VCS Methodology

VM0010

IMPROVED FOREST MANAGEMENT: CONVERSION FROM LOGGED TO PROTECTED FOREST

Version 1.4

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Sectoral Scope 14: Agriculture, forestry, and other land use (AFOLU)

Version 1.0 of this methodology was developed by GreenCollar Consulting Solutions (Mark Dangerfield, Charlie Wilson, Tim Pearson and James Schultz). Versions 1.1 and 1.2 of this methodology were also developed by GreenCollar Consulting Solutions.

Version 1.3 of this methodology was developed by GFA Consulting Group (Martin Burian, Lars Schmidt).

Version 1.4 of this methodology was developed by Verra.

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1 SUMMARY DESCRIPTION

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

This Logged to Protected Forest (LtPF) methodology provides a detailed procedure to estimate the net GHG emission reductions/removals resulting from the implementation of Improved Forest Management (IFM) projects aimed at the protection of forests that would be logged in the absence of the project.

The core methodological components are as follows:

- **Determine Eligibility:** Sets the criteria for eligibility of projects under the methodology.
- **Set Project Boundaries and Scope:** Provides guidelines for defining the geographical and temporal boundaries of the project and lists the GHG emissions sources and carbon pools to be included in the project.
- **Assess Baseline Scenario, Additionality and Baseline Modelling:** Provides guidelines to select the most conservative baseline scenario and to determine the additionality of the project.
- **Quantify Baseline Emissions:** Provides a detailed procedure to develop conservative estimates of net greenhouse gas emissions resulting from changes in carbon stocks as a result of planned timber harvest (i.e., selective logging) in the baseline scenario.
- **Quantify Project Emissions:** Provides a detailed procedure to develop conservative estimates of net greenhouse gas emissions resulting from changes in carbon stocks in the project scenario.
- **Quantify Leakage:** Describes the approach to account for leakage arising from the implementation of project activities.
- **Quantify Net Emission Reductions/Removals:** Provides the approach to determine the amount of net greenhouse gas emission reductions/removals at the end of each year for both the baseline and project scenarios.
- **Quantify Verified Carbon Units (VCUs):** Provides the approach to determine, on the basis of the amount of net greenhouse gas emission reductions/removals, and deductions to account for risk and uncertainty, the amount of Verified Carbon Units (VCUs) that should be credited to the project each year over the project crediting period.
- **Perform Ongoing Monitoring:** Provides guidelines for the implementation of a monitoring plan and identifies monitored parameters to assess carbon stock change and disturbance in the project scenario.

2 SOURCES

This methodology uses the latest versions of the following methodologies, modules and tools:

- *CDM Tool for Calculation of the Number of Sample Plots for Measurements within A/R CDM Project Activities.*
- *CDM Tool for testing significance of GHG emissions in A/R CDM project activities.*
- *VCS methodology VM0003 Methodology for Improved Forest Management through Extension of Rotation Age.*
- *VCS methodology VM0005 Methodology for Conversion of Low-Productive Forests to High-Productive Forests.*
- *VCS methodology VM0007 REDD+ Methodology Framework (REDD-MF).*
- *VCS methodology VM0011 Methodology for Improved Forest Management: Calculating GHG Benefits from Logged to Protected Forest.*
- *VCS VT0001 Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities.*

3 DEFINITIONS

In addition to the definitions set out in the VCS document *Program Definitions*, the definitions below apply to this methodology.

Commercial Timber Harvest
Felling (i.e., removal), transporting and processing of merchantable trees from a forest to obtain income from wood products.

Merchantable biomass
Is the biomass of trees, crops, or forest stands having the size, quality and condition suitable for marketing under a given economic condition, even if not immediately accessible for logging[1].

Diameter at Breast Height (DBH)
Diameter of the stem/bole outside bark of a tree at 1.3 meters or 4.5 feet.

[1] Definition extracted from the SAF's Dictionary of Forestry (2018).

Forestry Infrastructure
Physical infrastructure needed to carry out forestry operations, including (but not restricted to) roads, skid trails and log landings in the project area.

Forest Inventory
A system for measuring the extent, quantity and condition of a forest by sampling through:

- A set of objective sampling methods designed to quantify the spatial distribution, composition and rates of change of forest parameters within specified levels of precision for the purpose of management; and
- Listing of data from such survey.

Land Parcel
The area of land within a forest specified/allocated for annual logging and timber harvesting operations as defined in a timber harvest plan.

Logging Slash
A component of the deadwood pool, representing the downed or lying woody debris left in the forest (on-site) generated during a timber harvest event.

Planned Timber Harvest
Planned removal of merchantable trees from a forest to obtain income from the wood products under legal conditions for harvest and documented under a timber harvest plan.

Planted Forest
A forest that at maturity is predominantly composed of trees established through planting and/or deliberate seeding. Planted forests include but is not limited to plantation forests[2].

Plantation forests
Intensively managed planted forests that at maturity is composed of one or two species, has one age class, and has regular tree spacing, Plantation forests are a subset of planted forests.

Selective logging
A timber harvesting technique that involves removing only selected trees based on specific characteristics (e.g., diameter, height, species, market value) Unlike clear-cutting, where all trees are removed, selective logging means most trees remain in the forest stand with the objective of maintaining an uneven-aged structure[3]

Timber Harvest Plan
Description of the methods and operations needed to harvest timber from a forest under a given set of legal conditions for harvest that includes:

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[2] Adapted from FAO (2023) Global Forest Resources assessment (FRA) Terms and Definitions.

[3] Usually applied in tropical managed forests, selective logging intensity varies depending on species abundance, distribution and region. Intensity can range between 1-20 trees harvested per hectare over a minimum cutting diameter, with average rotation of 25-50 years (Burivalova et al. 2014 Current Biology 24 (16):1893-1898).

- Demarcation of non-harvest areas within the forest.
- Division of the harvestable forest into annual operating areas (land parcels or compartments) presented with descriptions and maps.
- Design and presentation of the transport system for the removal of harvested timber products, and a description of the harvest and transport machinery used for timber harvest.

3.1 Symbols and Notations

3.1.1 Physical quantities

This section presents the symbols that are used throughout the methodology to represent physical quantities used in the accounting equations.

Flows of greenhouse gas(es)
The symbol GHG is the common identifier used throughout this methodology to represent flows of greenhouse gas(es) to/from the atmosphere.

For these flows, the absolute value represents the magnitude of the flow, in tCO_2e $year^{-1}$, or the total amounts exchanged with the atmosphere, in tCO_2e.

Carbon stocks
The symbol C is the common identifier used throughout this methodology to represent carbon stocks. The values presented are either carbon stocks (in tC), or carbon stocks per unit area (in $tC{\cdot}ha^{-1}$) as indicated in the methodology described under Section 8.

Carbon stock changes
The symbol ΔC is the common identifier used throughout this methodology to represent changes in carbon stocks. The values presented could be either total changes in carbon stocks (in tC), annual changes in carbon stocks (in $tC{\cdot}year^{-1}$), or annual changes in carbon stocks per unit area (in $tC{\cdot}ha^{-1}{\cdot}year^{-1}$), as indicated in the methodology described under Section 8.

3.1.2 Scenario qualifiers

This section presents the symbols that are used throughout the methodology as scenario qualifiers, for the physical quantities used in the accounting equations as follows:

- Physical quantities referring to the baseline scenario feature the suffix ($_{BSL}$).
- Physical quantities referring to the project scenario feature the suffix ($_{PRJ}$).
- Physical quantities derived from baseline and project scenario accounting feature the suffix ($_{LtPF}$).

4 APPLICABILITY CONDITIONS

Projects must fall within the VCS AFOLU project category "IFM: Logged to Protected Forest" as defined in the most recent version *VCS Standard* and associated VCS Program documents.

This methodology is applicable under the following conditions:

- Forest management in the baseline scenario is planned selective logging.
- Planned selective logging must be estimated using forest inventory methods that determine allowable offtake as volume of timber (m^3 ha^{-1}).
- Boundaries of the forest land are clearly defined and documented.
- All applicability conditions of VCS and CDM tools used in conjunction with this methodology are met

This methodology **is not** applicable under the following conditions:

- The project area includes planted forests.
- Under the project scenario, forest use in the project area includes commercial timber harvest or activities that cause forest degradation.
- The baseline scenario includes conversion to managed plantations.
- The project occurs in wetlands or peatlands.
- The project occurs in a location where VM0045 is currently applicable.

4.1 Eligibility

Legal Right to Harvest
The legal right to harvest must pre-exist the implementation of the project.

The legal right to harvest must be issued by a relevant government body, define a legal allocation of rights to a forest timber resource, and includes a plan for forest management that contains a definition of the spatial extent of the forest, the volume of the timber resource to be extracted and a description of harvesting practices.

Rights to forest management must be demonstrated by documentary proof of legal permissibility for timber harvest, intent to harvest and a description of the timber resource. This proof must be issued by the relevant (governmental) regulatory body that has designated, sanctioned or approved the project area (or areas) for forest management.

Intent to Harvest
The project proponent must demonstrate intent to harvest through the following forms of evidence originating prior to the date of all evidence in pursuit of carbon finance/consideration of IFM. Projects must provide either:

- Documented evidence demonstrating that:
    - The project site is representative of other forestlands harvested in the country within the past two years; and,
    - The project site is within commercially viable distance to existing transport networks and a port for timber export or a mill for timber processing; or,
- A valid and verifiable government-approved timber management plan for harvesting the project area.

5 PROJECT BOUNDARY

5.1 Geographical Boundaries

The project proponent must clearly define the spatial boundaries of the project to facilitate accurate measurement, monitoring, accounting and verifying of the project's emission reductions and removals.

The IFM project activity may contain more than one discrete area of land.

When describing physical project boundaries, the following information must be provided per discrete area:

- Name of the project area (including compartment number, allotment number, local name).
- Unique identifier for each discrete land parcel used in the timber harvest plan.
- Map(s) of the area (preferably in digital format).
- Geographic coordinates of each polygon vertex (preferably obtained from a geodesic coordinate or from a geo-referenced digital map).
- Total land area.
- Details of forest land rights holder and user rights.

The geographic boundaries of an IFM project are fixed and thus do not change over the project crediting period.

The geographic boundaries for leakage from market effects are those of the country in which the project area is located.

5.2 Temporal Boundaries

The temporal boundaries are defined by the project start date and the length of the project crediting period.

The minimum duration of a monitoring period is one year, and the maximum duration is 10 years.

5.3 Carbon Pools

The carbon pools included or excluded from the project boundary are shown in Table 1 below.

Table 1: Carbon Pools

Carbon Pools	Included?	Justification/Explanation of choice
Aboveground trees	Included	The stock change in the above ground tree biomass must be estimated
Above ground non-tree	Excluded	Exclusion is always conservative when forests remain as forest
Belowground	Excluded	Unlikely to change significantly in forests remaining as forests, and is difficult to measure, thus omission is conservative
Deadwood (logging slash)	Included in the baseline	The dead wood (logging slash) carbon pool is expected to be larger in the baseline than in the project scenario, and therefore this pool must be included
Dead wood (naturally accumulated)	Excluded	Following IPCC guidelines[4], it is assumed that carbon stocks in the naturally occurring dead wood pool (both standing and lying) are equivalent in both the project and baseline scenario, and therefore this pool is conservatively excluded. It is not conservative to account for this pool in the baseline scenario only
Harvested wood products	Included	Will be significant and greater in the baseline compared to the project scenario
Litter	Excluded	Insignificant and exclusion is conservative
Soil organic carbon	Excluded	Exclusion is always conservative when forests remain as forest

5.4 Greenhouse Gas Emissions Sources

The emission sources included in or excluded from the project boundary are shown in Table 2 below.

The project proponent may choose to exclude accounting for GHG emissions related to the combustion of fossil fuels (please refer to Section 8.1.4), which is conservative. If the project proponent decides to include accounting for GHG emissions related to fossil fuel combustion,

[4] IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories; Volume 4 AFOLU, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

then the specific GHGs must be tested for significance, using the most recent version of the CDM *Tool for testing significance of GHG emissions in A/R CDM project activities*.

If the application of the tool leads to the conclusion that the emission source is insignificant[5], then this GHG must be neglected. In addition, the sum of decreases in carbon pools and increases in emissions that may be neglected must be less than 5% of the total project GHG benefits.

Table 2: Emission Sources

Source		Gas	Included?	Justification/Explanation
Baseline and Project	Combustion of fossil fuels (in vehicles, machinery and equipment)	CO_2	Included, if significant	Only included if tested as significant. Otherwise excluded, which is deemed conservative, as emissions will be greater in the baseline scenario than in the project scenario
		CH_4	Included, if significant	Only included if tested as significant. Otherwise excluded, which is deemed conservative, as emissions will be greater in the baseline scenario than in the project scenario
		N_2O	Included, if significant	Only included if tested as significant. Otherwise excluded, which is deemed conservative, as emissions will be greater in the baseline scenario than in the project scenario
	Removal of herbaceous vegetation	CO_2	Excluded	Based on CDM EB decision reflected in paragraph 11 of the report of the 23rd session of the board: https://cdm.unfccc.int/Panels/ar/023/ar_023_rep.pdf
	Burning of Biomass	CH_4	Included	Included as CO_2 equivalent emissions
		N_2O	Excluded	Potential emissions are negligible
	Nitrogen based fertilizer	N_2O	Excluded	Potential emissions are negligible. Following the VCS update to the *Tool for AFOLU Methodological Issues and Guidance for AFOLU Projects*, emissions via the use of fertilizer are considered insignificant and are not considered here.

[5] http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html

6 BASELINE SCENARIO

6.1 Selection of baseline

The project proponent must use the most recent version of the VCS tool, *VT0001 Tool for the Demonstration and Assessment of Additionality in AFOLU Project Activities* to assess which of the baseline alternatives must be excluded from further consideration.

As per the applicability conditions of this methodology, the project must demonstrate a baseline scenario of planned timber harvest (see Box 1 below). If such a baseline cannot be demonstrated, then this methodology cannot be applied.

Planned timber harvest events in the baseline scenario can occur in any year of the project activity, not just year zero (*0*).

6.2 Modeling the baseline scenario

Once the baseline scenario of planned timber harvest is demonstrated, the project proponent must determine how to model the baseline management scenario. A Historical Baseline Scenario (Section 6.2.1) must be used where data is available, otherwise a Common Practice Baseline Scenario (Section 6.2.2) must be used.

Irrespective of which baseline scenario is used, the same formulas (as set out in Sections 8.1.1 to 8.1.6) for the quantification of baseline emissions are applied. The major difference between the historical and common practice baseline scenarios is the source of data for the majority of parameters (see Section 9.1) that are used in Sections 8.1.1 to 8.1.6 to calculate baseline emissions.

Where the historical baseline scenario is applied, the historical data pathway must be followed regarding data sources for most parameters available at validation.

Where the common practice scenario is applied, the common practice data pathway must be followed regarding data sources for most parameters available at validation.

In principle, under the historical baseline scenario, historical records of timber harvesting from the baseline agent are used to determine the values of many of the parameters available at validation. Under the common practice scenario, other sources (e.g., data from other forestry companies in the region, regional default values, legal requirements, etc.) must be used. See Sections 8 and 9.1 for further details.

6.2.1 Historical Baseline Scenario

A baseline scenario and timber harvest plan (see
Box 1 below) derived from the historical practices of the baseline agent of timber harvest must be modelled as the baseline if the following documents exist for the project proponent:

1) Historical records of forest management exist for a minimum of 5 or more years preceding the project start date.
2) Historical records indicating that the management practices have surpassed the legal requirements (provided by conforming to all local and regional forest legislation).
3) Historical records indicating that the historical management surpasses financial barriers by providing above average financial returns.

6.2.2 Common Practice Baseline Scenario

All other cases must model baseline harvest based on common practice.

Common practice is defined as timber harvest under the legal requirements for forest management and will be determined from a timber harvest plan (see Box 1 below) developed from:

1) The project area through scenario modeling as if the legal requirements were implemented in the project area; and
2) A reference area[6] (or multiple reference areas) already under timber harvest management that complies with legal requirements for forest management and selected to be representative of local common practice for timber harvest.

Box 1: Timber Harvest Plan

The description of harvesting in the form of a timber harvest plan constitutes the basis of the baseline scenario for greenhouse gas accounting. The timber harvest plan describes the harvest of timber products and must:

1) Reference the forest volume inventory (see Section 8.1.1– parameter $V_{j,i|BSL}$) to identify the relative number of trees per hectare potentially available for harvest by species in each stratum;
2) Demarcate all non-harvest areas within the forest based on legally required exclusions for environmental features such as slope, swamp areas or conservation buffers;
3) Divide the harvestable forest into annual operating areas (referred to throughout this methodology as land parcels) using common practice;
4) Include a design and presentation of the forestry infrastructure to harvest, skid/haul, store and move harvested timber products from the land parcels to downstream

[6] Reference areas must be in the same region as the project area and must match the project area in terms of forest types, climate and elevation (identical mix of forest types ±20%; identical annual precipitation ±20%; elevation classes (500 m classes) in the reference region shall be in the same proportion as in the project area (+/-20%)). For forest types, a *de minimis* rule may be applied if not suitable reference area can be found. Forest types that cover less than 1% of the project area may be excluded for the purpose of finding a suitable reference area. However, in total, no more than 5% of the project area forest cover may be excluded in this way.

processing or market entry points. Where the project proponent accounts for emissions from forestry infrastructure, the design and presentation must include all forest roads, skidtrails and log landings that would be established under the baseline scenario as a georeferenced layer (shapefile or equivalent) and must list necessary harvest and transport machinery;

5) The timber harvest plan must follow local best practice for timber harvest, including planning of roads, skidtrails and log landings-and the timber resource volume and extraction quotas defined by any legal requirements.

For the purpose of estimating the net annual changes in carbon stocks resulting from planned timber harvest in the baseline scenario, a detailed planned timber harvesting schedule will be developed from the timber harvest plan, setting out details of harvest and forestry infrastructure establishment for each land parcel in the project area in terms of the following:

1) The species to be harvested.
2) The year (1,2,3…) in which timber harvest and/or forestry infrastructure establishment in each land parcel is scheduled to occur.
3) The number of years each land parcel is in a post-harvest and/or post forestry infrastructure establishment state during the project crediting period.
4) The maximum and minimum diameters at breast height (DBH), at stump and at top for tree harvesting.
5) The planned harvesting regime (i.e., number of log landings, species/stratum- and area subject to selective logging).
6) The fraction of merchantable timber volume from clearing of forest roads, skidtrails and log landings that is to be processed into wood products ($F_{V,INF,HWP}$). Based on this fraction, as well as forest inventory and forestry infrastructure data, $V_{EX,INF,j,i|BSL}$ and $V_{notEX,INF,j,i|BSL}$ (see points 2 and 3 below) will be calculated.
7) The technical specifications for the categories of wood products to be harvested.
8) The total volumes or fractions to be harvested, broken down by categories of wood products defined as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and/or others.

The planned timber harvest schedule is determined *ex ante* to reflect the timber harvesting plan as stipulated by the legal right to harvest. The *planned timber harvesting schedule* will be developed for the project area to include all land parcels within the project boundary for the proposed IFM activity.

The output of the timber harvest plan and timber harvesting schedule must include:

1) The mean extracted volume of extracted merchantable timber per unit area by species in each stratum in each year ($V_{EX,j,i|BSL}$).

2) Where the project proponent accounts for forestry infrastructure, the mean volume of merchantable timber extracted for wood processing that is harvested during the process of forestry infrastructure establishment per unit area by species in each stratum in each year ($V_{EX,INF,j,i|BSL}$).

3) Where the project proponent accounts for forestry infrastructure, the mean volume of merchantable timber that is cleared during the process of forestry infrastructure establishment and NOT extracted for wood processing per unit area by species in each stratum in each year ($V_{notEX,INF,j,i|BSL}$).

The planned timber harvesting schedule will be submitted by the project proponent as part of the project documents.

6.3 Stratification

If the proposed project area contains different forest types or forests with different carbon densities, stratification must be carried out to improve the accuracy and precision of carbon stock estimates.

For estimation of base year carbon stocks, strata must be defined based on parameters that are key variables in any method used to estimate changes in the managed forest carbon stocks. Strata will include either forest type, vegetation type and/or target timber species.

Based on the availability of data about the nature and composition of forest stocks in the project area, stratification will be developed based on either:

a) Existing vegetation mapping or stratification, where these are documented in the legal right to harvest; or

b) Estimates developed from sampling the project area using standard forest assessment protocols specific to the forest region where the project area is located.

Baseline stratification is developed *ex ante*.

As part of the project documents, the project proponent must submit a detailed description of the stratification adopted for the project area.

7 ADDITIONALITY

The project proponent must demonstrate the additionality of the project using the most recent version of VCS tool, *VT0001 VCS Tool for the Demonstration and Assessment of Additionality in AFOLU Project Activities*.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Calculation of baseline emissions for all land parcels under both the historical and common practice baseline scenarios requires the application of the equations presented in Sections 8.1.1 to Section 8.1.6. Table 3 lists the baseline emissions modeled by this methodology.

Table 3: Emission Included in Baseline Modeling

Nº	Included in modelling (All projects)
1	Emission from wood product conversion
2	Decomposition of deadwood from harvested trees
3	Emissions from wood product retirement
4	Stock change due to regrowth following timber harvest
5	Decomposition of trees incidentally killed during tree felling
Where project proponent accounts for forestry infrastructure:	
6	Decomposition of trees killed through skid trail creation
7	Decomposition of trees killed through road construction
Optional (as omission is conservative):	
8	Emissions from fossil fuels burned in baseline harvesting practices
Nº	**Conservatively excluded from modeling**
1	Emissions through subsequent forest re-entry

Baseline projections are calculated *ex-ante* and are not adjusted throughout the project crediting period.

Section 8.1.1 serves to calculate carbon stocks in commercial timber volumes. Next, baseline emissions are estimated based on the calculation of deadwood (i.e., logging slash) generated in the process of timber harvest and establishment of forestry infrastructure (Section 8.1.2). The emissions resulting from production and subsequent retirement of wood products are derived from timber harvesting (including timber harvesting from the establishment of forestry infrastructure - Section 8.1.3), the combustion of fossil fuels in forestry machinery including mechanized felling, skidding / forwarding /hauling, loading and transporting inside the project area, and processing (Section 8.1.4), minus the rates of forest regrowth post-timber harvest (Section 8.1.5).

Baseline commercial timber volumes must be derived for development of the timber harvest plan, and for *ex-post* accounting of emissions resulting from natural forest disturbances.

The equations below calculate the total emissions across the project crediting period for each emission source. Total emissions are averaged across the project crediting period to give annual emissions and are multiplied by $t*$ (time elapsed since the start of project activity). Ex-post $t*$ is updated, so baseline projections are available for each proposed future verification date.

Data for input into these carbon stock change calculations for the baseline scenario must be established from the same data used to create the timber harvesting plan.

Depending on which baseline scenario is applied (i.e., historical or common practice), the project proponent must follow either the 'historical data pathway' (for the historical baseline scenario) or the 'common practice data pathway' (for the common practice baseline scenario) when applying the formulas shown in Sections 8.1.1 to 8.1.6.

As a result, the sources for most parameters described in Section 9.1 must be chosen accordingly:

- **Under the historic data pathway:** Where applicable, parameters must be based on the historical logging practices of the baseline agent.
- **Under the common practice pathway:** Where applicable, parameters must be based on data that reflects common practice in the region (e.g., data from other forestry companies in the region, forest management according to the legal requirements, regional default values) that, in quantitative terms, reflect average values regarding forest management. Where data is not readily identifiable as reflecting common practice, the responsible forest department, or another equivalent institution, must confirm that the value in question is considered as being common practice in the region.

8.1.1 Calculation of carbon stocks in commercial timber volumes

This section calculates $C_{HB,j,i|BSL}$, the mean carbon stock in total harvested biomass in tC ha^{-1} and $C_{EX,j,i|BSL}$, the mean carbon stock in extracted timber (merchantable timber that leaves the forest) in tC· ha^{-1}. This includes harvested biomass from the clearing of roads, skid trails and log landings, where applicable. The following calculation of merchantable volume of timber per unit area ($V_{j,i|BSL}$), that is potentially available for harvest must be based on data from field measurements in sample plots.

It is acceptable to use pre-existing forest inventory data[7] for this purpose, provided that the pre-existing data:

a) Represents the project strata;

b) Is not more than 10 years old; and,

[7] Standard quality control / quality assurance procedures for forest inventory including field data collection and data management shall have been applied to the forest inventory assessment. Sampling data and methods shall be available for verification. Sample sizes shall have been sufficient to ensure inventory estimates are within the 95% confidence intervals with the estimated variance within +/- 15 percent from the mean.

c) Where forest inventory data is more than 10 years old, the volume estimate derived from the pre-existing data has been validated with limited sampling within the project area.

Validation of pre-existing forest inventory data must be carried out via field surveys. For each stratum, mean volume is estimated from sample plots/points measured within the project area using standard forest inventory assessment methods. The number of sample plots will be determined from the application of the most recent version of the CDM tool, *Tool for Calculation of the Number of Sample Plots for Measurements within A/R CDM Project Activities*[8].

If the validated estimate of volume is within the 90% confidence interval of the corresponding estimate or greater than the estimate calculated from pre-existing forest inventory data, the pre-existing forest inventory data may be used. If the validation estimate is less than the corresponding estimate calculated from pre-existing forest inventory data, the estimate from pre-existing data cannot be used.

Estimation of the merchantable volume of trees must be based on locally derived allometric equations or yield tables. If locally derived equations or yield tables for each species are not available, it is acceptable to use relevant regional, national or default data.

Yield tables or allometric equations must be used to convert field measurements of diameter (DBH, at typically 1.3 m [4.3 ft] aboveground level or above buttress where they exist), and total height H of each tree in the sample plots to merchantable volume, $V_{l,j,i,sp}$.

It is acceptable to combine DBH and allometric equations if field instruments (e.g., a relascope) that estimate the volume of each tree have been used.

The estimate of merchantable volume for each species *j* at the sample plot level will be calculated as:

$$V_{j,i,sp} = \sum_{l=1}^{L} V_{l,j,i,sp} \tag{1}$$

Where:

$V_{j,i,sp}$	Merchantable volume for species *j* in stratum *i* in sample plot *sp*, m^3;
$V_{l,j,i,sp}$	Merchantable volume for tree *l* of species *j* in stratum *i* in sample plot *sp*; m^3
l	1,2,3…*L* sequence of individual trees in sample plot;
i	1,2,3 …*M* strata;
sp	1,2,3 …*SP* sample plots; and
j	1,2,3 …*J* tree species.

[8] http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html

Therefore, the merchantable volume per unit area of species *j* in stratum *i* will be calculated as the mean merchantable volume in all sample plots in stratum *i*:

$$V_{j,i|BSL} = \frac{1}{SP} \times \sum_{sp=1}^{SP} \frac{V_{j,i,sp}}{A_{sp}} \quad (2)$$

Where:

$V_{j,i\|BSL}$	Mean merchantable volume per unit area of species *j* in stratum *i* in the baseline scenario, $m^3 \cdot ha^{-1}$;
$V_{j,i,sp}$	Merchantable volume for species *j* in stratum *i* in sample plot *sp*; m^3;
A_{sp}	Area of sample plot *sp*, ha;
i	1, 2, 3 …*M* strata;
sp	1, 2, 3 …*SP* sample plots; and
j	1, 2, 3 …*J* tree species.

$V_{j,i|BSL}$ will be used to develop the timber harvest plan (Box 1 above). Based on legal limits, the timber harvest plan sets the allowable mean extracted volume ($V_{EX,j,i|BSL}$) from this merchantable volume.

Further, based on $V_{j,i|BSL}$, the timber harvest plan will specify the mean extracted volume that is harvested for the purpose of building forestry infrastructure ($V_{EX,INF,j,i|BSL}$).

Once the timber harvest plan is complete and $V_{EX,j,i|BSL}$ *as well as* $V_{EX,INF,j,i|BSL}$ are calculated, the Biomass Conversion and Expansion Factor (BCEF) method[9,10] must be used to determine the carbon stocks in harvested biomass.

This method is appropriate as forest inventory data and allowable harvest must be based on volume estimates to which expansion factors can be readily applied. The selected *BCEF* must have a minimum DBH compatible with the minimum DBH defined in the timber harvest plan (see Box 1 above).

Therefore, the carbon stock of timber harvested per unit area for species *j* in stratum *i* will be calculated from this mean volume of extracted timber:

$$C_{HB,j,i|BSL} = (V_{EX,j,i|BSL} + V_{EX,INF,j,i|BSL}) \times BCEF_R \times CF_j \quad (3)$$

[9] Somogyi, Z., E. Cienciala, R. Mäkipää, P. Muukkonen, A. Lehtonen and P.Weiss. (2006) Indirect methods of large-scale forest biomass estimation, Eur.J.ForestRes. 126 (2) pp.197–207. http://dx.doi.org/10.1007/s10342-006-0125-7

[10] IPCC. (2019) Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize, S., Osako, A., Pyrozhenko, Y., Shermanau, P. and Federici, S. (eds). Published: IPCC, Switzerland. https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html .

Where:

$C_{HB,j,i\|BSL}$	Mean carbon stock of harvested biomass per unit area for species *j* in stratum *i*, $tC{\cdot}ha^{-1}$;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*, $m^3{\cdot}ha^{-1}$;
$V_{EX,INF,j,i\|BSL}$	Mean volume of extracted timber for forestry infrastructure per unit area for species *j* in stratum *i*, $m^3{\cdot}ha^{-1}$;
$BCEF_R$	Biomass conversion and expansion factor applicable to wood removals in the project area, t.d.m m^{-3};
CF_j	Carbon fraction of biomass for species *j*, tCt d.m.$^{-1}$;
i	1,2,3 …*M* strata; and
j	1,2,3 …*J* tree species.

Not all of the harvested biomass leaves the forest because the timber harvested has two components: 1) wood removed to market (extracted timber) and 2) wood remaining in the forest as a result of harvest (see Section 8.1.2).

Therefore, the mean carbon stock of extracted timber per unit area for species *j* in stratum *i* will be calculated from the mean volume of extracted timber, multiplied by density and carbon fractions:

$$C_{EX,j,i|BSL} = (V_{EX,j,i|BSL} + V_{EX,INF,j,i|BSL}) \times D_j \times CF_j \quad (4)$$

Where:

$C_{EX,j,i\|BSL}$	Mean carbon stock of extracted timber per unit area for species *j* in stratum *i*; $tC{\cdot}ha^{-1}$;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*; in $m^3{\cdot}ha^{-1}$;
$V_{EX,INF,j,i,p\|BSL}$	Mean volume of extracted timber for forestry infrastructure per unit area for species *j* in stratum *i*, $m^3{\cdot}ha^{-1}$;
D_j	Basic wood density of species *j*; t d.m. m^{-3};
CF_j	Carbon fraction of biomass for species *j*, tC t d.m.$^{-1}$;
i	1,2,3 …*M* strata; and
j	1,2,3 …*J* tree species.

8.1.2 Calculation of dead wood (logging slash) generated in the process of timber harvest

This section calculates $\Delta C_{DWSLASH,i,p|BSL}$. $\Delta C_{DWSLASH,i,p|BSL}$ and includes the following:

a) The change in carbon stock in dead wood (i.e., logging slash) left on the forest floor following timber harvest in stratum *i* in land parcel *p*, using $C_{EX,j,i|BSL}$ and $C_{HB,j,i|BSL}$ as calculated in Section 8.1.1.

b) The change in carbon stock in dead wood (i.e., logging slash) that results from residual stand damage ($C_{RSD,\ j,i|BSL}$). Residual stand damage is the breaking or uprooting of other neighboring trees during the process of tree felling. Residual stand damage is calculated using the residual stand damage factor $F_{RSD|BSL}$.

c) The change in carbon stock in dead wood (i.e., logging slash) left on the forest floor following the establishment of forestry infrastructure in stratum *i* in land parcel *p*. This is calculated using $C_{notHB,INF,j,i|BSL}$ based on $V_{notEX,INF,j,i|BSL}$ as defined in the timber harvest plan. This only includes the emissions from entire trees left to decay as a result of forestry infrastructure construction. Emissions from logging slash of trees harvested for consequent processing during the establishment of forestry infrastructure are included under point a) above.

The simplifying assumption made is that dead wood left on the forest floor following timber harvest follows a ten-year linear decay function, as permitted by the latest *VCS Methodology Requirements*. This decay function is applied when the net greenhouse gas emissions/removals are calculated on an annual basis in Equations 10 and 11 below.

Therefore, the change in carbon stock in the dead wood pool in stratum *i* in land parcel *p* is calculated as the difference between the total carbon stock of the harvested biomass and the carbon stock of the extracted timber, plus the residual stand damage and biomass of trees left to decay as a result forestry infrastructure establishment:

$$\Delta C_{DWSLASH,i,p|BSL} = \sum_{j=1}^{J}[C_{HB,j,i|BSL} - C_{EX,j,i|BSL} + C_{RSD,j,i|BSL} + \ C_{notHB,inf,j,i|BSL}] \qquad (5)$$

Where:

$\Delta C_{DWSLASH,i,p|BSL}$	Change in carbon stock of dead wood as logging slash resulting from timber harvest per unit area in stratum *i* in land parcel *p*, in tC ha^{-1};
$C_{HB,j,i|BSL}$	Mean carbon stock of harvested biomass per unit area for species *j* in stratum *i*, tC·ha^{-1};
$C_{EX,j,i|BSL}$	Mean carbon stock of extracted timber per unit area for species *j* in stratum *i*, tC·ha^{-1};
$C_{RSD,j,i|BSL}$	Mean carbon stock in timber from residual stand damage per unit area for species *j* in stratum *i*, tC·ha^{-1}

$C_{notHB,inf,j,i\|BSL}$	Mean carbon stock of biomass that is not harvested during the establishment of forestry infrastructure per unit area for species *j* in stratum *i*, tC·ha^{-1}
i	1, 2, 3 …*M* strata; and
j	1, 2, 3 …*J* tree species;
p	*1, 2, 3 …P* land parcels.

The mean carbon stock in timber from residual stand damage ($C_{RSD,j,i|BSL}$) is calculated as follows:

$$C_{RSD,j,i|BSL} = C_{EX,j,i|BSL} \times F_{RSD|BSL} \quad (6)$$

Where:

$C_{RSD,j,i\|BSL}$	Mean carbon stock in timber from residual stand damage per unit area for species *j* in stratum *i*, tC·ha^{-1};
$C_{EX,j,i\|BSL}$	Mean carbon stock of extracted timber per unit area for species *j* in stratum *i*, tC·ha^{-1};
$F_{RSD\|BSL}$	Factor for residual stand damage, dimensionless;
i	1, 2, 3 …M strata; and
j	1, 2, 3 …J tree species.

The mean of the carbon stock of biomass that is not harvested during the establishment of forestry infrastructure ($C_{notHB,INF,j,i|BSL}$) is calculated as follows:

$$C_{notHB,inf,j,i|BSL} = V_{notEX,inf,j,i|BSL} \times BCEF_R \times CF_j \quad (7)$$

Where:

$C_{notHB,inf,j,i\|BSl}$	Mean carbon stock of biomass that is not harvested during the establishment of forestry infrastructure per unit area for species *j* in stratum *i*, tC·ha^{-1}
$V_{notEX,inf,j,i\|BSL}$	Mean volume of timber that is not extracted for wood processing during the establishment of forestry infrastructure per unit area for species *j* in stratum *i*, m^3·ha^{-1};
$BCEF_R$	Biomass conversion and expansion factor applicable to wood removals in the project area, t.d.m m^{-3};
CF_j	Carbon fraction of biomass for species *j*, tC t d.m.$^{-1}$
i	1, 2, 3 …M strata; and
j	1, 2, 3 …J tree species.

8.1.3 Calculation of baseline carbon sequestered in wood products

This section calculates the net carbon stock change resulting from wood product conversion and retirement.

In all cases where wood is harvested for conversion to wood products, carbon stock in the wood products pool must be included in the baseline scenario.

Carbon stocks treated here are those stocks entering the wood products pool at the time of harvest.

All factors are derived from Winjum *et al* (1998)[11].

The carbon stock of extracted timber across species is calculated as:

$$C_{EX,i|BSL} = \sum_{j=1}^{J} C_{EX,j,i|BSL} \quad (8)$$

Where:

$C_{EX,i\|BSL}$	Change in carbon stock of extracted wood products resulting from timber harvest per unit area in stratum i, in tC ha^{-1};
$C_{EX,j,i\|BSL}$	Mean carbon stock of extracted wood per hectare, tC ha^{-1};
i	1, 2, 3 …*M* strata; and
j	1, 2, 3 …*J* tree species.

The wood product class(es), *k*, (i.e., sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other), that are the anticipated end use of the extracted timber must now be selected. It is acceptable practice to assign gross percentages of volume extracted to wood product classes on the basis of local expert knowledge of harvest activities and markets.

In accordance with the latest *VCS Methodology Requirements*, the amount of carbon stored in wood products that would decay within three (3) years after harvest (i.e., the Wood Waste -WW, and the Short-Lived Fraction -SLF), are assumed to be emitted at the time of harvest.

Wood products that are retired between 3 and 100 years after harvest (i.e., the Additional Oxidized Fraction, *OF*), must be accounted for according to a 20-year linear decay function. This decay function is applied when the net greenhouse gas emissions/removals are calculated on an annual basis as in Equations 10 and 11 below.

All other wood product pools are considered to permanently store carbon.

[11] https://academic.oup.com/forestscience/article/44/2/272/4626952

Therefore, the carbon stock of extracted timber that is immediately emitted to the atmosphere at the time of harvest is calculated as:

$$\Delta C_{WP0,i|BSL} = \sum_{k} C_{EX,i,k|BSL} \times (WW_k + SLF_k) \quad (9)$$

Where:

$\Delta C_{WP0,i\|BSL}$	Carbon stock of extracted timber from stratum *i* that is assumed to be emitted immediately at the time of harvest, in tC·ha^{-1};
$C_{EX,i,k\|BSL}$	Mean carbon stock of extracted timber per unit area in stratum *i*, for wood product type *k*, tC·ha^{-1};
WW_k	Fraction of biomass carbon from wood waste that is assumed to be emitted to the atmosphere immediately at the time of harvest for wood product *k*, dimensionless; [12]
SLF_k	Fraction of biomass carbon from the short-lived wood product pool that is assumed to be emitted to the atmosphere immediately at the time of harvest for wood product *k*, dimensionless;
i	1,2,3 …*M* strata; and
k	Wood products (i.e., sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other).

The amount of extracted carbon stock that is assumed to enter the wood products pool that is not immediately emitted at the time of harvest is calculated as per Equation (10) below:

$$C_{WPi|BSL} = \sum_{k} (C_{EX,i,k|BSL} - \Delta C_{WP0,i|BSL}) \quad (10)$$

Where:

$C_{WP,i\|BSL}$	Carbon stock of extracted timber from stratum *i* that is assumed to enter the wood products pool that is not immediately emitted at the time of harvest, in tC·ha^{-1};
$C_{EX,i,k\|BSL}$	Mean carbon stock of extracted timber per unit area in stratum *i*, for wood product type *k*, tC·ha^{-1};
$\Delta C_{WP0,i\|BSL}$	Carbon stock of extracted timber from stratum *i* that is assumed to be emitted immediately at the time of harvest, in tC·ha^{-1};
i	1,2,3 …*M* strata; and
k	Type of wood product (i.e., sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other).

[12] See Section 9.1 for information on data selection.

Therefore, the carbon stock of wood products assumed to be retired between 3-100 years following harvest is calculated as:

$$\Delta C_{WP100,i,p|BSL} = \sum_{k} (C_{WP,i|BSL} \times OF_k) \tag{11}$$

Where:

$\Delta C_{WP100,i,p\mid BSL}$	Carbon stored in wood products that are assumed to be retired between 3 - 100 years after harvest from stratum *i* in land parcel *p*, tC ha-1;
$C_{WP,i\mid BSL}$	Carbon stock of extracted timber from stratum *i* that is assumed to enter the wood products pool that is not immediately emitted at the time of harvest, in tC·ha^{-1};
OF_k	Fraction of biomass carbon for wood product type *k* that is assumed to be emitted to the atmosphere between 3 and 100 years of timber harvest, dimensionless;
i	1,2,3 …*M* strata;
k	Type of wood product (i.e., sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other).
p	*1, 2, 3 …P* land parcels.

8.1.4 Calculation of baseline emissions from the combustion of fossil fuels in forestry and wood processing machinery

The implementation of the baseline activity (selective logging and/or clearcutting from certain operations such as log landings) entails the use of forestry and wood processing machinery, which leads to GHG emissions from fossil fuel combustion. Omission of any or all of the associated GHG emission sources is conservative.

The total GHG emissions from fossil fuel combustion in the baseline scenario (C_{FUEL}) is determined from the summation of all the emission sources presented in Table 2 above using the following equation:

$$C_{FUEL} = \frac{E_{HARVEST} + E_{HAULING} + E_{TRANSPORT} + E_{PROCESSING}}{44/12} \tag{12}$$

Where:

C_{FUEL}	Total carbon emissions associated with the combustion of fossil fuel in forestry and wood processing machinery, in tC
$E_{HARVEST}$	Fossil fuel emissions due to harvesting operations such as felling and snigging, in tCO_2e;
$E_{HAULING}$	Fossil fuel emissions due to log hauling, in tCO_2e;

$E_{TRANSPORT}$	Fossil fuel emissions due to log transport from collection depot to processing plant, in tCO_2e;
$E_{PROCESSING}$	Fossil fuel emissions due to electricity consumption in sawmill, in tCO_2e.

8.1.4.1 Emissions Due to Harvesting Operations

Mechanical harvesting operations of merchantable logs contribute to GHG emissions. This operation in countries containing tropical forests commonly employs chainsaws, while in other regions harvesters are employed[13]. Fossil fuel emissions from log harvesting are determined using the following procedure:

- Step 1: For the common practice in the host country, select the typical equipment type, amount and type of fuel consumed that is used for harvesting. Information on harvesting practices can be found from reports on previous and existing harvesting practices in the host country. Potential sources should be a combination of direct measurements, manufacturer specifications, historical records of the project proponent (or other forest companies) and/or peer reviewed literature values.
- Step 2: Find the fuel consumption (in kL m^{-3}) of the selected equipment from the following data sources:
    - Reports on common practice for harvesting in the host country and/or manufacturers specifications.
    - Published peer reviewed studies on harvesting operations (e.g., Klvac and Skoupy, 2009[14] in Appendix 4).
    - If a range for fuel consumption is provided, the project proponent is required to provide justification for their choice of fuel consumption in the project documents. If no justification can be derived, it is conservative to select the lower end of the range.
- Step 3: Select the emission factor associated with the fuel employed for harvesting from IPCC default emission factors for CO_2, CH_4 and N_2O emissions for Off-Road Mobile Sources and Machinery for the Forestry Sector (IPCC, 2006, Volume 2, Chapter 3, Section 3.3.1, Table 3.3.1, p. 3.36).
    - Guidance for converting the emission factors to a CO_2 equivalent (CO_2-e) emission factor is provided in Appendix 1: Converting other greenhouse gases to CO_2e.
    - Guidance for unit conversions of fuel emission factors is provided in Appendix 2: Converting Units for Fuel Emission Factor.

[13] A machine that falls trees and performs two or more functions at the stump or on a felled tree, including delimbing, debarking, bucking, measuring, or chipping (SAF, 2018 Dictionary of Forestry).

[14] https://www.tandfonline.com/doi/abs/10.1007/s10310-009-0143-7

- Step 4: Harvesting emissions are calculated following the equation below:

$$E_{HARVEST} = FC_{HARVEST} \times EF_{FUEL} \times \sum_{j,i,p} V_{EX,j,i|BSL} \times A_i \quad (13)$$

Where:

$E_{HARVEST}$	Fossil fuel emissions due to harvesting operations such as felling and snigging, in tCO_2e;
$FC_{HARVEST}$	Fuel consumption of equipment employed for felling and snigging per m^3 of merchantable log harvested, in kL m^{-3};
EF_{FUEL}	Fuel emission factor, in tCO_2e kL^{-1};
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*, $m^3 \cdot ha^{-1}$;
A_i	Logging area in stratum *i*, in ha;
i	1, 2, 3 … *M* strata;
j	1, 2, 3 … *J* tree species; and
p	1,2,3 …*P* land parcels.

8.1.4.2 Emissions Due to Log Hauling

Emissions associated with log hauling to the collection depot are calculated using the following procedure:

- Step 1: Select the typical equipment type, amount and type of fuel consumed that is employed for hauling based on common practice for harvesting in the host country. Information on harvesting practices can be found from reports on previous and existing harvesting practices in the host country.
- Step 2: Find the fuel consumption (in kL m^{-3}) of the selected equipment from reports on common practice for harvesting in the host country and/or manufacturers specifications. If a range for fuel consumption is provided, the Project Proponent is required to provide justification for the choice of fuel consumption factor in the project documents. If no justification can be derived, it is conservative to select the lower end of the range.
- Step 3: Select the emission factor associated with CO_2, CH_4 and N_2O emissions for the fuel employed from IPCC default emission factors for Off-Road Mobile Sources and Machinery for the Forestry Sector (IPCC, 2006, Volume 2, Chapter 3, Section 3.3.1, Table 3.3.1, p. 3.36).
    - Guidance for converting the emission factors to a CO_2 equivalent (CO_2e) emission factor is provided in Appendix 1: Converting other greenhouse gases to CO2e.

- Guidance for unit conversions of fuel emission factors is provided in Appendix 2: Converting Units for Fuel Emission Factor.

- Step 4: Emissions from log hauling are then determined by applying the following equation:

$$E_{HAULING} = FC_{HAULING} \times EF_{FUEL} \times \sum_{j,i} V_{EX,j,i|BSL} \times A_i \quad (14)$$

Where:

$E_{HAULING}$	Fossil fuel emissions due to log hauling, in tCO_2e;
$FC_{HAULING}$	Fuel consumption of equipment for hauling one m^3 of merchantable log, in kLm^{-3};
EF_{FUEL}	Emissions due to log hauling, in $tCO_2e\ kL^{-1}$;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*, $m^3 ha^{-1}$;
A_i	Logging area in stratum *i*, in ha;
i	1, 2, 3 ...M strata; and
j	1, 2, 3 ... J tree species.

8.1.4.3 Emissions Due to Log Transport

Emissions associated with log transport from the collection depot to the processing plant are calculated using the following procedure:

- Step 1: Select the vehicle: type, load capacity (in m^3 $truck^{-1}$) and type of fuel consumed for log transport based on common practice for transport in the host country. Information on harvesting practices can be found from reports on previous and existing harvesting practices in the host country.

- Step 2: Determine the number of trucks required using the following equation:

$$N_{TRUCKS-TRANSPORT} = \frac{\sum_{j,i} V_{EX,j,i|BSL} \times A_i}{CAP_{TRUCK}} \quad (15)$$

Where:

$N_{TRUCKS-TRANSPORT}$	Number of truck trips required for log transport from collection depot to processing plant;
A_i	Logging area in stratum *i*, in ha;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*, $m^3 ha^{-1}$;
CAP_{TRUCK}	Truck load capacity, in m^3 $truck^{-1}$;
i	1, 2, 3 ... *M* strata; and

j	1, 2, 3 … J tree species;

- Step 3: Find the fuel efficiency (in km kL^{-1}) of the selected vehicle from the following data sources:
    - Manufacturers specifications;
    - Published peer reviewed studies on harvesting operations (e.g., Kinjo et al., 2005[15]);
    - If a range for fuel efficiency is provided, the Project Proponent is required to provide justification for the choice of fuel efficiency factor in the project documents. If no justification can be derived, it is conservative to select the upper end of the range.
- Step 4: Select the emission factor associated with CO_2, CH_4 and N_2O emissions for the fuel employed from IPCC default emission factors for Road Transport (IPCC, 2006, Volume 2, Chapter 3, Section 3.2.1.2, Table 3.2.1-2, p. 3.16-3.21).
    - Guidance for converting the emission factors to CO2-e emission factor is provided in Appendix 1: Converting other greenhouse gases to CO_2e.
    - Guidance for unit conversions of fuel emission factors is provided in Appendix 2: Converting Units for Fuel Emission Factor.
- Step 5: Estimate the transport distance from the collection depot to the processing plant using digital maps of the Project Area. If transport route(s) for the baseline scenario must be hypothesized, the Project Proponent is required to provide justification for their derivation of the transport route in the project documents. In addition, to be conservative, the transport route proposed must be the minimum possible route. The total log transport distance can be determined by the following:

$$KM_{TRANSPORT-TOTAL} = KM_{TRANSPORT} \times N_{TRUCKS-TRANSPORT} \times 2 \quad (16)$$

Where:

$KM_{TRANSPORT-TOTAL}$	Total log transport distance in km;
$KM_{TRANSPORT}$	Log transport distance from collection depot to processing plant in km;
$N_{TRUCKS-TRANSPORT}$	Number of truck trips required for log transport from collection depot to processing plant;
2	Constant, indicating return trip;

[15] Kinjo, M., Ohuchi, T., Kii, H., and Murase, Y. (2005). "Studies of life cycle assessment of Sugi Lumber," *Journal of the Faculty of Agriculture* 50(2), 343-351.

- Step 6: Emissions due to log transport are then determined by applying the following equation:

$$E_{TRANSPORT} = \frac{KM_{TRANSPORT-TOTAL}}{EFF_{VEHICLE}} \times EF_{FUEL} \quad (17)$$

Where:

$E_{TRANSPORT}$	Emissions due to log transport haulage from felling location to the collection depot/ sawmill, in tCO_2e;
$KM_{TRANSPORT-TOTAL}$	Total log transport distance in km;
$EFF_{VEHICLE}$	Fuel efficiency for vehicle type, in km kL^{-1};
EF_{FUEL}	Fuel emission factor, in tCO_2-e kL^{-1}.

8.1.4.4 Emissions Due to Timber Processing

Emissions resulting from processing, where the processing plant is situated in the project area depend on the electricity source available at the processing site. Electricity can be supplied via the national grid, or where this is not available, supplied via on-site generators. In addition, mill residue/waste may also be used as an energy source during timber processing.

To avoid double accounting, if a processing plant utilizes mill residue/waste as an electricity source, then the emissions from electricity generated by mill residue/waste must not be considered here, as these emissions are accounted for under the dead wood pool.

If grid electricity is available, then emissions due to processing will be calculated using the following procedure:

- Step 1: Select an electricity demand factor for the timber processing facility from the following data sources:
  - National electricity demand factors in relevant literature for timber processing. Various country specific electricity demand factors have been compiled in Appendix 5.
  - If a national electricity demand factor is not available, select an electricity demand factor from a country that uses similar timber processing technology to that of the project's host country.
  - If a range for the electricity demand factor is provided, the project proponent is required to provide justification for the choice of electricity demand factor in the project documents. If no justification can be derived, it is conservative to select the lower end of the range.
- Step 2: Using the volume of merchantable logs, determine the electricity consumption required for the processing mill:

$$Q_{PROCESSING} = \sum_{j,i} V_{EX,j,i|BSL} \times A_i \times E_{DEMAND} \tag{18}$$

Where:

$Q_{PROCESSING}$	Quantity of electricity consumption for processing in kWh;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*, $m^3 \cdot ha^{-1}$;
A_i	Logging area in stratum *i*, in ha;
E_{DEMAND}	Electricity demand for processing per volume processed, in kWh m^{-3};
i	1, 2, 3 … *M* strata; and
j	1, 2, 3 … *J* tree species.

- Step 3: Select an emission factor for electricity for the host country from IEA (2009), CO_2 emissions per kWh from electricity and heat generation, pp. 101-103.
- Step 4: Apply the following equation to determine the emissions due to processing:

$$E_{PROCESSING} = Q_{PROCESSING} \times EF_{ELECTRICITY} \tag{19}$$

Where:

$E_{PROCESSING}$	Emissions due to electricity consumption in sawmill, in tCO_2e;
$Q_{PROCESSING}$	Quantity of electricity consumption for processing in kWh;
$EF_{ELECTRICITY}$	Electricity emission factor for the host country, in tCO_2e kWh^{-1};

If grid electricity is not available, and an on-site generator is required to power the processing facility, then calculation of processing emissions is determined from the emissions associated with fuel consumption of the generator. Apply Steps 1 and 2 of Section 8.1.4.4 above to determine the electricity consumption involved for processing. Then use the following procedure:

- Step 1: Select the typical load capacity (i.e., 1/4, 1/2, full load), type of fuel consumed, and operating time of the generator employed to power the processing facility. Such data can be obtained from the following data sources:
    - National reports from the relevant national forestry authority;
    - Published peer reviewed literature on timber processing for cases of equivalent volumes and processing modes and of a country that uses similar timber processing technology to that of the project's host country.
- Step 2: Determine the power rating of the generator from the electricity required for processing and the operating hours required:

$$PR_{GENERATOR} = \frac{Q_{PROCESSING}}{T_{GENERATOR}} \quad (20)$$

Where:

$PR_{GENERATOR}$	Power rating of generator or generator size in kW;
$Q_{PROCESSING}$	Annual quantity of electricity consumption for processing in kWh;
$T_{GENERATOR}$	Operating time of generator in h;

- Step 3: Using a fuel consumption chart for the generator selected for the baseline case, apply the power rating (kW) and an appropriate load capacity (i.e., 1/4, 1/2, full) to determine the fuel consumption (kL h^{-1}) of the generator. Fuel consumption charts can be found from manufacturers of generators (see Appendix 3).
- Step 4: Select an emissions factor for the fuel employed in the generator from IPCC (2006), Volume 2, Chapter 2 Stationary Combustion, Table 2.5, p. 2.22.
- Step 5: Apply the following equation to determine emissions due to processing

$$E_{PROCESSING} = FC_{GENERATOR} \times T_{GENERATOR} \times EF_{FUEL} \quad (21)$$

Where:

$E_{PROCESSING}$	Emissions due to electricity consumption in sawmill in tCO_2e;
$FC_{GENERATOR}$	Fuel consumption per hour of operation of generator, in kL h^{-1};
$T_{GENERATOR}$	Operating time of generator in h;
EF_{FUEL}	Fuel emission factor, in tCO_2e kL^{-1}.

8.1.5 Change in carbon stocks due to forest regrowth after harvest

This section calculates $C_{RG,i,p|BSL}$, the carbon sequestration resulting from forest regrowth after timber harvest and establishment of forestry infrastructure in stratum *i* in land parcel *p* (tC ha^{-1}). The carbon sequestration in the baseline scenario resulting from forest regrowth after timber harvest up to year *t* is equal to the forest regrowth rate of each stratum.
Therefore, carbon sequestration resulting from forest regrowth after timber harvest is calculated as:

$$C_{RG,i,p|BSL} = RGR_i \times t^* \quad (22)$$

Where:

$C_{RG,i,p|BSL}$	Carbon sequestration (change in carbon stocks) resulting from forest regrowth after timber harvest and establishment of forestry infrastructure in stratum *i* in land parcel *p* at time $t*$, tC ha^{-1}

RGR_i	Regrowth rate of forest post timber harvest and establishment of forestry infrastructure for stratum *i*, tC ha^{-1} yr^{-1};
i	1,2,3 …*M* strata
p	1,2,3 … *P land parcels*
*t**	1, 2, …, *t** years elapsed since the start of the project (years)

8.1.6 Calculation of baseline scenario greenhouse gas emissions from change in carbon stocks

This section calculates $GHG_{NET|BSL}$, the net greenhouse gas emissions in the baseline scenario, in tCO_2e.

The net carbon stock change to be converted to emissions is equal to the carbon stock change as a result of timber harvest, plus the carbon stock change resulting from conversion and retirement of wood products, minus carbon sequestration from forest regrowth after harvest.

To generate the annual carbon stock change in the baseline scenario, the total net change in carbon stocks for parcels within is multiplied by the area of forest in the particular age class (i.e., years since harvest in the baseline).

The annualized calculations vary between years 1, 2-10; 11-20, and all years since the start of the project activity, depending on which decay functions apply.

Therefore, the net change in carbon stock from wood products and logging slash across all parcels within the first year of harvest in the baseline is calculated as:

$$\Delta C_{NET|BSL(1)} = \sum_{i,p} A_{1,i,p} \times \left(\Delta C_{DWSLASH,i,p\backslash BSL}/10 + \Delta C_{WP0,i,p\backslash BSL} + \Delta C_{WP100,i,p\backslash BSL}/20\right) \quad (23)$$

Where:

$\Delta C_{NET|BSL(1)}$	Net change in carbon stock across all parcels in the baseline scenario in the first year since harvest, in tC;
$\Delta C_{DWSLASH,i,p\backslash BSL}$	Change in carbon stock of dead wood as logging slash resulting from timber harvest per unit area in stratum *i* in land parcel *p*, in tC ha^{-1} (from Equation 5 above);
$\Delta C_{WP0,i,p\backslash BSL}$	Carbon stock of extracted timber from stratum *i* that is assumed to be emitted immediately at the time of harvest, in tC·ha^{-1} (see equation 9 above);
$\Delta C_{WP100,i,p\backslash BSL}$	Carbon stored in wood products that is assumed to be retired between 3 - 100 years after harvest from stratum *i* in land parcel *p*, tC ha^{-1} (see equation 11 above);
$A_{1,i,p}$	Area of stratum *i* in land parcel *p* that was harvested 1 year ago, ha;

i	1, 2, 3 …*M* strata; and
p	*1, 2, 3 …P* land parcels harvested within the project crediting period.

The net change in carbon stock from wood products and logging slash across all parcels the years 2 – 10 since harvest in the baseline are calculated as:

$$\Delta C_{NET|BSL(2-10)} = \sum_{i,p} A_{2-10,i,p} * \sum_{i=1}^{M} \left((\Delta C_{DWSLASH,i,p\backslash BSL}/10) + \ (\Delta C_{WP100,i,p\backslash BSL}/20) \right) \quad (24)$$

Where:

$\Delta C_{NET\|BSL(2\text{-}10)}$	Net change in carbon stock across all parcels in the baseline scenario in years 2 - 10 since harvest, in tC;
$\Delta C_{DWSLASH,i,p\backslash BSL}$	Change in carbon stock of dead wood as logging slash resulting from timber harvest per unit area in stratum *i* in land parcel *p*, in tC ha^{-1} (see equation 5 above);
$\Delta C_{WP100,i,p\backslash BSL}$	Carbon stored in wood products that is assumed to be retired between 3 - 100 years after harvest from stratum *i* in land parcel *p*, tC ha^{-1} (see equation 11 above);
$A_{2-10,i,p}$	Area of stratum *i* in land parcel *p* that was harvested between 2 and 10 years ago, ha; [16]
i	1, 2, 3 …*M* strata; and
p	*1, 2, 3 …P* land parcels harvested within the project crediting period.

The net change in carbon stock from wood products across all parcels the years 11 – 20 since harvest in the baseline is calculated as per equation 25 below. Note that, from this point there will be no more emissions quantified from decay of logging slash in these parcels.

$$\Delta C_{NET|BSL(11-20)} = \sum_{i,p} A_{11-20,i,p} * \sum_{i=1}^{M} (\Delta C_{WP100,i,p\backslash BSL}/20) \quad (25)$$

Where:

$\Delta C_{NET\|BSL(11\text{-}20)}$	Net change in carbon stock across all parcels in the baseline scenario in years 11 - 20 since harvest, in tC;
$\Delta C_{WP100,i,p\backslash BSL}$	Carbon stored in wood products that is assumed to be retired between 3 - 100 years after harvest from stratum *i* in land parcel *p*, tC ha^{-1};
$A_{11-20,i,p}$	Area of stratum *i* in land parcel *p* that was harvested between 11 and 20 years ago, ha;

[16] See Section 9.1 for information on data selection.

i	1, 2, 3 …M strata; and
p	*1, 2, 3 …P* land parcels harvested within the project crediting period.

The net change (sequestration) in carbon stock due to forest regrowth across all parcels in all years since harvest in the baseline scenario is calculated according to Equation 26 below. Note that there will be no more emissions quantified from decay of logging slash or wood products.

$$\Delta C_{NET|BSL(1+)} = \sum_{i} A_{t*,i,p} * \sum_{i=1}^{M} (\Delta C_{RG,i\backslash BSL}) \quad (26)$$

Where:

$\Delta C_{NET|BSL(1+)}$	Net change in carbon stock due to forest regrowth in all parcels that have been harvested in the baseline scenario, in tC;
$\Delta C_{RG,i,p\backslash BSL}$	Carbon sequestration resulting from forest regrowth after timber harvest in stratum i in land parcel p, tC ha^{-1};
$A_{t*,i,p}$	Cumulative area harvested until time $t*$, ha;[17]
$t*$	1, 2,….10, time elapsed since the start of the project, in years;
i	1, 2, 3 …M strata; and
p	*1, 2, 3 …P* land parcels harvested within the project crediting period.

Therefore, net change in carbon stock across all parcels harvested over each year of the project crediting period in the baseline scenario since the start of the project activity is calculated as:

$$\Delta C_{NET|BSL,t*} = \sum_{p=1}^{P} \left[-\Delta C_{NET,p|BSL(1)} - \Delta C_{NET,p|BSL(2-10)} - \Delta C_{NET,p|BSL(11-20)} + \Delta C_{NET,p|BSL(+1)} \right] \quad (27)$$

Where:

$\Delta C_{NET|BSL,t}$	Net change in carbon stock across all parcels in the baseline scenario in the year t* since the start of the project activity, in tC;
$\Delta C_{NET,p|BSL(1)}$	Net change in carbon stock in the baseline scenario for all parcels p that are within 1 year of harvest in the baseline scenario, in tC;
$\Delta C_{NET,p|BSL(2-10)}$	Net change in carbon stock in the baseline scenario for all parcels p, that were harvested between 2 – 10 years ago in the baseline scenario, in tC;
$\Delta C_{NET,p|BSL(11-20)}$	Net change in carbon stock in the baseline scenario in parcel p, that were harvested between 11 – 20 years ago in the baseline scenario, in tC;
$\Delta C_{NET,p|BSL(+1)}$	Net change in carbon stock due to forest growth in the baseline scenario for all parcels p that have been harvested in the baseline scenario, in tC;

[17] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection.

$t*$	Time elapsed since the start of the project, in years
p	1, 2, 3 …P land parcels harvested within the project crediting period

The net carbon stock change in the baseline scenario must be converted to net greenhouse gas emissions and is calculated as:

$$GHG_{NET|BSL,t*} = \Delta C_{NET|BSL,t*} \times * \frac{44}{12} \quad (28)$$

Where:

$GHG_{NET|BS,t*L}$	Net greenhouse gas emissions in the baseline scenario in the year t* since the start of the project activity, tCO_2e;
$\Delta C_{NET|BSL}$	Net change in carbon stock across all parcels in the baseline scenario in the year t* since the start of the project activity, tC; and
44/12	Ratio of molecular weights of carbon dioxide and carbon, tCO_2-e tC^{-1}.

8.2 Project Emissions

This section calculates $GHG_{NET|PRJ}$, the net greenhouse gas emissions in the project scenario, in tCO_2e.

Greenhouse gas emissions from Improved Forest Management (IFM) activities implemented in the project scenario must be accounted subject to application of the *de minimis* rule, as prescribed by the latest *VCS Methodology Requirements*. Project emissions include the change in carbon stocks of ongoing forest growth, forest disturbances, and illegal logging. As commercial timber harvest and activities that result in forest degradation are not eligible under the methodology in the project scenario, emissions sources from combustion of fossil fuels from vehicles, machinery and equipment are *de minimis* and not accounted by the methodology in the project scenario.

The type and extent of the activities implemented in the project scenario will be described by the project proponent as part of the documentation submitted with the project documents.

In accordance with the applicability conditions, **the project scenario does not allow commercial timber harvest.** As a result, carbon stock changes due to vegetation management and fuel removal will be negligible.

Thus, net greenhouse gas emissions in the project scenario will be equal to carbon sequestration through ongoing forest growth minus any emissions resulting from forest disturbance (both illegal logging and natural disturbances).

Ex-ante and *ex-post* estimations of natural disturbance for the project scenario must be estimated following Section 8.2.2.1 below[18].

The potential for illegal extraction of trees from the project area must be assessed *ex-ante* and *ex-post* through a participatory rural appraisal (PRA) of the communities in and surrounding the project area following Section 8.2.2.2 option a[19].

At all subsequent verifications, data collected for monitored parameters for natural disturbance and illegal logging must be included using the equations given under Sections 8.2.2 and 8.2.3 below.

Under the project scenario, the project proponents must only estimate carbon stock change from forest growth in areas that would have been harvested under the baseline scenario.

Ongoing forest growth can only be included for individual trees, species, strata and tree stands to be harvested under the baseline scenario and must reflect the harvesting plan timeframe. During a verification period, ongoing forest growth can only be accounted for in areas that would have been harvested under the baseline scenario, between the baseline year of harvest and the end of the verification period. When forest growth is included in the project scenario net GHG emissions, a detailed sampling plan that follows Section 8.2.1 below must be provided with the project documents.

8.2.1 Ongoing Forest Growth in the Project Scenario

This section calculates $\Delta C_{AB,t|PRJ}$ annual carbon stock change in aboveground biomass of trees in the project scenario, in tCO2e.

8.2.1.1 Allometry

The project proponent must select or develop an appropriate allometric equation for forest type/group of species *j* (e.g., tropical humid forest or tropical dry forest), or for each species or family *j* (i.e., group of species) found in the inventory (hereafter referred to as species group), that converts tree dimensions from field timber inventories on sample plots to aboveground biomass of trees.

Equation selection or development must follow the criteria described for *fj(X,Y…)*, the aboveground biomass of trees based on allometric equation for species group *j* based on measured tree variable(s), in the parameters section below.

[18] Ex ante estimations of areas burned and naturally disturbed shall be based on historic incidence of fire and natural disturbance in the Project region.

[19] If the belief is that zero illegal logging will occur within the project boundaries, then ex-ante this parameter may be set to zero if clear infrastructure, hiring and policies are in place to prevent illegal logging.

8.2.1.2 Sampling and Measurements

Only the individual trees, species and strata which were to be harvested in the baseline scenario are to be measured. Permanent sample plots must be established for each stratum to measure carbon stock changes over time. The number of permanent sample plots per stratum will be determined as described in Section 9.3.5. For the plots with selective harvesting in the baseline scenario, the selected trees must be given a unique ID, and their location must be recorded with a GPS to allow accurate re-measurement over time. The measurements should be consistent with the timber management plan, in terms of areas, species, minimum diameters and number of trees to be harvested.

The tree dimensions and minimum diameter at breast height (DBH) specified by the selected allometric equation in Section 8.2.1.1 must apply to these trees.

Any minimum values employed in inventories are held constant for the duration of the project.

8.2.1.3 Determining Sample Plot Carbon Stocks

The carbon stock in aboveground biomass for each individual tree of species group *j* in the sample plot located in stratum *i* will be estimated using the selected or developed allometric equation applied to the tree dimensions resulting from Section 8.2.1.2. Therefore, the sum of the carbon stock in each sample plot will be calculated as:

$$C_{AB,j,i,t,sp|PRJ} = \sum_{l=1}^{L_{j,i,sp,t}} f_j(X, Y \ldots) \times CFj \tag{29}$$

Where:

$C_{AB,j,i,t,sp\|PRJ}$	Carbon stock in aboveground biomass of trees of species *j* in plot *sp* in stratum *i* at time *t* in the project scenario, tC;
CF_j	Carbon fraction of biomass for tree group *j*, tC t d.m.$^{-1}$; [20]
$f_j(X,Y\ldots)$	Aboveground biomass of trees based on allometric equation for species group *j* based on measured tree variable(s), t. d.m. tree^{-1}; [21]
i	1, 2, 3, …M strata;
j	*1, 2, 3 … J* tree species;
l	*1, 2, 3, …* $L_{j,i,t,sp}$ sequence number of individual trees of species group *j* in stratum *i* at time *t* in sample plot *sp;*

[20] See Section 9.1 for information on data selection (p 51).

[21] See Section 9.1 for information on data selection (p 51).

t	$0, 1, 2, 3, \ldots t^{*}$ years elapsed since start of the project activity; and
sp	1, 2, 3 …*SP* sample plots.

8.2.1.4 Determining Stratum Carbon Stocks

The total carbon stock in the aboveground biomass of all trees present in sample plot *sp* in stratum *i* at time *t*, must be calculated as:

$$C_{AB,i,t,sp|PRJ} = \sum_{j=1}^{J} C_{AB,j,i,t,sp|PRJ} \quad (30)$$

Where:

$C_{AB,i,t,sp\|PRJ}$	Aboveground biomass carbon stock of all trees of stratum *i* at time *t* in sample plot *sp* in the project scenario, tC;
$C_{AB,j,i,t,sp\|PRJ}$	Carbon stock in aboveground biomass of trees of species *j* in stratum *i* at time *t* in plot *sp* in the project scenario, tC;
i	1, 2, 3, …M strata;
j	*1, 2, 3 … J* tree species; and
t	$0, 1, 2, 3, \ldots t^{*}$ years elapsed since start of the project activity.

8.2.1.5 Determining Mean Carbon Stocks

Therefore, the mean carbon stock in aboveground biomass for each stratum per unit area is calculated as:

$$C_{AB,i,t|PRJ} = \frac{1}{SP} \times \sum_{sp=1}^{SP} \left(\frac{C_{AB,i,t,sp|PRJ}}{A_{sp}} \right) \quad (31)$$

Where:

$C_{AB,i,t\|PRJ}$	Mean aboveground biomass carbon stock of trees in stratum *i* at time *t*, $tC \cdot ha^{-1}$;
$C_{AB,i,t,sp\|PRJ}$	Aboveground biomass carbon stock of trees in stratum *i* at time *t* in sample plot *sp*, tC;
A_{sp}	Area of sample plot *sp*, ha; [22]
sp	*1, 2, 3 … SP* sample plots;

[22] See Section 9.1 for information on data selection.

i	*1, 2, 3 … M* strata; and
t	*0, 1, 2, 3 … t** years elapsed since the start of the project activity.

8.2.1.6 Determining Carbon Stock Changes

The annual carbon stock change $\Delta C_{AB,t|PRJ}$ in aboveground biomass of trees in year t, is the difference in mean carbon stock in aboveground biomass between sampling events and, when expressed in tCO_2e, is calculated as:

$$\Delta C_{AB,t|PRJ} = \sum_{i,p} \left(A_{t*,i,p} \times \frac{C_{AB,i,t2|PRJ} - C_{AB,i,t1|PRJ}}{T} \right) \times \frac{44}{12} \tag{32}$$

Where:

$\Delta C_{AB,t\|PRJ}$	Annual carbon stock change in aboveground biomass of trees in year t, $tCO_2e\ yr^{-1}$
$C_{AB,i,t\|PRJ}$	Mean aboveground biomass carbon stock of trees in stratum i at time t, $tC\ ha^{-1}$
$A_{t*,i,p,}$	Cumulative area harvested in stratum i, at time $t*$, (ha)
T	Number of years between monitoring time $t1$ and $t2$ ($T = t2 - t1$), years;
$t1$	Beginning of the monitoring period or time of harvest event, whichever is later
i	1, 2, 3, … M strata
t	*0, 1, 2, 3, … t** years elapsed since start of the project activity
p	1, 2, 3, …, P land parcels harvested within the project crediting period; and
44/12	Ratio of molecular weights of carbon dioxide and carbon, $tCO_2e\ tC^{-1}$.

The carbon stock change in aboveground biomass of trees ($\Delta C_{AB,t|PRJ}$) is the output of this section and is necessary to calculate net greenhouse gas emissions in the project scenario.

8.2.2 Forest disturbance in the project scenario

This section calculates $\Delta C_{DIST\_FR,t|PRJ}$, carbon stock change due to fire disturbance in the project scenario (tCO_2e), and $\Delta C_{DIST,t|PRJ}$, carbon stock change due to non-fire natural disturbances in the project scenario (tCO_2e).

8.2.2.1 Natural disturbance

It is a requirement that any greenhouse gas emissions from natural disturbance above *de minimis* that may occur in the project area are monitored.

Estimation of emissions from natural disturbances must be calculated depending on the type of disturbance event. Disturbance due to fire is calculated following Option A, and all non-fire natural disturbances (e.g., wind, disease, pest events) are calculated following Option B.

Option A: Natural Disturbance – Fire

For fire damage, it is assumed that a fire burning in the project scenario would also have burned in the baseline scenario. Project emissions are therefore equal to the fire damage to biomass absent in the baseline scenario (harvested and removed), but present in the project scenario.

Where fires occur *ex post* in the project area, the area burned must be delineated.

Therefore, based on the *IPCC 2006 Inventory Guidelines*, estimation of greenhouse gas emissions from biomass burning must be calculated as:

$$\Delta C_{DIST-FR,t|PRJ} = \sum_{i=1}^{M} A_{burn,i,t} \times B_{i,t|PRJ} \times COMF_i \times G_{g,i} \times 10^{-3} \times GWP_{CH4} \quad (33)$$

Where:

$\Delta C_{DIST\_FR,t\|PRJ}$	Net greenhouse gas emissions resulting from fire disturbance in year t, tCO_2e
$A_{burn,i,t}$	Area burnt in stratum i at time t, ha; [23]
$B_{i,t\|PRJ}$	Average aboveground biomass stock present in the project scenario but absent in the baseline scenario before burning stratum i, time t; t d. m. ha^{-1};
$COMF_i$	Combustion factor for stratum i, dimensionless; [24]
$G_{g,i}$	Emission factor for stratum i for methane, g kg^{-1} dry matter burnt; [25]
GWP_{CH4}	Global warming potential for CH_4 (IPCC default: 21), tCO_2e tCH_4^{-1};
i	1, 2, 3 …M strata; and
t	1, 2, 3, … $t*$ years elapsed since the start of the IFM project activity.

The average aboveground biomass stock present in the project scenario, but absent in the baseline scenario before burning for a particular stratum must be calculated as:

$$B_{i,t|PRJ} = \sum_{j} V_{EX,j,i|BSL} \times BCEF_R \quad (34)$$

Where:

$B_{i,t\|PRJ}$	Average aboveground biomass stock present in the project scenario but absent in the baseline before burning for stratum i, time t, t d. m. ha^{-1};
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species j in stratum i, $m^3 \cdot ha^{-1}$;

[23] See Section 9.1 for information on data selection.
[24] See Section 9.1 for information on data selection.
[25] See Section 9.1 for information on data selection.

$BCEF_R$	Biomass conversion and expansion factor applicable to wood removals in the project area, t.d.m m^{-3}; [26]
i	1, 2, 3 … *M* strata;
j	1, 2, 3 … *J* tree species; and
t	1, 2, 3, … *t** years elapsed since the start of the IFM project activity.

Option B: Non-Fire Natural Disturbances

For non-fire natural disturbances, it is assumed that a disturbance event in the project scenario would also have occurred in the baseline scenario. Project emissions are therefore equal to the non-fire natural disturbance to biomass absent in the baseline scenario (harvested and removed), but present in the project scenario.

It is conservatively assumed that the natural disturbance is a stand-replacing disturbance, and that the biomass change as a result of the natural disturbance ($\Delta C_{DIST,t|PRJ}$) is emitted in the year of disturbance.

Where non-fire natural disturbances occur ex post in the project area, the area disturbed must be delineated.

$$\Delta C_{DIST,t|PRJ} = \sum_{i=1}^{M}\left(A_{dist,i,t} \times \sum_{j=1}^{J}\{C_{AB,i,j|BSL}\}\right) \times \frac{44}{12} \tag{35}$$

Where:

$\Delta C_{DIST,t|PRJ}$	Net greenhouse gas emissions resulting from non-fire natural disturbance in year *t*, tCO_2e;
$A_{dist,i,t}$	Area disturbed for stratum *i* at time *t*, ha; [27]
$C_{AB,i,j|BSL}$	Carbon stock in aboveground biomass per unit area for species *j* in stratum *i*,, tC· ha^{-1};
44/12	Ratio of molecular weights of carbon dioxide and carbon, $tCO_2e\ tC^{-1}$;
i	1, 2, 3 …*M* strata;
j	1, 2, 3 …*J* tree species; and
t	1, 2, 3, … *t** years elapsed since the start of the IFM project activity.

8.2.2.2 Illegal logging

It is a requirement that any greenhouse gas emissions from illegal logging above *de minimis,* that may occur in the project area ($\Delta C_{DIST\_IL,i,t|PRJ}$) are monitored.

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[26] See Section 9.1 for information on data selection.

[27] See data and parameters used in monitoring parameter list for information on data selection (p62).

At the time of methodology approval, remote sensing technology using optical sensors is not capable of direct measurements of biomass and changes therein[28], but has some capability to identify forest strata that have undergone a change in biomass[29].

As remote methods for monitoring illegal logging are not available at the time of methodology approval, the following ground-based methods must be used.

Option A: PRA

A participatory rural appraisal (PRA)[30] of the communities surrounding the project area must be completed to determine if there is the potential for illegal extraction of trees from the project area. If this assessment finds no potential pressure for these activities, then illegal logging ($\Delta C_{DIST\_IL,i,t|PRJ}$) can be assumed to be zero and no monitoring is needed.

The PRA must be repeated every 2 years.

Option B: Sampling

If the results of the PRA suggest that there is potential for illegal logging activities, then limited field sampling must be undertaken.

The area that is potentially subject to degradation ($A_{DIST\_IL,i}$) uses the distance of illegal logging penetration to the project area (determined from the PRA), from all access points (access buffer), such as roads and rivers or previously cleared areas..

The area subject to illegal logging must be delineated ($A_{DIST\_IL,i}$) based on an access buffer from all access points, such as roads and rivers or previously cleared areas, to the project area, with a width equal to the distance of degradation penetration.

$A_{DIST\_IL,I}$ must be sampled by surveying several transects of known length and width across the access-buffer area (equal in area to at least 1% of $A_{DIST\_IL,i}$) to determine the presence or absence of new tree stumps. The CDM tool for significance[31] must be applied to determine significance where there is evidence that trees are being harvested.

Where application of the CDM tool demonstrates that illegal logging is insignificant, then illegal logging can be assumed to be zero and no monitoring is needed.

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[28]However, technology is developing rapidly, including techniques such as RADAR, SAR, or LiDAR.

[29] For example, a multi-temporal set of remotely sensed data can be used to detect changes in the structure of the forest canopy. A variety of techniques, such as Spectral Mixture Analysis (Souza et al. 2005 *Remote Sensing of Environment* 98: 2–3: 329-343), SAR or LiDAR, can be used under this approach but no specific technology is prescribed here. Some of the newer technologies can estimate carbon contents for different forest types, if supported by field information such as sample plots to calibrate the technology and fieldwork leading to allometric equations of key species. The project proponent should use techniques that are suitable to their specific situation and that have been published in peer-reviewed papers.

[30] Participatory Rural Appraisal (PRA) describes a growing family of approaches and methods to enable local people to share, enhance and analyze their knowledge of life and conditions. Multiple guidelines are available to conduct a PRA (e.g., FAO, 2013 https://www.fao.org/family-farming/detail/en/c/292329/).

[31] http://cdm.unfccc.int/EB/031/eb31_repan16.pdf

This limited sampling must be repeated each time the PRA indicates potential for illegal logging.

Where limited sampling provides evidence that trees are being illegally removed in the buffer area, then systematic sampling must be implemented based on a detailed sampling plan. The sampling plan must be designed using plots systematically placed over the buffer zone so that at least 3% of the area of the buffer zone is sampled ($A_{DIST\_IL,i}$). The diameter of all tree stumps should be measured and conservatively assumed to be the same as the DBH of the removed tree(s). Where the stump is a large buttress, several individuals of the same species nearby must be located, and a ratio of the diameter at DBH to the diameter of buttress at the same height above ground as the measured stumps must be determined. This ratio will be applied to the measured stumps to estimate the likely DBH of the cut tree.

The aboveground carbon stock of each harvested tree will be estimated using the allometric regression equations chosen for forest growth in the project scenario[32]. The mean aboveground carbon stock of the harvested trees ($C_{DIST\_IL,i,t|PRJ}$) is conservatively estimated to be, the total emissions and, consequently, all emissions enter the atmosphere.

This sampling procedure must be repeated every five (5) years, and the results annualized by dividing the total emissions by five.

Therefore, where the PRA or the limited sampling indicate no illegal logging occurring:

$$\Delta C_{DIST-IL,t|PRJ} = 0 \tag{36}$$

Where the PRA and the limited sampling indicate that degradation is occurring, net carbon stock changes, as a result of illegal logging, must be calculated as:

$$\Delta C_{DIST-IL,t|PRJ} = \sum_{i=1}^{M} \left(A_{DIST-IL,i} \times \frac{C_{DIST-IL,i,t|PRJ}}{AP_i} \right) \times \left(1 + \frac{V_{EX,INF,j,i|BSL}}{V_{EX,j,i|BSL}} \right) + C_{FUEL} \times \frac{C_{DIST-IL,t|PRJ}}{\sum_{i=1}^{I} C_{EX,i|BSL} \times 44/12 \times A_i} \tag{37}$$

Where:

$\Delta C_{DIST\_IL,t|PRJ}$	Net carbon stock changes from illegal logging at time *t*, tCO_2e;
$A_{DIST\_IL,i}$	Area potentially impacted by illegal logging in stratum *i*, ha;
$C_{DIST-IL,i,t|PRJ}$	Biomass carbon of trees cut and removed through illegal logging in stratum *i* at time *t*, tCO_2e;
$V_{EX,j,i|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*, $m^3 \cdot ha^{-1}$;

[32] If species-specific equations are used and species cannot be identified from stumps, then it shall be assumed that the harvested species is the species most commonly harvested. A PRA shall be used to determine the most commonly harvested species.

$V_{EX,INF,j,i\|BSL}$	Mean volume of extracted timber for forestry infrastructure per unit area for species *j* in stratum *i*, $m^{3\cdot}$ ha^{-1};
C_{FUEL}	Total carbon emissions associated with the combustion of fossil fuel in forestry and wood processing machinery, in tC;
$C_{EX,i\|BSL}$	Change in carbon stock of extracted wood products resulting from timber harvest per unit area in stratum *i* in land parcel *p*, in tC ha^{-1};
AP_i	Total area of illegal logging sample plots in stratum *i*, ha;
A_i	Logging area in stratum *i*, in ha;
i	1, 2, 3 … *M* strata in the in the project case; and
t	1, 2, 3, … *t* years elapsed since the projected start of the project activity.

This approach not only considers the reductions of carbon stocks due to illegal logging, but also considers fuel emissions of illegal logging operations and potential emissions from infrastructure development during illegal logging.

The emissions of infrastructure development due to illegal logging are estimated by determining an expansion factor based on regular baseline harvesting practices (i.e., the relation of volume extracted due to infrastructure development compared to the merchantable volume extracted). As it is unlikely that illegal logging will result in large-scale infrastructure development (i.e., equating the baseline scenario), this approach is considered conservative.

Fuel emissions from illegal logging operations are determined by using the specific fuel emissions of the baseline scenario (i.e., total fuel emissions are divided by the total carbon stock changes due to baseline logging operations) which are then multiplied by the illegal logging volume. As it is unlikely that illegal logging would involve the deployment of large, fuel intensive machinery (i.e., equaling the baseline scenario), this is considered conservative.

The calculation of emissions from illegal logging therefore requires use of both parameters available at validation (Section 9.1) and parameters monitored (Section 9.2).

8.2.3 Net carbon stock change in the project scenario

The net carbon stock change in the project scenario is the annual carbon stock change in the aboveground biomass of trees due to forest growth minus the sum of net carbon stock changes resulting from fire, non-fire forest disturbance and illegal logging.

Therefore, the net carbon stock change in the project scenario in year *t*, is calculated as:

$$\Delta C_{NET,t|PRJ} = \Delta C_{AB,t|PRJ} - \left(\Delta C_{DIST-FR,t|PRJ} + \Delta C_{DIST,t,PRJ} + \Delta C_{DIST-IL,t|PRJ}\right) \quad (38)$$

Where:

$\Delta C_{NET,t\|PRJ}$	Net carbon stock change in the project scenario in year *t*, tCO_2-e;

$\Delta C_{AB,t\|PRJ}$	Annual carbon stock change in aboveground biomass of trees in year *t*, tCO_2e;
$\Delta C_{DIST\_FR,t\|PRJ}$	Net greenhouse gas emissions resulting from fire disturbance in year *t*, tCO_2e
$\Delta C_{DIST,t\|PRJ}$	Net carbon stock change resulting from non-fire natural disturbance in year *t*, tCO_2e;
$\Delta C_{DIST\_IL,t\|PRJ}$	Net carbon stock changes as a result of illegal logging in year *t*, tCO_2e;
t	*1, 2, 3, … t** years elapsed since start of the project activity.

The net carbon stock change across the project scenario since the start of the project is calculated as:

$$\Delta C_{NET|PRJ} = \sum_{t=1}^{t^*} \Delta C_{NET,t|PRJ} \tag{39}$$

Where:

$\Delta C_{NET\|PRJ}$	Net carbon stock change in the project scenario since the start of the project activity, tCO_2e;
$\Delta C_{NET,t\|PRJ}$	Net carbon stock change in the project scenario in year *t*, tCO_2e; and
t	*1, 2, 3, … t** years elapsed since start of the project activity.

8.3 Leakage Emissions

8.3.1 Activity shifting leakage

There may be no leakage due to activity shifting.

Where the project proponent controls multiple parcels of land within the country, the project proponent must demonstrate that the management plans and/or land-use designations of other lands they control have not materially changed as a result of the planned project (e.g., designating new lands as timber concessions or increasing harvest rates in lands already managed for timber), because such changes could lead to reductions in carbon stocks or increases in GHG emissions.

This must be demonstrated through:

- Historical records showing trends in harvest volumes paired with records from the with-project time period showing no deviation from historical trends;
- Forest management plans prepared ≥24 months prior to the start of the project showing harvest plans on all owned/managed lands paired with records from the with-project time period showing no deviation from management plans.

At each verification, documentation must be provided covering the other lands controlled by the project proponent where leakage could occur, including, at a minimum, their location(s), area and type of existing land use(s), and management plans.

Where activity shifting occurs or a project proponent is unable to provide the necessary documentation at first and subsequent verification, the project must not meet the requirements for verification. Therefore, the project must be subject to the conditions described in the *VCS AFOLU Guidance Document* on projects which fail to submit periodic verification after the commencement of the project. The project proponent may optionally choose to submit a methodology deviation with their future verifications to address activity shifting leakage.

Where the project proponent has control only over resource use in the project area and has no access to other forest resources, then the only type of leakage emissions calculated is GHG emissions due to market effects that result from project activity.

8.3.2 Market leakage

Leakage due to market effects (LF_{ME}) is equal to the net emissions from planned timber harvest activities in the baseline scenario multiplied by an appropriate leakage factor.

The leakage factor (see Box 2 below) is determined by considering where in the country logging will increase as a result of the decreased timber supply caused by the project.

If the ratio of merchantable biomass to total biomass is higher in the project area, it is likely that additional logging will be performed in these areas as a result of reduced logging in the project area in the project scenario.

The leakage factor is thus defined as a dimensionless number with values between 0 and 1, assigned *ex ante* based on a comparison between the ratio of merchantable biomass to total biomass across all strata in the base year, and the ratio of merchantable biomass to total biomass of the country's forest estate where harvesting would likely be displaced to.

Box 2: Leakage Factor Calculation

The leakage factor is determined by considering where in the country logging will increase as a result of the decreased supply of timber caused by the project. If the areas liable to be logged have a higher ratio of merchantable biomass to total biomass higher than the project area it is likely that the proportional leakage is higher and vice versa:

Therefore,

$LF_{ME} = 0$

if it can be demonstrated that no market-effects leakage will occur within national boundaries, that is if no new concessions are being assigned AND annual extracted volumes cannot be increased within existing national concessions AND illegal logging is absent (or *de minimis*) in the host country.

The amount of leakage is determined by where in the country's forest estate harvesting would likely be displaced. If harvesting is displaced to forests where a lower proportion of forest biomass is merchantable material from harvestable species compared to the project area, then in order to extract a given volume, higher emissions should be expected as more trees will need to be cut to supply the same volume.

In contrast, if a higher proportion of the total biomass of commercial species is merchantable in the displacement forest than in the project forests, then a smaller area would have to be harvested, and thus lower emissions would result.

Therefore, each project must calculate within each stratum the ratio of merchantable biomass to total biomass (PMP_i). This shall then be compared to the ratio of merchantable biomass to total biomass for each forest type (PML_{FT}).

The following deduction factors (LF_{ME}) shall be used:

PML_{FT} is equal (± 15%) to PMP_i LF_{ME} = 0.4

PML_{FT} is > 15% less than PMP_i LF_{ME} = 0.7

PML_{FT} is > 15% greater than PMP_i LF_{ME} = 0.2

Where:

PML_{FT}: mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type, %;

PMP_i: merchantable biomass as a proportion of total aboveground tree biomass for stratum *i* within the project boundaries, %; and

LF_{ME}: Leakage factor for market-effects calculations; dimensionless.

Where sufficient variation exists in PMP_i relative to PML_{FT} that multiple values of LF_{ME} result, then an area weighted final value for LF_{ME} shall be calculated. The area of stratum *i* as a proportion of the total project area shall be multiplied by LF_{ME}. All values are then summed up to arrive at the area weighted final value of LF_{ME}.

8.4 Summary of Net GHG Emission Reductions and Carbon Dioxide Removals

Net GHG emission reductions are calculated as:

$$ER_t = (C_{FUEL} - MIN\left(0, C_{NET|BSL,t*}\right) + MIN\left(0, \Delta C_{NET|PRJ}\right) \times (1 - LF_{ME}) \times (1 - U_{total|LtPF}) \quad (40)$$

Where:

ER_{t*}	Net GHG emission reductions in year t* since the start of the project activity, in the project scenario, tCO_2e;
C_{FUEL}	Total carbon emissions associated with the combustion of fossil fuel in forestry and wood processing machinery, in tCO_2e.
$C_{NET\|BS,t*}$	Net carbon stock change in the baseline scenario in the year t* since the start of the project activity, tCO_2e;

$\Delta C_{NET\|PRJ}$	Net carbon stock change in the project scenario since the start of the project activity, tCO_2e;
LF_{ME}	Leakage factor for market-effects calculations, dimentionless;
$U_{total\|LtPF}$	Total uncertainty for LtPF Project, dimensionless;
MIN	Function to find the lowest number in a range

Net carbon dioxide removals are calculated as

$$CR_{t*} = (MAX(0, \Delta C_{NET|PRJ}) - MAX(0, C_{NET|BSL,t*})) \times (1 - U_{total/LtPF}) \quad (41)$$

Where:

CR_{t*}	Net carbon dioxide removals in year t* since the start of the project activity, in the project scenario, tCO_2e;
$\Delta C_{NET\|PRJ}$	Net carbon stock change in the project scenario since the start of the project activity, tCO_2e;
$C_{NET\|BS,t*}$	Net greenhouse gas emissions in the baseline scenario in the year t* since the start of the project activity, tCO_2e;
LF_{ME}	Leakage factor for market-effects calculations, dimentionless;
$U_{total\|LtPF}$	Total uncertainty for LtPF Project, dimensionless;
MAX	Function to find the highest number in a range

8.5 Uncertainty

Estimated greenhouse gas emissions and emission reductions from IFM activities have uncertainties associated with parameters and coefficients including estimates of area, carbon stocks, regrowth and expansion factors. It is assumed that the uncertainties associated with input data are available, either as default uncertainty values given in most recent IPCC guidelines, or as statistical estimates based on sampling.

Uncertainty at all times is defined at the 95% confidence interval where the estimated variance exceeds +/- 15 percent from the mean. Procedures including stratification and the allocation of sufficient measurement plots will help ensure that low uncertainty results and ultimately full crediting can result.

It is good practice to consider uncertainty at an early stage to identify the data sources with the highest uncertainty to allow the opportunity to conduct further work to diminish uncertainty.

Uncertainties arising from the measurement and monitoring of carbon pools and greenhouse gases must always be quantified. Errors in each pool must be weighted by the size of the pool so that projects may reasonably target a lower precision level in pools that only form a small proportion of the total stock.

For both the baseline and the with-project case, total uncertainty is equal to the square root of the sum of the squares of each uncertainty component and is calculated at the time of reporting through propagating the error in the baseline stocks and the error in the project stocks.

Therefore, total uncertainty for LtPF project is calculated as:

$$U_{TOTAL|LtPF} = \sqrt{U^2{}_{|PRJ} + U^2{}_{|BSL}} \tag{42}$$

Where:

$U_{total|LtPF}$	Total uncertainty for LtPF Project, dimensionless;
$U_{|PRJ}$	Total uncertainty for the improved forest management activities in the project scenario, dimensionless; and
$U_{|BSL}$	Total uncertainty for the baseline scenario, dimensionless.

The project proponent must justify the selection of uncertainty propagation in the project documents. If $U_{total|LtPF} \leq 0.15$ then no deduction will result for uncertainty.

If $U_{total|LtPF} > 0.15$ then the amount of greenhouse gas emission credits associated with IFM activities will be deducted from the net reductions and removals.

8.6 Calculation of Verified Carbon Units

To calculate the number of Verified Carbon Units (VCUs) that may be issued, the project proponent must consider the number of buffer credits which must be deposited in the AFOLU pooled buffer account. The number of buffer credits that must be deposited is calculated by multiplying the non-permanence risk rating by the net change in carbon stocks (see Section 3.2.30 in the latest version of the VCS Standard Requirements). The buffer credits are quantified separately for removals and reductions as:

$$Bu_{CR,t*} = (MAX(0, \Delta C_{NET|PRJ}) - MAX(0, C_{NET|BSL,t*})) \times NPR\% \tag{43}$$

Where:

$Bu_{CR,t*}$	Buffer credits to be deducted from removals in year t* (t CO_2e)

$\Delta C_{NET\|PRJ}$	Net carbon stock change in the project scenario since the start of the project activity, tCO_2e;
$C_{NET\|BS,t*}$	Net greenhouse gas emissions in the baseline scenario in the year t* since the start of the project activity, tCO_2e;
$NPR\%$	Overall project non-permanence risk rating converted to a percentage

$$Bu_{ER,t*} = (MIN(0, \Delta C_{NET|PRJ}) - MIN(0, C_{NET|BSL,t*})) \times NPR\% \quad (44)$$

Where:

$Bu_{ER,t*}$	Buffer credits to be deducted from reductions in year t* ($t\ CO_2e$)
$\Delta C_{NET\|PRJ}$	Net carbon stock change in the project scenario since the start of the project activity, tCO_2e;
$C_{NET\|BS,t*}$	Net greenhouse gas emissions in the baseline scenario in the year t* since the start of the project activity, tCO_2e;
$NPR\%$	Overall project non-permanence risk rating converted to a percentage

The total VCUs that result from project activities leading to removals is calculated as:

$$VCU_{CR,t*} = CR_{t*} - Bu_{CR,t*} \quad (45)$$

Where:

$VCU_{CR,t*}$	Number of verified carbon units, in year t*, that result from project activities leading to removals
CR_{t*}	Net carbon dioxide removals in year t* since the start of the project activity, in the project scenario, tCO_2e;
$Bu_{CR,t*}$	Buffer credits to be deducted from removals in year t* ($t\ CO_2e$)

The total VCUs that result from project activities leading to reductions is calculated as:

$$VCU_{ER,t*} = ER_{t*} - Bu_{ER,t*} \quad (46)$$

Where:

$VCU_{ER,t*}$	Number of verified carbon units, in year t*, that result from project activities leading to reductions
ER_{t*}	Net emission reductions in year t* since the start of the project activity, in the project scenario, tCO_2e;
$Bu_{ER,t*}$	Buffer credits to be deducted from reductions in year t* ($t\ CO_2e$)

9 MONITORING

9.1 Data and Parameters Available at Validation

In addition to the parameters listed in the tables presented in the following sections, the provisions on data and parameters not monitored in the tools referred to in this methodology apply. In choosing key parameters or making important assumptions based on information that is not specific to project circumstances, such as in use of existing published data, the project proponent must follow a conservative approach. That is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

Note that the calculation of baseline emissions from fossil fuel combustion requires the determination of a set of parameters (e.g., specific fuel consumption of a harvester, in kL m^{-3}). As a general procedure, the determination of all parameters must follow one of the subsequent pathways:

1. **Historic Data Pathway:** Where the project proponent has a history of logging operations, the equipment type and fuel consumption data from the project proponent's operation must be considered.
2. **Common Practice Pathway:** Where the project proponent has no history of logging operations, regional or national standards and typical machinery (i.e., default values) must be considered. This includes:
    - Identification of equipment type (e.g., harvester or chain saw);
    - Identification of the specific fuel consumption (i.e., in kL m^{-3}) of equipment type.

    The following sources of information are permitted for the common practice pathway:

    - Data from other forest management companies in the region; or
    - Data from peer reviewed literature (i.e., available from a recognized, credible source and must be reviewed for publication by an appropriately qualified, independent organization or an appropriate peer review group, or published by a government agency).

Further, the source of all data must be appropriate to the methodology's geographic scope and eligible project activities.

Data / Parameter	$F_{V,INF,HWP}$
Data unit	%
Description	The fraction of merchantable timber volume from clearing of forest roads, skidtrails and log landings that is to be processed into wood products. Based on this fraction as well as forest inventory or sample plot data and forestry infrastructure data, $V_{EX,INF,j,i\|BSL}$ and $V_{notEX,INF,j,i\|BSL}$ will be calculated.
Equations	To be applied in the timber harvest plan
Source of data	A credible and conservative value for $F_{V,INF,HWP}$ must be set based on one of the following sources in order of their appearance: • Forest management records of the baseline agent or other similar forestry companies • Peer-reviewed literature • Government statistics from the region If the project proponent cannot provide such a credible estimate, then it is conservatively assumed that all timber cleared for the purpose of forestry infrastructure is processed into sawnwood and hence must be accounted for under the harvested wood products section.
Value applied	-
Justification of choice of data or description of measurement methods and procedures applied	n.a.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$V_{EX,INF,j,i\|BSL}$
Data unit	$m^3\ ha^{-1}$
Description	Mean volume of timber extracted for wood processing during the process of forestry infrastructure establishment per unit area for species *j* in stratum *i*
Equations	(3), (4), (37)

Source of data	$V_{EX,INF,j,i\|BSL}$ is provided in the timber harvest plan. It is calculated by multiplying $F_{V,INF,HWP}$ with the merchantable volume (from sample plots or existing forest inventory data) to be harvested/cleared for the purpose of forestry infrastructure development.
Value applied	-
Justification of choice of data or description of measurement methods and procedures applied	n.a.
Purpose of Data	Determination of baseline scenario
Comments	n.a.

Data / Parameter	$V_{notEX,INF,j,i\|BSL}$
Data unit	$m^3\ ha^{-1}$
Description	Mean volume of timber that is not extracted for wood processing during the establishment of forestry infrastructure per unit area for species *j* in stratum *i*
Equations	(7)
Source of data	$V_{notEX,INF,j,i\|BSL}$ is provided in the timber harvest plan. It is calculated by multiplying $1\text{-}F_{V,INF,HWP}$ with the merchantable volume (from sample plots or existing forest inventory data) to be harvested/cleared for the purpose of forestry infrastructure development.
Value applied	-
Justification of choice of data or description of measurement methods and procedures applied	n.a.
Purpose of Data	Determination of baseline scenario
Comments	n.a.

Data / Parameter	$F_{RSD\|BSL}$
Data unit	Dimensionless
Description	Residual Stand Damage Factor

Equations	(6)
Source of data	Choose data from peer reviewed literature (i.e., available from a recognized, credible source and must be reviewed for publication by an appropriately qualified, independent organization or an appropriate peer review group, or published by a government agency), e.g., Brown, S. Pearson T., Moore, N., Parveen A., Ambagis, S., Shoch, D. (2005). Impact of selective logging on the carbon stocks of tropical forests: Republic of Congo as a case study. Deliverable 6: Logging Impact on carbon stocks, Report submitted to United States Agency for International Development, Cooperative Agreement No. EEM-A-00-03-00006-00.
Value applied	see table below
Justification of choice of data or description of measurement methods and procedures applied	n.a.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Value applied:

f_{RSD} (tCdamaged tCextracted^{-1})	Commercial Log Length (m)	Country	Reference
1.74	22	Congo	Brown et al. (2005)
2.30	17	Malaysia	Pinard and Putz. (1996)
2.78	10.8	Belize	Brown et al. (2005)
3.10	9.8	Bolivia	Pearson et al. (2005)
2.40	20.2	Southern Amazonia, Brazil	Feldspauch et al. (2005)

Data / Parameter	EF_{FUEL}
Data unit	$tCO_2e\ kL^{-1}$
Description	Fuel emission factor
Equations	(14)

Source of data	Data must be determined by following either the historic data pathway, (if the PP has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$FC_{HARVEST}$
Data unit	kL m^{-3}
Description	Fuel consumption of equipment employed for felling, snigging/skidding, delimbing and bucking per m^3 of merchantable log harvested;
Equations	(14)
Source of data	Data must be determined by following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$FC_{HAULING}$
Data unit	kL m^{-3}
Description	Fuel consumption of equipment for hauling one m^3 of merchantable log.

Equations	(15)
Source of data	Data must be determined by following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$KM_{TRANSPORT}$
Data unit	km $truck^{-1}$
Description	Log transport distance from the collection depot to processing plant;
Equations	(17)
Source of data	Digital maps specifying harvesting areas and logging and transporting roads to processing facility
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline activity emissions
Comments	N.A.

Data / Parameter	CAP_{TRUCK}
Data unit	m^3 $truck^{-1}$
Description	Truck load capacity
Equations	(16)

Source of data	Data must be determined by following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$EFF_{VEHICLE}$
Data unit	km kL^{-1}
Description	Fuel efficiency for vehicle type
Equations	(18)
Source of data	Data must be determined by following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	E_{DEMAND}
Data unit	kWh m^{-3}
Description	Electricity demand for processing per volume processed
Equations	(19)

Source of data	Data must be determined by following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$EF_{ELECTRICITY}$
Data unit	$tCO_2e\ kWh^{-1}$
Description	Emission factor for electricity in the host country
Equations	(20)
Source of data	Country-specific data from International Energy Agency
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$T_{GENERATOR}$
Data unit	h
Description	Total operating time of generator
Equations	(21)

Source of data	Data must be determined by following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$FC_{GENERATOR}$
Data unit	kL h^{-1}
Description	Fuel consumption per hour of operation of generator
Equations	(22)
Source of data	Data must be determined by following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$PR_{GENERATOR}$
Data unit	kW
Description	Power rating of generator or generator size;
Equations	(21)

Source of data	Data must be determined by following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$V_{l,j,i,sp}$
Data unit	m^3
Description	Merchantable volume for tree *l* of species *j* in sample plots *p* in stratum *i*
Equations	(1)
Source of data	Calculated from volume tables or equations linking diameter at breast height (DBH, at typically 1.3 meters aboveground level), and/or merchantable height (MH), to commercial (merchantable) volume of trees in the sample plots above the minimum DBH set in the timber harvest plan. If locally derived equations or yield tables are not available, use relevant regional, national or default equations from IPCC literature, national inventory reports or published peer-reviewed studies– such as those provided in Tables 4.A.1 to 4.A.3 of the GPG-LULUCF (IPCC 2003).
Measurement procedures (if any)	N/A
Comments	It is necessary to verify the applicability of equations used. Allometric equations can be verified by both: 1. Verification of equation conditions Justification should be provided for the applicability of the equation to the project locations. Such justification should include identification of climatic, edaphic, geographical and taxonomic similarities between the project location and the location in which the equation was derived. Any equation used should have an r^2 value of greater than 0.5 (50%) and a p value that is significant (<0.05 at the 95% confidence level).

	2. Additional field verification The following limited measures method must be used for field verification: • select at least 10 trees per species distributed across the age range (but excluding trees less than 15 years old for which there is rarely a great relative inaccuracy in equations); • measure DBH, and height to a 10 cm diameter top or to the first branch; • calculate stem volume from measurements; and • plot the estimated volume of all the measured trees along with the curve of volume against diameter as predicted by the allometric equation. If the estimated volume of the measured trees is distributed both above and below the curve (as predicted by the allometric equation) the equation may be used. The equation may also be used if the measured individuals have a volume consistently higher than predicted by the equation. The equation may not be used if >75% of the measured trees have a volume lower than the predicted curve. In this instance another equation must be selected.

Data / Parameter	CF_j
Data unit	tC·td.m.$^{-1}$
Description	Carbon fraction of dry matter for species *j*
Equations	(3), (4), (7)
Source of data	Either the default value 0.5tC·td.m.$^{-1}$ or species-specific values from the literature must be used. he same value, however, must be used in all instances where this parameter is used.
Measurement procedures (if any)	N/A
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	D_j
Data unit	t.d.m. m^{-3}
Description	Basic wood density of species *j* in t d.m. m^{-3}
Equations	(4)

Source of data	Must be chosen with priority from higher to lower preference as follows: • National species-specific or group of species-specific values (e.g., from National GHG inventory); • Species-specific or group of species-specific values from neighboring countries with similar conditions. When species-specific data from neighboring countries is of higher quality, being more representative of the species in the project scenario, it may be preferable to use these values than lower quality national data; • Global species-specific or group of species-specific (e.g., IPCC 2006 AFOLU Chapter 4 Tables 4.13 and 4.14). Species-specific wood densities may not always be available and may be difficult to apply with certainty in the typically species-rich forests of the humid tropics, hence it is acceptable practice to use wood densities developed for forest types or plant families or species groups. For a detailed list of values for many species worldwide, the Global Wood Density Database can be used (Zanne et al. 2009)[33].
Measurement procedures (if any)	N/A
Comments	Default values must be updated whenever new guidelines are produced by the IPCC

Data / Parameter	$F_j(X,Y...)$
Data unit	t d.m. tree^{-1}
Description	Allometric equation(s) for species *j* linking measured tree variable(s) to aboveground biomass of living trees
Equations	(17)
Source of data	Equations must have been derived using a wide range of measured variables (e.g., DBH, Height, etc.) based on datasets that comprise at least 30 trees. Equations must be based on statistically significant regressions and must have an r^2 that is ≥ 0.8. The source of equation(s) must be chosen with priority from higher to lower preference, as available, as follows: • National species-, genus-, family-specific; • Species-, genus-, family-specific from neighboring countries with similar conditions (i.e., broad continental regions); • National forest-type specific;

[33] https://datadryad.org/stash/dataset/doi:10.5061/dryad.234

	• Forest-type specific from neighboring countries with similar conditions (i.e., broad continental regions); • Forest type-specific such as those provided Tables 4.A.1 to 4.A.3 of the GPG-LULUCF (IPCC 2003); or in Pearson, T., Walker, S. and Brown, S. 2005. Sourcebook for Land Use, Land-Use Change and Forestry Projects. Winrock International and the World Bank Biocarbon Fund. 57pp.; or in Chave, J., C. Andalo, S. Brown, M. A. Cairns, J. Q. Chambers, D. Eamus, H. Folster, F. Fromard, N. Higuchi, T. Kira, J.-P. Lescure, B. W. Nelson, H. Ogawa, H. Puig, B. Riera, T. Yamakura. 2005 Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: 87-99, or Chave et al. 2014. Improved allometric models to estimate the aboveground biomass of tropical trees; Global Change Biology 20 (10): 3177-3190. Species-, genus- and family-specific allometric equations may not always be available and may be difficult to apply with certainty in the typically species-rich forests of the humid tropics[34]. Hence it is acceptable practice to use equations developed for regional forest types, provided that their accuracy has been validated with direct site-specific data following guidance given below. If a forest-type specific equation is used, it should not be used in combination with species-specific equation(s) (i.e., it must be used for all tree species[35]). For extratropical projects, the *allodb* R package includes a database from 701 woody species identified at 24 large Forest Global Earth Observatory (ForestGEO) forest dynamics plots representing a wide diversity of extratropical forests. See more in: Gonzalez-Akre et al. (2021)[36].
Measurement procedures (if any)	N/A
Comments	It is necessary to validate the applicability of equations used. Source data from which equation(s) was derived should be reviewed and confirmed to be representative of the forest type/species and conditions in the project and covering the range of potential independent variable values. Allometric equations can be validated either by: 1. Limited Measurements

[34] Continuously updated database for allometric equations can be found from FAO's GlobAllomeTree database http://www.globallometree.org/

[35]Note that forest type specific and pantropical equations will typically not include palm species or hollow-stem species (e.g. Cecropia) and so specific equations for these growth forms will be needed.

[36] https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/2041-210X.13756

- select at least 30 trees (if validating forest type-specific equation, selection should be representative of the species composition in the project area, i.e., species representation roughly in proportion to relative basal area). Minimum diameter of measured trees must be 20cm and maximum diameter must reflect the largest trees present or potentially present in the future in the project area (and/or leakage belt);
- measure DBH, and height to a 10 cm diameter top or to the first branch;
- calculate stem volume from measurements and multiply by species-specific density to gain biomass of bole;
- apply a biomass expansion factor to estimate total aboveground biomass from stem biomass[37]; and
- plot the estimated biomass of all the measured trees along with the curve of biomass against diameter as predicted by the allometric equation.

If the estimated volume of the measured trees is distributed both above and below the curve (as predicted by the allometric equation) the equation may be used. The equation may also be used if the measured individuals have a biomass consistently higher than predicted by the equation. If >75% of the measured trees have a biomass lower than the predicted curve, destructive sampling must be undertaken, or another equation must be selected.

2. Destructive Sampling

- select at least 5 trees (if validating forest type-specific equation, selection should be representative of the species composition in the project area, i.e., species representation in roughly in proportion to relative basal area) at the upper end of the range of independent variable values existing in the project area;
- measure DBH and commercial height and calculate volume using the same procedures/equations used to generate commercial volumes to which BCEFs will be applied;
- fell and weigh the aboveground biomass to determine the total (wet) mass of the stem, branch, twig, leaves, etc. Extract and immediately weigh subsamples from each of the wet stem and branch components, followed by oven drying at 70 degrees C to determine dry biomass;
- determine the total dry weight of each tree from the wet weights and the averaged ratios of wet and dry weights of the stem and branch components; and

[37] See IPCC 2006 INVGLs AFOLU Chapter4 Table 4.5

	• plot the estimated biomass of all the measured trees along with the curve of biomass against diameter as predicted by the allometric equation. If the estimated volume of the measured trees is distributed both above and below the curve (as predicted by the allometric equation) the equation may be used. The equation may also be used if the measured individuals have a biomass consistently higher than predicted by the equation. If >75% of the measured trees have a biomass lower than the predicted curve another equation must be selected. Details of destructive sampling measurements are given in several publications: Brown, S. 1997. Estimating biomass and biomass change of tropical forests: a primer. FAO Forestry Paper 134, Rome, Italy. Available at http://www.fao.org/docrep/W4095E/W4095E00.htm Picard N., Saint-André L., Henry M. 2012. Manual for building tree volume and biomass allometric equations: from field measurement to prediction. Food and Agricultural Organization of the United Nations, Rome, and Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Montpellier, 215 pp. https://www.fao.org/4/i3058e/i3058e.pdf If using species-specific equations, and new species are encountered while monitoring, new allometric equations must be sourced from the literature and validated, if necessary, as per requirements and procedures above. Default values must be updated whenever new guidelines are produced by the IPCC

Data / Parameter	$BCEF_R$
Data unit	$t.d.mm^{-3}$
Description	Biomass conversion and expansion factor applicable to wood removals in the project area
Equations	(3), (34)
Source of data	The source of data must be chosen with priority from higher to lower preference as follows: • Existing local forest type-specific; • National forest type-specific or eco-region-specific (e.g., from national GHG inventory); • Forest type-specific or eco-region-specific from neighboring countries with similar conditions. Sometimes (c) might be preferable to (b);

	• Global forest type or eco-region-specific (e.g., IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.5). Alternatively: $BCEF_R = BEF_R * D$ Where BCEF values are not directly available, they can be calculated as Biomass Expansion Factor (BEF)* basic wood density (D). Application of this equation requires caution because basic wood density and biomass expansion factors tend to be correlated. If the same sample of trees was used to determine D, BEF or BCEF, conversion will not introduce error, therefore, it is acceptable to use this equation. If, however, basic wood density is not known with certainty, transforming one into the other might introduce error, as BCEF implies a specific but unknown basic wood density, therefore, all conversion and expansion factors must be derived or their applicability checked locally.
Measurement procedures (if any)	N/A
Comments	The combustion factor is a measure of the proportion of the fuel that is actually combusted, which varies as a function of the size and architecture of the fuel load (i.e., a smaller proportion of large, coarse fuel such as tree stems will be burnt compared to fine fuels, such as grass leaves), the moisture content of the fuel and the type of fire (i.e., intensity and rate of spread). Default values must be updated whenever new guidelines are produced by the IPCC.

Data / Parameter	G_{gi}
Data unit	g kg^{-1} dry matter burnt
Description	Emission factor for stratum *i* for gas *g*
Equations	(20)
Source of data	Defaults can be found in Volume 4, Chapter 2, of the IPCC 2006 Inventory Guidelines in table 2.5
Measurement procedures (if any)	N/A
Comments	Default values must be updated whenever new guidelines are produced by the IPCC

Data / Parameter	*OF, SLF, WW*
Data unit	Kg kg^{-1}
Description	*OF* = Fraction of wood products that will be emitted to the atmosphere between 3- and 100-years after production; *SLF* = Fraction of wood products that will be emitted to the atmosphere within 3 years of production; and *WW* = Fraction of extracted biomass effectively emitted to the atmosphere during production Wood waste fraction (*WW*): Winjum et al. 1998 indicates that the proportion of extracted biomass that is oxidized (burning or decaying) from the production of commodities to be equal to 19% for developed countries, 24% for developing countries. Short-lived fraction (*SLF*) Winjumetal (1998) give decay rates for proportions of wood products, which were converted to short-term (<3yr) uses (applicable internationally) as below: Sawnwood 0.12 Woodbase panels 0.06 Other industrial roundwood 0.18 Paper and Paperboard 0.24 Additional oxidized fraction (*OF*) Winjum et al 1998 gives annual oxidation fractions for each class of wood products split by forest region (boreal, temperate and tropical). This methodology projects these fractions over 95 years to give the additional proportion that is oxidized between the 3rd and the 100th year after initial harvest:

Wood Product Class	*OF*		
	Boreal	Temperate	Tropical
Sawnwood	0.39	0.62	0.86
Woodbase panels	0.62	0.86	0.98
Other industrial roundwood	0.86	0.98	0.99
Paper and paperboard	0.39	0.62	0.99

Equations	(9), (11)
Source of data	The source of data is the published paper of Winjum et al.1998 [38]

[38] Winjum,J.K., Brown,S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. Forest Science 44:272-28431

Measurement procedures (if any)	N/A
Comments	Parameter needs to be reviewed as part of the baseline re-evaluation.

Data / Parameter	PML_{FT}
Data unit	%
Description	Mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type.
Equations	Section 8.3.2, Box 2.
Source of data	The source of data must be chosen with priority from higher to lower preference as follows: • peer-reviewed published sources (including carbon/biomass maps or growing stock volume[39] maps with a scale of at least 1 km); • official Government data and statistics; or • original field measurements. The forest types considered must be only those relevant for the specific market effects leakage, that is, only forest types with active timber production. An appropriate source of data will be Government records on annual allowable cuts for the areas of commercial forests. Where volumes are used the source of data wood density is required to convert to merchantable biomass. The source of data on wood densities must be chosen as per the species-specific density parameter, D_j.
Measurement procedures (if any)	
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	RGR_i
Data unit	$tC.ha^{-1}.yr^{-1}$
Description	Forest regrowth rate post timber harvest for stratum *i*

39 Volumes shall be converted to merchantable biomass using wood densities / specific gravities. A weighted Wood density shall be used to convert multi-species data on growing stock volume to merchantable biomass

Equations	(22)
Source of data	Regrowth rate must be calculated from either • data generated in a reference area using measurements of timber volume in a chronosequence of replicated sample plots; or • published data on forest growth after timber harvest of the same forest type within the same region as the project; or • IPCC default values for aboveground net biomass growth in natural forests[40].
Measurement procedures (if any)	
Comments	Default values must be updated whenever new guidelines are produced by the IPCC

Data / Parameter	$V_{EX,j,i\|BSL}$
Data unit	$m^3\ ha^{-1}$
Description	Mean volume of extracted timber per unit area for species *j* in stratum *i*
Equations	(3), (4), (34), (37)
Source of data	The timber harvest plan sets the allowable mean extracted volume from the merchantable volume of timber in the forest inventory ($V_{j,i\|BSL}$),based on legal limits.
Measurement procedures (if any)	N/A
Comments	

Data / Parameter	$TH_{i,p}$
Data unit	Years
Description	Number of years since timber harvest in stratum *i* in land parcel *p*
Equations	n.a

[40] 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use, Table 4.9.

Source of data	The timber harvest schedule specifies the year (*1,2,3…*) timber harvest in each land parcel is scheduled to occur and the number of years each land parcel is in a post-harvest state during the project crediting period.
Measurement procedures (if any)	
Comments	

Data / Parameter	$A_{i,p}$
Data unit	ha
Description	Area covered by stratum *i* over land parcel *p*
Equations	(23), (24), (25)
Source of data	Geodetic coordinates and/or Remote Sensing data and/or legal parcel records
Measurement procedures (if any)	
Comments	It must be assumed ex-ante that land parcel boundaries and strata areas must not change through time

Data / Parameter	$A_{t*,i,p}$
Data unit	ha
Description	Cumulative area harvested in stratum *i* in parcel *p* at time *t**
Equations	(26), (31)
Source of data	Timber harvesting plan. Geodesic coordinates, remote sensing data and/or legal parcel records.
Measurement procedures (if any)	
Comments	Land parcel boundaries and strata areas must be set at project validation and must not change through time

Data / Parameter	$A_{1,i,p}$
Data unit	ha

Description	The area of stratum *i* in land parcel *p* that was harvested 1 year ago
Equations	(23)
Source of data	Geodesic coordinates, GIS Files or legal parcel records
Measurement procedures (if any)	
Comments	

Data / Parameter	$A_{2\text{-}10,i,p}$
Data unit	ha
Description	The area of stratum *i* in land parcel *p* that was harvested between 2 and 10 years ago
Equations	(24)
Source of data	Geodesic coordinates, GIS Files or legal parcel records
Measurement procedures (if any)	
Comments	

Data / Parameter	$A_{11\text{-}20,i,p}$
Data unit	ha
Description	The area of stratum *i* in land parcel *p* that was harvested between 11 and 20 years ago
Equations	(25)
Source of data	Geodesic coordinates, GIS Files or legal parcel records
Measurement procedures (if any)	
Comments	

Data / Parameter	A_{sp}
Data unit	ha

Description	Area of sample plots *p*
Equations	(2), (30)
Source of data	Recording and archiving of size of sample plots
Measurement procedures (if any)	Standard procedures for plot delineation in forest timber inventory surveys must be used (see references in Box 3 for example procedures)
Comments	*Ex-ante* the size of the plots must be defined and recorded in the monitoring plan.

9.2 Data and Parameters Monitored

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply. In choosing key parameters or making important assumptions based on information that is not specific to the project circumstances, such as in use of existing published data, the project proponent must retain a conservative approach. That is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

Data / Parameter:	Illegal Logging PRA Results
Data unit:	Dimensionless
Description:	Used in Section 8.2.2.20 Option A
Equations	
Source of data:	PRA
Description of measurement methods and procedures to be applied:	The PRA must evaluate whether timber harvest may be occurring in the project area and must consist of semi-structured interviews / questionnaires. If ≥10% of those interviewed / surveyed believe that illegal logging may be occurring within the project boundary then the limited on-the-ground illegal logging survey must be triggered. An additional output of the PRA must be a depth of penetration of illegal logging pressure. A maximum distance must be recorded for penetration into the forest from access points (such as roads, rivers, already cleared areas) for the purpose of harvesting timber.
Frequency of monitoring/recording:	Every two years
QA/QC procedures to be applied:	

Purpose of data:	
Calculation method:	
Comments:	*Ex ante* estimation must be made of illegal logging in the with-project case. If the belief is that zero illegal logging will occur within the project boundaries then this parameter may be set to zero if clear infrastructure, hiring and policies are in place to prevent illegal logging.

Data / Parameter:	Result of Limited Illegal Logging Survey
Data unit:	Dimensionless
Description:	Section 8.2.2.2 option B
Equations	
Source of data:	Limited on-the-ground illegal logging survey
Description of measurement methods and procedures to be applied:	Sampled by surveying multiple transects of known length and width across the access-buffer area to check whether new tree stumps are evident or not. The access-buffer area must be equal in area to at least 1% of $A_{DIST\_IL,i}$
Frequency of monitoring/recording:	Must be repeated each time the PRA indicates a potential for illegal logging.
QA/QC procedures to be applied:	
Purpose of data:	
Calculation method:	
Comments:	An *ex ante* estimation must be made of illegal logging in the with-project case. If the belief is that zero illegal logging will occur within the project boundaries then this parameter may be set to zero if clear infrastructure, hiring and policies are in place to prevent illegal logging.

Data / Parameter:	$A_{burn,i,t}$
Data unit:	ha
Description:	Area burnt in stratum *i* at time *t*
Equations	(33)
Source of data:	Geodesic coordinates and / or Remote Sensing data

Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Areas burnt must be monitored at least every five years
QA/QC procedures to be applied:	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the IPCC GPG LULUCF 2003, is recommended.
Purpose of data:	
Calculation method:	
Comments:	*Ex ante* estimations of areas burned must be based on historic incidence of fire in the Project region.

Data / Parameter:	$A_{dist,i,t}$
Data unit:	ha
Description:	Area disturbed in stratum *i* at time *t*
Equations	(35)
Source of data:	Geodesic coordinates and / or Remote Sensing data
Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Areas disturbed must be monitored at least every five years
QA/QC procedures to be applied:	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the IPCC GPG LULUCF 2003, is recommended.
Purpose of data:	
Calculation method:	
Comments:	*Ex ante* estimations of areas disturbed must be based on historic incidence of natural disturbance in the Project region

Data / Parameter:	$A_{DIST\_IL,i}$
Data unit:	ha
Description:	Area potentially impacted by illegal logging in stratum *I*
Equations	(37)
Source of data:	GIS delineation and ground-truthing
Description of measurement methods and procedures to be applied:	$A_{DIST\_IL,i}$ must be composed of a buffer from all access points (access buffer), such as roads and rivers or previously cleared areas. The width of the buffer must be determined by the depth of degradation penetration as defined as a PRA output
Frequency of monitoring/recording:	Repeated each time the PRA indicates a potential for degradation
QA/QC procedures to be applied:	
Purpose of data:	
Calculation method:	
Comments:	*Ex ante* limited survey can be used to determine a likely depth of degradation penetration

Data / Parameter:	$C_{DIST\_IL,i,t\|PRJ}$
Data unit:	tCO_2e
Description:	Biomass carbon of trees cut and removed through illegal logging in stratum *i* at time *t*
Equations	(37)
Source of data:	Field measurements in sample plots
Description of measurement methods and procedures to be applied:	The sampling plan must be designed using plots systematically placed over the buffer zone so that they sample at least 3% of the area of the buffer zone ($A_{DIST\_IL,i}$). The diameter of all tree stumps will be measured and conservatively assumed to be the same as the DBH. Where the stump is a large buttress, several individuals of the same species nearby must be located and a ratio of the diameter at DBH to the diameter of buttress at the same height above ground as the measured stumps must be determined. This ratio will be applied to the measured stumps to estimate the likely DBH of the cut tree. The aboveground carbon stock of each harvested tree will be estimated using the allometric regression equations chosen for forest growth in the project scenario. The mean aboveground carbon stock of the

	harvested trees is conservatively estimated to be the total emissions and to all enter the atmosphere
Frequency of monitoring/recording:	Repeated each time limited sampling of A_{DIST_IL}, indicates illegal logging
QA/QC procedures to be applied:	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the IPCC GPG LULUCF 2003, is recommended.
Purpose of data:	
Calculation method:	
Comments:	If species-specific equations are used and species cannot be identified from stumps then it must be assumed that the harvested species is the species most commonly harvested. A PRA must be used to determine the most commonly harvested species.

Data / Parameter:	AP_i
Data unit:	ha
Description:	Total area of illegal logging sample plots in stratum *i*
Equations	(37)
Source of data:	Ground measurement
Description of measurement methods and procedures to be applied:	A sampling plan must be designed using multiple sample plots systematically placed across the buffer zone so that they sample at least 3% of the area of the buffer zone.
Frequency of monitoring/recording:	Not more than five years
QA/QC procedures to be applied:	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the IPCC GPG LULUCF 2003, is recommended.
Purpose of data:	
Calculation method:	
Comments:	*Ex ante* estimation should be made of area of plots. This should be set to exactly 3% of the buffer zone $A_{DIST\_IL,i}$

Data / Parameter:	PMP_i
Data unit:	%
Description:	Merchantable biomass as a proportion of total aboveground tree biomass for stratum *i* within the project boundaries
Equations	Section 8.3.2, Box 2: Leakage Factor Calculation
Source of data:	Within each stratum divide the summed merchantable biomass (defined as total gross biomass of a tree with 15cm DBH or larger) by the summed total of aboveground tree biomass.
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	Not more than five years
QA/QC procedures to be applied:	Standard quality control /quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the *IPCC GPGLULUCF 2003*, is recommended.
Purpose of data:	
Calculation method:	
Comments:	Ex-ante a time zero measurement must be made of this factor. The timber harvest plan sets the allowable mean extracted volume from the merchantable volume of timber in the forest inventory ($V_{j,i\|BSL}$), based on legal limits.

Data / Parameter:	$A_{i,}$
Data unit:	ha
Description:	Area covered by stratum *i*
Equations	(13), (14), (18)
Source of data:	Geodetic coordinates and/or Remote Sensing data and/or legal parcel records
Description of measurement methods and procedures to be applied:	

Frequency of monitoring/recording:	
QA/QC procedures to be applied:	
Purpose of data:	
Calculation method:	
Comments:	In the baseline scenario strata areas must not change through time. In the project scenario it must be assumed *ex-ante* that stand boundaries and strata areas must not change through time. *Ex post* adjustments of the project scenario strata may be needed if unexpected disturbances occur during the project crediting period, severely affecting different parts of an originally homogenous stratum. This disturbance will be delineated as a separate stratum for the purpose of monitoring the carbon stock changes.

9.3 Description of the Monitoring Plan

The following parameters must be monitored in this methodology:

- Illegal logging PRA
- Result of limited illegal logging survey
- Area burnt in stratum *i* at time *t* ($A_{burn,i,t}$)
- Area potentially impacted by illegal logging in stratum *i* ($A_{DIST\_IL,\ i}$)
- Total area of illegal logging sample plots in stratum *i* (AP_i)
- Merchantable biomass as a proportion of total aboveground tree biomass for stratum *i* (PMP_i)
- Area covered by stratum *i* (A_i)
- Diameter at breast height of tree (*DBH*)

These parameters will be required at each verification.

9.3.1 Scope of monitoring and the monitoring plan

Monitoring is required to:

a) Determine changes in forest carbon stocks and greenhouse gas emissions from project activity;

b) Confirm project activity; and

c) Determine changes in forest carbon stocks and greenhouse gas emissions from fires and non-fire natural disturbances (e.g., windthrows, insects) and anthropogenic disturbances (e.g., illegal logging).

In some project cases monitoring may also be implemented to update stratification.

It is a requirement that the monitoring plan presented in the project documents must address the monitoring of project implementation, the monitoring of actual carbon stock changes from project activity, and estimation of ex-post net carbon stock changes from disturbance and illegal logging.

The description of the monitoring plan in the project documents will include the following for each of these monitoring tasks:

a) Technical description of the monitoring task;

b) A list of data and parameters to be collected;

c) Overview of data collection procedures;

d) Quality control and quality assurance procedures;

e) Data archiving; and

f) Organization and responsibilities of the parties involved in all the above.

9.3.2 General requirements for monitoring

All data collected as part of monitoring will be archived electronically and be kept at least for 2 years after the end of the project crediting period. All measurements will be conducted according to relevant standards.

Data archiving must take both electronic and paper forms, and copies of all data must be provided to each project proponent. Online cloud-based tools can also be used for this purpose.

All electronic data and reports must also be copied onto durable media such as CDs and copies of the CDs are to be stored in multiple locations.

The archives must include:

- Copies of all original field measurement data, laboratory data, data analysis spreadsheets;
- Estimates of the carbon stock changes in all pools and non-CO2 GHG and corresponding calculation spreadsheets;
- GIS products; and
- Copies of the measuring and monitoring reports.

9.3.3 Monitoring of project implementation

Information must be provided, and recorded in the project documents, to establish that:

- Geographic position of the project boundary is recorded for all areas of land;
- Geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded and archived. This will be achieved by field survey (e.g., using Geodetic coordinates) or by using georeferenced spatial data (e.g., maps, GIS datasets, aerial photography, or georeferenced remote sensing images);
- Commonly accepted principles of forest inventory and management are implemented;
- Standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of SOPs already applied in national forest monitoring or available from published handbooks or from the IPCC GPG LULUCF 2003 is recommended; and
- Project plan, together with a record of the plan as actually implemented during the project, must be available for validation or verification as appropriate.

9.3.4 Stratification

This methodology requires that an *ex-ante* stratification of the project area in the project scenario is described in the project documents as detailed in the timber harvest plan or developed by the project proponent through sampling in the project area.

The monitoring plan may include sampling to adjust the number and boundaries of the strata defined ex ante where an update is required because of:

a) Unexpected disturbances occurring during the project crediting period affecting differently various parts of an originally homogeneous stratum and/or
b) Forest management activities that are implemented in a way that affects the existing stratification in the project scenario.

Established strata may also be merged if the reasons for their establishment have disappeared.

9.3.5 Monitoring of actual stock changes

Carbon stocks will be measured according to the stock assessment equations in this methodology with field sampling based on forest inventory methods. Various sources exist to assist with the design of a verifiable forest field inventory based on best practice for sampling, data management and analysis (Box 3).

In the project area (or areas) the inventory plan must be specified in the project documents and include:

a) Adequate forest stratification, sample size estimation methods and consider uncertainty; and

b) Sampling framework including sample size, plot size, plot shape and information to determine plot location.

To determine the sample size and allocation among strata, this methodology uses the most recent version of the tool for the "Calculation of the number of sample plots for measurements within A/R CDM project activities"[41] approved by the CDM Executive Board.

Carbon stock changes over time in trees that would have been harvested under the baseline scenario must be estimated by taking measurements in permanent sample plots at each monitoring event. The design of the sampling regime will be determined by the number of strata and timber harvest under the baseline case.

Monitoring events must take place at intervals of 5, or preferably 3 years. For intermittent years it is good practice to use extrapolations of trends as they have occurred up till that moment. Monitoring reports can use such extrapolated parameter values for the determination of net emissions by sources and removals resulting from the project.

9.3.6 Conservative approach and uncertainty

The project proponent must also apply all relevant equations for the ex-ante calculation of net anthropogenic GHG removals by sinks with care and provide transparent estimations for the parameters that are monitored during the project crediting period. These estimates must be based on measured or existing published data where possible and the project proponent should retain a conservative approach. That is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

An uncertainty analysis is required for all estimates from monitoring related to change in area, change in carbon stocks and emissions for both the baseline and project case.

Box 3: Resource Material for the Design of Forest Field Inventories

IPCC Good Practice Guidance on Land Use. Land Use Change and Forestry (IPCC 2003) http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html
The Sourcebook for Land Use Change and Forestry Projects (Pearson et al. 2005) http://www.winrock.org/feature_ecosystem_200802.asp
Measurement guidelines for the sequestration of forest carbon (Pearson et al. 2007) http://www.nrs.fs.fed.us/pubs/3292
Field Measurements for Forest Carbon Monitoring A Landscape-Scale Approach (Hoover. 2008)
The Winrock sampling calculator http://www.winrock.org/Ecosystems/tools.asp?BU=9086
The CDM A/R Methodological Tool "Calculation of the number of sample plots for measurements within A/R CDM project activities" (Version 02) http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html

[41] http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html

The California Climate Action Reserve Registry Forest Project Protocol (Version 2) 2009 http://www.climateactionreserve.org/how-it-works/protocols/adopted- protocols/forest/forest-project-protocol-update/ Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States (Smith et al. 2006) http://nrs.fs.fed.us/pubs/8192 A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects (MacDicken. 1997) http://www.winrock.org/fnrm/publications.asp?BU=9058 Carbon Stock Assessment Guidance: Inventory and Monitoring Procedures. Diaz & Delaney (2011). Forest Trends, L&C Carbon. https://www.forest-trends.org/publications/carbon-stock-assessment-guidance/

10 REFERENCES

Brown, S. 1997. Estimating biomass and biomass change of tropical forests: a primer. FAO Forestry Paper 134, Rome, Italy. Available at http://www.fao.org/docrep/W4095E/W4095E00.htm

Brown, S., Pearson, T., Moore, T., Parveen, A., Ambagis, S., Shoch, D. (2005). Impact of selective logging on the carbon stocks of tropical forests: Republic of Congo as a case study. Report submitted to the United States Agency for International Development Cooperative Agreement No. EEM-A-00-03-00006-00 https://pdf.usaid.gov/pdf_docs/Pnade434.pdf

Burivalova, Z., Çağan Hakkı Şekercioğlu, Lian Pin Koh (2014). Thresholds of Logging Intensity to Maintain Tropical Forest Biodiversity. Current Biology 24 (16): 1893-1898. https://doi.org/10.1016/j.cub.2014.06.065.

FAO (2023) Global Forest Resources assessment (FRA) Terms and Definitions.

Feldpausch, T., Jirka, S., Passos, C., Jasper, F., Riha, S. (2005) When big trees fall: Damage and carbon export by reduced impact logging in southern Amazonia, Forest Ecology and Management 219 (2–3):199-215.

Gonzalez-Akre, E., Piponiot, C., Lepore, M., Herrmann, V., Lutz, J. A., Baltzer, J. L., Dick, C. W., Gilbert, G. S., He, F., Heym, M., Huerta, A. I., Jansen, P. A., Johnson, D. J., Knapp, N., Král, K., Lin, D., Malhi, Y., McMahon, S. M., Myers, J. A., … Anderson-Teixeira, K. J. (2022). allodb: An R package for biomass estimation at globally distributed extratropical forest plots. Methods in Ecology and Evolution, 13, 330–338. https://doi.org/10.1111/2041-210X.13756

IEA (2009). IEA Statistics: Emissions from Fuel Combustion Highlights (2009 Ed). CO2 emissions per kWh from electricity and heat generation, pp. 101-103.

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories; Volume 4 AFOLU, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

IPCC. (2019) Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize, S., Osako, A., Pyrozhenko, Y., Shermanau, P. and Federici, S. (eds). Published: IPCC, Switzerland. https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html .

Kinjo, M., Ohuchi, T., Kii, H., and Murase, Y. (2005). "Studies of life cycle assessment of Sugi Lumber," Journal of the Faculty of Agriculture 50(2), 343-351.

Klvac, R., Skoupy, A. (2009). Characteristic fuel consumption and exhaust emissions in fully mechanized logging operations. Journal of Forest Research, 14 (6), 328-334.

Pearson T, Walker S and Brown S 2005 Sourcebook for BioCarbon Fund projects. Prepared for BioCarbon Fund of World Bank. Available at: www.winrock.org/sites/default/files/publicatson/attachments/Winrock-BioCarbon Fund Sourcebook-compressed.pdf

Picard N., Saint-André L., Henry M. 2012. Manual for building tree volume and biomass allometric equations: from field measurement to prediction. Food and Agricultural Organization of the United Nations, Rome, and Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Montpellier, 215 pp. https://www.fao.org/4/i3058e/i3058e.pdf

Pinard, M. A., & Putz, F. E. (1996). Retaining Forest Biomass by Reducing Logging Damage. Biotropica, 28(3), 278–295. https://doi.org/10.2307/2389193

Poole, A. and Pinheiro, P. (2003). Developing energy profiles for sawmills in the Amazon region - First field visit to Rondolandia and Ji-Parana. Accessed 25 July 2009.

Society of American Foresters – SAF (2018). The SAF Dictionary of Forestry, 2nd Edition. Edited by Robert Deal, Bethesda, MD, USA. 208 p.

Souza, C., Roberts, D., Cochrane, M. (2005). Combining spectral and spatial information to map canopy damage from selective logging and forest fires. Remote Sensing of Environment 98 (2-3): 329-343.

Somogyi, Z., E. Cienciala, R. Mäkipää, P. Muukkonen, A. Lehtonen and P.Weiss. (2006) Indirect methods of large-scale forest biomass estimation, Eur.J.ForestRes. 126 (2) pp.197–207. http://dx.doi.org/10.1007/s10342-006-0125-7

Winjum,J.K., Brown,S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. Forest Science 44:272-28431

Zanne, A., Lopez-Gonzalez, G., Coomes, D., Ilic, J., Jansen., S., Lewis, S., Miller, R., Swenson, N., Wiemann, M., Chave, J. (2009). Global Wood Density Database. https://datadryad.org/stash/dataset/doi:10.5061/dryad.234

APPENDIX 1: CONVERTING OTHER GREENHOUSE GASES TO CO_2e

Other GHGs considered in this methodology (subject to significance as determined in Section 5.4) are methane (CH_4) and nitrous oxide (N_2O).

Non-CO_2 gas emission factors must be expressed in carbon dioxide equivalents by multiplying their emission factors by their corresponding global warming potentials (GWPs) and summating the results together to obtain an overall emission factor in terms of carbon dioxide equivalents:

$$EF = EF_{CH4} \times GWP_{CH4} + EF_{N2O} \times GWP_{N2O} \quad (47)$$

Where:

EF_{CH4}	Emission factor for methane gas, activity data-specific, tCH_4/activity data unit;
GWP_{CH4}	Global warming potential of methane, tCO_2e/tCH_4;
EF_{N2O}	Emission factor for nitrous oxide gas, activity data-specific, tN_2O/activity data unit;
GWP_{N2O}	Global warming potential of nitrous oxide, in tCO_2e/tN_2O;

Where CH_4 and N_2O are determined to be insignificant to the overall calculations, and HFCs, PFCs and SF_6 are not included, then CO_2 becomes the sole greenhouse gas quantified. Throughout this methodology, even where CO_2 becomes the sole GHG emission quantified, it is expressed as CO_2-e.

APPENDIX 2: CONVERTING UNITS FOR FUEL EMISSION FACTOR

IPCC (2006) emission factors for GHGs (CO_2, CH_4 and N_2O) are recorded in units of kg of GHG (TJ of fuel)$^{-1}$. As such, for each GHG, the emission factor must be multiplied by the fuel heating value (in TJ kg^{-1}) and density (kg kL^{-1}) to obtain an emission factor in tGHG kL^{-1}. (e.g., tCO_2-e kL^{-1}, tCH_4 kL^{-1} and tN_2O kL^{-1}).

$$EEF_{FUEL-GHG} = \frac{EF_{IPCC-FUEL} \times HV_{FUEL} \times \rho_{FUEL}}{1000} \quad (48)$$

Where:

$EF_{FUEL-GHG}$	Fuel emission factor for the greenhouse gas (CO_2, CH_4 or N_2O), in tGHG/kL;
$EF_{IPCC-FUEL}$	IPCC fuel emission factor for greenhouse gas (CO_2, CH_4 or N_2O), in kgGHG/TJ;
HV_{FUEL}	Heating value of fuel, in TJ/kg;
p_{FUEL}	Density of fuel, in kg/kL;

APPENDIX 3: FUEL CONSUMPTION CHARTS

As referenced in Section 8.1.4, the fuel consumption rate of a generator can be derived from fuel consumption charts for generators. Table A3 offers default factors depending on the generator size (kW) and on the anticipated load (Diesel Service and Supply, 2009).

Table A3: Fuel Consumption Chart for a Diesel Generator

Generator Size (Kw)	¼ Load (kL h^{-1})	Full Load (Kl h^{-1})
20	0.002	0.006
40	0.006	0.015
60	0.007	0.018
100	0.01	0.028
125	0.012	0.034
150	0.014	0.041
200	0.018	0.055
300	0.026	0.081
500	0.042	0.135
750	0.062	0.202
1000	0.082	0.269
1250	0.102	0.336
1500	0.122	0.403
1750	0.142	0.47
2000	0.162	0.537
2250	0.182	0.604

APPENDIX 4: HARVESTER FUEL CONSUMPTION FACTOR

As referenced in Section 8.1.4.1, the emission factors for equipment required for harvesting operations derived from Klvac and Skoupy (2009) are listed in Table A4.

Table A4: Equipment Types and Fuel Consumption for Harvesting Operations

Operation	Equipment	Factor	Data	Unit
Felling	Harvester	Fuel consumption, $FC_{harvest}$	1.28 -1.73	L m^{-3}

APPENDIX 5: ELECTRICITY DEMAND OF SAWMILL PROCESSES

An electricity demand factor may be used to determine the electricity consumption (kWh) required for a particular volume of merchantable logs. As referenced in Section 8.1.4.4, the table below presents data from three international sawmill processes and shows that an approximate range for the electricity demand is 20-40 kWh/m^3.

Where a country specific value for electricity demand is available, it must be used. Where a country-specific value is not available, a factor from a country that uses similar timber processing technology to that of the project's host country must be used.

Table A5: Electricity Demand for Sawmill Processing in Various Countries

Country	Electricity (kWh day^{-1})	Harvest Volume (m^3 day^{-1})	e_{demand} (Kwh m^{-3})	Data Source
Indonesia	600	20	30	Budiono (unknown)
Brazil	2756	136	20	Poole and Pinheiro (2003)
New Zealand	-	-	26-41	Li et al. (2006)

DOCUMENT HISTORY

Version	Date	Comment
v1.0	11 Feb 2011	Initial version released.
v1.1	10 Nov 2011	Updates: • In Equation (7) parameter $C_{EX,i,k\|BSL}$ was clarified to be the mean carbon stock of extracted timber per unit area in stratum *I*, for wood product type *k*. • Section 4.1.2, was clarified that only individual trees, species and strata which were to be harvested in the baseline scenario may be modeled for on-going forest growth in the project scenario. • Equation 21 was modified to clarify that net greenhouse gas emissions in the project scenario are a result of the sum of emission from disturbance minus the annual carbon stock change in the aboveground biomass of trees due to forest growth. • Parameter $BECF_R$ was clarified to have the unit t.d.m m^{-3}.
v1.2	27 Mar 2013	The methodology was updated to comply with Section 4.5.3 of the VCS *AFOLU Requirements*, v3.2, which requires methodologies to set out criteria and procedures to reliably establish the pattern of carbon loss in the baseline scenario. Specifically, the methodology has been updated to account for a 10-year linear decay of the dead wood pool, an immediate release of the wood waste and short-term wood product pools and a 20-year linear decay of the medium-term wood product pool.
v1.3	28 Apr 2016	Inclusion of emissions from: • Cleared biomass as a result of forestry infrastructure such as forestry roads, skidtrails and log landings • Residual stand damage • Fossil fuel combustion in forestry and wood processing machinery
v1.4	24 Oct 2024	Minor revisions, including the following changes: • Separation of GHG emission reduction and carbon dioxide removals under section 8 of quantification of GHG Emission Reductions and Carbon removals • Restriction of ongoing forest growth accounting to individual trees, species, strata and tree stands to be harvested under the baseline scenario • Modified applicability condition to exclude planted forests • Modified applicability condition to restrict baseline scenario activity to selective logging • Correction of requirement for accounting for carbon stock increase associated with forest growth

		• Corrections to equations 12, 14, 16, 19, 23, 24, 25, 26, 32 and 34. Equation 40 for total leakage now removed, and new equations 40, 41, 43, and 44 added for quantification of GHG Emission Reductions and Carbon removals, and associated VCUs. • Title changed to “Improved Forest Management: Conversion from Logged to Protected Forest”