The American Carbon Registry™

Improved Forest Management Methodology for Quantifying GHG Removals and Emission Reductions through Increased Forest Carbon Sequestration on Non-Federal U.S. Forestlands

Version 1.3

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Methodology developed by Columbia Carbon, LLC

Contents

ABOUT AMERICAN CARBON REGISTRY® (ACR)

A leading carbon offset program founded in 1996 as the first private voluntary GHG registry in the world, ACR operates in the voluntary and regulated carbon markets. ACR has unparalleled experience in the development of environmentally rigorous, science-based offset methodologies as well as operational experience in the oversight of offset project verification, registration, offset issuance and retirement reporting through its online registry system.

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A. METHODOLOGY DESCRIPTION

A1. SCOPE AND DEFINITIONS

This methodology is designed to quantify GHG emission reductions resulting from forest carbon projects that reduce emissions by exceeding baseline forest management practices. Removals are quantified for increased sequestration through retention of annual forest growth when project activities exceed the baseline.

Baseline determination is project-specific and must describe the harvesting scenario that would maximize net present value (NPV) of perpetual wood products harvests per the assumptions as described in section C1, where various discount rates for different land ownership classes are used as proxies for the multiple forest management objectives typical of each owner class eligible under this methodology.

Project Proponents must demonstrate there is no activity-shifting leakage above the *de minimis* threshold. Market leakage must be assessed and accounted for in the quantification of net project benefits.

Definitions and Acronyms

ACR	American Carbon Registry
ATFS	American Tree Farm System
Activity Shifting Leakage	Increases in harvest levels on non-project lands owned or under management control of the project area timber rights owner
Baseline Management	Scenario in the absence of project activities
Carrying Costs	Property taxes, mortgage interest, and insurance premiums
Crediting Period	The period of time in which the baseline is considered to be valid and project activities are eligible to generate ERTs
De minimis	Threshold of 3% of the final calculation of emission reductions or removals
CO_2	Carbon Dioxide. All pools and emissions in this methodology are represented by either CO_2 or CO_2 equivalents. Biomass is converted to carbon by multiplying by 0.5 and then to CO_2 by multiplying by the molecular weight ratio of CO_2 to Carbon (3.664)
CO_2e	Carbon Dioxide equivalent. The amount of CO_2 that would have the same global warming potential (GWP) as other greenhouse

gases over a 100-year lifetime using SAR-100 GWP values from the IPCC's fourth assessment report.

ERT	Emission Reduction Ton
Ex ante	Prior to project certification
Ex post	After the event, a measure of past performance
FSC	Forest Stewardship Council
Forestland	Forest land is defined as land at least 10 percent stocked by trees of any size, or land formerly having such tree cover, and not currently developed for non-forest uses. Land proposed for inclusion in this project area shall meet the stocking requirement, in aggregate, over the entire area
IFM	Improved Forest Management
IPCC	Intergovernmental Panel on Climate Change
Minimum Project Term	Time Period for which project activities must be maintained and monitored through third-party verification
Native Species	Trees listed as native to a particular region by the Native Plant Society, SAF Forestry Handbook, or State-adopted list
Net Present Value (NPV)	The difference between the present value of cash inflows and the present value of cash outflows over the life of the project
SFI	Sustainable Forestry Initiative
Timberlands	Forestlands managed for commercial timber production
Tree	A perennial woody plant with a diameter at breast height (4.5') greater than or equal to 1" and a height of greater than 4.5', with the capacity to attain a minimum diameter at breast height of 5" and a minimum height of 15' (shrub species are not eligible).
Ton	A unit of mass equal to 1000 kg
VCS	Verified Carbon Standard

A2. APPLICABILITY CONDITIONS

- This methodology is applicable only on non-federally owned forestland within the United States
- The methodology applies to lands that can be legally harvested by entities owning or controlling timber rights on forestland
- Private or non-governmental organization ownerships subject to commercial timber harvesting at the project Start Date in the with-project scenario must be certified by FSC, SFI, or ATFS or become certified within one year of the project Start Date. If there are no ongoing harvests at the project Start Date, but harvests occur later in the project life cycle, the project area must become certified before any commercial timber harvesting can occur
- All Tribal lands in the United States, except those lands that are managed or administered by the Bureau of Indian Affairs, are eligible under this methodology, provided that they meet ACR requirements for Tribal lands
- Public non-federal ownerships currently subject to commercial timber harvesting in the with-project scenario must:
    - be certified by FSC, SFI, or ATFS or become certified within one year of the project Start Date; *or*
    - have its forest management plan sanctioned by a by a senior government official within a state, or a state agency, or a federal agency
        - Please note that any such forest management plans must be updated at minimum every 10 years
    - If there are no ongoing harvests on a public non-federal ownership at the project Start Date, but harvests occur later in the project life cycle, the project area must become certified by FSC, SFI, or ATFS, or develop a sanctioned management plan before any commercial timber harvesting can occur
- Use of non-native species is prohibited where adequately stocked native stands were converted for forestry or other land uses after 1997
- Draining or flooding of wetlands is prohibited
- Project proponent must demonstrate its ownership or control of timber rights at the project start date
- The project must demonstrate an increase in on-site stocking levels above the baseline condition by the end of the Crediting Period

A3. POOLS AND SOURCES

Carbon pools	Included / Optional / Excluded	Justification / Explanation of choice
Above-ground biomass carbon	Included	Major carbon pool subjected to the project activity
Below-ground biomass carbon	Included	Major carbon pool subjected to the project activity
Standing dead wood	Included/Optional	Major carbon pool in unmanaged stands subjected to the project activity. Project Proponents may also elect to include the pool in managed stands. Where included, the

		pool must be estimated in both the baseline and with project cases.
Lying dead wood	Optional	Project Proponents may elect to include the pool. Where included, the pool must be estimated in both the baseline and with project cases.
Harvested wood products	Included	Major carbon pool subjected to the project activity
Litter / Forest Floor	Excluded	Changes in the litter pool are considered *de minimis* as a result of project implementation
Soil organic carbon	Excluded	Changes in the soil carbon pool are considered *de minimis* as a result of project implementation

Gas	Source	Included/ Excluded	Justification / Explanation of choice
CO_2	Burning of biomass	Excluded	However, carbon stock decreases due to burning are accounted as a carbon stock change
CH_4	Burning of biomass	Included	Non-CO_2 gas emitted from biomass burning
N_2O	Burning of biomass	Excluded	Potential emissions are negligibly small

Leakage Source		Included / Optional / Excluded	Justification / Explanation of choice
Activity-Shifting	Timber Harvesting	Excluded	Project Proponent must demonstrate no activity-shifting leakage beyond the *de minimis* threshold will occur as a result of project implementation
	Crops	Excluded	Forestlands eligible for this methodology do not produce agricultural crops that could cause activity shifting
	Livestock	Excluded	Grazing activities, if occurring in the baseline scenario, are assumed to continue at the same levels under the project scenario and thus there are no leakage impacts.
Market Effects	Timber	Included	Reductions in product outputs due to project activity may be compensated by other entities in the marketplace. Those emissions must be included in the quantification of project benefits.

A4. METHODOLOGY SUMMARY

This methodology is designed to quantify GHG emission reductions resulting from forest carbon projects that reduce emissions by exceeding baseline forest management practices. Removals are quantified for increased sequestration through retention of annual forest growth when project activities exceed the baseline.

The IFM baseline is the legally permissible harvest scenario that would maximize net present value (NPV) of perpetual wood products harvests, used as a proxy for the multiple forest management objectives typical of each owner class eligible under this methodology. The baseline management scenario shall be based on silvicultural prescriptions recommended by published state or federal agencies to perpetuate existing onsite timber-producing species while fully utilizing available growing space.

In developing the baseline scenario, exceptions to the requirement that the baseline management scenario shall perpetuate existing onsite timber-producing species may be made where it can be demonstrated that a baseline management scenario involving replacement of existing onsite timber producing species (e.g. where forest is converted to plantations, replacing existing onsite timber-producing species) is feasible and has been implemented in the region within 10 years of the project start date. This shall be substantiated either by (1) demonstrating with management records that the baseline management scenario involving replacement of existing onsite timber producing species has been implemented within 10 years of the project start date on lands in the state containing the project area owned or managed by the project proponent (or by the previous project area owner/manager) or by (2) providing dated (from previous 10 years) aerial imagery that identifies at least two properties (of similar site conditions and forest type) in the state showing, first, the initial or existing onsite timber, and second, the replacement use (e.g. commercial plantation). The areas of forest conversion identified must have combined acreage equal to or greater than the annual acreage converted in the project baseline scenario. Published or written evidence that the baseline scenario (e.g., conversion of existing onsite timber) is common practice in the region (this can be a state or local forester, a consulting forester, an owner of a mill, etc.) must also be provided.

The resulting harvest schedule is used to establish baseline stocking levels through the Crediting Period.

This methodology is similar to a previously approved ACR IFM methodology developed by Finite Carbon Corporation[1] in that it quantifies GHG emission reductions resulting from forest carbon projects that reduce emissions by exceeding baseline management practice levels.

The discount rate assumptions for calculating NPV vary by ownership class (see Table 1, Section C1) and include the 6% rate for private industrial timberlands from the earlier IFM methodology. Actual landowner discount rate assumptions are typically not publicized in the scientific literature and companies, individuals, and organizations by and large do not share the values they use. However,

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[1] American Carbon Registry *Improved Forest Management Methodology for Quantifying GHG Removals and Emission Reductions through Increased Forest Carbon Sequestration on U.S. Timberlands.* September 2010.

approximate discount rates can be indirectly estimated by using forest economic theory and the age-class structure distribution of different U.S. forest ownership classes.

This methodology establishes an average baseline determination technique for all major forest ownership classes in the United States with the exception of federal lands. The appropriate ownership class is used to identify a project-specific NPV-maximizing baseline scenario as described in section C1. Project Proponents then design a project scenario for the purposes of increased carbon sequestration. The project scenario by definition will result in a lower NPV than the baseline scenario. Project Proponents use the baseline discount rate values for NPV maximization for the appropriate ownership class and run a project scenario for purposes of increased carbon sequestration. The difference between these two harvest forecasts are the basis for determining carbon impacts and ERTs attributable to the project.

B. ELIGIBILITY, BOUNDARIES, ADDITIONALITY, AND PERMANENCE

B1. PROJECT ELIGIBILITY

This methodology applies to non-federal U.S. forestlands that are able to document 1) clear land title or timber rights and 2) offsets title. Projects must also meet all other requirements of the *ACR Standard, Version 5.0*.

This methodology applies to lands that could be legally harvested by entities owning or controlling timber rights.

Proponents must demonstrate that the project area, in aggregate, meets the definition of Forestland provided in Section A1 above.

B2. PROJECT GEOGRAPHIC BOUNDARY

The Project Proponent must provide a detailed description of the geographic boundary of project activities. Note that the project activity may contain more than one discrete area of land, that each area must have a unique geographical identification, and that each area must meet the eligibility requirements. Information to delineate the project boundary must include:

- Project area delineated on USGS topographic map
- General location map
- Property parcel map

Aggregation of forest properties with multiple landowners is permitted under the methodology consistent with Chapter 6 of the *ACR Standard, Version 5.0* which provides guidelines for aggregating multiple landholdings into a single forest carbon project, as a means to reduce per-acre transaction costs of inventory and verification.

B3. PROJECT TEMPORAL BOUNDARY

Projects with a Start Date of November 1, 1997 or later are eligible[2]. The Start Date is when the Project Proponent began to apply the land management regime to increase carbon stocks and/or reduce emissions.

In accordance with the *ACR Standard, Version 5.0*, all projects will have a Crediting Period of twenty (20) years. The minimum Project Term is forty (40) years. The minimum Project Term begins on the Start Date (not the first or last year of crediting).

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[2] American Carbon Registry (2018), *American Carbon Registry Standard, Version 5.0.* Winrock International, Little Rock, Arkansas.

If the project Start Date is more than one year before submission of the GHG plan, the Project Proponent shall provide evidence that GHG mitigation was seriously considered in the decision to proceed with the project activity. Evidence shall be based on official and/or legal documentation. Early actors undertaking voluntary activities to increase forest carbon sequestration prior to the release of this requirement may submit as evidence recorded conservation easements or other deed restrictions that affect onsite carbon stocks.

B4. ADDITIONALITY

Projects must apply a three-prong additionality test[3] to demonstrate that they exceed currently effective and enforced laws and regulations; exceed common practice in the forestry sector and geographic region; and face a financial implementation barrier.

The regulatory surplus test involves existing laws, regulations, statutes, legal rulings, or other regulatory frameworks that directly or indirectly affect GHG emissions associated with a project action or its baseline candidates, and which require technical, performance, or management actions. Voluntary guidelines are not considered in the regulatory surplus test.

The common practice test requires Project Proponents to evaluate the predominant forest industry technologies and practices in the project's geographic region. The Project Proponent shall demonstrate that the proposed project activity exceeds the common practice of similar landowners managing similar forests in the region. Projects initially deemed to go beyond common practice are considered to meet the requirement for the duration of their Crediting Period. If common practice adoption rates of a particular practice change during the Crediting Period, this may make the project non-additional and thus ineligible for renewal, but does not affect its additionality during the current Crediting Period.

An implementation barrier represents any factor or consideration that would prevent the adoption of the practice/activity proposed by the Project Proponent. Financial barriers can include high costs, limited access to capital, or an internal rate of return in the absence of carbon revenues that is lower than the Proponent's established minimum acceptable rate. Financial barriers can also include high risks such as unproven technologies or business models, poor credit rating of project partners, and project failure risk. When applying the financial implementation barrier test, Project Proponents should include solid quantitative evidence such as NPV and Internal Rate of Return (IRR) calculations. The project must face capital constraints that carbon revenues can potentially address; or carbon funding is reasonably expected to incentivize the project's implementation; or carbon revenues must be a key element to maintaining the project action's ongoing economic viability after its implementation.[4]

B5. PERMANENCE

Project Proponents commit to a minimum Project Term of 40 years. Projects must have effective risk mitigation measures in place to compensate fully for any loss of sequestered carbon whether this occurs through an unforeseen natural disturbance or through a Project Proponent or landowners' choice to discontinue forest carbon project activities. Such mitigation measures can include contributions to the buffer pool, insurance, or other risk mitigation measures approved by ACR.

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[3] Ibid.

[4] American Carbon Registry (2018), *American Carbon Registry Standard, Version 5.0.* Winrock International, Little Rock, Arkansas.

If using a buffer contribution to mitigate reversals, the Project Proponent must conduct a risk assessment addressing both general and project-specific risk factors. General risk factors include risks such as financial failure, technical failure, management failure, rising land opportunity costs, regulatory and social instability, and natural disturbances. Project-specific risk factors vary by project type but can include land tenure, technical capability and experience of the project developer, fire potential, risks of insect/disease, flooding and extreme weather events, illegal logging potential, and others. If they are using an alternate ACR-approved risk mitigation product, they will not do this risk assessment.

Project Proponents must conduct their risk assessment using the ACR *Tool for Risk Analysis and Buffer Determination.* The output of either tool is an overall risk category, expressed as a fraction, for the project translating into the buffer deduction that must be applied in the calculation of net ERTs (section G1). This deduction must be applied unless the Project Proponent uses another ACR-approved risk mitigation product.

C. BASELINE

C1. IDENTIFICATION OF BASELINE

The Finite Carbon Corporation IFM methodology[5] (approved by ACR in September 2010), takes a Faustmann approach to baseline determination using NPV maximization with a 6% discount rate on future cash flows. The literature supporting Faustmann's original 1849 work forms the basis for modern optimal rotation/investment decisions and forest economics (summarized in Newman 2002[6]) in addition to appearing in over 300 other book and journal articles. One of the reasons there is such an extensive literature base for NPV maximization is that the Faustmann approach to forest investment and optimal rotation is not perfect. Like the basic economic model of supply and demand, these underlying theorems go far to predict how agents will act, however they do not correctly account for all situations.

In the Finite IFM methodology, the 6% discount is an assumption for how a common industrial forest landowner would make their forest management decisions. This 6% NPV maximization determination of the baseline level of emission and sequestration is appropriate in that it gives a common transparent and conservative metric by which landowners, project developers, verifiers, and offset purchasers can base their assessment of an ACR IFM carbon project. However, less than 40% of aggregate U.S. timber supply comes from Private Industrial (PI) timberland[7] necessitating an adaption of the methodology to allow consideration of other landowner classes who are actively managing their forests.

This methodology is the same as the Finite Carbon methodology in that it quantifies GHG emission reductions resulting from forest carbon projects that reduce emissions by exceeding baseline management practice levels. Emission Reduction Tons (ERTs) are quantified for increased sequestration through retention of annual forest growth when project activities exceed the baseline.

The baseline determination is project-specific and must describe the harvesting scenario that would maximize NPV of perpetual wood products harvests over a 100-year modeling period. The discount rate assumptions for calculating NPV[8] vary by ownership class (Table 1) and include the 6% rate for PI timberlands from the Finite methodology. Actual landowner discount rate assumptions are typically not

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[5] ACR Approved Methodology (2010), *Methodology for Quantifying GHG Removals and Emission Reductions through Increased Forest Carbon Sequestration on U.S. Timberlands.* Finite Carbon Corporation. https://americancarbonregistry.org/carbon-accounting/standards-methodologies/improved-forest-management-ifm-methodology-for-non-federal-u-s-forestlands/ifm-methodology-for-non-federal-u-s-forestlands_v1-0_semptember-2011_final.pdf

[6] Newman, D.H. 2002. Forestry's golden rule and the development of the optimal forest rotation literature. J. Econ. 8: 5–27

[7] See Tables 7-10 in Adams, D.M.; Haynes, R.W. and A. Daigneault. 2006. Estimated timber harvest by U.S. region and ownership, 1950-2002. PNW-GTR-659. Portland, OR: USDA, Forest Service, Pacific Northwest Research Station. 64 p

[8] Sewall, Sizemore & Sizemore, Mason, Bruce & Girard, Inc and Brookfield internal research.2010.Global Timberlands Research Report. http://www.industryintel.com/Corporate/downloads/4QBrookfield2010.pdf

publicized in the scientific literature and companies, individuals, and organizations by and large do not share the values they use. However, approximate discount rates can be indirectly estimated by using forest economic theory and the age-class structure distribution of different U.S. forest ownership classes.

Amacher et al. (2003)[9] and Beach et al. (2005)[10] provide literature reviews and a basis of economic analysis of non-industrial private forest (NIPF) harvesting decisions.   Newman and Wear (1993)[11] show that Industrial and NIPF owners both demonstrate behavior consistent with profit maximization, yet the determinants of profit differ with the NIPF owners deriving significant non-market benefits associated with standing timber. Pattanayak et al. (2002)[12] revisited the problem as they studied NIPF timber supply and found joint optimization of timber and non-timber values while Gan et al. (2001)[13] showed that the impact of a reduced discount rate actually had the same impact as the addition of an amenity value.

The United States Department of Agriculture (USDA) Forest Inventory and Analysis (FIA) group provides inventory data on forests in their periodic assessment of forest resources (Smith et al. 2009[14]). This data allows for the analysis of total U.S. forest acres by age class for three broad ownership classes: Private, State, and National Forest. While the publicly available FIA data does not include any further breakdown of the private ownership group, we were provided with the twenty-year age class data from USDA FIA research foresters, including private corporate and private non-corporate classes. Bringing this economic theoretical framework together with this data aided in the derivation of discount rate value estimates for other forestland ownership classes (Table 1).

This methodology establishes an average baseline determination technique for all major non-federal forest ownership classes in the United States. Project Proponents shall use the baseline discount rate values in Table 1 for the appropriate ownership class to identify a project-specific NPV-maximizing baseline scenario. Project Proponents then design a project scenario for the purposes of increased carbon sequestration. The project scenario by definition will result in a lower NPV than the baseline scenario.   The difference between these two harvest forecasts are the basis for determining carbon impacts and ERTs attributable to the project.

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[9] Amacher, G.S., Conway, M.C., and J. Sullivan. 2003. Econometric analyses of nonindustrial forest landowners: is there anything left to study? Journal of Forest Economics 9, 137–164

[10] Beach, R.H., Pattanayak, S.K., Yang, J.C., Murray, B.C., and R.C. Abt. 2005. Econometric studies of non-industrial private forest management a review and synthesis. Forest Policy and Economics, 7(3), 261-281

[11] Newman, D.H. and D.N. Wear. 1993. Production economics of private forestry: a comparison of industrial and nonindustrial forest owners. American Journal of Agricultural Economics 75:674-684

[12] Pattanayak, S., Murray, B., Abt, R., 2002. How joint is joint forest production? An econometric analysis of timber supply conditional on endogenous amenity values. Forest Science 47 (3), 479– 491

[13] Gan, J., Kolison Jr., S.H. and J.P. Colletti. 2001. Optimal forest stock and harvest with valuing non-timber benefits: a case of U.S. coniferous forests. Forest Policy and Economics 2(2001), 167-178

[14] Smith, W. Brad, tech. coord.; Miles, Patrick D., data coord.; Perry, Charles H., map coord.; Pugh, Scott A., Data CD coord. 2009. Forest Resources of the United States, 2007. GTR WO-78. Washington, DC: USDA, Forest Service, Washington Office. 336 p

Table 1. Discount rates for Net Present Value determinations by U.S. Forestland Ownership Class.

Ownership	Annual Discount Rate
Private Industrial	6%
Private Non-Industrial	5%
Tribal	5%
Non-governmental organization	4%
Non-federal public lands	4%

The IFM baseline is the legally permissible harvest scenario that would maximize NPV of perpetual wood products harvests. The baseline management scenario shall be based on silvicultural prescriptions recommended by published state or federal agencies to perpetuate existing onsite timber producing species while fully utilizing available growing space. Where the baseline management scenario involves replacement of existing onsite timber producing species (e.g. where forest is converted to plantations, replacing existing onsite timber-producing species), the management regime should similarly be based on silvicultural prescriptions recommended by published state or federal agencies, and must adhere to all applicable laws and regulations. The resulting harvest schedule is used to establish baseline stocking levels through the Crediting Period.

Required inputs for the project NPV calculation include the results of a recent timber inventory of the project lands, prices for wood products of grades that the project would produce, costs of logging, reforestation and related costs, silvicultural treatment costs, and carrying costs. Project Proponents shall include roading and harvesting costs as appropriate to the terrain and unit size. Project Proponents must model growth of forest stands through the Crediting Period. Project Proponents should use a constrained optimization program that calculates the maximum NPV for the harvesting schedule while meeting any forest practice legal requirements. The annual real (without inflation) discount rate for each non-federal owner class is given in Table 1. Wood products must be accounted.

Consideration shall be given to a reasonable range of feasible baseline assumptions and the selected assumptions should be plausible for the duration of the baseline application.

The ISO 14064-2 principle of conservativeness must be applied for the determination of the baseline scenario. In particular, the conservativeness of the baseline is established with reference to the choice of assumptions, parameters, data sources and key factors so that project emission reductions and removals are more likely to be under-estimated rather than over-estimated, and that reliable results are maintained over a range of probable assumptions. However, using the conservativeness principle does not always imply the use of the "most" conservative choice of assumptions or methodologies[15].

C 1.1 Confidentiality of Proprietary Information

While it remains in the interest of the general public for Project Proponents to be as transparent as possible regarding GHG reduction projects, the Project Proponent may choose at their own option to designate any information regarded as confidential due to proprietary considerations. If the Project Proponent chooses to identify information related to financial performance as confidential, the Project Proponent must submit the confidential baseline and project documentation in a separate file marked

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[15] ISO 14064-2:2006(E)

"Confidential" to ACR and this information shall not be made available to the public. ACR and the validation/verification body shall utilize this information only to the extent required to register the project and issue ERTs. If the Project Proponent chooses to keep financial information confidential, a publically available GHG Project Plan must still be provided to ACR.

C2. BASELINE STRATIFICATION

If the project activity area is not homogeneous, stratification may be used to improve the modeling of management scenarios and precision of carbon stock estimates. Different stratifications may be used for the baseline and project scenarios. For estimation of baseline carbon stocks, strata may be defined on the basis of parameters that are key variables for estimating changes in managed forest carbon stocks, for example:[16]

    a. Management regime
    b. Species or cover types
    c. Size and density class
    d. Site class
    e. Age Class

C3. BASELINE NET REDUCTIONS AND REMOVALS

Baseline carbon stock change must be calculated for the entire Crediting Period. The baseline stocking level used for the stock change calculation is derived from the baseline management scenario developed in section C1. This methodology requires 1) annual baseline stocking levels to be determined for the entire Crediting Period, 2) a long-term average baseline stocking level be calculated for the Crediting Period, and 3) the change in baseline carbon stocks be computed for each time period, t.

The following equations are used to construct the baseline stocking levels using models described in section 3.1 and wood products calculations described in section 3.2:

$$\Delta C_{BSL,TREE,t} = \left(C_{BSL,TREE,t} - C_{BSL,TREE,t-1} \right) \tag{1}$$

where:

t	Time in years
$\Delta C_{BSL,TREE,t}$	Change in the baseline carbon stock stored in above and below ground live trees (in metric tons CO_2) for year t.
$C_{BSL,TREE,t}$	Change in the baseline value of carbon stored in above and below ground live trees at the beginning of the year t (in metric tons CO_2) and t-1 signifies the value in the prior year.

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[16] Please note this list is not exhaustive and only includes examples of some common stratification parameters.

$$\Delta C_{BSL,DEAD,t} = \left(C_{BSL,DEAD,t} - C_{BSL,DEAD,t-1} \right) \tag{2}$$

where:

t	Time in years
$\Delta C_{BSL,\ DEAD,t}$	Change in the baseline carbon stock stored in dead wood (in metric tons CO_2) for year t.
$C_{BSL,\ DEAD,t}$	Change in the baseline value of carbon stored in dead wood at the beginning of the year t (in metric tons CO_2) and t-1 signifies the value in the prior year.

$$\overline{C}_{BSL,HWP} = \frac{\sum\limits_{t=1}^{20} C_{BSL,HWP,t}}{20} \tag{3}$$

where:

t	Time in years
$\overline{C}_{BSL,HWP}$	Twenty-year average value of annual carbon remaining stored in wood products 100 years after harvest (in metric tons of CO_2)
$C_{BSL,HWP,t}$	Baseline value of carbon remaining in wood products 100 years after being harvested in the year t (in metric tons CO_2).

Note: Please see section 3.2 for detailed instructions on baseline wood products calculations.

$$\overline{GHG}_{BSL} = \frac{\sum\limits_{t=1}^{20} \left(BS_{BSL,t} \cdot ER_{CH_4} \cdot \frac{16}{44} \cdot GWP_{CH_4} \right)}{20} \tag{4}$$

where:

t	Time in years
$\overline{GHG}_{BSL}$	Twenty-year average value of greenhouse gas emissions (in metric tons CO_2e) resulting from the implementation of the baseline.
$BS_{BSL,t}$	Carbon stock (in metric tons CO_2) in logging slash burned in the baseline in year t.

ER_{CH4} Methane (CH_4) emission ratio (ratio of CO_2 as CH_4 to CO_2 burned). If local data on combustion efficiency is not available or if combustion efficiency cannot be estimated from fuel information, use IPCC default value[17] of 0.012

16/44   Molar mass ratio of CH_4 to CO_2

GWP_{CH4} 100-year global warming potential (in CO_2 per CH_4) for CH_4 (IPCC SAR-100 value of 21 per the Fourth Assessment Report)[18]

Carbon stock calculation for logging slash burned ($BS_{BSL,t}$) shall use the method described in Section 3.1.1 for bark, tops and branches, and section 3.1.2 if dead wood is selected. The reduction in carbon stocks due to slash burning in the baseline must be properly accounted in equations 1 and 2.

To calculate long-term average baseline stocking level for the Crediting Period use:

$$C_{BSL,AVE} = \frac{\sum_{t=0}^{20}\left(C_{BSL,TREE,t} + C_{BSL,DEAD,t}\right)}{20} + \overline{C}_{BSL,HWP}$$

(5)

where:

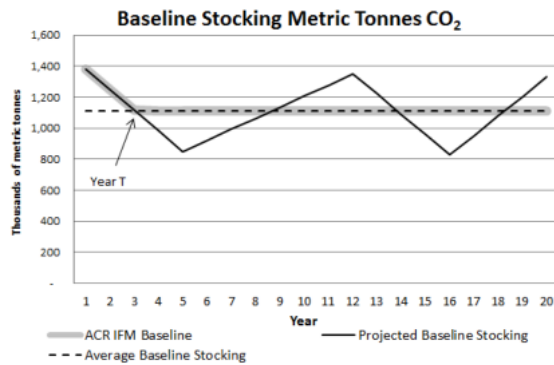t Time period (in years)

$t*$ A rolling value from 1 to 21 years to reference the accumulated stock in HWP in each year t=1 to t=21

$C_{BSL,AVE}$ 20-year average baseline carbon stock (in metric tons CO_2)

$C_{BSL,TREE,t}$ Baseline value of carbon stored in above and below ground live trees (in metric tons CO_2) at the beginning of the year t

$C_{BSL,DEAD,t}$ Baseline value of carbon stored in standing and lying dead trees at the beginning of the year t (in metric tons CO_2)

$\overline{C}_{BSL,HWP}$ Twenty-year average value of annual carbon remaining stored in wood products 100 years after harvest (in metric tons of CO_2)

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[17] Table 3A.1.15, Annex 3A.1, GPG-LULUCF (IPCC 2003)

[18] Table 2.14, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://ipccwg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch02.pdf.

Change in baseline carbon stock is computed for each time period. The Project Proponent shall provide a graph of the projected baseline stocking levels and the long-term average baseline stocking level for the entire Crediting Period (see Figure1). Annual projected stocking levels are used for the baseline stock change calculation until the projected stocking level reaches the long term average (time t = T). Thereafter, the long-term average stocking level is used in the baseline stock change calculation for the entire Project Period.

a) Above average stocking   b) Below average stocking
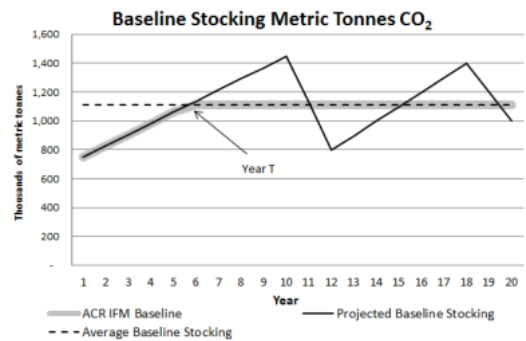

Figure 1. Sample Baseline Stocking Graph for project beginning: a) above 20-year average baseline stocking, and b) below 20-year baseline stocking.

The following equations must be applied until year t equals T:

$$\Delta C_{BSL,t} = \Delta C_{BSL,TREE,t} + \Delta C_{BSL,DEAD,t} + \overline{C}_{BSL,HWP} - \overline{GHG}_{BSL}$$

(6)

where:

t	Time in years
$\Delta C_{BSL,t}$	Change in the baseline carbon stock (in metric tons CO_2) for year t.
$\Delta C_{BSL,TREE,t}$	Change in the baseline carbon stock stored in above and below ground live trees (in metric tons CO_2) for year t.
$\Delta C_{BSL,DEAD,t}$	Change in the baseline carbon stock stored in dead wood pools live trees (in metric tons CO_2) for year t.
$\overline{C}_{BSL,HWP}$	Twenty-year average value of annual carbon remaining in wood products 100 years after harvest (in metric tons CO_2).
$\overline{GHG}_{BSL}$	Twenty-year average value of annual greenhouse gas emissions (in metric tons CO_2) resulting from the implementation of the baseline.

Prior to year T (T = year projected stocking reaches the long-term baseline average) the value of $\Delta C_{BSL,t}$ will most likely be negative for projects with initial stocking levels higher than $C_{BSL,AVE}$ or positive for

projects with initial stocking levels lower than $C_{BSL,AVE}$. If years elapsed since the start of the IFM project activity (t) is $\geq T$ to compute long-term average stock change use:

$$\Delta C_{BSL,t} = 0 \tag{7}$$

3.1 Stocking Level Projections in the Baseline

$C_{BSL,TREE,t}$ and $C_{BSL,DEAD,t}$ must be estimated using models of forest management across the baseline period. Modeling must be completed with a peer reviewed forestry model that has been calibrated for use in the project region. The GHG Plan must detail what model is being used and what variants have been selected. All model inputs and outputs must be available for inspection by the verifier. The baseline must be modeled over a 20-year period.

Examples of appropriate models include:

- FVS: Forest Vegetation Simulator
- SPS: Stand Projection System
- FIBER: USDA, Forest Service
- FPS: Forest Projection System by Forest Biometrics
- CRYPTOS and CACTOS: California Conifer Timber Output Simulator

Models must be:

- Peer reviewed in a process involving experts in modeling and biology/forestry/ecology
- Used only in scenarios relevant to the scope for which the model was developed and evaluated
- Parameterized for the specific conditions of the project

The output of the models must include either projected total aboveground and below ground carbon per acre, volume in live aboveground tree biomass, or another appropriate unit by strata in the baseline. Where model projections are output in five or ten year increments, the numbers shall be annualized to give a stock change number for each year.

If the output for the tree is the volume, then this must be converted to biomass and carbon using equations in Section 3.1.1. If processing of alternative data on dead wood is necessary, equations in section 3.1.2 may be used. Where models do not predict dead wood dynamics, the baseline harvesting scenario may not decrease dead wood more than 50% through the Crediting Period.

3.1.1 Tree Carbon Stock Calculation

The mean carbon stock in aboveground biomass per unit area is estimated based on field measurements in sample plots. A sampling plan must be developed that describes the inventory process including sample size, determination of plot numbers, plot layout and locations, and data collected. Plot data used for biomass calculations may not be older than 10 years. Plots may be permanent or temporary and they may have a defined boundary or use variable radius sampling methods. Biomass for each tree is calculated from its merchantable volume using a component ratio method. The Project Proponent must use the same set of equations, diameter at breast height thresholds, and selected biomass components for *ex ante* and *ex post* baseline and project estimates.

To ensure accuracy and conservative estimation of the mean aboveground live biomass per unit area within the Project Area, Projects must account for missing cull in both the *ex ante* and *ex post* baseline and project scenarios. Determine missing cull deductions with cull attribute data collected during field measurement of sample plots.

The following steps are used to calculate tree biomass:

Step 1: Determine the biomass of the merchantable component of each tree based on appropriate volume equations published by USDA Forest Service (if locally derived equations are not available use regional or national equations as appropriate) and green volume inside bark, oven-dry tree specific gravity for each species.

Step 2: Determine aboveground biomass by choosing a combination of the following components: stump, bark, tops and branches, and/or foliage, in addition to below-ground biomass, by applying component ratios from Jenkins *et al* (2003) Table 6[19], where biomass of each component is calculated as its component ratio * merchantable stem biomass from Step 1 * (1 / stem wood component ratio). If stump, top, and branch components are included, please use the quantification methodology found in Woodall et al. 2011[20].   Note that the same components must be calculated for *ex ante* and *ex post* baseline and project estimates.

Step 3: Using the sum of the selected biomass components for individual trees, determine the per plot estimate of total tree biomass for each plot.

Step 4: Determine the tree biomass estimate for each stratum by calculating a mean biomass per acre estimate from plot level biomass derived in step 3 multiplied by the number acres in the stratum.

Step 5: Determine total project carbon (in metric tons CO_2) by summing the biomass of each stratum for the project area and converting biomass to carbon by multiplying by 0.5, kilograms to metric tons by dividing by 1000, and finally carbon to CO_2 by multiplying by 3.664.

Note: The FVS Fire and Fuels Extension volume-based default estimates[21] of Live Carbon are compliant with the above, but do not include bark and stump components.

3.1.2 Dead Wood Calculation

Dead wood included in the methodology comprises two components only – standing dead wood and lying dead wood. Below-ground dead wood is conservatively neglected. Considering the differences in the two components, different sampling and estimation procedures shall be used to calculate the changes in dead wood biomass of the two components.

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[19] Jenkins, J.; Chojnacky, D.C.; Heath, L.S.; Birdsey, R.A. 2003. National Scale Biomass Estimators for United States Tree Species. Forest Science. 49(1): 12-35

[20] Woodall, Christopher W.; Heath, Linda S.; Domke, Grant M.; Nichols, Michael C. 2011. Methods and equations for estimating aboveground volume, biomass, and carbon for trees in the U.S. forest inventory, 2010. Gen. Tech. Rep. NRS-88. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

[21] Hoover, C.M. and Rebain, S.A., 2011. Forest carbon estimation using the Forest Vegetation Simulator: Seven things you need to know. http://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs77.pdf

3.1.2.1 Standing Dead Wood (if included)

Step 1: Standing dead trees shall be measured using the same criteria and monitoring frequency used for measuring live trees. The decomposed portion that corresponds to the original above-ground biomass is discounted.

Step 2: The decomposition class of the dead tree and the diameter at breast height shall be recorded and the standing dead wood is categorized under the following four decomposition classes:

1. Tree with branches and twigs that resembles a live tree (except for leaves)
2. Tree with no twigs but with persistent small and large branches
3. Tree with large branches only
4. Bole only, no branches

Step 3: Biomass must be estimated using the component ratio method used for live trees for decomposition classes 1, 2, and 3 with deductions as stated in Step 4 (below). When the standing dead tree is in decomposition class 4, the biomass estimate must be limited to the main stem of the tree. If the top of the standing dead tree is missing, then top and branch biomass may be assumed to be zero. Identifiable tops on the ground meeting category 1 criteria may be directly measured. For trees broken below minimum merchantability specifications used in the tree biomass equation, existing standing dead tree height shall be used to determine tree bole biomass.

Step 4: The biomass of dead wood is determined by using the following dead wood density classes deductions: Class 1 – 97% of live tree biomass; Class 2 – 95% of live tree biomass; Class 3 – 90% of live tree biomass; Class 4 – 80% of live tree biomass[22].

Step 5: Determine total project standing dead carbon (in metric tons CO_2) by summing the biomass of each stratum for the project area and converting biomass to carbon by multiplying by 0.5, kilograms to metric tons by dividing by 1000, and finally carbon to CO_2 by multiplying by 3.664.

Note: The FVS Fire and Fuels Extension estimates of Standing Dead Carbon are compliant with this methodology, but do not include bark and stump components.

3.1.2.2 Lying Dead Wood (if selected)

The lying dead wood pool is highly variable, and stocks may or may not increase as the stands age depending if the forest was previously unmanaged (mature or unlogged) where it would likely increase or logged with logging slash left behind where it may decrease through time.

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[22] IPCC Good Practice Guidelines 2006. http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp4/Chp4_3_Projects.pdf

Step 1: Lying dead wood must be sampled using the line intersect method (Harmon and Sexton 1996).[23,24] At least two 50-meter lines (164 ft) are established bisecting each plot and the diameters of the lying dead wood (≥ 10 cm diameter [≥ 3.9 inches]) intersecting the lines are measured.

Step 2: The dead wood is assigned to one of the three density states (sound, intermediate and rotten) by species using the 'machete test', as recommended by IPCC Good Practice Guidance for LULUCF (2003), Section 4.3.3.5.3. The following dead wood density class deductions must be applied to the three decay classes: For Hardwoods, sound – no deduction, intermediate - 0.45, rotten - 0.42; for Softwoods, sound – no deduction, intermediate - 0.71, rotten - 0.45.[25]

Step 3: The volume of lying dead wood per unit area is calculated using the equation (Warren and Olsen 1964)[26] as modified by Van Wagner (1968)[27] separately for each density class

$$V_{LDW,DC} = \pi^2 \left(\sum_{n=1}^{N} D_{n,DC}^2 \right) \Big/ (8 \cdot L) \qquad (8)$$

where:

$V_{LDW, DC}$ Volume (in cubic meters per hectare) of lying dead wood in density class DC per unit area;

$D_{n,DC}$ Diameter (in centimeters) of piece number n, of N total pieces in density class DC along the transect;

L Length (in meters) of transect

Step 4: Volume of lying dead wood shall be converted into biomass using the following relationship:

$$B_{LDW} = A \sum_{DC=1}^{3} V_{LDW,DC} \cdot WD_{DC} \qquad (9)$$

where:

B_{LDW} Biomass (in kilograms per hectare) of lying dead wood per unit area;

A Area (in hectares);

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[23] Harmon, M.E. and J. Sexton. (1996) Guidelines for measurements of wood detritus in forest ecosystems. U.S. LTER Publication No. 20. U.S. LTER Network Office, University of Washington, Seattle, WA, USA.

[24] A variant on the line intersect method is described by Waddell, K.L. 2002. Sampling coarse wood debris for multiple attributes in extensive resource inventories. Ecological Indicators 1: 139-153. This method may be used in place of Steps 1 to 3

[25] USFS FIA Phase 3 proportions

[26] Warren, W.G. and Olsen, P.F. (1964) A line intersect technique for assessing logging waste. *Forest Science* 10:267-276

[27] Van Wagner, C.E. (1968). The line intersect method in forest fuel sampling. *Forest Science* 14: 20-26

$V_{LDW,DC}$ Volume (in cubic meters per hectare) of lying dead wood in density class DC per unit area

WD_{DC} Basic wood density (in kilograms per cubic meter) of dead wood in the density class—sound (1), intermediate (2), and rotten (3)

Step 5: Determine total project lying dead carbon by summing the biomass of each stratum for the project area and converting biomass to dry metric tons of Carbon by multiplying by 0.5, kilograms to metric tons by dividing by 1000, and finally carbon to CO_2 by multiplying by 3.664.

3.2 Wood Products Calculations

There are five steps required to account for the harvesting of trees and to determine carbon stored in wood products in the baseline and project scenarios[28]:
1. Determining the amount of carbon in trees harvested that is delivered to mills (bole without bark).
2. Accounting for mill efficiencies.
3. Estimating the carbon remaining in in-use wood products 100 years after harvest.
4. Estimating the carbon remaining in landfills 100 years after harvest.
5. Summing the carbon remaining in wood products 100 years after harvest.

Step 1: Determine the Amount of Carbon in Harvested Wood Delivered to Mills

The following steps must be followed to determine the amount of carbon in harvested wood if the biomass model does not provide metric tons carbon in the bole, without bark. If it does, skip to step 2

1. Determine the amount of wood harvested (actual or baseline) that will be delivered to mills, by volume (cubic feet) or by green weight (lbs.), and by species for the current year (y). In all cases, harvested wood volumes and/or weights must exclude bark.
   a. Baseline harvested wood quantities and species are derived from modeling a baseline harvesting scenario using an approved growth model.
   b. Actual harvested wood volumes and species must be based on verified third party scaling reports, where available. Where not available, documentation must be provided to support the quantity of wood volume harvested.
      i. If actual or baseline harvested wood volumes are reported in units besides cubic feet or green weight, convert to cubic feet using the following conversion factors:

Volume multipliers for converting timber and chip units to Cubic Feet	
Unit	**Factor**

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[28] Adapted from Appendix C of the California Air Resources Board Compliance Offset Protocol - U.S. Forest Projects, November 14, 2014.

Bone Dry Tons	71.3
Bone Dry Units	82.5
Cords	75
Cubic Meters	35.3
Cunits-Chips (CCF)	100
Cunits-Roundwood	100
Cunits-Whole tree chip	126
Green tons	31.5
MBF-Doyle	222
MBF-International 1/4"	146
MBF-Scribner ("C" or "Small")	165
MBF-Scribner ("Large" or "Long")	145
MCF-Thousand Cubic Feet	1000
Oven Dried Tonnes	75.8

2. If a volume measurement is used, multiply the cubic foot volume by the appropriate green specific gravity by species from table 5-3a of the USFS Wood Handbook[29]. This results in pounds of biomass with zero moisture content. If a particular species is not listed in the Wood Handbook, it shall be at the verifier's discretion to approve a substitute species. Any substitute species must be consistently applied across the baseline and with-project calculations.

3. If a weight measurement is used, subtract the water weight based on the moisture content of the wood. This results in pounds of biomass with zero moisture content.

4. Multiply the dry weight values by 0.5 pounds of carbon/pound of wood to compute the total carbon weight.

5. Divide the carbon weight by 2,204.6 pounds/metric ton and multiply by 3.664 to convert to metric tons of CO_2. Sum the CO2 for each species into saw log and pulp volumes (if applicable), and then again into softwood species and hardwood species. These values are used in the next step, accounting for mill efficiencies. Please note that the categorization criteria (upper and lower DBH limits) for hardwood/softwood saw log and pulp volumes are to remain the same between the baseline and project scenario.

Step 2: Account for Mill Efficiencies

Multiply the total carbon weight (metric tons of carbon) for each group derived in Step 1 by the mill efficiency identified for the project's mill location(s) in the Regional Mill Efficiency Database, found on the Reference documents section of this methodology's website. This is the total carbon transferred into

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[29] Forest Products Laboratory. Wood handbook - Wood as an engineering material. General Technical Report FPL-GTR-190. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory: 508 p. 2010.

wood products. The remainder (sawdust and other byproducts) of the harvested carbon is considered to be immediately emitted to the atmosphere for accounting purposes in this methodology.

Step 3: Estimate the Carbon Storage 100 Years after Harvest in In-Use Wood Products

The amount of carbon that will remain stored in in-use wood products for 100 years depends on the rate at which wood products either decay or are sent to landfills. Decay rates depend on the type of wood product that is produced. Thus, in order to account for the decomposition of harvested wood over time, a decay rate is applied to methodology wood products according to their product class. To approximate the climate benefits of carbon storage, this methodology accounts for the amount of carbon stored 100 years after harvest. Thus, decay rates for each wood product class have been converted into "storage factors" in the table below.

100-year storage factors[30]		
Wood Product Class	**In-Use**	**Landfills**
Softwood Lumber	0.234	0.405
Hardwood Lumber	0.064	0.490
Softwood Plywood	0.245	0.400
Oriented Strandboard	0.349	0.347
Non Structural Panels	0.138	0.454
Miscellaneous Products	0.003	0.518
Paper	0	0.151

Steps to Estimate Carbon Storage in In-Use Products 100 Years after Harvest

To determine the carbon storage in in-use wood products after 100 years, the first step is to determine what percentage of a Project Area's harvest will end up in each wood product class for each species (where applicable), separated into hardwoods and softwoods. This must be done by either:

- Obtaining a verified report from the mill(s) where the Project Area's logs are sold indicating the product categories the mill(s) sold for the year in question; or
- If a verified report cannot be obtained, looking up default wood product classes for the project's Assessment Area, as given in the most current Assessment Area Data File found on the Reference Documents section of this methodology's website.

If breakdowns for wood product classes are not available from either of these sources, classify all wood products as "miscellaneous."

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[30] Smith JE, Heath LS, Skog KE, Birdsey RA (2006) Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. In: General Technical Report NE-343 (eds Usdafs), PP. 218. USDA Forest service, Washington, DC, USA.

Once the breakdown of in-use wood product categories is determined, use the 100-year storage factors to estimate the amount of carbon stored in in-use wood products 100 years after harvest:

1. Assign a percentage to each product class for hardwoods and softwoods according to mill data or default values for the project.
2. Multiply the total carbon transferred into wood products by the % in each product class
3. Multiply the values for each product class by the storage factor for in-use wood products
4. Sum all of the resulting values to calculate the carbon stored in in-use wood products after 100 years (in units of CO2-equivalent metric tons).

Step 4: Estimate the Carbon Storage 100 Years after Harvest for Wood Products in Landfills

To determine the appropriate value for landfill carbon storage, perform the following steps:

1. Assign a percentage to each product class for hardwoods and softwoods according to mill data or default values for the project.
2. Multiply the total carbon transferred into wood products by the % in each product class.
3. Multiply the values for each product class by the storage factor for landfill carbon.
4. Sum all of the resulting values to calculate the carbon stored in landfills after 100 years (in units of CO2-equivalent metric tons).

Step 5: Determine Total Carbon Storage in Wood Products 100 Years after Harvest

The total carbon storage in wood products after 100 years for a given harvest volume is the sum of the carbon stored in landfills after 100 years and the carbon stored in in-use wood products after 100 years. This value is used for input into the ERT calculation worksheet. The value for the actual harvested wood products will vary every year depending on the total amount of harvesting that has taken place. The baseline value is the 100-year average value, and does not change from year to year.

C4. MONITORING REQUIREMENTS FOR BASELINE RENEWAL

A project's Crediting Period is the finite length of time for which the baseline scenario is valid and during which a project can generate offsets against its baseline.

A Project Proponent may apply to renew the Crediting Period by[31]:

- Re-submitting the GHG Project Plan in compliance with then-current ACR standards and criteria
- Re-evaluating the project baseline
- Demonstrating additionality against then-current regulations, common practice and implementation barriers

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[31] American Carbon Registry (2018), *American Carbon Registry Standard, Version 5.0.* Winrock International, Little Rock, Arkansas.

- Using ACR-approved baseline methods, emission factors, and tools in effect at the time of Crediting Period renewal, and
- Undergoing validation and verification by an approved validation/verifier body

C5. ESTIMATION OF BASELINE UNCERTAINTY

It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default values given in IPCC Guidelines (2006), IPCC GPG-LULUCF (2003), or estimates based on sound statistical sampling. Uncertainties arising from the measurement and monitoring of carbon pools and the changes in carbon pools shall always be quantified.

Indisputably conservative estimates can also be used instead of uncertainties, provided that they are based on verifiable literature sources. In this case the uncertainty is assumed to be zero. However, this section provides a procedure to combine uncertainty information and conservative estimates resulting in an overall project scenario uncertainty.

It is important that the process of project planning consider uncertainty. Procedures including stratification and the allocation of sufficient measurement plots can help ensure low uncertainty. It is good practice to consider uncertainty at an early stage to identify the data sources with the highest risk to allow the opportunity to conduct further work to diminish uncertainty. Estimation of uncertainty for pools and emissions sources for each measurement pool requires calculation of both the mean and the 90% confidence interval. In all cases uncertainty should be expressed as the 90% confidence interval as a percentage of the mean.

The uncertainty in the baseline scenario should be defined as the square root of the summed errors in each of the measurement pools. For modeled results use the confidence interval of the input inventory data. For wood products and logging slash burning emissions use the confidence interval of the inventory data. The errors in each pool shall 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.

Therefore,

$$UNC_{BSL} = \frac{\sqrt{\left(C_{BSL,TREE,1} \cdot e_{BSL,TREE}\right)^2 + \left(C_{BSL,DEAD,1} \cdot e_{BSL,DEAD}\right)^2 + \left(\overline{C}_{BSL,HWP} \cdot e_{BSL,TREE}\right)^2 + \left(\overline{GHG}_{BSL} \cdot e_{BSL,TREE}\right)^2}}{C_{BSL,TREE,1} + C_{BSL,DEAD,1} + C_{BSL,HWP} + \overline{GHG}_{BSL}} \qquad (10)$$

where:

UNC_{BSL} Percentage uncertainty in the combined carbon stocks in the baseline.

$C_{BSL,TREE,1}$ Carbon stock in the baseline stored in above and below ground live trees (in metric tons CO_2) for the initial inventory in year 1.

$C_{BSL,DEAD,1}$ Carbon stock in the baseline stored in dead wood (in metric tons CO_2) for the initial inventory in year 1.

$\overline{C}_{BSL,HWP}$ Twenty-year baseline average value of annual carbon (in metric tons CO_2) remaining stored in wood products 100 years after harvest.

$\overline{GHG}_{BSL}$ Twenty-year average value of annual greenhouse gas emissions (in metric tons CO_2e) resulting from the implementation of the baseline.

$e_{BSL,TREE}$ Percentage uncertainty expressed as 90% confidence interval percentage of the mean of the carbon stock in above and below ground live trees (in metric tons CO_2) for the initial inventory in year *1*.

$e_{BSL,DEAD}$ Percentage uncertainty expressed as 90% confidence interval percentage of the mean of the carbon stock in dead wood (in metric tons CO_2) for the initial inventory in year *1*.

D. WITH-PROJECT SCENARIO

D1. WITH-PROJECT STRATIFICATION

If the project activity area is not homogeneous, stratification may be carried out to improve the precision of carbon stock estimates. Different stratifications may be used for the baseline and project scenarios.   For estimation of with-project scenario carbon stocks, strata may be defined on the basis of parameters that are key variables determining forest carbon stocks, for example:

a. Management regime
b. Species or cover types
c. Size and density class
d. Site class
e. Age class

Project Proponents must present in the GHG Plan an *ex ante* stratification of the project area or justify the lack of it. The number and boundaries of the strata defined *ex ante* may change during the Crediting Period (*ex post*).

The *ex post* stratification shall be updated due to the following reasons:

• Unexpected disturbances occurring during the Crediting Period (e.g. due to fire, pests or disease outbreaks), affecting differently various parts of an originally homogeneous stratum
• Forest management activities (e.g. cleaning, planting, thinning, harvesting, coppicing, replanting) may be implemented in a way that affects the existing stratification
• Established strata may be merged if reason for their establishment has disappeared

D2. MONITORING PROJECT IMPLEMENTATION

Information shall be provided, and recorded in the GHG Plan, to establish that:

- The geographic position of the project boundary is recorded for all areas of land
- The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded and archived. This can be achieved by field mapping (e.g. using GPS), or by using georeferenced spatial data (e.g. maps, GIS datasets, orthorectified aerial photography or georeferenced remote sensing images)
- Professionally 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 shall 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
- Where commercial timber harvesting occurs in the project area in the with-project scenario, the forest management plan, together with a record of the plan as actually implemented during the project shall be available for validation and verification, as appropriate

D3. MONITORING OF CARBON STOCKS IN SELECTED POOLS

Information shall be provided, and recorded in the GHG Plan, to establish that professionally 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 shall 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. The forest management plan, together with a record of the plan as actually implemented during the project shall be available for validation and verification, as appropriate.

The 90% statistical confidence interval (CI) of sampling can be no more than ±10% of the mean estimated amount of the combined carbon stock at the project area level[32]. If the Project Proponent cannot meet the targeted ±10% of the mean at 90% confidence, then the reportable amount shall be the lower bound of the 90% confidence interval.

At a minimum the following data parameters must be monitored:

- Project area
- Sample plot area
- Tree species
- Tree Biomass
- Wood products volume
- Dead wood pool, if selected

D4. MONITORING OF EMISSION SOURCES

Emissions from biomass burning must be monitored during project activities. When applying all relevant equations provided in this methodology for the *ex ante* calculation of net anthropogenic GHG removals by sinks, Project Proponents shall provide transparent estimations for the parameters that are monitored during the Crediting Period. These estimates shall be based on measured or existing published data where possible. In addition, Project Proponents must apply the principle of

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[32] For calculating pooled CI of carbon pools across strata, see equations in Barry D. Shiver, *Sampling Techniques for Forest Resource Inventory (John Wiley & Sons, Inc, 1996)*

conservativeness. 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.

D5. ESTIMATION OF PROJECT EMISSION REDUCTIONS OR ENHANCED REMOVALS

This section describes the steps required to calculate $\Delta C_{P,t}$ (net annual carbon stock change under the project scenario; tons CO_2e). This methodology requires: 1) carbon stock levels to be determined in each time period, t, for which a valid verification report is submitted, and 2) the change in project carbon stock be computed from the prior verification time period, t-1.

The following equations are used to construct the project stocking levels using models described in section 3.1 and wood products calculations described in section 3.2:

$$\Delta C_{P,TREE,t} = \left(C_{P,TREE,t} - C_{P,TREE,t-1} \right)$$
(11)

where:

t	Time in years
$\Delta C_{P,TREE,t}$	Change in the project carbon stock stored in above and below ground live trees (in metric tons CO_2) for year t.
$C_{P,TREE,t}$	Change in the project value of carbon stored in above and below ground live trees at the beginning of the year t (in metric tons CO_2) and t-1 signifies the value in the prior year.

$$\Delta C_{P,DEAD,t} = \left(C_{P,DEAD,t} - C_{P,DEAD,t-1} \right)$$
(12)

where:

t	Time in years
$\Delta C_{P,DEAD,,t}$	Change in the project carbon stock (in metric tons CO_2) for year t.
$C_{P,DEAD,t}$	Change in the project value of carbon stored in dead wood at the beginning of the year t (in metric tons CO_2) and t-1 signifies the value in the prior year.

$$GHG_{P,t} = BS_{P,t} \cdot ER_{CH_4} \cdot \frac{16}{44} \cdot GWP_{CH_4}$$
(13)

where:

t	Time in years
$GHG_{P,t}$	Greenhouse gas emission (in metric tons CO2e) resulting from the implementation of the project in year (t).

$BS_{P,t}$ Carbon stock (in metric tons CO_2) in logging slash burned in the project in year t.

ER_{CH4} Methane (CH_4) emission ratio (ratio of CO_2 as CH_4 to CO_2 burned). If local data on combustion efficiency is not available or if combustion efficiency cannot be estimated from fuel information, use IPCC default value of 0.012[33]

16/44   Molar mass ratio of CH_4 to CO_2

GWP_{CH4} 100-year global warming potential (in CO_2e per CH_4) for CH_4 (IPCC SAR-100 value of 21 per the Fourth Assessment Report)[34]

Carbon stock calculation for logging slash burned shall use the method described in Section 3.1.1 for bark, tops and branches, and Section 3.1.2 if dead wood is selected. The reduction in carbon stocks due to slash burning due to project activities must be properly accounted in equations 11 and 12.

To compute change in project carbon stock for each time period use:

$$\Delta C_{P,t} = \Delta C_{P,TREE,t} + \Delta C_{P,DEAD,t} + C_{P,HWP,t} - GHG_{P,t}$$

(14)

where:

t Time in years

$\Delta C_{P,t}$ Change in the project carbon stock (in metric tons CO_2) for year t.

$\Delta C_{P,TREE,t}$ Change in the project carbon stock stored in above and below ground live trees (in metric tons CO_2) for year t.

$\Delta C_{P,DEAD,t}$ Change in the project carbon stock stored in dead wood pools live trees (in metric tons CO_2) for year t.

$C_{P,HWP,t}$ Carbon remaining stored in wood products 100 years after harvest (in metric tons CO_2) for the project in year t.

$GHG_{P,t}$ Greenhouse gas emission (in metric tons CO2e) resulting from the implementation of the project in year (t).

5.1 Tree Biomass, Dead Wood Carbon Calculation, Wood Products

The Project Proponent must use the same set of equations used in Section C3.1.1, C3.1.2, and C3.2 to calculate carbon stocks in the project scenario.

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[33] Table 3A.1.15, Annex 3A.1, GPG-LULUCF (IPCC 2003)

[34] Table 2.14, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

D6. MONITORING OF ACTIVITY-SHIFTING LEAKAGE

There may be no leakage beyond *de minimis* levels through activity shifting to other lands owned, or under management control, by the timber rights owner.

If the project decreases wood product production by >5% relative to the baseline then the Project Proponent and all associated land owners must demonstrate that there is no leakage within their operations – i.e., on other lands they manage/operate outside the bounds of the ACR carbon project.

Such a demonstration must include one of the following:

- Historical records covering all Project Proponent ownership trends in harvest volumes paired with records from the with-project time period showing no deviation from historical trends over most recent 10-year average; *or*

- 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; *or*

- Entity-wide management certification that requires sustainable practices (programs can include FSC, SFI, or ATFS). Management certification must cover *all* entity owned lands with active timber management programs.

D7. ESTIMATION OF EMISSIONS DUE TO MARKET LEAKAGE

Reductions in product outputs due to project activity may be compensated by other entities in the marketplace. Those emissions must be included in the quantification of project benefits. Market Leakage shall be quantified by either of the following:

1. Applying the appropriate default market leakage discount factor (15, 16, or 17):

   - If the project is able to demonstrate that any decrease in total wood products produced by the project relative to the baseline is less than 5% over the Crediting Period then:

     $LK = 0$ (15)

   - Where project activities decrease total wood products produced by the project relative to the baseline by more than 5% but less than 25% over the Crediting Period, the market leakage deduction is 10% (according to VCS AFOLU Guidance Document[35]).

     $LK = 0.1$ (16)

   - Where project activities decrease total wood products produced by the project relative to the baseline by 25% or more over the Crediting Period, the market leakage deduction is 40%[36].

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[35] http://www.v-c-s.org/sites/v-c-s.org/files/Guidance for AFOLU Projects.pdf
[36] We assume that any decrease in production would be transferred to forests of a similar type.

$$LK = 0.4 \tag{17}$$

2. Directly accounting for market leakage associated with the project activity:

Where directly accounting for leakage, market leakage shall be accounted for at the regional-scale applied to the same general forest type as the project (ie, forests containing the same or substitutable commercial species as the forest in the project area) and shall be based on verifiable methods for quantifying leakage. It is at the verifier's discretion to determine whether the method for quantifying market leakage is appropriate for the project.

D8. ESTIMATION OF WITH-PROJECT UNCERTAINTY

It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default values given in IPCC Guidelines (2006), IPCC GPG-LULUCF (2003), or estimates based on sound statistical sampling. Uncertainties arising from the measurement and monitoring of carbon pools and the changes in carbon pools shall always be quantified.

Indisputably conservative estimates can also be used instead of uncertainties, provided that they are based on verifiable literature sources. In this case the uncertainty is assumed to be zero. However, this section provides a procedure to combine uncertainty information and conservative estimates resulting in an overall project scenario uncertainty.

As with baseline uncertainty, it is important that the process of project planning consider uncertainty. Procedures including stratification and the allocation of sufficient measurement plots can help ensure low uncertainty. It is good practice to consider uncertainty at an early stage to identify the data sources with the highest risk to allow the opportunity to conduct further work to diminish uncertainty. Estimation of uncertainty for pools and emissions sources for each measurement pool requires calculation of both the mean and the 90% confidence interval. In all cases uncertainty should be expressed as the 90% confidence interval as a percentage of the mean.

The uncertainty in the project scenario should be defined as the square root of the summed errors in each of the measurement pools. For modeled results use the confidence interval of the input inventory data. For wood products with measured and documented harvest volume removals use zero as the confidence interval. For estimated wood product removal use the confidence interval of the inventory data. The errors in each pool can 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.

Therefore,

$$UNC_{P,t} = \frac{\sqrt{\left(C_{P,TREE,t} \cdot e_{P,TREE}\right)^2 + \left(C_{P,DEAD,t} \cdot e_{P,DEAD}\right)^2 + \left(C_{P,HWP,t} \cdot e_{P,TREE}\right)^2 + \left(GHG_{P,t} \cdot e_{P,TREE}\right)^2}}{C_{P,TREE,t} + C_{P,DEAD,t} + C_{P,HWP,t} + GHG_{P,t}} \tag{18}$$

where:

$UNC_{P,t}$ Percentage uncertainty in the combined carbon stocks in the project in year *t*.

$C_{P,TREE,t}$ Carbon stock in the project stored in above and below ground live trees (in metric tons CO_2) in year t.

$C_{P,DEAD,t}$ Carbon stock in the baseline stored in dead wood (in metric tons CO_2) in year t.

$C_{P,HWP,t}$ Annual carbon (in metric tons CO_2) remaining stored in wood products in the project 100 years after harvest in year t.

$GHG_{P,t}$ Greenhouse gas emission (in metric tons CO_2e) resulting from the implementation of the project in year t.

$e_{P,TREE}$ Percentage uncertainty expressed as 90% confidence interval percentage of the mean of the carbon stock in above and below ground live trees (in metric tons CO_2) for the last remeasurement of the inventory prior to year t.

$e_{P,DEAD}$ Percentage uncertainty expressed as 90% confidence interval percentage of the mean of the carbon stock in dead wood (in metric tons CO_2) for the last remeasurement of the inventory prior to year t.

E. EX-ANTE ESTIMATION

E1. EX-ANTE ESTIMATION METHODS

The Project Proponent must make an *ex ante* calculation of all net anthropogenic GHG removals and emissions for all included sinks and sources for the entire Crediting Period. Project Proponents shall provide estimates of the values of those parameters that are not available before the start of monitoring activities. Project Proponents must retain a conservative approach in making these estimates.

Uncertainties arising from, for example, biomass expansion factors or wood density, could result in unreliable estimates of both baseline net GHG removals by sinks and the actual net GHG removals by sinks especially when global default values are used. Project Proponents shall identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances must then be obtained for these key parameters, whenever possible. These values must be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources; *or*

- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; *or*

- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value must be briefly noted in the GHG

plan. For any data provided by experts, the GHG Plan shall also record the expert's name, affiliation, and principal qualification as an expert– plus inclusion of a 1-page summary CV for each expert consulted, included in an annex.

When choosing key parameters based on information that is not specific to the project circumstances, such as in use of default data, Project Proponents must select values that will lead to an accurate estimation of net GHG removals by sinks, taking into account uncertainties. If uncertainty is significant, Project Proponents must choose data such that it tends to under-estimate, rather than over-estimate, net GHG removals by sinks[37].

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[37] CDM Approved Consolidated Methodology AR-ACM0001, "Afforestation and Reforestation of Degraded Land"

F. QA/QC AND UNCERTAINTY

F1. METHODS FOR QUALITY ASSURANCE

Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management shall be documented. 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.

F2. METHODS FOR QUALITY CONTROL

Project Proponents shall consider all relevant information that may affect the accounting and quantification of GHG reductions/removals, including estimating and accounting for any decreases in carbon pools and/or increases in GHG emission sources. This methodology sets a *de minimis* threshold of 3% of the final calculation of emission reductions. For the purpose of completeness any decreases in carbon pools and/or increases in GHG emission sources must be included if they exceed the *de minimis* threshold. Any exclusion using the *de minimis* principle shall be justified using fully documented *ex ante* calculations.

F3. CALCULATION OF TOTAL PROJECT UNCERTAINTY

The following equation must be applied:

$$UNC_t = \frac{\sqrt{\left(\Delta C_{BSL,t} \cdot UNC_{BSL}\right)^2 + \left(\Delta C_{P,t} \cdot UNC_{P,t}\right)^2}}{\Delta C_{BSL,t} + \Delta C_{P,t}}$$

(19)

where:

UNC_t	Total project uncertainty in year *t*, in %
$\Delta C_{BSL,t}$	Change in the baseline carbon stock and GHG emissions (in metric tons CO_2e) for year *t*. (Section C3)
UNC_{BSL}	Baseline uncertainty, in % (Section C5)
$\Delta C_{P,t}$	Change in the project carbon stock and GHG emissions (in metric tons CO_2e) for year *t*. (Section D5)
$UNC_{P,t}$	With-project uncertainty in year *t*, in % (Section D8)

If calculated *UNC* in equation (19) is <10%, then *UNC* shall be considered 0% in equation (20).

Improved Forest Management Methodology for Quantifying Removals and Emission Reductions through Increased Forest Carbon Sequestration on Non-Federal U.S. Forestlands

American Carbon Registry

G. CALCULATION OF ERTs

This section describes the process of determining additional annual net greenhouse gas emission reductions and Emission Reduction Tons (ERTs) issued for a time period for which a valid verification report has been filed with ACR. Annual net greenhouse gas emission reductions ($C_{ACR,t}$) are calculated using equation 20 by adjusting the difference between the project and baseline carbon stock changes for leakage and uncertainty then multiplying by a non-permanence buffer deduction.

$$ERT_t = C_{ACR,t} = (\Delta C_{P,t} - \Delta C_{BSL,t}) \cdot (1 - LK) \cdot (1 - UNC_t) \cdot (1 - BUF) \qquad (20)$$

where:

ERT_t	Emission Reduction Tons issued with vintage year t.
$C_{ACR,t}$	Annual net greenhouse gas emission reductions (in metric tons CO_2e) at time *t.*
$\Delta C_{P,t}$	Change in the project carbon stock and GHG emissions (in metric tons CO_2e) for year *t*. (Section D5)
$\Delta C_{BSL,t}$	Change in the baseline carbon stock and GHG emissions (in metric tons CO_2e) for year *t*. (Section C3)
LK	Leakage discount (Section D7)
UNC_t	Total Project Uncertainty, (in %) for year *t* (Section F3). UNC_t will be set to zero if the project meets ACR's precision requirement of within ±10% of the mean with 90% confidence. If the project does not meet this precision target, UNC_t should be the half-width of the confidence interval of calculated net GHG emission reductions.
BUF	The non-permanence buffer deduction as calculated in Section B5. *BUF* will be set to zero if an ACR approved insurance product is used.

Negative project stock change ($C_{ACR,t}$) before the first offset credit issuance is a negative balance of greenhouse gas emissions. After the first offset issuance, negative project stock change is a Reversal. AFOLU reversals must be reported and compensated following requirements detailed in the Reversal Risk Mitigation Agreement and the Buffer Pool Terms and Conditions, Exhibit 1 of the *ACR Standard, Version 5.0*. As outlined in Exhibit 1, sequestration projects will terminate automatically if a Reversal causes project stocks to decrease below baseline levels prior to the end of the Minimum Project Term.