the central estimate and not as a

formal statistical confidence interval. Uncertainty is expected to decrease progressively during project implementation as site-specific monitoring data, restoration performance records, ecosystem condition assessments, and MPA management effectiveness evaluations become available.

The sensitivity range bounds the central estimates as follows::

Project Timeline	Central Estimate (tCO₂e)	Lower Estimate (-30%)	Upper Estimate (+30%)
Mid-term	170,461	119,323	221,600
End of Project Implementation (2032)	483,322	338,326	628,319
End of Project Lifespan (20 years)	1,298,901	909,231	1,688,571

Conservative Approach

To reduce the risk of overestimating mitigation outcomes, several conservative assumptions will be adopted:

- The analysis uses the lower and more conservative values where multiple estimates are available.
- No mitigation benefits are claimed for carbon pools or ecosystem services that cannot be robustly quantified.
- The project applies a phased Effectiveness Index (EI) rather than assuming immediate full effectiveness of management interventions.
- Double counting risks between Activities 1.1.1 and 2.1.1 will be addressed through spatial delineation and EI adjustments.

Restoration benefits are only attributed to areas directly restored under project financing and above the baseline assumption of zero restoration.

Management of Uncertainty

During project implementation, this sensitivity interval will be progressively narrowed. Monitored parameters—such as the extent of intact ecosystems, surface area of restored sites, and solar energy generation usage—captured via the automated digital DBMS platform will replace ex-ante literature assumptions with site-specific empirical field measurements, including:

- Update ecosystem extent data annually using satellite imagery and GIS analyses aligned with SNI 7717:2020 (Mangrove Mapping) and SNI 7716:2012 (Seagrass Habitat Validation).
- Conduct field verification and ecological monitoring of restored mangrove and seagrass sites.
- Reassess management effectiveness through periodic EVIKA evaluations.
- Apply QA/QC procedures through the KI M&E Team and GIS Unit before data are incorporated into annual GCF reporting.
- Undertake independent third-party verification through the Year 3 Interim Evaluation and Year 6 Final Evaluation.

APPENDIX

Appendix 1: Ecosystem maps for WPP 572

Map images removed

Appendix 2: Effectiveness Index used to calculate ex-ante emissions reductions

Type of MPAs	For expansion MPAs	For existing MPAs			
Interventions	Support on MPA regulatory framework	Support MPA surveillance practices	Support of MPA management planning	Awareness raising for communities	Sustainable livelihood support (ecotourism, sustainable fishing)
Relative Importance	10%	60%	10%	10%	10%
Project Deliverables	(a) develop MPA working groups at Y1 (15%) (b) develop MPA initiation document at Y2 (15%) (c) MPA designation decree at Y3 (20%) (d) develop MPA zoning plan at Y4 (20%) (e) MPA establishment decree at Y5 (20%) (f) MPAs are updated within the provincial zoning plan at Y5 (10%)	(a) training on surveillance at Y1 (30%) (b) develop SOP on patrolling/surveillance at Y2 (30%) (c) conduct collaborative patrolling at Y3 (20%) (d) collaborative patrolling mechanism/system is running/on going (10%)	(a) develop MPA's SOP (30%) (b) community participation (30%) (c) collaborative MPA monitoring activities (40%)	(a) training to local communities and fishers (30%)	(a) develop local community enterprise on ecotourism (5%) (b) develop sustainable fishing livelihood (5%)
BEAM related project activities/sub-activities	Activity 1.1.1 (Sub-Activity 1.1.1.2)	Activity 1.1.1 (Sub-Activity 1.1.1.2) Activity 2.1.1 (Sub-Activity 2.1.1.2)	Activity 2.1.1 (Sub-Activity 2.1.1.2)	Activity 1.1.1 (Sub-Activity 1.1.1.2)	Activity 2.1.1 (Sub-Activity 2.1.1.1) Activity 2.1.1 (Sub-Activity 2.1.1.3)
Project year t	Impact				
1	15%	30%	30%	30%	10%
2	30%	60%	60%	60%	20%
3	50%	80%	100%	90%	30%
4	70%	90%	100%	90%	40%
5	100%	90%	100%	90%	50%
6	100%	90%	100%	90%	60%
7	100%	50%	100%	50%	60%
8	100%	50%	100%	50%	60%

Type of MPAs	For expansion MPAs	For existing MPAs			
9	100%	50%	100%	50%	60%
10	100%	50%	100%	50%	60%
11	100%	50%	100%	50%	60%
12	100%	50%	100%	50%	60%
13	100%	50%	100%	50%	60%
14	100%	50%	100%	50%	60%
15	100%	50%	100%	50%	60%
16	100%	50%	100%	50%	60%
17	100%	50%	100%	50%	60%
18	100%	50%	100%	50%	60%
19	100%	50%	100%	50%	60%
20	100%	50%	100%	50%	60%

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