California Environmental Protection Agency

AIR RESOURCES BOARD

Compliance Offset Protocol Livestock Projects

Capturing and Destroying Methane from Manure Management Systems

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Abbreviations and Acronyms

ARB	California Air Resources Board
BCS	Biogas control system
BDE	Biogas destruction efficiency
CAR	Climate Action Reserve
CH_4	Methane
CNG	Condensed natural gas
CO_2	Carbon dioxide
EPA	U.S. Environmental Protection Agency
GHG	Greenhouse gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
lb	Pound
LNG	Liquefied natural gas
MS	Management system
MT or t	Metric ton
N_2O	Nitrous oxide
NG	Natural gas
QA/QC	Quality Assurance/Quality Control
Regulation	Regulation, title 17, California Code of Regulations, sections 95800 et seq.
scf	Standard cubic foot
SSR	Source, sink, and reservoirs
STP	Standard temperature and pressure

TAM	Typical average mass
VS	Volatile solids

1 Introduction

The Compliance Offset Protocol Livestock Projects provides methods to quantify and report greenhouse gas (GHG) emission reductions associated with the installation of a biogas control system (BCS) for manure management on dairy cattle and swine farms. The protocol focuses on quantifying the change in methane emissions, but also accounts for effects on carbon dioxide emissions. The protocol is based on the Climate Action Reserve's Livestock Project Protocol Version 2.2[1] and includes some clarifications and updates from Version 3.0.[2].

Offset Project Operators or Authorized Project Designees that install manure biogas capture and destruction technologies use the methods contained in this protocol to quantify and report GHGs. The protocol provides eligibility rules, methods to quantify GHG reductions, offset project-monitoring instructions, and procedures for preparing Offset Project Data Reports. Additionally, all offset projects must submit to annual, independent verification by ARB-accredited verification bodies. Requirements for verification bodies to verify Offset Project Data Reports are provided in the Cap and Trade Regulation (Regulation).

This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification of GHG emission reductions associated with a livestock digester project. The protocol is comprised of both quantification methodologies and regulatory program requirements to develop a livestock project and generate ARB or registry offset credits.

AB 32 exempts quantification methodologies from the Administrative Procedure Act (APA)[3], however those elements of the protocol are still regulatory. The exemption allows future updates to the quantification methodologies to be made through a public review and Board adoption process but without the need for rulemaking documents. Each protocol identifies sections that are considered quantification and exempt from APA requirements. Any changes to the non-quantification elements of the offset protocols would be considered a regulatory update subject to the full regulatory development process. Those sections that are considered to be a quantification methodology are clearly indicated in the title of the chapter or subchapter if only a portion of that chapter is considered part of the quantification methodology of the protocol.

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[1] Climate Action Reserve (2009) Livestock Project Protocol Version 2.2. November 3, 2009. http://www.climateactionreserve.org/wp-content/uploads/2009/03/Livestock-Project-Protocol-Version2.2.pdf (accessed November 3, 2009)

[2] Climate Action Reserve (2010) Livestock Project Protocol Version 3.0. September 29, 2010.] http://www.climateactionreserve.org/wp-content/uploads/2009/03/U.S._Livestock_Project_Protocol_V3.02.pdf (accessed September 29, 2010)

[3] Health and Safety Code section 38571

2 The GHG Reduction Project

2.1 Background

Manure treated and stored under anaerobic conditions decomposes to produce methane, which, if uncontrolled, is emitted to the atmosphere. This predominantly occurs when livestock operations manage waste with anaerobic liquid-based systems (e.g. in lagoons, ponds, tanks, or pits). Within the livestock sector, the primary drivers of methane generation include the amount of manure produced and the fraction of volatile solids that decompose anaerobically. Temperature and the retention time of manure during treatment and storage also affect methane production.

2.2 Project Definition – Quantification Methodology

For purposes of this protocol, offset project is defined as the installation of a biogas control system that captures and destroys methane gas from anaerobic manure treatment and/or storage facilities on livestock operations.[4] The biogas control system must destroy methane gas that would otherwise have been emitted to the atmosphere in the absence of the offset project from uncontrolled anaerobic treatment and/or storage of manure.[5]

Captured biogas can be destroyed on-site, or transported for off-site use (e.g. through gas distribution or transmission pipeline), or used to power vehicles. Regardless of how biogas is utilized, the ultimate fate of the methane must be destruction.

"Centralized digesters" that integrate waste from more than one livestock operation may also meet the definition of an offset project.[6]

2.3 Offset Project Operator or Authorized Project Designee

The Offset Project Operator or Authorized Project Designee is responsible for project listing, monitoring, reporting and verification. The Offset Project Operator or Authorized Project Designee must submit the information in the Regulation and in Appendices C and D of this protocol. The Offset Project Operator or Authorized Project Designee must have legal authority to implement the offset project.

[4] Biogas control systems are commonly called digesters, which may be designed and operated in a variety of ways, from ambient temperature covered lagoons to heated lagoons to mesophilic plug flow or complete mix concrete tank digesters.

[5] The installation of a BCS at an existing livestock operation where the primary manure management system is aerobic (produces little to no methane) may result in an increase of the amount of methane emitted to the atmosphere. Thus, the BCS must digest manure that would primarily be treated in an anaerobic system in the absence of the project in order for the project to meet the definition of an offset project.

[6] The protocol does not preclude Offset Project Operators or Authorized Project Designees from co-digesting organic matter in the biogas control system. However, the additional organics could impact the nutrient properties of digester effluent, which Offset Project Operators or Authorized Project Designees should consider when assessing the offset project's associated water quality impacts.

3 Eligibility Rules

Offset projects that meet the project definition and requirements in section 2.2 must fully satisfy the eligibility requirements in the Regulation in addition to the eligibility rules listed below to be eligible to receive ARB or registry offset credits.

3.1 Location

Only projects located in the United States and its territories are eligible under this protocol. In addition, offset projects situated on the following categories of land are only eligible under this protocol if they meet the requirements of this protocol and the Regulation, including the waiver of sovereign immunity requirements of section 95975(l) of the Regulation:

1. Land that is owned by, or subject to an ownership or possessory interest of a Tribe;
2. Land that is “Indian lands” of a Tribe, as defined by 25 U.S.C. §81(a)(1); or
3. Land that is owned by any person, entity, or Tribe, within the external borders of such Indian lands.

3.2 Offset Project Commencement

For this protocol, Offset Project Commencement is defined as the date at which the offset project’s biogas control system (BCS) becomes operational. A BCS is considered *operational* on the date at which the system begins producing and destroying methane gas upon completion of an initial start-up period. Offset projects may always be submitted for listing prior to their commencement date.

3.3 Project Crediting Period

The crediting period for this protocol is ten years.

3.4 Additionality

Offset projects must meet the additionality requirements in the Regulation in addition to the requirements below.

3.4.1 Anaerobic Baseline - Quantification Methodology

The Offset Project Operator or Authorized Project Designee must demonstrate that the depth of the anaerobic lagoons or ponds prior to the offset project’s implementation were sufficient to prevent algal oxygen production and create an oxygen-free bottom layer; which means at least 1 meter in depth.

Greenfield livestock projects (i.e., projects that are implemented at new livestock facilities that have no prior manure management system) are eligible only if the Offset Project Operator or Authorized Project Designee can demonstrate that uncontrolled anaerobic storage and/or treatment of manure is common practice in the industry and geographic region where the offset project is located.

3.5 Regulatory Compliance

As stated in the Regulation, an Offset Project Operator or Authorized Project Designee must fulfill all applicable local, regional and national requirements on environment impact assessments that apply based on the offset project location. Offset projects must also fulfill all local, regional, and national regulatory requirements that apply based on the offset project location. Offset projects are not eligible to receive ARB or registry offset credits for GHG reductions or GHG removal enhancements that are not in compliance with regulatory requirements.

4 Offset Project Boundary – Quantification Methodology

The Offset Project Boundary delineates the GHG sources, GHG sinks, and GHG reservoirs (SSRs) that shall be assessed to determine the net change in emissions associated with installing a BCS. For this protocol, the Offset Project Boundary captures sources from waste production to disposal, including off-site manure disposal. However, the calculation procedure only incorporates methane and carbon dioxide, so while nitrous oxide sources are technically within the Offset Project Boundary they are not assessed in the calculation procedure.

This protocol does not account for carbon dioxide emission reductions associated with displacing grid-delivered electricity or fossil fuel use.

Figure 4.1 provides a general illustration of the Offset Project Boundary, indicating which SSRs are included or excluded from the Offset Project Boundary. All SSRs within the dashed line are accounted for under this protocol.

Table 4.1 provides greater detail on each SSR and information for the SSRs and gases from the Offset Project Boundary.

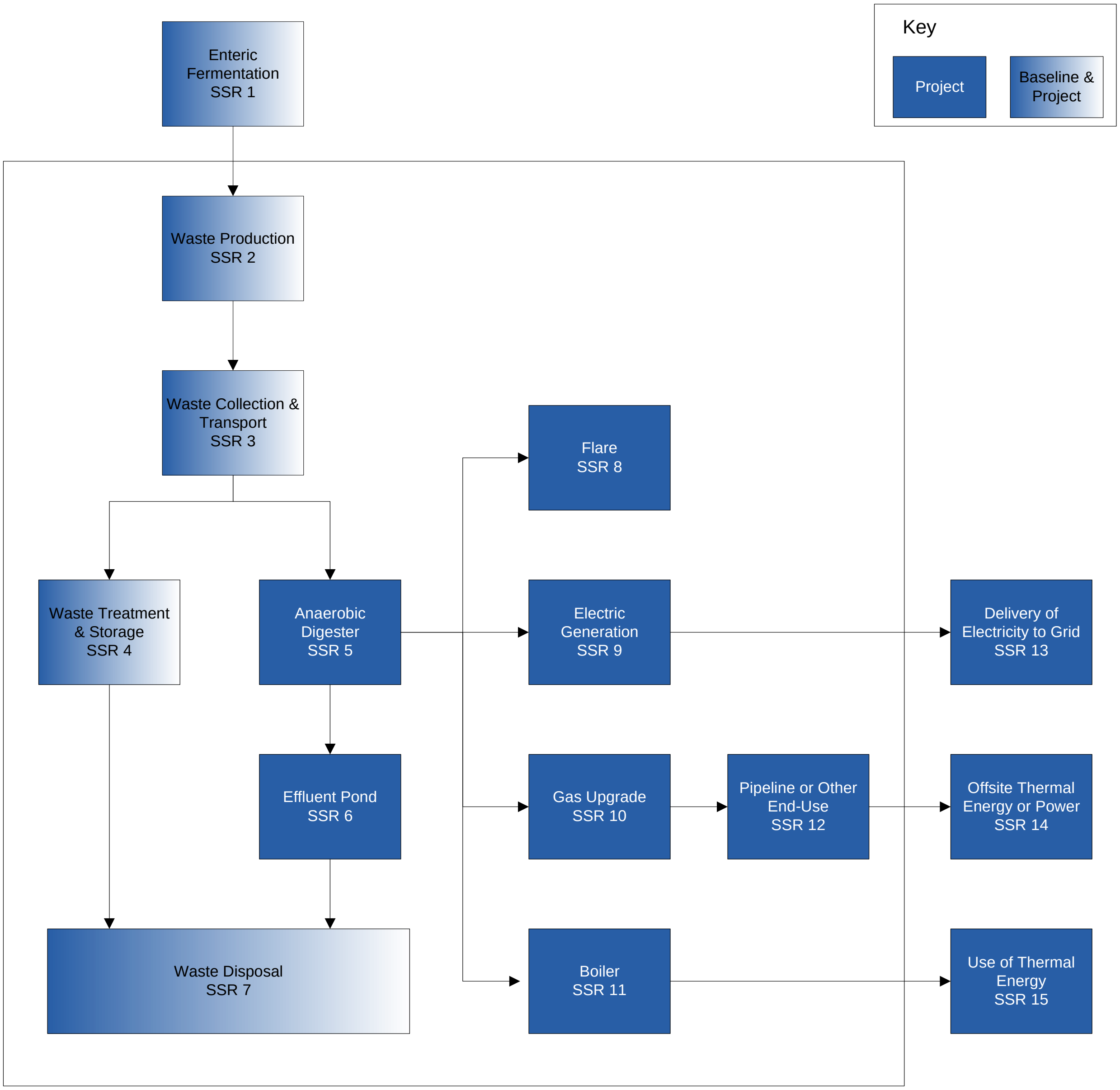


Figure 4.1. General Illustration of the Offset Project Boundary

Table 4.1 relates GHG source categories to sources and gases, and indicates inclusion in the calculation methodology. It is intended to be illustrative – GHG sources are indicative for the source category, GHGs in addition to the main GHG are also mentioned, where appropriate.

Table 4.1. Description of all GHG Sources, GHG Sinks, and GHG Reservoirs

SSR	GHG Source	Gas	Relevant to Project Baseline (B) or Offset Project (P)	Included/ Excluded
1	Emissions from enteric fermentation	CH_4	B, P	*Excluded*
2	Emissions from waste deposits in barn, milking parlor, or pasture/corral	N_2O	B, P	*Excluded*
	Emissions from mobile and stationary support equipment	CO_2	B, P	*Included*
		CH_4		*Excluded*
		N_2O		*Excluded*
3	Emissions from mechanical systems used to collect and transport waste (e.g. engines and pumps for flush systems; vacuums and tractors for scrape systems)	CO_2	B, P	*Included*
		CH_4		*Excluded*
		N_2O		*Excluded*
	Vehicle emissions (e.g. for centralized digesters)	CO_2		*Included*
		CH_4		*Excluded*
		N_2O		*Excluded*
4	Emissions from waste treatment and storage including: anaerobic lagoons, dry lot deposits, compost piles, solid storage piles, manure settling basins, aerobic treatment, storage ponds, etc.	CO_2	B, P	*Excluded*
		CH_4		*Included*
		N_2O		*Excluded*
	Emissions from support equipment	CO_2		*Included*
		CH_4		*Excluded*
		N_2O		*Excluded*
5	Emissions from the anaerobic digester due to biogas collection inefficiencies and venting events	CH_4	P	*Included*
6	Emissions from the effluent pond	CH_4	B, P	*Included*
		N_2O		*Excluded*
7	Emissions from land application	N_2O	B, P	*Excluded*
	Vehicle emissions for	CO_2	B, P	*Included*

SSR	GHG Source	Gas	Relevant to Project Baseline (B) or Offset Project (P)	Included/ Excluded
	land application and/or off-site transport	CH_4		*Excluded*
		N_2O		*Excluded*
8	Emissions from combustion during flaring, including emissions from incomplete combustion of biogas	CO_2	P	*Excluded*
		CH_4		*Included*
		N_2O		*Excluded*
9	Emissions from combustion during electric generation, including incomplete combustion of biogas	CO_2	P	*Excluded*
		CH_4		*Included*
		N_2O		*Excluded*
10	Emissions from equipment upgrading biogas for pipeline injection or use as CNG/LNG fuel	CO_2	P	*Included*
		CH_4		*Excluded*
		N_2O		*Excluded*
11	Emissions from combustion at boiler including emissions from incomplete combustion of biogas	CO_2	P	*Excluded*
		CH_4		*Included*
		N_2O		*Excluded*
12	Emissions from combustion of biogas by end user of pipeline or CNG/LNG, including incomplete combustion	CO_2	P	*Excluded*
		CH_4		*Excluded*
		N_2O		*Excluded*
13	Delivery and use of project electricity to grid	CO_2 CH_4 N_2O	P	*Excluded*
14	Off-site thermal energy or power	CO_2 CH_4 N_2O	P	*Excluded*
15	Use of project-generated thermal energy	CO_2 CH_4 N_2O	P	*Excluded*
16	Project construction and decommissioning emissions	CO_2 CH_4 N_2O	P	*Excluded*

5 Quantifying GHG Emission Reductions – Quantification Methodology[7]

GHG emission reductions from a livestock offset project are quantified by comparing actual project emissions to baseline emissions at the offset project site. Project baseline emissions are an estimate of the GHG emissions from GHG sources within the Offset Project Boundary that would have occurred in the absence of the livestock offset project. Project emissions are actual GHG emissions that occur at sources within the Offset Project Boundary. Project emissions must be subtracted from the project baseline emissions to quantify the offset project's total net GHG emission reductions (Equation 5.1), and the total number of GHG reductions submitted for issuance of ARB or registry offset credits must be rounded to the nearest whole ton.

The Offset Project Operator~~s~~ or Authorized Project Designee should take note that some equations to calculate project baseline and project emissions are run on a month-by-month basis and activity data monitoring takes place at varying levels of frequency. As applicable, monthly emissions data (for project baseline and offset project) are summed together to calculate annual GHG emission reductions.

The current methodology for quantifying the GHG emissions and GHG emission reductions associated with installing a BCS requires the use of both modeled reductions (following Equation 5.2 to Equation 5.4 and Equation 5.6 to Equation 5.9), as well as the utilization of ex-post metered data from the BCS to be used as a check on the modeled GHG reductions.

There can be material differences between modeled methane emission reductions and the actual metered quantity of methane that is captured and destroyed by the BCS due to digester start-up periods, venting events, and other BCS operational issues. These operational issues have the potential to result in substantially less methane destruction than is modeled, leading to an overestimation of GHG reductions in the modeled case.

To address this issue and maintain consistency with international best practice, ARB requires the modeled methane emission reduction results to be compared to the ex-post metered quantity of methane that is captured and destroyed by the BCS. The lesser of the two values will represent the total methane emission reductions for the reporting period. Equation 5.1 below outlines the quantification methodology for calculating the GHG emission reductions from the installation of a BCS.[8]

[7]The entirety of Section 5 is considered a quantification method.

[8]The calculation procedure only addresses direct emissions sources and does not incorporate reductions in electricity consumption, which impacts indirect emissions associated with power plants owned and operated by entities other than the Offset Project Operator or Authorized Project Designee. Equation 5.1 accounts for any increase in CO2 if the project results in an increase in electricity consumption.

Equation 5.1. GHG Reductions from Installing a Biogas Control System

$$\textit{Total GHG Reductions} = (\textit{Modeled project baseline emissions}_{CH4} - \textit{Project emissions}_{CH4}) + (\textit{project baseline emissions}_{CO2} - \textit{Project emissions}_{CO2})$$

The (*Modeled project baseline emissions* $_{CH4,}$ – *Project emissions* $_{CH4}$) term shall be calculated according to Equation 5.2 to Equation 5.4 and Equation 5.6 to Equation 5.9. The resulting aggregated quantity of methane reductions must then be compared to the ex-post quantity of methane that is metered and destroyed in the biogas collection system, as expressed in Equation 5.10. In the case that the total ex-post quantity of metered and destroyed methane is less than the modeled methane reductions, the metered quantity of destroyed methane will replace the modeled methane reductions.

Therefore, the above equation then becomes:

$$\textit{Total GHG Reductions} = (\textit{Total quantity of metered and destroyed methane}) + (\textit{Project baseline emissions}_{CO2} - \textit{Project emissions}_{CO2})$$

5.1 Quantifying Baseline Methane Emissions

Project baseline emissions represent the GHG emissions within the Offset Project Boundary that would have occurred if not for the installation of the BCS. For the purposes of this protocol, project baseline emissions must be calculated according to the manure management system in place prior to installing the BCS. This is referred to as a "continuation of current practices" project baseline scenario. Additionally, project baseline emissions must be calculated each year of the offset project.[9] The procedure assumes there is no BCS in the project baseline system. Regarding new livestock operations that install a BCS, a modeled project baseline scenario must be established using the prevailing system type in use for the geographic area, animal type, and farm size that corresponds to their operation.

The procedure to determine the modeled project baseline methane emissions follows Equation 5.2, which combines Equation 5.3 and Equation 5.4.

Equation 5.3 calculates methane emissions from anaerobic manure storage/treatment systems based on site-specific information on the mass of volatile solids degraded by the anaerobic storage/treatment system and available for methane conversion.[10] It incorporates the effects of temperature through the van't Hoff-Arrhenius '*f*' factor and accounts for the retention of volatile solids through the use of monthly assessments. Equation 5.4 is less intensive and applies to non-anaerobic storage/treatment systems. Both Equation 5.3 and Equation 5.4 reflect basic biological principles of methane production from available volatile solids, determine methane generation for each livestock category, and account for the extent to which the waste management system handles each category's manure.

[9] Conversely, under a "static baseline," the project baseline emissions would be assessed once before offset project implementation and that value would be used throughout the offset project lifetime.
[10] Anaerobic storage/treatment systems generally refer to anaerobic lagoons, or storage ponds, etc.

Equation 5.2. Modeled Project Baseline Methane Emissions

$$BE_{CH4} = \left(\sum_{S,L} BE_{CH4,AS,L} + BE_{CH4,non-AS,L} \right)$$

Where,

			Units
BE_{CH4}	=	Total annual project baseline methane emissions, expressed in carbon dioxide equivalent	tCO_2e/yr
$BE_{CH4,AS,L}$	=	Total annual project baseline methane emissions from anaerobic storage/treatment systems by livestock category 'L', expressed in carbon dioxide equivalent	tCO_2e/yr
$BE_{CH4,non\text{-}AS,L}$	=	Total annual project baseline methane emissions from non-anaerobic storage/treatment systems, expressed in carbon dioxide equivalent	tCO_2e/yr

Equation 5.3. Modeled Project Baseline Methane Emissions from Anaerobic Storage/Treatment Systems

$$BE_{CH4,AS} = \sum_{L,AS} VS_{\deg,AS,L} \times B_{0,L} \times 0.68 \times 0.001 \times 21$$

Where, Units

$BE_{CH4,AS}$	=	Total annual project baseline methane emissions from anaerobic manure storage/treatment systems, expressed in carbon dioxide equivalent	tCO_2e/yr
$VS_{deg,AS,L}$	=	Annual volatile solids degraded in anaerobic manure storage/treatment system 'AS' from livestock category 'L'	kg dry matter
$B_{0,L}$	=	Maximum methane producing capacity of manure for livestock category 'L' – see Appendix A, Table A.3	m^3 CH_4/kg of VS
0.68	=	Density of methane (1 atm, 60^oF)	kg/m^3
0.001	=	Conversion factor from kg to metric tons	
21	=	Global Warming Potential factor of methane to carbon dioxide equivalent	

$$VS_{\deg,AS,L} = \sum_{AS,L} VS_{avail,AS,L} \times f$$

Where, Units

$VS_{deg,AS,L}$	=	Annual volatile solids degraded by anaerobic manure storage/ treatment system 'AS' by livestock category 'L'	kg dry matter
$VS_{avail,AS,L}$	=	Monthly volatile solids available for degradation from anaerobic manure storage/treatment system 'AS' by livestock category 'L'()	kg dry matter
f	=	The van't Hoff-Arrhenius factor = "the proportion of volatile solids that are biologically available for conversion to methane based on the monthly temperature of the system"	

$$VS_{avail,AS,L} = (VS_L \times P_L \times MS_{AS,L} \times dpm \times 0.8) + (VS_{avail-1,AS} - VS_{\deg-1,AS})$$

Where, Units

$VS_{avail,AS,L}$	=	Monthly volatile solids available for degradation in anaerobic storage/treatment system 'AS' by livestock category 'L'	kg dry matter
VS_L	=	Volatile solids produced by livestock category 'L' on a dry matter basis. *Important* – refer to Box 5.1 for using appropriate units for VS_L values from Appendix A	kg/ animal/ day
P_L	=	Annual average population of livestock category 'L' (based on monthly population data)	
$MS_{AS,L}$	=	Percent of manure sent to (managed in) anaerobic manure storage/treatment system 'AS' from livestock category 'L' [11]	%
dpm	=	Days per month	days/ month
0.8	=	System calibration factor	
$VS_{avail-1,AS}$	=	Previous month's volatile solids available for degradation in anaerobic system 'AS'	kg
$VS_{deg-1,AS}$	=	Previous month's volatile solids degraded by anaerobic system 'AS'	kg

[11]The MS value represents the percent of manure that would be sent to (managed by) the anaerobic manure storage/treatment systems in the project baseline case – as if the biogas control system was never installed.

$$f = \exp\left[\frac{E(T_2 - T_1)}{RT_1T_2}\right]$$

Where,			Units
f	=	The van't Hoff-Arrhenius factor	
E	=	Activation energy constant (15,175)	cal/mol
T_1	=	303.16	Kelvin
T_2	=	Monthly average ambient temperature (K = °C + 273). If T_2 < 5 °C then f = 0.104	Kelvin
R	=	Ideal gas constant (1.987)	cal/Kmol

Equation 5.4. Modeled Project Baseline Methane for Non-Anaerobic Storage/Treatment Systems

$$BE_{CH4,nAS} = \left(\sum_{L,S} P_L \times MS_{L,nAS} \times VS_L \times 365 \times MCF_{nAS} \times B_{0,L}\right) \times 0.68 \times 0.001 \times 21$$

Where,			Units
$BE_{CH4,nAS}$	=	Total annual project baseline methane emissions from non-anaerobic storage/treatment systems, expressed in carbon dioxide equivalent	tCO_2e/yr
P_L	=	Annual average population of livestock category 'L' (based on monthly population data)	
$MS_{L,nAS}$	=	Percent of manure from livestock category 'L' managed in non-anaerobic storage/treatment systems	%
VS_L	=	Volatile solids produced by livestock category 'L' on a dry matter basis. *Important* – refer to Box 5.1 for using appropriate units for VS_L values from Appendix A	kg/ animal/ day
365	=	Days in a year	days/yr
$MCF_{,nAS}$	=	Methane conversion factor for non-anaerobic storage/treatment system 'S' – See Appendix A	%
$B_{0,L}$	=	Maximum methane producing capacity for manure for livestock category 'L' – Appendix A, Table A.3	m^3 CH_4/kg of VS dry matter
0.68	=	Density of methane (1 atm, 60^oF)	kg/m^3
0.001	=	Conversion factor from kg to metric tons	
21	=	Global Warming Potential factor of methane to carbon dioxide equivalent	

Box 5.1. Daily Volatile Solids for All Livestock Categories

Consistent with international best-practice, it is recommended that appropriate VS_L values for Dairy livestock categories be obtained from the State-specific lookup table Table A.5. provided in Appendix A.

VS_L values for all other livestock can be found in Appendix A, Table A.3.

Important - Units provided for all VS values in Appendix A are in (kg/day/1000kg), in order to get VS_L in the appropriate units (kg/animal/day), the following equation must be used:

$$VS_L = VS_{table} \times \frac{Mass_L}{1000}$$

Where,

			Units
VS_L	=	Volatile solid excretion on a dry matter weight basis	kg/ animal/ day
VS_{Table}	=	Volatile solid excretion from lookup table (Table A.3 and Table A.5a. - A.5.d.)	kg/ day/ 1000kg
$Mass_L$	=	Average live weight for livestock category 'L', if site specific data is unavailable, use values from Appendix A, Table A.2	kg

5.1.1 Variables for Calculating Project Baseline Methane

The calculation procedure uses a combination of site-specific values and default factors.

Population – PL

The procedure requires the offset project to differentiate between livestock categories ('L') – e.g. lactating dairy cows, non-milking dairy cows, heifers, etc. This accounts for differences in methane generation across livestock categories (see Appendix A, Table A.2). The population of each livestock category is monitored on a monthly basis, and for Equation 5.4 averaged for an annual total population.

Volatile Solids – VS_L

This value represents the daily organic material in the manure for each livestock category and consists of both biodegradable and non-biodegradable fractions. The VS content of manure is a combination of excreted fecal material (the fraction of a livestock category's diet consumed and not digested) and urinary excretions, expressed in a dry matter weight basis (kg/animal). This protocol requires that the VS value for all livestock categories be determined as outlined in Box 5.1.

$Mass_L$

This value is the annual average live weight of the animals, per livestock category. This data is necessary because default VS values are supplied in units of kg/day/1000kg mass, therefore the average mass of the corresponding livestock category is required in order to convert the units of VS into kg/day/animal. Site specific livestock mass is preferred for all livestock categories. If site specific data is unavailable, Typical Average Mass (TAM) values can be used (Appendix A, Table A.2).

Maximum methane production – $B_{0,L}$

This value represents the maximum methane-producing capacity of the manure, differentiated by livestock category ('L') and diet. Default B_0 factors from Appendix A, Table A.3 must be used.

MS

The MS value apportions manure from each livestock category to an appropriate manure management system component ('S'). It reflects the reality that waste from the operation's livestock categories are not managed uniformly. The MS value accounts for the operation's multiple types of manure management systems. It is expressed as a percent (%), relative to the total amount of waste produced by the livestock category. As waste production is normalized for each livestock category, the percentage should be calculated as percent of population for each livestock category. For example, a dairy operation might send 85% of its milking cows' waste to an anaerobic lagoon and 15% could be deposited in a corral. In this situation an MS value of 85% would be assigned to Equation 5.3 and 15% to Equation 5.4.

Importantly, the MS value indicates where the waste would be managed in the project baseline scenario – i.e. where the manure would end-up if the digester was never installed.

Methane Conversion Factor – *MCF*

Each manure management system component has a volatile solids-to-methane conversion efficiency, which represents the degree to which maximum methane production (B_0) is achieved. Methane production is a function of the extent of anaerobic conditions present in the system, the temperature of the system, and the retention time of organic material in the system.

For anaerobic lagoons, storage ponds, liquid slurry tanks etc., this protocol requires site-specific calculation of the mass of volatile solids degraded by the anaerobic storage/treatment system. This is expressed as "degraded volatile solids" or "VS_{deg}" in Equation 5.3, which equals the system's monthly available VS-multiplied by "f," the van't Hoff-Arrhenius factor. The 'f' factor effectively converts total available VS in the anaerobic manure storage/treatment system to methane-convertible VS, based on the monthly temperature of the system.

The multiplication of "VS_{deg}" by "B_0" gives a site-specific quantification of the uncontrolled methane emissions that would have occurred in the absence of a digester – from the anaerobic storage and/or treatment system, taking into account each livestock category's contribution of manure to that system.

This method to calculate methane emissions reflects the site-specific monthly biological performance of the operation's anaerobic manure handling systems that existed pre-project, as predicted by the van't Hoff-Arrhenius equation using farm-level data on temperature, VS loading, and system VS retention time.

Default MCF values for non-anaerobic manure storage/treatment are available in Appendix A, which are used for Equation 5.4.

5.2 Quantifying Project Methane Emissions

Project emissions are actual GHG emissions that occur within the Offset Project Boundary after the installation of the BCS. Project emissions are calculated on an annual, *ex-post* basis. But like project baseline emissions, some parameters are monitored on a monthly basis. Methane emissions from manure storage and/or treatment systems other than the digester are modeled much the same as in the baseline scenario.

As shown in Equation 5.5, project methane emissions equal:

- The amount of methane created by the BCS that is not captured and destroyed by the control system, plus
- Methane from the digester effluent storage pond (if necessary), plus
- Methane from sources in the waste treatment and storage category other than the BCS and associated effluent pond. This includes all other manure treatment systems such as compost piles, solids storage, daily spread, etc.

Consistent with ACM0010 and this protocol's project baseline methane calculation approach, the formula to account for project methane emissions incorporates all potential GHG sources within the waste treatment and storage category. Non-BCS-related sources follow the same calculation approach as provided in the project baseline methane equations. Several activity data for the variables in Equation 5.9 will be the same as those in Equation 5.2 – Equation 5.4.

Although not common under normal digester operation, it is possible that a venting event may occur due to failure of digester cover materials, the digester vessel, or the gas collection system, or due to a planned maintenance event. In the event that a system failure or planned operation results in the venting of biogas, the quantity of methane released to the atmosphere shall be estimated according to Equation 5.7.

Equation 5.5. Project Methane Emissions

$$PE_{CH4} = [(PE_{CH4,\ BCS} + PE_{CH4,\ EP} + PE_{CH4,\ non\text{-}BCS}) \times 21]$$

Where,

			<u>Units</u>
PE_{CH4}	=	Total annual project methane emissions, expressed in carbon dioxide equivalent	tCO_2e/yr
$PE_{CH4,\ BCS}$	=	Annual methane emissions from the BCS – Equation 5.6	tCH_4/yr
$PE_{CH4,\ EP}$	=	Annual methane emissions from the BCS Effluent Pond – Equation 5.8	tCH_4/yr
$PE_{CH4,\ non\text{-}BCS}$	=	Annual methane emissions from sources in the waste treatment and storage category other than the BCS and associated Effluent Pond – Equation 5.9	tCH_4/yr
21	=	Global Warming Potential factor of methane to carbon dioxide equivalent	

Equation 5.6. Project Methane Emissions from the Biogas Control System

$$PE_{CH4,BCS} = \left[\left(CH_{4,meter} \right) \left(\left(\frac{1}{BCE} \right) - BDE_{i,weighted} \right) \right] + CH_{4,vent,i}$$

Where, Units

$PE_{CH4, BCS}$	=	Monthly methane emissions from the BCS, to be aggregated annually	tCH_4/yr
$CH_{4,meter}$	=	Monthly quantity of methane collected and metered	tCH_4/ month
BCE	=	Monthly methane collection efficiency of the BCS. Offset Project Operators or Authorized Project Designees use the appropriate default value provided in Table A.4	% (as a decimal)
$BDE_{i,weighted}$	=	Monthly weighted average of all destruction devices used in month i.	% (as a decimal)
$CH_{4,vent,i}$	=	The monthly quantity of methane that is vented to the atmosphere due to BCS venting events, as quantified in Equation 5.7 below.	

$$CH_{4,meter} = F \times (520/T)^{\pi} \times (P/1)^{\pi} \times CH_{4,conc} \times 0.0423 \times 0.000454$$

Where, Units

$CH_{4,meter}$	=	Monthly quantity of methane collected and metered[12]	tCH_4/ month
F	=	Measured volumetric flow of Biogas per month	scf/month

[12]This value reflects directly measured biogas mass flow and methane concentration in the biogas to the combustion device.

Equation 5.6. Continued

T	=	Temperature of the Biogas flow ($^oR = ^oF + 459.67$)	^oR (Rankine)
P	=	Pressure of the Biogas flow	atm
$CH_{4,conc}$	=	Measured methane concentration of Biogas from the most recent methane concentration measurement	% (as a decimal)
0.0423	=	Density of methane gas (1atm, 60^{o}F)	lbsCH_4/scf
0.000454	=	Conversion factor, lbs to metric tons	

** The terms (520/T) and (P/1) should be omitted if the continuous flow meter internally corrects for temperature and pressure to 60^{o}F and 1atm.*

$$BDE_{i,weighted} = \frac{\sum_{DD}\left(BDE_{DD} \times F_{i,DD}\right)}{F_i}$$

Where, | Units

$BDE_{i,weighted}$	=	Monthly weighted average of all destruction devices used in month i	fraction
BDE_{DD}	=	Default methane destruction efficiency of a particular destruction device 'DD'. See Appendix A for default destruction efficiencies by destruction device[13]	fraction
$F_{i,DD}$	=	Monthly flow of biogas to a particular destruction device 'DD'	scf/month
F_i	=	Total monthly measured volumetric flow of biogas to all destruction devices	scf/month

Equation 5.7. Project Methane Emissions from Venting Events

$$CH_{4,vent,i} = \left(MS_{BCS} + (F_{pw} \times t)\right) \times CH_{4,conc} \times 0.04230 \times 0.000454$$

Where, | Units

MS_{BCS}	=	Maximum biogas storage of the BCS system	SCF
F_{pw}	=	The average total flow of biogas from the digester for the entire week prior to the venting event	SCF/day
t	=	The number of days of the month that biogas is venting uncontrolled from the BCS system (can be a fraction)	days

[13] Offset Project Operators or Authorized Project Designees have the option to use either the default methane destruction efficiencies provided, or site specific methane destruction efficiencies as provided by an ARB approved source test plan, for each of the combustion devices used in the project.

Equation 5.8. Project Methane Emissions from the BCS Effluent Pond[14]

$$PE_{CH4,EP} = VS_{ep} \times B_{o,ep} \times 365 \times 0.68 \times MCF_{ep} \times 0.001$$

Where,			Units
$PE_{CH4,\,EP}$	=	Methane emissions from the Effluent Pond	tCH_4/yr
VS_{ep}	=	Volatile solid to effluent pond – 30% of the average daily VS entering the digester	kg/day
$B_{o,ep}$	=	Maximum methane producing capacity (of VS dry matter)[15]	m^3CH_4/kg
365	=	Days in a year	days/yr
0.68	=	Density of methane (1 atm, 60^{o}F)	kg/m^3
MCF_{ep}	=	Methane conversion factor, Appendix A. Offset Project Operators or Authorized Project Designees shall use the *liquid slurry* MCF value for effluent ponds	Fraction
0.001	=	Conversion factor from kg to metric tons	

$$VS_{ep} = \left(\sum_{L} (VS_L \times P_L \times MS_{L,BCS}) \right) \times 0.3$$

Where,			Units
VS_L	=	VS produced by livestock category 'L' on a dry matter basis. *Important* – refer to Box 5.1 for using appropriate units for VS_L values from Appendix A	kg/ animal/ day
P_L	=	Annual average population of livestock category 'L' (based on monthly population data	
$MS_{L,BCS}$	=	Fraction of manure from livestock category 'L' that is managed in the BCS	fraction
0.3	=	Default value representing the amount of VS that exits the digester as a percentage of the VS entering the digester	fraction

[14]If no effluent pond exists and Offset Project Operators or Authorized Project Designees send digester effluent (VS) to compost piles or apply directly to land, for example, then the VS for these cases should also be tracked using Equation 5.8

[15]The B_o value for the project effluent pond is not differentiated by livestock category. Offset Project Operators or Authorized Project Designees could use the B_o value that corresponds with an average of the operation's livestock categories that contributes manure to the biogas control system. Supporting laboratory data and documentation need to be supplied to the verifier to justify the alternative value.

Equation 5.9. Project Methane Emissions from *Non*-BCS Related Sources[16]

$$PE_{CH4,nBCS} = \left(\sum_{L} (EF_{CH4,L}(nBCSs) \times P_L) \right) \times 0.001$$

Where,			Units
$PE_{CH4,\ nBCS}$	=	Methane from sources in the waste treatment and storage category other than the BCS and associated Effluent Pond	tCH_4/yr
$EF_{CH4,L}$	=	Emission factor for the livestock population from non-BCS-related sources (nBCSs, calculated below)	$kgCH_4$/ head/ yr
P_L	=	Population of livestock category 'L'	
0.001	=	Conversion factor from kg to metric tons	

$$EF_{CH4,L}(nBCSs) = (VS_L \times B_{o,L} \times 365 \times 0.68) \times \left(\sum_{S} (MCF_S \times MS_{L,S}) \right)$$

Where,			Units
$EF_{CH4,L}$	=	Methane emission factor for the livestock population from non-biogas control system related sources (nBCSs)	$kgCH_4$/ head/ yr
VS_L	=	Volatile solids produced by livestock category 'L' on a dry matter basis. *Important* – refer to Box 5.1 for using appropriate units for VS_L values from Appendix A	kg/ animal/ day
$B_{o,L}$	=	Maximum methane producing capacity for manure for livestock category 'L' (of VS dry matter), Appendix A, Table A.3	m^3 CH_4/kg
365	=	Days in a year	days/yr
0.68	=	Density of methane (1 atm, 60^oF)	kg/m^3
MCF_S	=	Methane conversion factor for system component 'S', Appendix A	fraction
$MS_{L,S}$	=	Percent of manure from livestock category L that is managed in non-BCS system component 'S'	fraction

5.3 Metered Methane Destruction Comparison

As described above, all offset projects must compare the modeled methane emission reductions for the reporting period, as calculated in Equation 5.2 - Equation 5.4 and Equation 5.6 - Equation 5.9 above, with the actual metered amount of methane that is destroyed in the BCS over the same period. The lesser of the two values is to be used as the total methane emission reductions for the reporting period in question.

In order to calculate the metered methane reductions, the monthly quantity of biogas that is metered and destroyed by the BCS must be aggregated over the reporting period. In the event that an Offset Project Operator or Authorized Project Designee is reporting GHG reductions for a period of time that is less than a full year, the total modeled methane emission reductions would be aggregated over this time period and compared with the metered methane that is destroyed in the BCS over the same period of time. For example, if a project is reporting and verifying only 6 months of data, July – December for instance, the modeled emission reductions over this 6 month period would be compared to the total metered biogas destroyed over the same six month

[16] According to this protocol, non-BCS-related sources means manure management system components (system component 'S') other than the biogas control system and the BCS effluent pond (if used).

period, and the lesser of the two values would be used as the total methane emission reduction quantity for this 6 month period.

Equation 5.10 below details the metered methane destruction calculation.

Equation 5.10. Metered Methane Destruction

$$CH_{4,destroyed} = \sum_{months} (CH_{4,meter} \times BDE_{i,weighted}) \times 21$$

Where,

			Units
$CH_{4,destroyed}$	=	Aggregated quantity of methane collected and destroyed during the reporting period	tCO_2e/yr
$CH_{4,meter}$	=	Monthly quantity of methane collected and metered. See Equation 5.6	tCH_4/ month
$BDE_{i,weighted}$	=	Monthly weighted average of all destruction devices used in month i[17] See Equation 5.6	% (as a decimal)
21	=	Global Warming Potential factor of methane to carbon dioxide equivalent	

Determining the methane emission reductions

- If $CH_{4,destroyed}$ is less than ($BE_{CH4} – PE_{CH4}$) as calculated in Equation 5.2 - Equation 5.4 and Equation 5.6 - Equation 5.9 for the reporting period, the methane emission reductions are equal to $CH_{4,destroyed}$
- Otherwise, the methane emission reductions are equal to ($BE_{CH4} – PE_{CH4}$)

5.4 Quantifying Project Baseline and Project Carbon Dioxide Emissions

Carbon dioxide emissions associated with the project baseline or project activities include sources like electricity use by pumps and equipment, fossil fuel generators used to destroy biogas or power pumping systems or milking parlor equipment, flares, tractors that operate in barns or freestalls, on-site manure hauling trucks, or vehicles that transport manure off-site. Any net increase in emissions shall be accounted for. Use Equation 5.11 to calculate the net change in carbon dioxide emissions, or, if it can be demonstrated during verification that project carbon dioxide emissions are estimated to be equal to or less than 5% of the total project baseline emissions of methane, project baseline and project carbon dioxide emissions may be estimated. All estimates or calculations of anthropogenic carbon dioxide emissions within the Offset Project Boundary must be verified and included in GHG emission reduction calculations.

If calculations or estimates indicate that the offset project results in a net decrease in carbon dioxide emissions from grid-delivered electricity, mobile and stationary sources, then for quantification purposes the net change in these emissions must be specified as zero (i.e., $CO_{2,net}$ = 0 in Equation 5.11).

[17] The Offset Project Operator or Authorized Project Designee has the option to use either the default methane destruction efficiencies provided, or site specific methane destruction efficiencies as provided by an ARB approved source test plan, for each of the combustion devices used in the project.

Carbon dioxide emissions from the combustion of biogas are considered biogenic emissions and are excluded from the GHG Assessment Boundary.

Equation 5.11 below calculates the net change in anthropogenic carbon dioxide emissions resulting from the offset project activity.

Equation 5.11. Carbon Dioxide Emission Calculations

$CO_{2,net} = (BE_{CO2MSC} - PE_{CO2MSC})$

Where,

			Units
$CO_{2,net}$	=	Net change in anthropogenic carbon dioxide emissions from electricity consumption and mobile and stationary combustion sources resulting from project activity	tCO_2/yr
BE_{CO2MSC}	=	Total annual baseline carbon dioxide emissions from electricity consumption and mobile and stationary combustion sources (see equation below)	tCO_2/yr
PE_{CO2MSC}	=	Total annual project carbon dioxide emissions from electricity consumption and mobile and stationary combustion sources (see equation below)	tCO_2/yr

All electricity consumption and stationary and mobile combustion are calculated using the equation:

$$CO_{2,MSC} = \left(\sum_c QE_c \times EF_{CO2,e}\right) + \left[\left(\sum_c QF_c \times EF_{CO2,f}\right) \times 0.001\right]$$

Where,

			Units
$CO_{2,MSC}$	=	Anthropogenic carbon dioxide emissions from electricity consumption and mobile and stationary combustion sources	tCO_2
QE_c*	=	Quantity of electricity consumed for each emissions source ‘c’	MWh/yr
$EF_{CO2,e}$	=	CO_2 emission factor *e* for electricity used; see Appendix A for emission factors by eGRID subregion	tCO_2/MWh
$EF_{CO2,f}$	=	Fuel-specific emission factor *f* from Appendix A	kg CO_2/ MMBTU or kg CO_2/ gallon
QF_c	=	Quantity of fuel consumed for each mobile and stationary emission source ‘c’	MMBTU/yr or gallon/yr
0.001	=	Conversion factor from kg to metric tons	

* If total electricity being generated by project activities is > the additional electricity consumption, then QE_c shall not be accounted for in the project emissions and shall be omitted from the equation above.

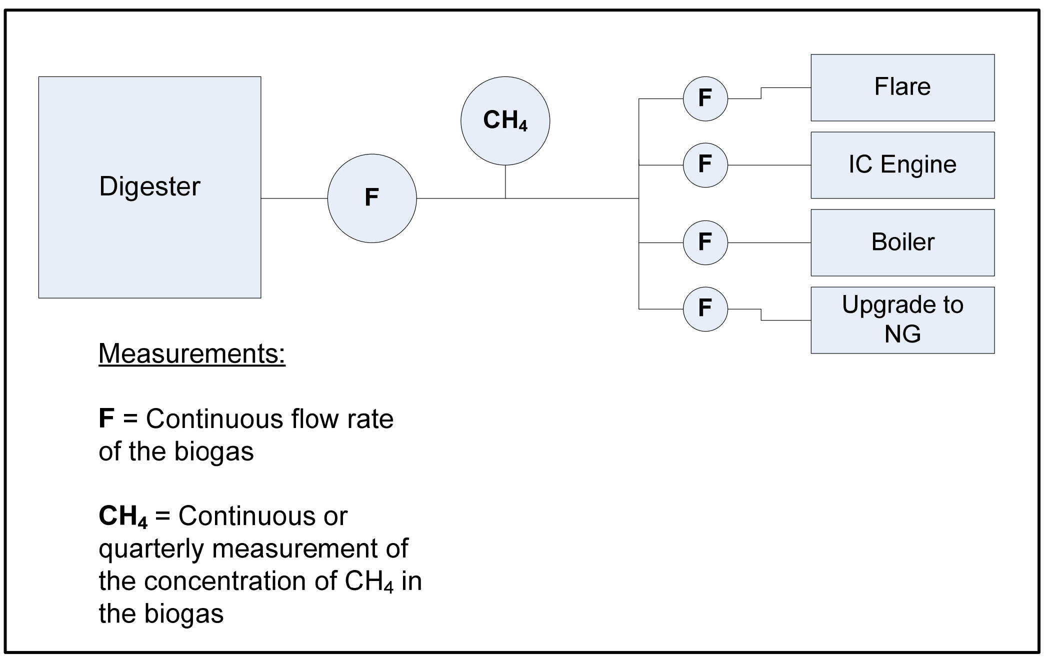
6 Offset Project Documentation and Monitoring Requirements

The Offset Project Operator or Authorized Project Designee is responsible for monitoring the performance of the offset project and operating each component of the biogas collection and destruction system in a manner consistent with the manufacturer's specifications. The methane capture and control system must be monitored with measurement equipment that directly meters:

1. The total flow of biogas, measured continuously and recorded every 15 minutes or totalized and recorded at least daily, adjusted for temperature and pressure, prior to delivery to the destruction device(s)
2. The flow of biogas delivered to each destruction device[18], measured continuously and recorded every 15 minutes or totalized and recorded at least daily, adjusted for temperature and pressure
3. The fraction of methane in the biogas, measured with a continuous analyzer or, alternatively, with quarterly measurements

Flow data must be corrected for temperature and pressure at 60^{o}F and 1 atm, either internally or by following Equation 5.6.

Figure 6.1 represents the suggested arrangement of the biogas flow meters and methane concentration metering equipment.



Note: The number of flow meters must be sufficient to track the total flow as well as the flow to each combustion device. The above example includes one more flow meter than would be necessary to achieve this objective.

[18] A single-meter may be used for multiple, identical destruction devices. In this instance, methane destruction in these units will be eligible only if all these units are monitored to be operational.

Operational activity of the destruction devices shall be monitored and documented at least hourly to ensure actual methane destruction. GHG reductions will not be accounted for or credited during periods in which the destruction device is not operational.

If for any reason the destruction device or the operational monitoring equipment (for example, the thermal coupler on the flare or an engine) is inoperable, all metered biogas going to the particular device shall be assumed to be released to atmosphere during the period of inoperability. During the period of inoperability, the destruction efficiency of the device must be assumed to be zero. In Equation 5.10, the monthly biogas destruction efficiency (BDE) value shall be adjusted accordingly. See Box 6.1 for an example BDE adjustment.

Box 6.1. Example BDE Adjustment

As an example, consider a situation where the primary destruction device is an open flare with a BDE of 96%, and it is found to be inoperable for a period of 5 days of a 30 day month. Assume that the total flow of biogas to the flare for the month is 3,000,000 scf, and that the total flow recorded for the 5 day period of inoperability is 500,000 SCF. In this case the monthly BDE would be adjusted as follows:

*BDE =[(0.96*2,500,000) +(0.0 * 500,000)] / 3,000,000 = 80%*

6.1 Biogas Measurement Instrument QA/QC – Quantification Methodology

All gas flow meters[19] and continuous methane analyzers must be:

- Cleaned and inspected on a quarterly basis, with the activities performed and "as found/as left condition" of the equipment documented

- Field checked by a trained professional for calibration accuracy with the percent drift documented, using either a portable instrument (such as a pitot tube)[20] or manufacturer specifications, at the end of but no more than two months prior to the end date of the reporting period[21]

- Calibrated by the manufacturer or a certified calibration service per manufacturer's specifications or every 5 years, whichever is more frequent

If the field check on a piece of equipment reveals accuracy outside of a +/- 5% threshold, calibration by the manufacturer or a certified service provider is required for that piece of equipment.

[19]Field checks and calibrations of flow meters shall assess the volumetric output of the flow meter.
[20]It is recommended that a professional third party calibration service be hired to perform flow meter field checks if using pitot tubes or other portable instruments, as these types of devices require professional training in order to achieve accurate readings.
[21]Instead of performing field checks, the Offset Project Operators or Authorized Project Designees may instead have equipment calibrated by the manufacturer or a certified calibration service per manufacturer's specifications, at the end of but no more than two months prior to the end date of the reporting period to meet this requirement.

For the interval between the last successful field check and any calibration event confirming accuracy below the +/- 5% threshold, all data from that meter or analyzer must be scaled according to the following procedure. These adjustments must be made for the entire period from the last successful field check until such time as the meter is properly calibrated.

- For calibrations that indicate the flow meter was outside the +/- 5% accuracy threshold, the project developer shall estimate total emission reductions using i) the metered values without correction, and ii) the metered values adjusted based on the greatest calibration drift recorded at the time of calibration. The lower of the two emission reduction estimates shall be reported as the scaled emission reduction estimate.

For example, if a project conducts field checks quarterly during a year-long reporting period, only three months of data will be subject at any one time to the penalties above. However, if the Offset Project Operator or Authorized Project Designee feels confident that the meter does not require field checks or calibration on a greater than annual basis, then failed events will accordingly require the penalty to be applied to the entire year's data. Frequent calibration may minimize the total accrued drift (by zeroing out any error identified), and result in smaller overall deductions.

In order to provide flexibility in verification, data monitored up to two months after a field check may be verified. As such, the end date of the reporting period must be no more than two months after the latest successful field check.

If a portable instrument is used (such as a handheld methane analyzer), the portable instrument shall be calibrated at least annually by the manufacturer or at an ISO 17025 accredited laboratory.

6.1.1 Missing Data – Quantification Methodology

In situations where the flow rate or methane concentration monitoring equipment is missing data, the Offset Project Operator or Authorized Project Designee shall apply the data substitution methodology provided in Appendix B. If for any reason the destruction device monitoring equipment is inoperable (for example, the thermal coupler on the flare or an engine), no emission reductions can be credited for the period of inoperability.

6.2 Monitoring Parameters – Quantification Methodology

Provisions for monitoring other variables to calculate project baseline and project emissions are provided in Table 6.1. The parameters are organized by general project factors and then by the calculation methods.

Table 6.1. Project Monitoring Parameters

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
General Project Parameters					
Regulations	Offset Project Operator and Authorized Project Designee compliance with regulatory requirements relating to the manure digester offset project	Environmental regulations	n/a	Annually	Information used to: 1) To demonstrate ability to meet the Legal Requirement Test – where regulation would require the installation of a BCS. 2) To demonstrate compliance with associated regulatory requirements and environmental assessments as required by the Regulation, e.g. criteria pollutant and effluent discharge limits. *Verifier:* Determine regulatory agencies responsible for regulating livestock operation; Review regulations, environmental assessments and site permits pertinent to livestock operation
L	Type of livestock categories on the farm	Livestock categories	o	Monthly	Select from list provided in Appendix A, Table A.2. *Verifier:* Review herd management software; Conduct site visit; Interview operator.
MS_L	Fraction of manure from each livestock category managed in the baseline waste handling system 'S'	Percent (%)	o	Annually	Reflects the percent of waste handled by the system components 'S' pre-project. Applicable to the entire operation. Within each livestock category, the sum of MS values (for all treatment/storage systems) equals 100%. Select from list provided in Appendix A, Table A.1. *Verifier:* Conduct site visit; Interview operator; Review baseline scenario documentation.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
P_L	Average number of animals for each livestock category	Population (# head)	o	Monthly	*Verifier*: Review herd management software; Review local air and water quality agency reporting submissions, if available (e.g. in CA, dairies with more than 500 cows report farm information to ARB).
$Mass_L$	Average live weight by livestock category	kg	o, r	Monthly	From operating records, or if on-site data is unavailable, from lookup table (Appendix A Table A.2). *Verifier*: Conduct site visit; Interview livestock operator; Review average daily gain records, operating records.
T	Average monthly temperature at location of the operation	^oC	m/o	Monthly	Used for van't Hoff Calculation and for choosing appropriate MCF value. *Verifier*: Review temperature records obtained from weather service.
Baseline Methane Calculation Variables					
$B_{0,L}$	Maximum methane producing capacity for manure by livestock category	(m^3 CH_4/kgVS)	r	Annually	From Appendix A, Table A.3. *Verifier*: Verify correct value from table used.
MCF_S	Methane conversion factor for manure management system component 'S'	Percent (%)	r	Annually	From Appendix A. Differentiate by livestock category *Verifier*: Verify correct value from table used.
VS_L	Daily volatile solid production	(kg/animal/day)	r, c	Annually	Appendix A, Table A.3 and Table A.5a-d; see Box 5.1 to convert units from (kg/day/1000kg) to (kg/animal/day). *Verifier*: Ensure appropriate year's table is used; Review data units.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
VS_{avail}	Monthly volatile solids available for degradation in each anaerobic storage system, for each livestock category	kg	c, o	Monthly	Calculated value from operating records. *Verifier*: Ensure proper calculations; Review operating records.
VS_{deg}	Monthly volatile solids degraded in each anaerobic storage system, for each livestock category	kg	c, o	Monthly	Calculated value from operating records. *Verifier*: Ensure proper calculations; Review operating records.
f	van't Hoff-Arrhenius factor	n/a	c	Monthly	The proportion of volatile solids that are biologically available for conversion to methane based on the monthly temperature of the system. *Verifier*: Ensure proper calculations; Review calculation; Review temperature data.
Project Methane Calculation Variables – BCS + Effluent Pond					
$CH_{4,\ destroyed}$	Aggregated amount of methane collected and destroyed in the BCS	Metric tons of CH_4	c, m	Annually	Calculated as the collected methane times the destruction efficiency (see the '$CH_{4,meter}$' and 'BDE' parameters below) *Verifier:* Review meter reading data, confirm proper operation of the destruction device(s); Ensure data is accurately aggregated over the correct amount of time.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
$CH_{4,meter}$	Amount of methane collected and metered in BCS	Metric tons of CH_4 (tCH_4)	c, m	Monthly	Calculated from biogas flow and methane fraction meter readings (See 'F' and '$CH_{4,conc}$' parameters below). *Verifier*: Review meter reading data; Confirm proper operation and maintenance in accordance with the manufacturer's specifications; Confirm meter calibration data.
F	Monthly volume of biogas from digester to destruction devices	scf/month	m	Continuously, aggregated monthly	Measured continuously from flow meter and recorded every 15 minutes or totalized and recorded at least once daily. Data to be aggregated monthly. *Verifier*: Review meter reading data; Confirm proper aggregation of data; Confirm proper operation in accordance with the manufacturer's specifications; Confirm meter calibration data.
T	Temperature of the biogas	°R (Rankine)	m	Continuously, averaged monthly	Measured to normalize volume flow of biogas to STP. No separate monitoring of temperature is necessary when using flow meters that automatically measure temperature and pressure, expressing biogas volumes in normalized cubic feet.
P	Pressure of the biogas	atm	m	Continuously, averaged monthly	Measured to normalize volume flow of biogas to STP. No separate monitoring of pressure is necessary when using flow meters that automatically measure temperature and pressure, expressing biogas volumes in normalized cubic feet.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
$CH_{4,conc}$	Methane concentration of biogas	Percent (%)	m	Quarterly	Use a direct sampling approach that yields a value with at least 95% confidence. Samples to be taken at least quarterly. Calibrate monitoring instrument in accordance with the manufacturer's specifications. *Verifier*: Review meter reading data; Confirm proper operation in accordance with the manufacturer's specifications.
BDE	Methane destruction efficiency of destruction device(s)	Percent (%)	r, c	Monthly	Reflects the actual efficiency of the system to destroy captured methane gas – accounts for different destruction devices. See Equation 5.6. *Verifier*: Confirm evidence of proper and continuous operation in accordance with the manufacturer's specifications.
BCE	Biogas capture efficiency of the anaerobic digester, accounts for gas leaks.	Percent (%)	r	Annually	Use default value from Table A.4 *Verifier:* Review operation and maintenance records to ensure proper functionality of BCS.
VS_{ep}	Average daily volatile solid of digester effluent to effluent pond	kg/day	c	Annually	If project uses effluent pond, equals 30% of the average daily VS entering the digester (From ACM0010 -V2 Annex I). *Verifier*: Review VS_{ep} calculations.
$MS_{L,BCS}$	Fraction of manure from each livestock category managed in the BCS	Percent (%)	o	Annually	Used to determine the total VS entering the digester. The percentage should be tracked in operational records. *Verifier*: Check operational records and conduct site visit.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
Bo_{ep}	Maximum methane producing capacity for manure to effluent pond	(m^3 CH_4/kgVS)	c	Annually	An average of the Bo_{ep} value of the operation's livestock categories that contributes manure to the BCS. *Verifier:* Check calculation.
MCF_{ep}	Methane conversion factor for BCS effluent pond	Percent (%)	r	Annually	Referenced from Appendix A. The Offset Project Operators or Authorized Project Designee should use the *liquid slurry* MCF value. *Verifier*: Verify value from table.
MS_{BCS}	The maximum biogas storage of the BCS system	scf	r	Annually	Obtained from digester system design plans. Necessary to quantify the release of methane to the atmosphere due to an uncontrolled venting event.
F_{pw}	The average flow of biogas from the digester for the entire week prior to the uncontrolled venting event	scf/day	m	Weekly	The average flow of biogas can be determined from the daily records from the previous week.
t	The number of days of the month that biogas is venting uncontrolled from the project's BCS.	Days	m, o	Monthly	The number of days of the month that biogas is venting uncontrolled from the project's BCS.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
Project Methane Calculation Variables – Non-BCS Related Sources					
$MS_{L,S}$	Fraction of manure from each livestock category managed in non-anaerobic manure management system component 'S'	Percent (%)	o	Monthly	Based on configuration of manure management system, differentiated by livestock category. *Verifier*: Conduct site visit; Interview operator.
$EF_{CH4,L}$ *(nBCSs)*	Methane emission factor for the livestock population from non-BCS-related sources	($kgCH_4$/head/year)	c	Annually	Emission factor for all non-BCS storage systems, differentiated by livestock category. See Equation 5.9. *Verifiers*: Review calculation, operation records.
Baseline and Project CO_2 Calculation Variables					
$EF_{CO2,f}$	Fuel-specific emission factor for mobile and stationary combustion sources	kg CO_2/MMBTU or kg CO_2/gallon	r	Annually	Refer to Appendix A for emission factors. If biogas produced from digester is used as an energy source, the emission factor is zero. *Verifier*: Review emission factors.
QF_c	Quantity of fuel used for mobile/stationary combustion sources	MMBTU/year or gallon/year	o, c	Annually	Fuel used by project for manure collection, transport, treatment/storage, and disposal, and stationary combustion sources including supplemental fossil fuels used in combustion device. *Verifier:* Review operating records and quantity calculation.
$EF_{CO2,e}$	Emission factor for electricity used by project	tCO2/MWh	r	Annually	Refer to Appendix A for emission factors. If biogas produced from digester is used to generate electricity consumed, the emission factor is zero. *Verifier*: Review emission factors.
QE_c	Quantity of electricity consumed	MWh/year	o, c	Annually	Electricity used by project for manure collection, transport, treatment/storage, and disposal. *Verifier:* Review operating records and quantity calculation.

7 Reporting Parameters

General requirements for reprinting and record retention are included in the Regulation. This section includes additional requirements specific to this protocol. A priority of this protocol is to facilitate consistent and transparent information disclosure by Offset Project Operators or Authorized Project Designees.

7.1 Annual Reporting Requirements

The Offset Project Operator~~s~~ or Authorized Project Designee~~s~~ must submit an Offset Project Data Report according to the requirements in the Regulation. The Offset Project Data Report must include the information listed in the Regulation and this protocol and cover a single Reporting Period. See the Regulation and Appendix D for specific requirements.

7.2 Document Retention

The Offset Project Operator~~s~~ or Authorized Project Designee~~s~~ is required to keep all documentation and information outlined in the Regulation and this protocol. Record retention requirements are set forth in the Regulation.

System Information that should be retained by the Offset Project Operator or Authorized Project Designee should include, but is not limited to:

- All data inputs for the calculation of the project baseline emissions and project emission reductions
- CO_2e annual tonnage calculations
- Relevant sections of the BCS operating permits
- BCS information (installation dates, equipment list, etc.)
- Biogas flow meter information (model number, serial number, manufacturer’s calibration procedures)
- Cleaning and inspection records for all biogas meters
- Field check results for all biogas meters
- Calibration results for all biogas meters
- Methane monitor information (model number, serial number, calibration procedures)
- Biogas flow data (for each flow meter)
- Biogas temperature and pressure readings (only if flow meter does not correct for temperature and pressure automatically)
- Methane concentration monitoring data
- Destruction device monitoring data (for each destruction device)
- Destruction device, methane monitor and biogas flow monitor information (model numbers, serial numbers, calibration procedures)
- All maintenance records relevant to the BCS, monitoring equipment, and destruction devices

If using a calibrated portable gas analyzer for CH_4 content measurement:

- Date, time, and location of methane measurement

- Methane content of biogas (% by volume) for each measurement
- Methane measurement instrument type and serial number
- Date, time, and results of instrument calibration
- Corrective measures taken if instrument does not meet performance specifications

See the Regulation for record-keeping requirements.

7.3 Verification Cycle

Offset project verification schedules are set forth in the Regulation.

8 Glossary of Terms[22]

Anaerobic	Pertaining to or caused by the absence of oxygen.
Biogas	Gas that is produced from the breakdown of organic material in the absence of oxygen. Biogas is produced in processes including, but not limited to, anaerobic digestion, anaerobic decomposition, and thermochemical decomposition. These processes are applied to biodegradable biomass materials, such as manure, sewage, municipal solid waste, green waste, and waste from energy crops, to produce landfill gas, digester gas, and other forms of biogas.
Biogas control system (BCS)	A system designed to capture and destroy the biogas that is produced by the anaerobic treatment and/or storage of livestock manure and/or other organic material. Commonly referred to as a "digester."
Biogenic CO_2 emissions	CO_2 emissions resulting from the combustion and/or aerobic decomposition of organic matter. Biogenic emissions are considered to be a natural part of the carbon cycle, as opposed to anthropogenic emissions.

[22] For terms not defined in this section, the definitions in the Regulation apply.

Emission factor	A unique value for determining an amount of a greenhouse gas emitted for a given quantity of activity data (e.g. metric tons of carbon dioxide emitted per barrel of fossil fuel burned).
Flare	A destruction device that uses an open flame to burn combustible gases with combustion air provided by uncontrolled ambient air around the flame.
Livestock project	Installation of a biogas control system that, in operation, causes a decrease in GHG emissions from the baseline scenario through destruction of the methane component of biogas.
Methane (CH_4)	A potent GHG with a GWP of 21, consisting of a single carbon atom and four hydrogen atoms.
MMBtu	One million British thermal units.
Mobile combustion	Emissions from the transportation of materials, products, waste, and employees resulting from the combustion of fuels in company owned or controlled mobile combustion sources (e.g. cars, trucks, tractors, dozers, etc.).
Stationary combustion source	A stationary source of emissions from the production of electricity, heat, or steam, resulting from combustion of fuels in boilers, furnaces, turbines, kilns, and other facility equipment.
van't Hoff-Arrhenius factor	The proportion of volatile solids that are biologically available for conversion to methane based on the monthly temperature of the system.

9 References

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Appendix A Emission Factor Tables – Quantification Methodology

Table A.1. Manure Management System Components

System	Definition
Pasture/Range/ Paddock	The manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed.
Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
Solid storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
Dry lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year.
Uncovered anaerobic lagoon	A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilize fields.
Pit storage below animal confinements	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year.
Anaerobic digester	Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel or covered lagoon. Digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CO2 and CH4, which is captured and flared or used as a fuel.
Burned for fuel	The dung and urine are excreted on fields. The sun dried dung cakes are burned for fuel.
Cattle and Swine deep bedding	As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system also is known as a bedded pack manure management system and may be combined with a dry lot or pasture.
Composting – In-vessel*	Composting, typically in an enclosed channel, with forced aeration and continuous mixing.
Composting – Static pile*	Composting in piles with forced aeration but no mixing.
Composting – Intensive windrow*	Composting in windrows with regular (at least daily) turning for mixing and aeration.
Composting – Passive windrow*	Composting in windrows with infrequent turning for mixing and aeration.
Aerobic treatment	The biological oxidation of manure collected as a liquid with either forced or natural aeration. Natural aeration is limited to aerobic and facultative ponds and wetland systems and is due primarily to photosynthesis. Hence, these systems typically become anoxic during periods without sunlight.

*Composting is the biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production.

Table A.2. Livestock Categories and Typical Average Mass (TAM)

Livestock Category (L)	Livestock Typical Average Mass (TAM) in kg
Dairy cows (on feed)	604
Non-milking dairy cows (on feed)	684
Heifers (on feed)	476
Bulls (grazing)	750
Calves (grazing)	118
Heifers (grazing)	420
Cows (grazing)	533
Nursery swine	12.5
Grow/finish swine	70
Breeding swine	198

Table A.3. Volatile Solids and Maximum Methane Potential by Livestock Category

Livestock category (L)	VS_L (kg/day/1,000 kg mass)	$B_{o,L}$ (m^3 CH_4/kg VS added)
Dairy cows	See Appendix A, Table A.5.	0.24
Non-milking dairy cows	5.56	0.24
Heifers	See Appendix A, Table A.5.	0.17
Bulls (grazing)	6.04	0.17
Calves (grazing)	6.41	0.17
Heifers (grazing)	See Appendix A, Table A.5.	0.17
Cows (grazing)	See Appendix A, Table A.5.	0.17
Nursery swine	8.89	0.48
Grow/finish swine	5.36	0.48
Breeding swine	2.71	0.35

Table A.4. Biogas Collection Efficiency (BCE) by Digester Type

Digester Type	Cover Type	Biogas Collection Efficiency (BCE) as a decimal
Covered Anaerobic Lagoon	Bank-to-Bank, impermeable	0.95 (95%)
Complete mix, plug flow, or fixed film digester	Enclosed vessel	0.98 (98%)

Table A.5. 2007 Volatile Solid (VS) Default Values for Dairy Cows, Heifers, Heifers-Grazing and Cows-Grazing by State (kg/day/1000 kg mass)

State	VS Dairy Cow	VS Heifer	VS Heifer –Grazing	VS Cows-Grazing
Alabama	8.02	7.42	7.82	7.02
Alaska	8.18	7.42	10.08	9.02
Arizona	10.55	7.42	10.41	9.02
Arkansas	7.11	8.22	7.87	7.00
California	8.98	7.42	7.92	6.85
Colorado	9.11	7.42	7.65	6.46
Connecticut	8.22	6.70	7.66	6.90
Delaware	7.60	6.70	7.89	6.90
Florida	8.40	7.42	7.77	7.02
Georgia	8.80	7.42	7.89	7.02
Hawaii	7.52	7.42	10.30	9.02
Idaho	10.34	7.42	10.80	9.02
Illinois	8.08	7.42	8.11	6.91
Indiana	8.49	7.42	8.01	6.91
Iowa	8.43	7.42	8.20	6.91
Kansas	8.35	7.42	7.68	6.46
Kentucky	7.70	7.42	7.97	7.02
Louisiana	6.88	8.22	7.75	7.00
Maine	7.88	6.70	7.66	6.90
Maryland	7.94	6.70	7.85	6.90
Massachusetts	7.69	6.70	7.78	6.90
Michigan	9.05	7.42	7.95	6.91
Minnesota	8.13	7.42	8.05	6.91
Mississippi	8.09	7.42	7.85	7.02
Missouri	7.21	7.42	7.88	6.91
Montana	8.05	7.42	7.21	6.46
Nebraska	7.98	7.42	7.64	6.46
Nevada	9.75	7.42	10.5	9.02
New Hampshire	8.58	6.70	7.78	6.90
New Jersey	7.64	6.70	7.92	6.90
New Mexico	10.03	7.42	10.64	9.02
New York	8.24	6.70	7.99	6.90
North Carolina	9.07	7.42	7.85	7.02
North Dakota	7.29	7.42	7.40	6.46
Ohio	7.94	7.42	7.94	6.91
Oklahoma	8.04	8.22	8.09	7.00
Oregon	9.49	7.42	10.61	9.02
Pennsylvania	8.27	6.70	8.03	6.90
Rhode Island	7.56	6.70	7.66	6.90
South Carolina	8.73	7.42	7.85	7.02
South Dakota	8.24	7.42	7.50	6.46
Tennessee	8.21	7.42	7.92	7.02
Texas	9.19	8.22	8.20	7.00
Utah	9.75	7.42	10.58	9.02
Vermont	7.95	6.70	7.92	6.90
Virginia	8.64	7.42	7.95	7.02
Washington	10.54	7.42	10.87	9.02
West Virginia	7.29	6.70	7.82	6.90
Wisconsin	8.25	7.42	7.88	6.91
Wyoming	8.13	7.42	7.34	6.46

Table A.6.a IPCC 2006 Methane Conversion Factors by Manure Management System Component/Methane Source 'S'

MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS																					
System[a]		**MCFs by average annual temperature (°C)**																			**Source and comments**
		Cool					**Temperate**											**Warm**			
		≤ 10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**≥ 28**	
Pasture/Range/Paddock		1.0%					1.5%											2.0%			Judgment of IPCC Expert Group in combination with Hashimoto and Steed (1994).
Daily spread		0.1%					0.5%											1.0%			Hashimoto and Steed (1993).
Solid storage		2.0%					4.0%											5.0%			Judgment of IPCC Expert Group in combination with Amon et al. (2001), which shows emissions of approximately 2% in winter and 4% in summer. Warm climate is based on judgment of IPCC Expert Group and Amon et al. (1998).
Dry lot		1.0%					1.5%											2.0%			Judgment of IPCC Expert Group in combination with Hashimoto and Steed (1994).
Liquid / Slurry	With natural crust cover	10%	11%	13%	14%	15%	17%	18%	20%	22%	24%	26%	29%	31%	34%	37%	41%	44%	48%	50%	Judgment of IPCC Expert Group in combination with Mangino et al. (2001) and Sommer (2000). The estimated reduction due to the crust cover (40%) is an annual average value based on a limited data set and can be highly variable dependent on temperature, rainfall, and composition. When slurry tanks are used as fed-batch storage/digesters, MCF should be calculated according to Formula 1.
	W/out natural crust cover	17%	19%	20%	22%	25%	27%	29%	32%	35%	39%	42%	46%	50%	55%	60%	65%	71%	78%	80%	Judgment of IPCC Expert Group in combination with Mangino et al. (2001). When slurry tanks are used as fed-batch storage/digesters, MCF should be calculated according to Formula 1.

Table A.6.a Continued

MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS																					
System[a]		MCFs by average annual temperature (°C)																			Source and comments
		Cool					Temperate											Warm			
		≤ 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	≥ 28	
Uncovered anaerobic lagoon		66%	68%	70%	71%	73%	74%	75%	76%	77%	77%	78%	78%	78%	79%	79%	79%	79%	80%	80%	Judgment of IPCC Expert Group in combination with Mangino et al. (2001). Uncovered lagoon MCFs vary based on several factors, including temperature, retention time, and loss of volatile solids from the system (through removal of lagoon effluent and/or solids).
Pit storage below animal confinements	< 1 month	3%					3%											3%			Judgment of IPCC Expert Group in combination with Moller et al. (2004) and Zeeman (1994). Note that the ambient temperature, not the stable temperature is to be used for determining the climatic conditions. When pits used as fed-batch storage/digesters, MCF should be calculated according to Formula 1.
	> 1 month	17%	19%	20%	22%	25%	27%	29%	32%	35%	39%	42%	46%	50%	55%	60%	65%	71%	78%	80%	Judgment of IPCC Expert Group in combination with Mangino et al. (2001). Note that the ambient temperature, not the stable temperature is to be used for determining the climatic conditions. When pits used as fed-batch storage/digesters, MCF should be calculated according to Formula 1.

Table A.6.a Continued

MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS																					
System[a]		**MCFs by average annual temperature (°C)**																			**Source and comments**
		Cool					**Temperate**											**Warm**			
		≤ 10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**≥ 28**	
Anaerobic digester		0-100%					0-100%											0-100%			Should be subdivided in different categories, considering amount of recovery of the biogas, flaring of the biogas and storage after digestion. Calculation with Formula 1.
Burned for fuel		10%					10%											10%			Judgment of IPCC Expert Group in combination with Safley et al. (1992).
Cattle and Swine deep bedding	< 1 month	3%					3%											30%			Judgment of IPCC Expert Group in combination with Moller et al. (2004). Expect emissions to be similar, and possibly greater, than pit storage, depending on organic content and moisture content.
Cattle and Swine deep bedding (cont.)	> 1 month	17%	19%	20%	22%	25%	27%	29%	32%	35%	39%	42%	46%	50%	55%	60%	65%	71%	78%	90%	Judgment of IPCC Expert Group in combination with Mangino et al. (2001).
Composting - In-vessel[b]		0.5%					0.5%											0.5%			Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are less than half of solid storage. Not temperature dependant.
Composting - Static pile[b]		0.5%					0.5%											0.5%			Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are less than half of solid storage. Not temperature dependant.

Table A.6.a Continued

Composting - Intensive windrow[b]	0.5%	1.0%	1.5%	Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are slightly less than solid storage. Less temperature dependant.
Composting – Passive windrow[b]	0.5%	1.0%	1.5%	Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are slightly less than solid storage. Less temperature dependant.
Aerobic treatment	0%	0%	0%	MCFs are near zero. Aerobic treatment can result in the accumulation of sludge which may be treated in other systems. Sludge requires removal and has large VS values. It is important to identify the next management process for the sludge and estimate the emissions from that management process if significant.

a Definitions for manure management systems are provided in Table A.1.
b Composting is the biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production.

Table A.6.b. Biogas Destruction Efficiency Default Values by Destruction Device

If available, the actual source test results for the measured methane destruction efficiency shall be used in place of the default methane destruction efficiency. Otherwise, the Offset Project Operator~~s~~ or Authorized Project Designee~~s~~ has the option to use either the default methane destruction efficiencies provided, or the site specific methane destruction efficiencies as provided by a state or local agency accredited source test service provider, for each of the destruction devices used in the project case performed on an annual basis.

Biogas Destruction Device	Biogas Destruction Efficiency (BDE)*
Open Flare	0.96
Enclosed Flare	0.995
Lean-burn Internal Combustion Engine	0.936
Rich-burn Internal Combustion Engine	0.995
Boiler	0.98
Microturbine or large gas turbine	0.995
Upgrade and use of gas as CNG/LNG fuel	0.95
Upgrade and injection into natural gas transmission and distribution pipeline	0.98

Table A.7. CO_2 Emission Factors for Fossil Fuel Use

Fuel Type	Heat Content	Carbon Content (Per Unit Energy)	Fraction Oxidized	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Coal and Coke	**MMBtu / Short ton**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / Short ton**
Anthracite Coal	25.09	28.26	1.00	103.62	2,599.83
Bituminous Coal	24.93	25.49	1.00	93.46	2,330.04
Sub-bituminous Coal	17.25	26.48	1.00	97.09	1,674.86
Lignite	14.21	26.30	1.00	96.43	1,370.32
Unspecified (Residential/ Commercial)	22.05	26.00	1.00	95.33	2,102.29
Unspecified (Industrial Coking)	26.27	25.56	1.00	93.72	2,462.12
Unspecified (Other Industrial)	22.05	25.63	1.00	93.98	2,072.19
Unspecified (Electric Utility)	19.95	25.76	1.00	94.45	1,884.53
Coke	24.80	31.00	1.00	113.67	2,818.93
Natural Gas (By Heat Content)	**Btu / Standard cubic foot**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / Standard cub. ft.**
975 to 1,000 Btu / Std cubic foot	975 – 1,000	14.73	1.00	54.01	Varies
1,000 to 1,025 Btu / Std cubic foot	1,000 – 1,025	14.43	1.00	52.91	Varies
1,025 to 1,050 Btu / Std cubic foot	1,025 – 1,050	14.47	1.00	53.06	Varies
1,050 to 1,075 Btu / Std cubic foot	1,050 – 1,075	14.58	1.00	53.46	Varies
1,075 to 1,100 Btu / Std cubic foot	1,075 – 1,100	14.65	1.00	53.72	Varies
Greater than 1,100 Btu / Std cubic foot	> 1,100	14.92	1.00	54.71	Varies
Weighted U.S. Average	1,029	14.47	1.00	53.06	0.0546
Petroleum Products	**MMBtu / Barrel**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / gallon**
Asphalt & Road Oil	6.636	20.62	1.00	75.61	11.95
Aviation Gasoline	5.048	18.87	1.00	69.19	8.32
Distillate Fuel Oil (#1, 2 & 4)	5.825	19.95	1.00	73.15	10.15
Jet Fuel	5.670	19.33	1.00	70.88	9.57
Kerosene	5.670	19.72	1.00	72.31	9.76
LPG (average for fuel use)	3.849	17.23	1.00	63.16	5.79
Propane	3.824	17.20	1.00	63.07	5.74
Ethane	2.916	16.25	1.00	59.58	4.14
Isobutene	4.162	17.75	1.00	65.08	6.45
n-Butane	4.328	17.72	1.00	64.97	6.70
Lubricants	6.065	20.24	1.00	74.21	10.72
Motor Gasoline	5.218	19.33	1.00	70.88	8.81
Residual Fuel Oil (#5 & 6)	6.287	21.49	1.00	78.80	11.80
Crude Oil	5.800	20.33	1.00	74.54	10.29
Naphtha (<401 deg. F)	5.248	18.14	1.00	66.51	8.31
Natural Gasoline	4.620	18.24	1.00	66.88	7.36
Other Oil (>401 deg. F)	5.825	19.95	1.00	73.15	10.15
Pentanes Plus	4.620	18.24	1.00	66.88	7.36
Petrochemical Feedstocks	5.428	19.37	1.00	71.02	9.18
Petroleum Coke	6.024	27.85	1.00	102.12	14.65
Still Gas	6.000	17.51	1.00	64.20	9.17
Special Naphtha	5.248	19.86	1.00	72.82	9.10
Unfinished Oils	5.825	20.33	1.00	74.54	10.34
Waxes	5.537	19.81	1.00	72.64	9.58

Source: EPA Climate Leaders, Stationary Combustion Guidance (2008), Table B-2 except:
Default CO_2 emission factors (per unit energy) are calculated as: Carbon Content × Fraction Oxidized × 44/12.
Default CO_2 emission factors (per unit mass or volume) are calculated as: Heat Content x Carbon Content × Fraction Oxidized × 44/12× Conversion Factor (if applicable). Heat content factors are based on higher heating values (HHV).

Table A.8. CO_2 Electricity Emission Factors

eGRID subregion acronym	eGRID subregion name	Annual output emission rates	
		(lb CO_2/MWh)	(metric ton CO_2/MWh)*
AKGD	ASCC Alaska Grid	1,232.36	0.559
AKMS	ASCC Miscellaneous	498.86	0.226
AZNM	WECC Southwest	1,311.05	0.595
CAMX	WECC California	724.12	0.328
ERCT	ERCOT All	1,324.35	0.601
FRCC	FRCC All	1,318.57	0.598
HIMS	HICC Miscellaneous	1,514.92	0.687
HIOA	HICC Oahu	1,811.98	0.822
MROE	MRO East	1,834.72	0.832
MROW	MRO West	1,821.84	0.826
NEWE	NPCC New England	927.68	0.421
NWPP	WECC Northwest	902.24	0.409
NYCW	NPCC NYC/Westchester	815.45	0.370
NYLI	NPCC Long Island	1,536.80	0.697
NYUP	NPCC Upstate NY	720.80	0.327
RFCE	RFC East	1,139.07	0.517
RFCM	RFC Michigan	1,563.28	0.709
RFCW	RFC West	1,537.82	0.698
RMPA	WECC Rockies	1,883.08	0.854
SPNO	SPP North	1,960.94	0.889
SPSO	SPP South	1,658.14	0.752
SRMV	SERC Mississippi Valley	1,019.74	0.463
SRMW	SERC Midwest	1,830.51	0.830
SRSO	SERC South	1,489.54	0.676
SRTV	SERC Tennessee Valley	1,510.44	0.685
SRVC	SERC Virginia/Carolina	1,134.88	0.515

Source: U.S. EPA eGRID2007, Version 1.1 Year 2005 GHG Annual Output Emission Rates (December 2008).
* Converted from lbs CO_2/MWh to metric tons CO_2/MWH using conversion factor 1 metric ton = 2,204.62 lbs.

Appendix B Data Substitution – Quantification Methodology

This appendix shows how to calculate GHG emission reductions when data integrity has been compromised either due to missing data points or a failed calibration. No data substitution is permissible for equipment such as thermocouples which monitor the proper functioning of destruction devices. Rather, the methodologies presented below are to be used only for the methane concentration and flow metering parameters.

B.1 Missing Data

ARB expects that offset projects will have continuous, uninterrupted data for the entire verification period. However, ARB recognizes that unexpected events or occurrences may result in brief data gaps.

The following data substitution methodology may be used only for flow and methane concentration data gaps that are discrete, limited, non-chronic, and due to unforeseen circumstances. Data substitution can only be applied to methane concentration *or* flow readings, but not both simultaneously. If data is missing for both parameters, no reductions can be credited.

Further, substitution may only occur when two other monitored parameters corroborate proper functioning of the destruction device and system operation within normal ranges. These two parameters must be demonstrated as follows:

1. Proper functioning can be evidenced by thermocouple readings for flares or engines, energy output for engines, etc.
2. For methane concentration substitution, flow rates during the data gap must be consistent with normal operation.
3. For flow substitution, methane concentration rates during the data gap must be consistent with normal operations.

If corroborating parameters fail to demonstrate any of these requirements, no substitution may be employed. If the requirements above can be met, the following substitution methodology may be applied:

Duration of Missing Data	Substitution Methodology
Less than six hours	Use the average of the four hours immediately before and following the outage
Six to 24 hours	Use the 90% lower or upper confidence limit of the 24 hours prior to and after the outage, whichever results in greater conservativeness
One to seven days	Use the 95% lower or upper confidence limit of the 72 hours prior to and after the outage, whichever results in greater conservativeness
Greater than one week	No data may be substituted and no credits may be generated

Note: It is conservative to use the upper confidence limit when calculating emissions from the BCS (Equation 5.6); however it is conservative to use the lower confidence limit when calculating the total amount of methane that is destroyed in the BCS Equation 5.10.

Appendix C Offset Project Listing Information

All information, if applicable, must be completed, even if the answer is also provided elsewhere;

1. Offset project name
2. Offset Project Operator or Authorized Project Designee
3. Facility owner
4. Technical consultants
5. Other parties with a material interest
6. Date of form completion
7. Form completed by (name, organization)
8. Offset project description: 1-2 paragraphs (including type of digester & method of destruction)
9. Offset project site address (including all governing jurisdictions & lat/lon)
10. Name & address of animal facility (if different from project site)
11. Description of type of facility (e.g. dairy, swine, etc.)
12. Offset project commencement date
13. Reporting period
14. Have any GHG reductions associated with the offset project ever been registered with or claimed by another registry or program, or sold to a third party prior to our listing? If yes, identify the registry or program (vintage and reporting period)
15. Is this offset project being implemented and conducted as the result of any law, statute, regulation, court order, or other legally binding mandate? If yes, explain.

Appendix D Offset Project Data Report Information

1. Offset project name
2. Offset Project Operator or Authorized Project Designee
3. Report date
4. Contact information for Offset Project Operator or Authorized Project Designee
    a. Address, email, phone number
5. Name of individual completing report
6. Reporting period
7. Does offset project meet all local, state, or federal regulatory requirements
8. Offset project commencement date
9. Facility name and location
10. Is all the information in the offset project listing still accurate? If not provide~~d~~ updates.
11. Project baseline emissions
12. Project emissions
13. Total GHG reductions

California Environmental Protection Agency

AIR RESOURCES BOARD

Compliance Offset Protocol Ozone Depleting Substances Projects

Destruction of U.S.
Ozone Depleting Substances Banks

Adopted: October 20, 2011

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Abbreviations and Acronyms

A/C	Air conditioning
AHRI	Air-Conditioning, Heating and Refrigeration Institute
CAA	Clean Air Act
CAR	Climate Action Reserve
CEMS	Continuous emissions monitoring system
CFC	Chlorofluorocarbons
CH_4	Methane
CO_2	Carbon dioxide
CPT	Comprehensive Performance Test
DOT	U.S. Department of Transportation
DRE	Destruction and removal efficiency
EPA	United States Environmental Protection Agency
GWP	Global warming potential
HBFC	Hydrobromofluorocarbons
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HWC	Hazardous waste combustor
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
ODS	Ozone depleting substances
PU	Polyurethane
RCRA	Resource Conservation and Recovery Act

Regulation	Cap-and-Trade Regulation, title 17, California Code of Regulations, sections 95800 et seq.
SSR	GHG Sources, GHG Sinks, and GHG Reservoirs
TEAP	Technology & Economic Assessment Panel

1 Introduction

The Compliance Offset Protocol Ozone Depleting Substances Projects provides methods to quantify and report greenhouse gas (GHG) emission reductions associated with the destruction of high global warming potential ozone depleting substances (ODS) sourced from and destroyed within the U.S. that would have otherwise been released to the atmosphere. This project category includes ODS used in foam blowing agent and refrigerant applications. All destroyed ODS must be fully documented, chemically analyzed, and destroyed at a qualifying facility to be eligible for crediting under this protocol. All ODS must originate in the United States. The protocol is built off of The Climate Action Reserve's U.S. Ozone Depleting Substances Project Protocol Version 1.0[1] and includes the information provided in the Errata and Clarification[2].

ODS Offset Project Operators or Authorized Project Designees must use this protocol to quantify and report GHG reductions. The protocol provides eligibility rules, methods to quantify GHG reductions, offset project-monitoring instructions, and procedures for preparing Offset Project Data Reports. Additionally, all offset projects must submit to annual, independent verification by ARB-accredited verification bodies. Requirements for verification bodies to verify Offset Project Data Reports are provided in the Cap and Trade Regulation (Regulation).

This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification of GHG emission reductions associated with an ODS destruction project. The protocol is comprised of both quantification methodologies and regulatory program requirements to develop an ODS project and generate ARB or registry offset credits.

AB 32 exempts quantification methodologies from the Administrative Procedure Act (APA)[3], however those elements of the protocol are still regulatory. The exemption allows future updates to the quantification methodologies to be made through a public review and Board adoption process but without the need for rulemaking documents. Each protocol identifies sections that are considered quantification and exempt from APA requirements. Any changes to the non-quantification elements of the offset protocols would be considered a regulatory update subject to the full regulatory development process. Those sections that are considered to be a quantification methodology are clearly indicated in the title of the chapter or subchapter if only a portion of that chapter is considered part of the quantification methodology of the protocol.

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[1] Climate Action Reserve (2010) U.S. Ozone Depleting Substances Project Protocol Version 1.0. February 3, 2010. http://www.climateactionreserve.org/how/protocols/adopted/ods/current/ (accessed August 30, 2010)
[2] Climate Action Reserve (2010) U.S. Ozone Depleting Substances Project Protocol Errata and Clarifications. May 7, 2010. http://www.climateactionreserve.org/how/protocols/adopted/ods/current/ (accessed August 30, 2010)
[3] Health and Safety Code section 38571.

2 The GHG Reduction Project

2.1 Background

The term “ozone depleting substances” (ODS) refers to a large group of chemicals known to destroy the stratospheric ozone layer when released into the atmosphere. ODS were historically used in a wide variety of applications including refrigerants, foam blowing agents, solvents, and fire suppressants. In addition to their potency as ozone depleting substances, the ODS addressed by this protocol also exhibit high global warming potentials (GWP). The GWP of these ODS range from several hundred to several thousand times that of carbon dioxide (see Table 5.1).

2.2 Offset Project Definition – Quantification Methodology

For the purposes of this protocol, an offset project is defined as any set of activities undertaken by a single Offset Project Operator or Authorized Project Designee resulting in the destruction of eligible ODS at a single qualifying destruction facility over a 12-month period. Destruction may take place under one or more Certificates of Destruction. Each Certificate of Destruction must document the ODS destroyed. The ODS destroyed may come from a single origin (e.g., one supermarket) or from numerous sources. However, the entire quantity of eligible ODS destroyed must be documented on one or more Certificates of Destruction issued by a qualifying destruction facility.

Although Offset Project Operators or Authorized Project Designees may engage in ongoing collection and destruction activities, destruction events that fall outside of the single calendar year designated for an offset project may only be counted as part of a separately registered offset project. Offset Project Operators or Authorized Project Designees may choose a shorter time horizon for a single offset project (e.g., 3 months or 6 months), but no offset project may run longer than a calendar year.

In order for multiple Certificates of Destruction to be included under a single offset project, all of the following conditions must be met:

- The Offset Project Operator or Authorized Project Designee of GHG emission reductions are the same for all ODS destroyed
- The qualifying destruction facility is the same for all Certificates of Destruction
- The destruction activities span a timeframe occurring in one calendar year
- No Certificate of Destruction is included as part of another offset project

For all offset projects, the end fate of the ODS must be destruction at either an approved Hazardous Waste Combustor (HWC) subject to the Resource Conservation and Recovery Act (RCRA), CAA, and the National Emissions Standards for Hazardous Air Pollutants (NESHAP) standards, or any other transformation or destruction facility that meets or exceeds the Montreal Protocol’s Technology & Economic Assessment Panel (TEAP) standards provided in the *Report of the Task Force on Destruction Technologies* and listed in The Climate Action Reserve’s *U.S. Ozone Depleting Substances Project Protocol Version 1.0*. All facilities must meet any applicable requirements under the CAA and NESHAP. Non-RCRA permitted facilities cannot receive and destroy ODS materials that are classified as hazardous waste and must demonstrate compliance with the Title VI requirements of the CAA for destruction of ODS, as well as demonstrate destruction and removal efficiency (DRE) of 99.99% and emission levels consistent with the guidelines set forth in the aforementioned TEAP report.

2.3 Eligible ODS – Quantification Methodology

This protocol provides requirements for the accounting of GHG reductions from two general sources of ODS eligible under the offset project definition:

- **Refrigerants:** an offset project may collect eligible ODS refrigerant (see Section 2.3.1) from industrial, commercial or residential equipment, systems, and appliances or stockpiles, and destroy it at a qualifying destruction facility.

- **Foams:** an offset project may extract eligible ODS blowing agent (see Section 2.3.2) from appliance foams and destroy the concentrated ODS foam blowing agent at a qualifying destruction facility; or, an offset project may destroy intact foam sourced from building insulation at a qualified destruction facility.

A single offset project may incorporate ODS obtained from one or both of these ODS source categories. Tracking procedures and calculation methodologies differ depending on the source of ODS.

ODS that were produced for, used as, or intended for use as solvents, medical aerosols, or other ODS applications are not eligible.

2.3.1 Refrigerant Sources

This source category consists of ODS material produced prior to the U.S. production phase-out that could legally be sold into the U.S. refrigerant market. The ODS must originate from domestic U.S. supplies; imported refrigerant is not eligible under this protocol.

In the absence of an offset project, this material may be illegally vented or recovered for re-sale into the refrigerant recharge market. As described in Section 5.1.1, for GHG reduction calculation purposes, this protocol conservatively assumes that the refrigerant would be reclaimed.

Only destruction of the following ODS refrigerants is eligible to generate ARB or registry offset credits under this protocol:

- CFC-11
- CFC-12
- CFC-13
- CFC-113
- CFC-114

- CFC-115

ODS extracted from a foam source for use in refrigeration equipment is not considered part of this source category, and must instead be considered as a foam source. ODS sourced from federal government installations or stockpiles is not eligible under this protocol.

Additionally, all refrigerant collection, handling, and destruction must be performed in accordance with the reporting and operation requirements of the Regulation.

2.3.2 Foam Sources

This source category consists of ODS blowing agent entrained in foams that, absent a GHG reduction project, would have been released at end-of-life. The ODS blowing agent must originate from U.S. foam sources; imported foams are not eligible under this protocol.

Only the following ODS foam blowing agents are eligible to generate ARB or registry offset credits under this protocol:

- CFC-11
- CFC-12
- HCFC-22
- HCFC-141b

To be eligible to generate ARB or registry offset credits, the ODS blowing agent must be destroyed in one of two ways:

1. **ODS blowing agent extracted from appliance foam and destroyed.** The ODS blowing agent must be extracted from the foam to a concentrated form prior to destruction. This must be done under negative pressure to ensure that fugitive release of ODS cannot occur. The recovered ODS blowing agent must be collected, stored, and transported in cylinders or other hermetically sealed containers.

2. **Intact foam containing ODS blowing agent from buildings destroyed intact.** When the intact foam is separated from building panels, it must be stored, transported, and destroyed in sealed containers.

All foam collection, handling, extraction, and destruction must be performed in accordance with the reporting and operation requirements in the Regulation.

2.4 Offset Project Operator or Authorized Project Designee

The Offset Project Operator or Authorized Project Designee is responsible for offset project listing, monitoring, reporting, and verification. The Offset Project Operator or Authorized Project Designee must submit the information in the Regulation and in Appendix C. The Offset Project Operator or Authorized Project Designee must have legal authority to implement the offset project.

3 Eligibility Rules

Offset projects that meet the requirements in Section 2.2 must fully satisfy the eligibility requirements in the Regulation in addition to the eligibility rules in this protocol in order to be eligible to receive ARB or registry offset credits.

3.1 Location

For ODS destruction to be eligible as an offset project under this protocol, all ODS must be sourced from stocks in the United States or its territories and destroyed within the United States or its territories. In addition, offset projects situated on the following categories of land are only eligible under this protocol if they meet the requirements of this protocol and the Regulation, including the waiver of sovereign immunity requirements of section 95975(l) in the Regulation:

1. Land that is owned by, or subject to an ownership or possessory interest of a Tribe;
2. Land that is "Indian lands" of a Tribe, as defined by 25 U.S.C. §81(a)(1); or
3. Land that is owned by any person, entity, or Tribe, within the external borders of such Indian lands.

3.2 Offset Project Commencement

For this protocol, Offset Project Commencement is defined as the date on which destruction activities commence, as documented on a Certificate of Destruction. Offset projects may always be submitted for listing prior to their commencement date.

3.3 Project Crediting Period

An ODS project is a discrete series of destruction events over a single calendar year. For the purposes of this protocol, it is assumed that, absent the offset project, the avoided ODS emissions would have occurred over a longer time horizon.

Under this protocol, the offset project crediting period is the period of time over which avoided emissions are quantified for the purpose of determining creditable GHG reductions. Specifically, ODS projects will be issued ARB or registry offset credits for the quantity of ODS that would have been released over a ten-year period following a destruction event. At the time the offset project is verified, ARB or registry offset credits are issued for all ODS emissions avoided by an offset project over the 10-year crediting period.

3.4 Additionality

Offset projects must meet the additionality requirements set out in the Regulation in addition to the requirements in this protocol.

The destruction of ODS by the U.S. government is common practice and considered business-as-usual, and therefore ineligible for crediting under this protocol.

3.5 Regulatory Compliance

As stated in the Regulation, an Offset Project Operator~~s~~ or Authorized Project Designee~~s~~ must fulfill all applicable local, regional and national requirements on environment impact assessments that apply based on the offset project location. Offset projects must also meet any other local, regional, and national requirements that might apply. Offset projects are not eligible to receive ARB or registry offset credits for GHG reductions that occur as the result of collection or destruction activities that are not in compliance with regulatory requirements.

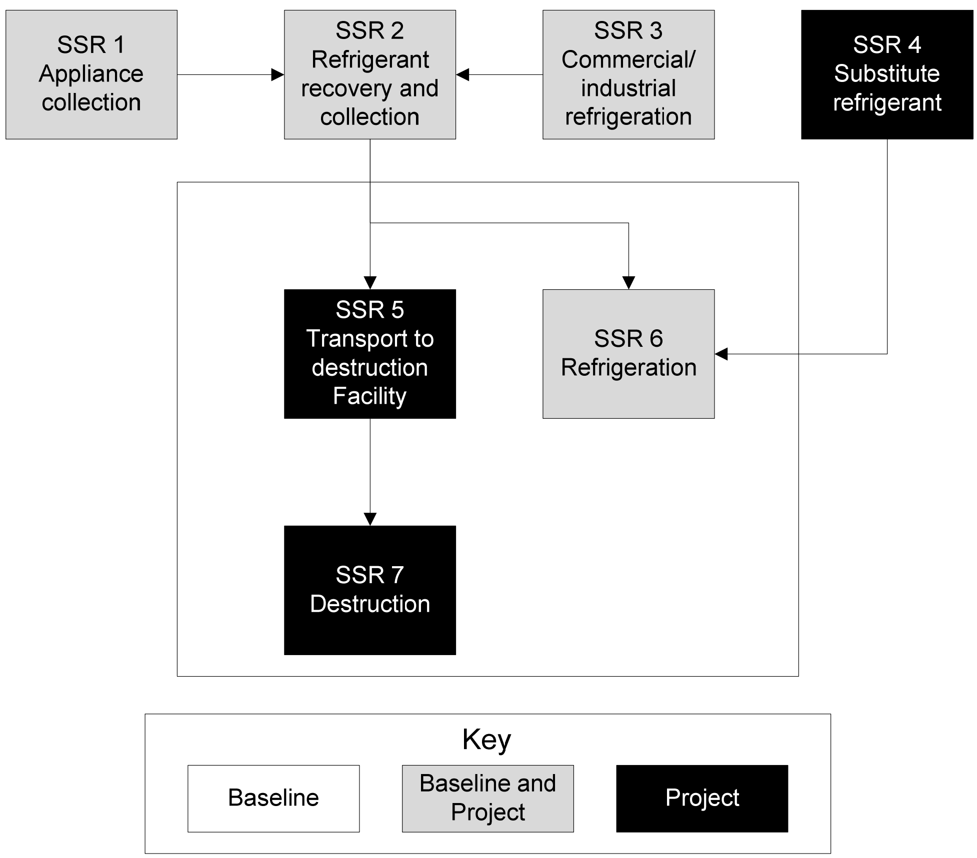
The regulatory compliance requirement extends to the operation of destruction facilities where the ODS is destroyed. Destruction facilities have the potential to contribute to environmental impacts beyond ozone depletion and climate change. Accordingly, all destruction facilities must meet the full burden of applicable regulatory requirements during the time the ODS destruction occurs. Any upsets or exceedences of permitted emission limits must be managed in keeping with an authorized startup, shutdown, and malfunction plan required by EPA (40 CFR 63.1206).

4 Offset Project Boundary – Quantification Methodology

The Offset Project Boundary delineates the GHG sources, GHG sinks, and GHG reservoirs (SSRs) that shall be assessed by the Offset Project Operators or Authorized Project Designees in order to determine the total net change in GHG emissions caused by an ODS project.

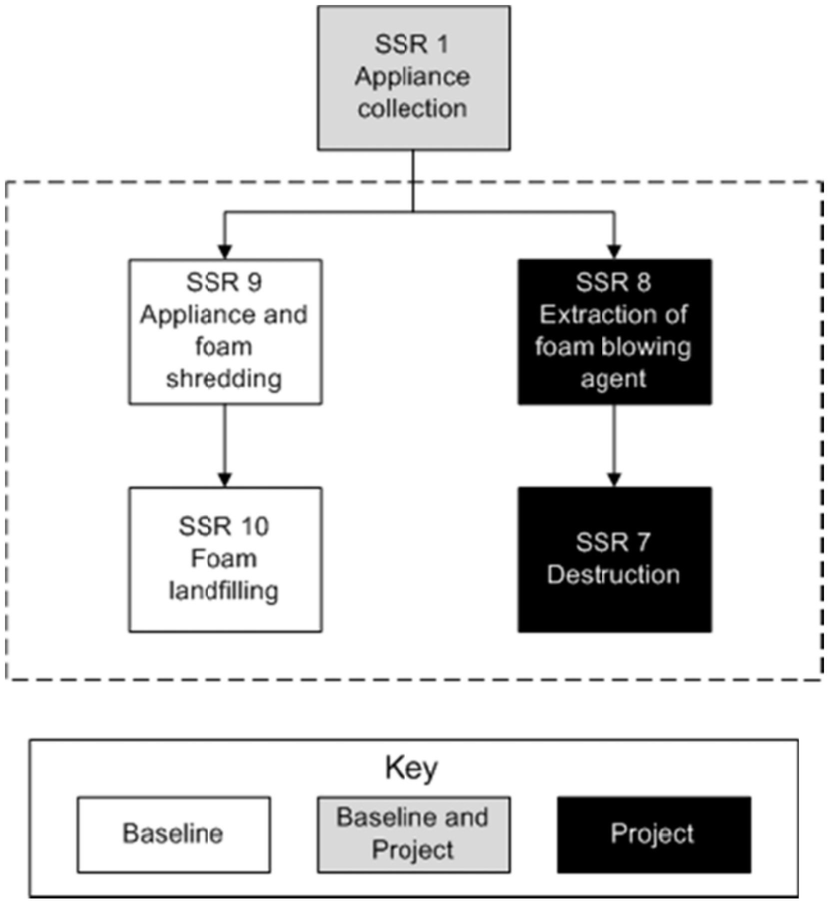
Figure 4.1, Figure 4.2, and Figure 4.3 provide a general illustration of the Offset Project Boundaries for different types of ODS destructions projects, indicating which SSRs are included or excluded from the boundary.

Table 4.1 gives greater detail on each SSR and provides information for all SSRs and gases that are excluded from the Offset Project Boundary.



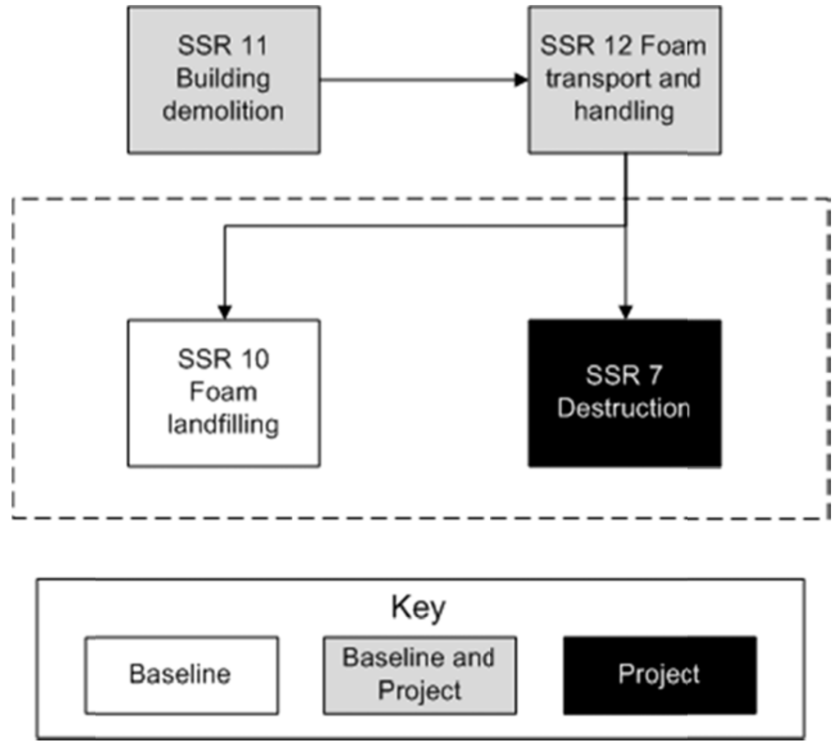
Note: Emissions from all GHG sources within the box above are accounted for within this protocol.

Figure 4.1. Illustration of the Offset Project Boundary for Refrigerant Projects



Note: Emissions from all GHG sources within the dashed box above are accounted for within this protocol.

Figure 4.2. Illustration of the Offset Project Boundary for Appliance Foam Projects



Note: Emissions from all GHG sources within the dashed box above are accounted for within this protocol.

Figure 4.3. Illustration of the Offset Project Boundary for Building Foam Projects

Table 4.1. Summary of Identified GHG Sources, GHG Sinks, and GHG Reservoirs – Quantification Methodology

SSR		Source Description	Gas	Included (I) or Excluded (E)	Quantification Method
1	Appliance Collection	Fossil fuel emissions from the collection and transport of end-of-life residential appliances	CO_2	E	N/A
			CH_4	E	N/A
			N_2O	E	N/A
2	Refrigerant Recovery and Collection	Emissions of ODS from the recovery and collection of refrigerant at end-of-life or servicing	ODS	E	N/A
		Fossil fuel emissions from the recovery and collection of refrigerant at end-of-life or servicing	CO_2	E	N/A
			CH_4	E	N/A
			N_2O	E	N/A
3	Commercial/ Industrial Refrigeration	Emissions of ODS from equipment leak and servicing	ODS	E	N/A
		Fossil fuel emissions from the operation of refrigeration and A/C equipment	CO_2	E	N/A
			CH_4	E	N/A
			N_2O	E	N/A
4	Substitute Refrigerant Production	▪ Emissions of substitute refrigerant occurring during production ▪ Fossil fuel emissions from the production of substitute refrigerants	CO_2e	E	N/A
			CO_2	E	N/A
			CH_4	E	N/A
			N_2O	E	N/A
5	Transport to Destruction Facility	Fossil fuel emissions from the vehicular transport of ODS from aggregation point to final destruction facility	CO_2	I	**Baseline:** N/A **Project:** Estimated based on distance and weight transported

SSR		Source Description	Gas	Included (I) or Excluded (E)	Quantification Method
			CH_4	E	N/A
			N_2O	E	N/A
6	Refrigeration	Emissions of ODS from leaks and servicing through continued operation of equipment	ODS	I	**Baseline:** Estimated based on market-weighted emission rates **Project:** N/A
		Emissions of substitute from leaks and servicing through continued operation of equipment	CO_2e	I	**Baseline:** N/A **Project:** Estimated based on market-weighted emissions
		Indirect emissions from grid-delivered electricity	CO_2	E	N/A
			CH_4	E	N/A
			N_2O	E	N/A
7	Destruction	Emissions of ODS from incomplete destruction at destruction facility	ODS	I	**Baseline:** N/A **Project:** Estimated based on ODS destroyed, or included in default deduction
		Emissions from the oxidation of carbon contained in destroyed ODS	CO_2	I	**Baseline:** N/A **Project:** Estimated based on ODS destroyed, or included in default deduction
		Fossil fuel emissions from the destruction of ODS at destruction facility	CO_2	I	**Baseline:** N/A **Project:** Estimated based on ODS destroyed, or included in default deduction

SSR		Source Description	Gas	Included (I) or Excluded (E)	Quantification Method
			CH_4	E	N/A
			N_2O	E	N/A
		Indirect emissions from the use of grid-delivered electricity	CO_2	I	**Baseline:** N/A **Project:** Estimated based on ODS destroyed, or included in default deduction
			CH_4	E	N/A
			N_2O	E	N/A
8	Extraction of ODS Blowing Agent from Appliance Foam	Emissions of ODS released during the separation of foam from appliance	ODS	I	**Baseline:** N/A **Project:** Estimated based on recovery efficiency
9	Appliance and Foam Shredding	Emissions of ODS from the shredding of appliances for materials recovery, releasing ODS from foam	ODS	I	**Baseline:** Estimated based on total quantity of ODS destroyed and default shredding factors **Project:** N/A
10	Foam Landfilling	Emissions of ODS released from foam disposed of in landfills	ODS	I	**Baseline:** Estimated based on release and degradation of ODS in landfill **Project:** N/A
		Emissions of ODS degradation products from foam disposed of in landfills	HFC, HCFC	E	N/A
		Fossil fuel emissions from the transport and placement of shredded foam waste in landfill	CO_2	E	N/A
			CH_4	E	N/A

SSR		Source Description	Gas	Included (I) or Excluded (E)	Quantification Method
			N_2O	E	N/A
11	Building Demolition	Emissions of ODS from the demolition of buildings and damage to foam insulation panels	ODS	E	N/A
		Fossil fuel emissions from the demolition of buildings	CO_2	E	N/A
			CH_4	E	N/A
			N_2O	E	N/A
12	Foam transport and handling	Emissions of ODS released from foam during transport and handling	ODS	E	N/A
		Fossil fuel emissions from the transport and handling of building foam	CO_2	E	N/A
			CH_4	E	N/A
			N_2O	E	N/A

5 Quantifying GHG Emission Reductions - Quantification Methodology[4]

GHG emission reductions from an ODS project are quantified by comparing actual project emissions to calculated project baseline emissions. Project baseline emissions are an estimate of the GHG emissions from GHG sources within the Offset Project Boundary (see Section 4) that would have occurred in the absence of the ODS destruction project. Project emissions are actual GHG emissions that occur at GHG sources within the Offset Project Boundary. Project emissions must be subtracted from the project baseline emissions to quantify the offset project's total net GHG emission reductions (Equation 5.1).

An offset project may not span more than a single calendar year, although an Offset Project Operator or Authorized Project Designee may choose a shorter time length than 12 months for their offset project. GHG emission reductions must be quantified and verified at least once for the entire project time length. The quantification methodologies presented below are specified for a single reporting period, which may be less than or equal to the entire project time length.

Equation 5.1. Total Emission Reductions

$$ER_t = BE_t - PE_t$$

Where,

			Units
ER_t	=	Total quantity of GHG emission reductions during the reporting period	tCO_2e
BE_t	=	Total quantity of project baseline emissions during the reporting period	tCO_2e
PE_t	=	Total quantity of project emissions during the reporting period	tCO_2e

5.1 Quantifying Project Baseline Emissions

Total project baseline emissions must be estimated by calculating and summing the calculated project baseline emissions for all relevant SSRs (as indicated in Table 4.1) using Equation 5.2 and the supporting equations presented below. This includes GHG emissions from continued use of ODS in the secondary recharge market for refrigerants, and the GHG emissions from end-of-life disposal for foams.

Equation 5.2. Total Project Baseline Emissions

$$BE_t = BE_{refr} + BE_{foam}$$

Where, Units

[4] The entirety of Section 5 is considered a quantification method

BE	=	Total quantity of project baseline emissions	tCO_2e
BE_{refr}	=	Total quantity of project baseline emissions from refrigerant ODS	tCO_2e
BE_{foam}	=	Total quantity of project baseline emissions from ODS blowing agent	tCO_2e

Project baseline emissions for an ODS destruction project include the total calculated project baseline emissions from each eligible source category – ODS refrigerant and ODS blowing agent. If an offset project does not destroy any ODS from a particular source category, project baseline emissions for that source category are assumed to be zero.

Table 5.1 provides the applicable GWP to be used for calculating project baseline emissions in units of CO_2-equivalent metric tons.

Table 5.1. Global Warming Potential of Eligible ODS

ODS Species	100-yr Global Warming Potential (CO_2e)
CFC-11	4,750
CFC-12	10,900
CFC-13	14400
CFC-113	6130
CFC-114	10,000
CFC-115	7,370
HCFC-22	1,810
HCFC-141b	725

5.1.1 Calculating Project Baseline Emissions from Refrigerant Recovery and Resale

To ensure that actual GHG reductions from ODS destruction are not overestimated, this protocol project estimates baseline emissions according to the assumption that refrigerant ODS would be entirely recovered and resold.

Equation 5.3 shall be used to estimate the project baseline emissions that would have occurred over ten years had the destroyed ODS been used in existing refrigeration or air conditioning equipment. This equation requires the use of the ODS-specific GWP provided in Table 5.1, and emission rate (inclusive of both leak rate and servicing emissions) provided in Table 5.2.

Equation 5.3. Project Baseline Emissions from Refrigerant ODS

$$BE_{refr} = \sum_i \left(Q_{refr,i} \times ER_{refr,i} \times GWP_i\right)_i$$

Where,			Units
BE_{refr}	=	Total quantity of refrigerant project baseline emissions during the reporting period	tCO_2e
$Q_{refr,i}$	=	Total quantity of refrigerant ODS *i* sent for destruction by the offset project	tODS
$ER_{refr,i}$	=	10-year cumulative emission rate of refrigerant ODS *i* (see Table 5.2)	%
GWP_i	=	Global warming potential of ODS *i* (see Table 5.1)	tCO_2e/ tODS

Table 5.2. Emission rate for ODS refrigerants

ODS Species	Annual Weighted Average Emission Rate (%/yr)	10-year Cumulative Emission Rate (%/10 years) (ER_{refr})
CFC-11	20%	89%
CFC-12	26%	95%
CFC-13	9%	61%
CFC-113	20%	89%
CFC-114	14%	78%
CFC-115	9%	61%

5.1.2 Calculating Project Baseline Emissions from Shredding and/or Landfilling ODS Foam Blowing Agents

Depending on the origin of the foam, there are two different predominant baseline practices applicable to foams containing ODS blowing agent. The two baseline practices are as follows:

Origin	Baseline Practice
Insulation foam recovered from appliances	The foam is shredded, and subsequently landfilled
Foam recovered from building demolition	The foam is landfilled

Equation 5.4 shall be used to calculate the ODS emissions that would have resulted from the assumed project baseline practice applied to foams in the absence of the offset project. Project baseline emissions include the total GHG emissions that would have occurred as a result of foam shredding and landfilling. In order to calculate total project baseline emissions, offset projects destroying blowing agent extracted from appliance foam must calculate an offset project-specific recovery efficiency for use in Equation 5.4. Methods for developing the recovery efficiency can be found in Appendix A.

Equation 5.4. Project Baseline Emissions from ODS Blowing Agent

$$BE_{foam} = \sum_{i,j}\left[\left(BA_{app,i} + BA_{build,i}\right) \times ER_{i,j} \times GWP_i\right]$$

Where, Units

BE_{foam}	=	Total quantity of ODS blowing agent project baseline emissions	tCO_2e
$BA_{app,i,}$	=	Total quantity of ODS blowing agent *i* from appliance foam prior to treatment or processing, including blowing agent lost during processing	tODS
$BA_{build,i}$	=	Total quantity of ODS blowing agent *i* from building foam sent for destruction	tODS
$ER_{i,j}$	=	Lifetime emission rate of ODS blowing agent *i* from application *j* at end-of-life (see Table 5.3)	%
GWP_i	=	Global warming potential of ODS *i* (see Table 5.1)	tCO_2e/ tODS

$$BA_{app,i} = Q_{recover} + Q_{recover}\left(\frac{1-RE}{RE}\right)$$

Where, Units

$BA_{app,i}$	=	Total quantity of ODS foam blowing agent in foam prior to treatment or processing, including ODS foam blowing agent lost during processing	tODS
$Q_{recover}$	=	Total quantity of ODS foam blowing agent recovered during processing and sent for destruction, as determined according to Section 6.5	tODS
RE	=	Recovery efficiency of the ODS foam blowing agent recovery process[5] (See Appendix A for calculation of RE)	%

$$BA_{build} = Q_{foam} \times BA\%$$

Where,

BA_{build}	=	Total quantity of ODS blowing agent *i* from building foam sent for destruction	tODS
Q_{foam}	=	Total weight of foam with entrained ODS blowing agent sent for destruction	Metric tons
BA%	=	Mass ratio of ODS blowing agent entrained in building foam, as determined according to Section 6.3	% (0-1)

[5] RE does not extend to the ODS destruction efficiency, which is handled separately under this protocol.

The total percent of ODS foam blowing agent that would be released throughout the end-of-life processing (i.e., 10-year emission rates) for each ODS foam blowing agent and foam origin is presented in Table 5.3. These values include emissions from:

1. ODS blowing agent released during foam shredding,[6] plus
2. ODS blowing agent released during foam compaction, plus
3. Landfilled ODS blowing agent that is released during anaerobic conditions (but is not degraded).

Table 5.3. 10-year Emission Rates of Appliance and Building Foam at End-of-Life

ODS Blowing Agent	Appliance ODS blowing agent 10-year emission rate ($ER_{i,j}$)	Building ODS blowing agent 10-year emission rate ($ER_{i,j}$)
CFC-11	44%	20%
CFC-12	55%	36%
HCFC-22	75%	65%
HCFC-141b	50%	29%

5.2 Quantifying Project Emissions

Project emissions are actual GHG emissions that occur within the Offset Project Boundary as a result of offset project activities.

As shown in Equation 5.5, project emissions equal:

- GHG emissions from non-ODS substitutes (applicable only to refrigerant projects), plus
- GHG emissions from ODS foam blowing agent extraction (applicable only to appliance foam projects), plus
- GHG emissions from the transportation of ODS, plus
- GHG emissions from the destruction of ODS

Equation 5.5. Total Project Emissions

$$PE_t = Sub_{ref} + BA_{pr} + Tr + Dest$$

Where,

			Units
PE	=	Total quantity of project emissions during the reporting period	tCO_2e
Sub_{ref}	=	Total GHG emissions from substitute refrigerant	tCO_2e
BA_{pr}	=	Total quantity of ODS blowing agent from appliance foam released during ODS extraction	tCO_2e
Tr	=	Total GHG emissions from transportation of ODS (calculated using either the default value in Equation 5.8 or Equation 5.14)	tCO_2e
Dest	=	Total GHG emissions from the process associated with destruction of ODS (calculated using either the default value in Equation 5.8 or Equation 5.9 through Equation 5.13)	tCO_2e

[6] Note that the emissions from foam shredding have only been factored into the emission rates from appliance ODS blowing agents in Table 5.3, as building foam is not typically shredded before being landfilled.

5.2.1 Calculating Project Emissions from the Use of Refrigerant Substitutes

When refrigerant ODS are destroyed, continued demand for refrigeration will lead to the production and consumption of other refrigerant chemicals whose production is still legally allowed. Offset projects that destroy refrigerant ODS must therefore estimate the GHG emissions associated with the non-ODS substitute chemicals that are assumed to be used in their place. Like the estimates of project baseline emissions, substitute emissions shall be accounted for based on the projected emissions over a ten year crediting period.

Project emissions from the use of substitute refrigerants shall be calculated for all ODS refrigerant projects according to Equation 5.6 using the emission factors from Table 5.4. The use of site-specific substitute parameters (refrigerant, GWP, and leak rate) is not permitted.

Equation 5.6. Project Emissions from the Use of Non-ODS Refrigerants

$$Sub_{refr} = \sum_{i} \left(Qref_i \times SE_i \right)$$

Where,

			Units
Sub_{refr}	=	Total quantity of refrigerant substitute emissions	tCO_2e
$Qref_i$	=	Total quantity of refrigerant *i* sent for destruction	t
SE_i	=	Emission factor for substitute(s) for refrigerant *i*, per Table 5.4	tCO_2e/ tODS destroyed

ODS substitute emissions presented in Table 5.4 are based on the weighted average of expected new refrigerant supplies into the refrigeration market. These substitute refrigerants were modeled using the EPA Vintaging Model and data provided by industry sources.

Table 5.4. Refrigerant Substitute Emission Factors[7][8]

ODS Refrigerant	Substitute Emissions ($t\ CO_2e/t\ ODS$) (SE_i)
CFC-11	223
CFC-12	686
CFC-13	7144
CFC-113	220
CFC-114	659
CFC-115	1139

5.2.2 Calculating Project Emissions from ODS Blowing Agent Extracted from Appliance Foam

Offset projects that extract ODS blowing agent from appliance foam must account for the GHG emissions of ODS that occur during processing, separation, and extraction using Equation 5.7. These GHG emissions are calculated in Equation 5.7 based on the quantity of ODS blowing agent sent for destruction ($BA_{app,i}$, as calculated in Equation 5.4), and an offset project-specific recovery efficiency that represents the percentage of ODS that is not lost during these steps. Recovery efficiency must be independently established once for each individual offset project according to the methods provided in Appendix A.

Equation 5.7. Calculating Project Emissions from the Release of ODS Blowing Agent during Processing

$$BA_{pr} = \sum_i \left(BA_{app,i} \times (1 - RE) \times GWP_i\right)$$

Where,

			Units
BA_{pr}	=	Total quantity of ODS blowing agent from appliance foam released during ODS extraction	tCO_2e
$BA_{app,i}$	=	Total quantity of appliance ODS foam blowing agent in foam prior to treatment or processing, including ODS foam blowing agent lost during processing (see Equation 5.4 to calculate this term)	tODS
RE	=	Recovery efficiency of the ODS foam blowing agent recovery process (See Appendix A to calculate RE)	%
GWP_i	=	Global warming potential of ODS *i* (see Table 5.1)	tCO_2e/ tODS

[7] IPCC (2007). Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Table 2.14 Errata. 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://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

[8] Substitute emissions were developed using a weighted average of 10-year emissions rates in CO_2 equivalent based on the market share, amounts, and leakage rates of the ODS subsitutes. If a substitute is a mix of gases, the GWP for each gas and proportion of each in the mixture is used to determine the GWP of the mixture. The GWPs for the refrigerant substitutes are from the Second Assessment Report, cited in the above footnote.

5.2.3 Calculating Default Project Emissions from ODS Transportation and Destruction

Offset projects must account for GHG emissions that result from the transportation and destruction of ODS. Because these GHG emission sources are both individually and in aggregate very small, the protocol default emission factors for ODS projects are based on conservative assumptions and the SSRs outlined in Table 4.1:

- 7.5 metric tons CO_2e per metric ton ODS for refrigerant or extracted ODS blowing agent projects
- 75 metric tons CO_2e per metric ton ODS for intact building foam projects

These emission factors aggregate both transportation and destruction emissions. An Offset Project Operator~~s~~ or Authorized Project Designee has the option of using the default emission factors or using the methods in Sections 5.2.4 and 5.2.5 to calculate offset project-specific emissions.

Equation 5.8 shall be used to calculate ODS transportation and destruction emissions if default emission factors are used. If an Offset Project Operator or Authorized Project Designee elects not to use the default emission factors, GHG emissions associated with transportation and destruction of ODS must be calculated separately.

Equation 5.8. Project Emissions from Transportation and Destruction Using the Default Emission Factors

$$Tr + Dest = \sum_i \left(Q_{ODS,i} \times EF_i \right)$$

Where, Units

Tr+Dest	=	Total GHG emissions from ODS transportation and destruction, as calculated using default emission factors	tCO_2e
$Q_{ODS,i}$	=	Total quantity of ODS *i* sent for destruction in the project	tODS
EF_i	=	Default emission factor for transportation and destruction of ODS *i* (7.5 for refrigerant or extracted ODS blowing agent projects, 75 for intact building foam projects)	tCO_2e/ tODS

5.2.4 Calculating Site-Specific Project Emissions from ODS Destruction

Under this protocol, ODS must be destroyed at facilities that have a RCRA permit for hazardous waste destruction or that demonstrate compliance with the TEAP recommendations. TEAP facilities are required to demonstrate their ability to achieve destruction efficiencies upwards of 99.99% for substances with thermal stability ratings higher than the ODS included under this protocol.[9] Associated with the operation of these facilities are emissions of CO_2 from the fuel and electricity used to power the destruction, as well as emissions of undestroyed ODS. Equation 5.9 through Equation 5.11 provide requirements for calculating GHG emissions from ODS destruction in cases where Offset Project Operators or Authorized Project Designees opt not to use the default factors provided in Section 5.2.3.

Equation 5.9. Project Emissions from the Destruction of ODS

$$Dest = FF_{dest} + EL_{dest} + ODS_{emissions} + ODS_{CO2}$$

Where, Units

Dest	=	Total GHG emissions from the destruction of ODS	tCO_2e
FF_{dest}	=	Total GHG emissions from fossil fuel used in the destruction facility (Equation 5.10)	tCO_2
EL_{dest}	=	Total indirect GHG emissions from grid electricity used at the destruction facility (Equation 5.11)	tCO_2
$ODS_{emissions}$	=	Total GHG emissions of undestroyed ODS (Equation 5.12)	tCO_2e
ODS_{CO2}	=	Total GHG emissions of CO_2 from ODS oxidation (Equation 5.13)	tCO_2

Equation 5.10. Fossil Fuel Emissions from the Destruction of ODS

$$FF_{dest} = \frac{\sum_k \left(FF_{PR,k} \times EF_{FF,k} \right)}{1000}$$

Where, Units

[9] Demonstration of compliance with TEAP recommendations must be conducted by a third party verifier.

FF_{dest}	=	Total carbon dioxide emissions from the destruction of fossil fuel used to destroy ODS	tCO_2
$FF_{PR,k}$	=	Total fossil fuel *k* used to destroy ODS	volume fossil fuel
$EF_{FF,k}$	=	Fuel specific emission factor (see Appendix B)	kg CO_2/ volume fossil fuel
1000	=	kg/t of CO_2	$kgCO_2$/ tCO_2

Equation 5.11. Electricity Emissions from the Destruction of ODS

$$EL_{dest} = \frac{(EL_{PR} \times EF_{EL})}{2204.6}$$

Where, Units

EL_{dest}	=	Total carbon dioxide emissions from the consumption of electricity from the grid used to destroy ODS	tCO_2
EL_{PR}	=	Total electricity consumed to destroy ODS	MWh
EF_{EL}	=	Carbon emission factor for electricity used (see Appendix B)	lb CO_2/ MWh

Equation 5.12. Calculating Project Emissions from ODS Not Destroyed

$$ODS_{emissions} = \sum_i Q_{ODS,i} \times 0.01\% \times GWP_i$$

Where, Units

$ODS_{emissions}$	=	Total GHG emissions of undestroyed ODS	tCO_2e
$Q_{ODS,i}$	=	Total quantity of ODS *i* sent for destruction in the project	tODS
0.01	=	Maximum allowable percent of ODS fed to destruction that is not destroyed	%
GWP_i	=	Global warming potential of ODS *i* (see Table 5.1)	tCO_2e/ tODS

Equation 5.13. Calculating Project Emissions of CO_2 from the Oxidation of ODS

$$ODS_{CO_2} = \sum_i Q_{ODS,i} \times 0.9999 \times CR_i \times \frac{44}{12}$$

Where, Units

ODS_{CO2}	=	Total GHG emissions of CO_2 from ODS oxidation	tCO_2
$Q_{ODS,i}$	=	Total quantity of ODS *i* sent for destruction in the project	tODS
0.9999	=	Minimum destruction efficiency of destruction facility	% (0-1)

CR_i	=	Carbon ratio of ODS *i* CFC-11: 12/137 CFC-12: 12/121 CFC-113: 12/90 CFC-114: 24/187 CFC-115: 12/74 HCFC-22: 12/87 HCFC-141b: 24/117	mole C/ mole ODS
44/12	=	Ratio of CO_2 to C	mole CO_2/ mole C

5.2.5 Calculating Site-Specific Project Emissions from ODS Transportation

As part of any ODS destruction project, ODS will be transported from aggregators to destruction facilities, and GHG emissions from this transportation must be accounted for under this protocol. Equation 5.14 must be used to calculate CO_2 emissions associated with the transport of ODS in cases where an Offset Project Operator or Authorized Project Designee chooses not to use the default emission factors presented in Section 5.2.3. Emissions shall be calculated for each leg of the transportation process separately, and then summed according to Equation 5.14 below.

Equation 5.14. Calculating Project Emissions from the Transportation of ODS

$$Tr = \sum_i \left(\frac{TMT_i \times EF_{TMT}}{1000} \right)$$

Where,

			Units
Tr	=	Total GHG emissions from transportation of ODS	tCO_2e
TMT_i	=	Ton-miles-traveled[10] for ODS *i* destroyed (to be calculated including the ODS, any accompanying material, and containers from point of aggregation to destruction)	ton-miles
EF_{TMT}	=	CO_2 emissions per ton-mile-traveled On-road truck transport = 0.297 Rail transport = 0.0252 Waterborne craft = 0.048 Aircraft = 1.5279	$kgCO_2$ / ton-mile
1000	=	Conversion from kg to tons	kg/ton

6 Project Documentation Requirements

An ODS destruction project must comply with documentation requirements in the Regulation. The monitoring, reporting, and record retention requirements cover all aspects of this protocol and the documentation must specify how data for all relevant parameters in Table 6.2 was collected and recorded.

[10] A ton-mile is defined as the product of the distance travelled in miles and the mass transported in metric tons. Therefore, half a ton transported four miles is equal to two ton-miles.

The Offset Project Operator or Authorized Project Designee is responsible for monitoring the performance of the offset project and ensuring that there is no double-counting of GHG reductions associated with ODS destruction.

6.1 Point of Origin Documentation Requirements

As in the Regulation, the Offset Project Operators or Authorized Project Designee is responsible for collecting data on the point of origin of each quantity of ODS as part of tracking chain of custody, as defined in Table 6.1. The Offset Project Operator or Authorized Project Designee must maintain detailed acquisition records of all quantities of ODS destroyed under the offset project.

Table 6.1. Identification of Point of Origin

ODS	Defined Point of Origin
1. Refrigerant ODS stockpiled for greater than 24 months; or stockpiled prior to the adoption date of this protocol and destroyed within twelve months of the adoption date of this protocol.	Location of stockpile
2. Refrigerant ODS quantities less than 500 lbs	Location where ODS is first aggregated with other ODS to greater than 500 lbs[b]
3. Refrigerant ODS quantities greater than 500 lbs	Site of installation where ODS is removed
4. ODS blowing agent extracted from foam	Facility where ODS blowing agent is extracted
5. ODS blowing agent in building foam	Location of building from which foam was taken

[b] The point of origin for ODS collected by service technicians in individual quantities less than 500 pounds is defined as the holding facility at which several small quantities were combined and exceeded 500 pounds in aggregate. That is, those handling quantities less than 500 pounds need not provide documentation. However, once smaller quantities are aggregated and exceed 500 pounds collectively, tracking will be required from that location and point in time forward.

All data must be generated *at the time of collection* from the point of origin. Documentation of the point of origin of ODS must include the following:

- Facility name and physical address
- Point of origin zip code
- Identification of the system by serial number, if available, or description, location, and function, if serial number is unavailable (for quantities greater than 500 pounds)
- Serial or ID number of containers used for storage and transport

6.2 Chain of Custody Documentation Requirements

In conjunction with establishing the point of origin for each quantity of ODS, the Offset Project Operators or Authorized Project Designee must also document the custody and ownership of ODS beginning from the point of origin as required in the Regulation. These records shall include names, addresses, and contact information of persons/entities buying/selling material for destruction and the quantity of the material (the combined mass of refrigerant and contaminants) bought/sold. Such records may include Purchase Orders, Purchase Agreements, packing lists, bills of lading, lab test results, transfer container information, receiving inspections, freight bills, transactional payment information, and any other type of information that will support previous ownership of the material and the transfer of beneficial ownership rights. The verifier will review these records and will perform other tests necessary to authenticate the previous owners of the material, the physical transfer of the product, and the transfer of beneficial ownership rights to the Offset Project Operator or Authorized Project Designee.

6.3 Building Foam Requirements – Quantification Methodology

The following information shall be collected and recorded related to ODS blowing agents from building insulation foam destroyed by the offset project:

- Building address
- Date of construction
- Blowing agent used
- Approximate building dimensions

All recovered foam pieces must be placed in air- and water-tight storage for transport to the destruction facility.

ODS blowing agent from building insulation foam may be destroyed intact without extraction of the blowing agent if the following procedures are followed to characterize the mass of foam and type(s) and mass ratio of ODS blowing agent contained in that foam.

1. The mass of the foam shall be determined through weight measurements taken at the destruction facility on scales calibrated quarterly. Scales are considered calibrated if they demonstrate accuracy of +/- 5% of reading.

2. The composition and mass ratio of the ODS foam blowing agent(s) present in the building insulation foam shall be determined based on a selection of a minimum two samples per building surface taken prior to demolition. Accordingly, a building with four exterior walls and a roof would be required to analyze a total of 10 samples: two for each wall, and two for the roof.

3. All samples must be collected and analyzed according to the following requirements:

    - Each foam sample shall be at a minimum 2 inches in length, 2 inches in width, and 2 inches thick
    - Each sample shall be placed and sealed in a separate waterproof, air-tight container, that is at minimum 2 millimeters thick for storage and transport
    - The analysis of ODS foam blowing agent content and mass ratio shall be done at an independent laboratory unaffiliated with the Offset Project Operator or Authorized Project Designee
    - The analysis shall be done using the heating method to extract ODS foam blowing agent from the foam samples described in Scheutz et al (2007)

referenced in The Climate Action Reserve's *U.S. Ozone Depleting Substances Project Protocol Version 1.0*:
    - Each sample shall be prepared to a thickness no greater than 1 cm, placed in a 1123 mL glass bottle, weighed using a calibrated scale, and sealed with Teflon-coated septa and aluminum caps
    - To release the ODS blowing agent from the foam, the samples must be incubated in an oven for 48 hours at 140 degrees C
    - When cooled to room temperature, gas samples must be redrawn from the headspace and analyzed by gas chromatography
    - The lids must be removed after analysis, and the headspace must be flushed with atmospheric air for approximately 5 minutes using a compressor. Afterwards, septa and caps must be replaced and the bottles subjected to a second 48-hr heating step to drive out the remaining ODS blowing agent from the sampled foam
    - When cooled down to room temperature after the second heating step, gas samples must be redrawn from the headspace and analyzed by gas chromatography
  - The mass of ODS blowing agent(s) recovered shall then be divided by the total mass of the initial foam samples prior to analysis to determine the mass ratio of each ODS foam blowing agent present

The results from all samples from a single building shall be averaged to determine the mass ratio of blowing agent to foam, and this value multiplied by the weight of destroyed foam. The result shall represent the total quantity of ODS blowing agent from building foams destroyed for that building, and shall be used for the quantity as BA_{build} in Equation 5.4**.**

These practices shall be documented and must be demonstrated during verification activities.

6.4 Appliance Foam Requirements – Quantification Methodology

The following information shall be collected and recorded related to ODS blowing agent from appliance foams destroyed by the project:

- Number of appliances processed
- Facility at which ODS foam blowing agent is extracted to concentrated form
- Facility at which appliance de-manufacture occurs, if applicable

All appliance foam must be processed to recover and destroy concentrated ODS blowing agent. The following requirements must be met:

- The ODS blowing agent must be extracted from the foam to a concentrated form prior to destruction
- ODS blowing agent must be extracted under negative pressure to ensure that fugitive release of ODS is limited

- The recovered ODS blowing agent must be collected, stored, and transported in containers meeting U.S. Department of Transportation (DOT) standards for refrigerants

Extraction of the foam blowing agent may be performed using any technology capable of recovering concentrated ODS foam blowing agent. The processes, training, QA/QC, and management systems must be documented. The same process must be followed during project implementation and during the calculation of the project-specific recovery efficiency, as described in Appendix A.

Concentrated ODS blowing agent shall be measured according to the procedures provided in Section 6.5.

6.5 Concentrated ODS Composition and Quantity Analysis Requirements – Quantification Methodology

The requirements of this section must be followed to determine the quantities of both ODS refrigerants and concentrated ODS blowing agent. Prior to destruction, the precise mass and composition of ODS to be destroyed must be determined. The following analysis must be conducted:

Mass shall be determined by individually measuring the weight of each container of ODS: (1) when it is full prior to destruction; and (2) after it has been emptied and the contents have been fully purged and destroyed. The mass of ODS and any contaminants is equal to the difference between the full and empty weight, as measured. The following requirements must be met when weighing the containers of ODS:

1. A single scale must be used for generating both the full and empty weight tickets at the destruction facility
2. The scale used must be properly calibrated per the facility's RCRA permit, or for non-RCRA facilities calibrated at least quarterly to an accuracy of within 5% of reading. RCRA facilities that do not have calibration requirements defined in their RCRA permits must calibrate scales quarterly to an accuracy of within 5% of reading.
3. The full weight must be measured no more than two days prior to commencement of destruction per the Certificate of Destruction
4. The empty weight must be measured no more than two days after the conclusion of destruction per the Certificate of Destruction

Composition and concentration of ODS shall be established for each individual container by taking a sample from each container of ODS and having it analyzed for composition and concentration at an Air-Conditioning, Heating and Refrigeration Institute (AHRI) certified laboratory using the AHRI 700-2006 standard as referenced in The Climate Action Reserve's *U.S. Ozone Depleting Substances Project Protocol*

Version 1.0. The laboratory performing the composition analysis must not be affiliated with the Offset Project Operator or Authorized Project Designee.

The following requirements must be met for each sample:

1. The sample must be taken while ODS is in the possession of the company that will destroy the ODS
2. Samples must be taken by a technician unaffiliated with the Offset Project Operator or Authorized Project Designee [11]
3. Samples must be taken with a clean, fully evacuated sample bottle that meets applicable U.S. Department of Transportation requirements with a minimum capacity of one pound
4. Each sample must be taken in liquid state
5. A minimum sample size of one pound must be drawn for each sample
6. Each sample must be individually labeled and tracked according to the container from which it was taken, and the following information recorded:
    a) Time and date of sample
    b) Name of Offset Project Operator or Authorized Project Designee
    c) Name of technician taking sample
    d) Employer of technician taking sample
    e) Volume of container from which sample was extracted
    f) Ambient air temperature at time of sampling[12]
7. Chain of custody for each sample from the point of sampling to the AHRI lab must be documented by paper bills of lading or electronic, third-party tracking that includes proof of delivery (e.g., FedEx, UPS)

All project samples shall be analyzed using ARI 700-2006 to confirm the mass percentage and identity of each component of the sample. The analysis shall provide:

1. Identification of the refrigerant
2. Purity (%) of the ODS mixture by weight using gas chromatography
3. Moisture level in parts per million. The moisture content of each sample must be less than 75% of the saturation point for the ODS based on the temperature recorded at the time the sample was taken.
4. Analysis of high boiling residue, which must be less than 10% by mass
5. Analysis of other ODS in the case of mixtures of ODS, and their percentage by mass

If any of the requirements above are not met, no GHG reductions may be verified for ODS destruction associated with that container.

[11] For instances where the Offset Project Operator or Authorized Project Designee is the destruction facility itself, an outside technician must be employed for taking samples.
[12] Offset projects that destroy ODS prior to the adoption date of this protocol may use proxy data from NOAA recording stations in the area.

If the container holds non-mixed ODS (defined as greater than 90% composition of a single ODS species) no further information or sampling is required to determine the mass and composition of the ODS.

If the container holds mixed ODS, which is defined as less than 90% composition of a single ODS species, the Offset Project Operator or Authorized Project Designee must meet additional requirements as provided in Section 6.5.1.

6.5.1 Analysis of Mixed ODS

If a container holds mixed ODS, its contents must also be processed and measured for composition and concentration according to the requirements of this section (in addition to the requirements of Section 6.5). The sampling required under this section may be conducted at the final destruction facility or prior to delivery to the destruction facility. However, the circulation and sampling activities must be conducted by a third-party (i.e., not the Offset Project Operator or Authorized Project Designee), and by individuals who have been properly trained for the functions they perform. Circulation and sampling may be conducted at the Offset Project Operator or Authorized Project Designee's facility, but all activities must be directed by a properly trained and contracted third-party. The offset project's documentation must specify the procedures by which mixed ODS are analyzed.

The composition and concentration of ODS on a mass basis must be determined using the results of the analysis of this section for each container. The results of the composition analysis in Section 6.5 shall be used by verifiers to confirm that the destroyed ODS is the same ODS that is sampled under these requirements.

Prior to sampling, the ODS mixture must be circulated in a container that meets all of the following criteria:

1. The container has no solid interior obstructions[13]
2. The container was fully evacuated prior to filling
3. The container must have sampling ports to sample liquid and gas phase ODS
4. The sampling ports must be located in the middle third of the container (i.e., not at one end or the other)
5. The container and associated equipment can circulate the mixture via a closed loop system from the bottom to top

If the original mixed ODS container does not meet these requirements, the mixed ODS must be transferred into a temporary holding tank or container that meets all of the above criteria. The weight of the contents placed into the temporary container shall be calculated and recorded. During transfer of ODS into and out of the temporary container, ODS shall be recovered to the vacuum levels required by the U.S. EPA for that ODS (see 40 CFR 82.156).

[13] Mesh baffles or other interior structures that do not impede the flow of ODS are acceptable.

Once the mixed ODS is in a container or temporary storage unit that meets the criteria above, circulation of mixed ODS must be conducted as follows:

1. Liquid mixture shall be circulated from the liquid port to the vapor port
2. A volume of the mixture equal to two times the volume in the container shall be circulated
3. Circulation must occur at a rate of at least 30 gallons/minute
4. Start and end times shall be recorded

Within 30 minutes of the completion of circulation, a minimum of two samples shall be taken from the bottom liquid port according to the procedures in Section 6.5. Both samples shall be analyzed at an AHRI approved laboratory per the requirements of Section 6.5. The analysis will determine the GWP weighted concentrations for both samples. The Offset Project Operator or Authorized Project Designee will use the results with the lesser GWP-weighted concentration for the protocol.

6.6 Destruction Facility Requirements – Quantification Methodology

Destruction of ODS must occur at a facility that meets all of the aforementioned TEAP requirements. This includes any RCRA-permitted HWC as well as any other facility that meets the aforementioned TEAP requirements. Facilities permitted as RCRA HWCs are considered to meet the guidelines by default; no further testing for TEAP compliance is required.

At the time of ODS destruction, all destruction facilities must have a valid Title V air permit, if applicable, and any other air or water permits required by local, state, or federal law to destroy ODS. Facilities must document compliance with all monitoring and operational requirements associated with the destruction of ODS materials, as dictated by these permits, including emission limits, calibration schedules, and training. Any upsets or exceedences must be managed in keeping with an authorized startup, shutdown, and malfunction plan. Non-RCRA facilities must further document operation consistent with the TEAP requirements. A third party must certify that the non-RCRA facility meets the TEAP requirements.

Operating parameters during destruction of ODS material shall be monitored and recorded as described in the Code of Good Housekeeping approved by the Montreal Protocol. This data will be used in the verification process to demonstrate that during the destruction process, the destruction unit was operating similarly to the period in which the DRE[14] was calculated. The DRE is determined using the Comprehensive Performance Test (CPT)[15] as a proxy for DRE and is disclosed to the public in the destruction facility's Title V operating permit.

To monitor that the destruction facility operates in accordance with applicable regulations and within the parameters recorded during DRE testing, the following parameters must be tracked continuously during the entire ODS destruction process:

[14] DRE disclosed in Title V operating permit.
[15] CPT must have been conducted with a less combustible chemical than the ODS in question.

- The ODS feed rate
- The amount and type of consumables used in the process (not required if default project emission factor for transportation and destruction is used)
- The amount of electricity and amount and type of fuel consumed by the destruction unit (not required if default project emission factor for transportation and destruction is used)
- Operating temperature and pressure of the destruction unit during ODS destruction
- Effluent discharges measured in terms of water and pH levels
- Continuous emissions monitoring system (CEMS) data on the emissions of carbon monoxide during ODS destruction

The Offset Project Operator or Authorized Project Designee must maintain records of all of these parameters for review during the verification process.

Destruction facilities shall provide valid Certificate(s) of Destruction for all ODS destroyed as part of the offset project. The Certificate of Destruction shall include:

- Offset Project Operator or Authorized Project Designee
- Destruction facility
- Generator name
- Certificate of Destruction ID number
- Serial, tracking, or ID number of all containers for which ODS destruction occurred
- Weight and type of material destroyed from each container
- Start destruction date
- Ending destruction date

6.7 Monitoring Parameters – Quantification Methodology

Prescribed monitoring parameters necessary to calculate project baseline and offset project emissions are provided in Table 6.2. In addition to the parameters below that are used in the calculations provided in Section 5, the Offset Project Operator~~s~~ or Authorized Project Designee~~s~~ is responsible for maintaining all records required by the Regulation and this protocol.

Table 6.2. ODS Project Monitoring Parameters – Quantification Methodology

Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
		Legal Requirement Test	N/A	For each offset project		Must be monitored and determined for each project
		Mass of ODS (or ODS mixture) in each container	mass of mixture	Per container	M	Must be determined for each container
		Concentration of ODS (or ODS mixture) in each container	mass ODS/ mass of mixture	Per container	M	Must be determined for each container
Equation 5.1	ER_t	Total quantity of GHG emission reductions during the reporting period	tCO_2e	For each offset project	C	
Equation 5.1, Equation 5.2	BE_t	Total quantity of project baseline emissions during the reporting period	tCO_2e	For each offset project	C	
Equation 5.1, Equation 5.5	PE_t	Total quantity of project emissions during the reporting period	tCO_2e	For each offset project	C	
Equation 5.2, Equation 5.3	BE_{refr}	Total quantity of project baseline emissions from refrigerant ODS	tCO_2e	For each offset project	C	
Equation 5.2, Equation 5.4	BE_{foam}	Total quantity of project baseline emissions from ODS blowing agent	tCO_2e	For each offset project	C	
Equation 5.3, Equation 5.6	$Q_{refr,i}$	Total quantity of refrigerant ODS *i* sent for destruction	tODS	For each offset project	M	
Equation 5.3	$ER_{refr,i}$	10-year cumulative emission rate of refrigerant ODS *i*	0 - 1.0	N/A	R	See Table 5.1
Equation 5.3, Equation 5.4, Equation 5.7, Equation 5.12	GWP_i	Global warming potential of ODS *i*	tCO_2e/ tODS	N/A	R	See Table 5.1
Equation 5.4, Equation 5.7	$BA_{app,i,}$	Total quantity of ODS blowing agent *i* from appliance foam prior to treatment or processing, including blowing agent lost during processing	tODS	For each offset project	C	

Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
Equation 5.4	$BA_{build,i}$	Total quantity of ODS blowing agent *i* from building foam sent for destruction.	tODS	For each offset project	C	
Equation 5.4	$ER_{i,j}$	Lifetime emission rate of ODS blowing agent *i* from application *j* at end-of-life (see Table 5.3)	% (0-1)	N/A	R	
Equation 5.4	$Q_{recover}$	Total quantity of ODS foam blowing agent recovered during processing and sent for destruction	tODS	For each offset project	M	
Equation 5.4, Equation 5.7	RE	Recovery efficiency of the ODS foam blowing agent recovery process	% (0-1)	Once for each offset project	C	See Appendix A for calculation of RE
Equation 5.4	Q_{foam}	Total weight of foam with entrained ODS blowing agent sent for destruction	tonnes	For each offset project	M	
Equation 5.4	BA%	Mass ratio of ODS blowing agent entrained in building foam, as determined according to Section 6.3	% (0-1)	For each offset project	M	
Equation 5.5, Equation 5.6	Sub_{refr}	Total GHG emissions from substitute refrigerant	tCO_2e	For each offset project	C	
Equation 5.5, Equation 5.7	$BA_{pr,i}$	Total quantity of ODS foam blowing agent *i* from appliance foam released during ODS extraction	tCO_2e	For each offset project	C	
Equation 5.5, Equation 5.8, Equation 5.14	Tr	Total GHG emissions from transportation of ODS	tCO_2e	For each offset project	C	
Equation 5.5, Equation 5.8, Equation 5.9	Dest	Total GHG emissions from the destruction process associated with destruction of ODS	tCO_2e	For each offset project	C	
Equation 5.6	SE_i	Emission factor for substitute emissions of refrigerant *i*, per Table 5.5	tCO_2e/ tODS destroyed	Per container	R	See Table 5.4 (see 10 for summary of the development of SE)

Eq. #	Parameter	Description	Data Unit	Measurement Frequency	Calculated (c) Measured (m) Reference (r) Operating records (o)	Comment
Equation 5.8, Equation 5.12, Equation 5.13	$Q_{ODS,i}$	Total quantity of ODS *i* sent for destruction	tODS	For each offset project	M	
Equation 5.8,	EF_i	Default emission factor for transportation and destruction of ODS *i*	tCO_2e/ tODS	N/A	R	Equal to 7.5 for refrigerant projects, and 75 for foam projects
Equation 5.9, Equation 5.10	FF_{dest}	Total GHG emissions from fossil fuel used in the destruction facility	tCO_2e	For each offset project	C	Use only if calculating site-specific project emissions from ODS destruction
Equation 5.9, Equation 5.11	EL_{dest}	Total GHG emissions from grid electricity at the destruction facility	tCO_2e	For each offset project	C	Use only if calculating site-specific project emissions from ODS destruction
Equation 5.10	$FF_{PR,k}$	Total fossil fuel *k* used to destroy ODS	tCO_2e	For each offset project	M	Use only if calculating site-specific project emissions from ODS destruction
Equation 5.10	$EF_{FF,k}$	Fuel specific emission factor	$kgCO_2$/ volume fuel	N/A	R	Use only if calculating site-specific project emissions from ODS destruction
Equation 5.11	EL_{PR}	Total electricity consumed to destroy ODS	MWh	For each offset project	M	Use only if calculating site-specific project emissions from ODS destruction
Equation 5.11	EF_{EL}	Carbon emission factor for electricity used	$lbCO_2$/ MWh	N/A	R	Use only if calculating site-specific project emissions from ODS destruction
Equation 5.9, Equation 5.12	$ODS_{emissions}$	Total GHG emissions of un-destroyed ODS	tCO_2e	For each offset project	C	Use only if calculating site-specific project emissions from ODS destruction
Equation 5.9, Equation 5.13	ODS_{CO2}	Total emissions of CO_2 from ODS oxidation	tCO_2	For each offset project	C	Use only if calculating site-specific project emissions from ODS destruction
Equation 5.13	CR_i	Carbon ratio of ODS *i*	mole C/ mole ODS	N/A	R	Use only if calculating site-specific project emissions from ODS destruction
Equation 5.14	TMT_i	Tonne-miles-traveled for ODS *i* destroyed	tonne-miles	For each offset project	M	Use only if calculating site-specific project emissions from ODS transportation
Equation 5.14	EF_{TMT}	Mode-specific emission factor	$kgCO_2$/ tonne-mile	N/A	R	Use only if calculating site-specific project emissions from ODS transportation

7 Reporting Parameters

General requirements for reporting and record retention are included in the Regulation. This section provides additional requirements on reporting rules and procedures specific to this protocol. A priority of this protocol is to facilitate consistent and transparent information disclosure by the Offset Project Operator or Authorized Project Designee.

7.1 Annual Reporting Requirements

The Offset Project Operator~~s~~ or Authorized Project Designee~~s~~ must submit an Offset Project Data Report according to the requirements in the Regulation. The Offset Project Data Report must include the information listed in the Regulation and this protocol and cover a single Reporting Period. See the Regulation and Appendix D for specific requirements.

7.2 Document Retention

The Offset Project Operator or Authorized Project Designee is required to retain all documentation and information outlined in the Regulation and this protocol. Record retention requirements are set forth in the Regulation.

System information the Offset Project Operator or Authorized Project Designee should retain includes, but is not limited to:

- All data inputs for the calculation of the offset project emission reductions, including all required sampled data
- Copies of all permits, Notices of Violations (NOVs), and any relevant administrative or legal consent orders dating back at least 3 years prior to the project commencement date
- Destruction facility monitor information (CEMS data, DRE documentation, scale readings, calibration procedures, and permits)
- Chain of custody and point of origin documentation
- ODS composition and quantity lab reports

See section 95976 for regulatory record-keeping requirements.

7.3 Verification Cycle

Project verification schedules can be found in the Regulation.

8 Regulatory Verification Requirements

All Offset Project Data Reports are subject to regulatory verification as set forth in the Regulation by an ARB accredited verification body. The Offset Project Data Reports must receive a positive or qualified positive verification statement to be issued ARB or registry offset credits.

9 Glossary of Terms[16]

Certificate of Destruction	An official document provided by the destruction facility certifying the date, quantity, and type of ODS destroyed.
Project commencement	The date of the beginning of the destruction activity.
Commercial refrigeration equipment	The refrigeration appliances used in the retail food, cold storage warehouse or any other sector that requires cold storage. Retail food includes the refrigeration equipment found in supermarkets, grocery and convenience stores, restaurants, and other food service establishments. Cold storage includes the refrigeration equipment used to house perishable goods or any manufactured product requiring refrigerated storage.
Container	An air- and water-tight unit for storing and/or transporting ODS material without leakage or escape of ODS.
Destruction	Destruction of ozone depleting substances by qualified destruction, transformation or conversion plants achieving greater than 99.99% destruction and removal efficiency, in order to avoid their emissions. Destruction may be performed using any technology, including transformation, that results in the complete breakdown of the ODS into either a waste or usable by-product.
Destruction facility	A facility that destroys, transforms or converts ozone depleting substances using a technology that meets the standards defined by the UN Environment Programme Technology and Economic Assessment Panel Task Force on Destruction Technologies as provided in the *Report of the Task Force on Destruction Technologies* and listed in The Climate Action Reserve's *U.S. Ozone Depleting Substances Project Protocol Version 1.0*.

[16] For terms not defined in this section, the definitions in the Regulation apply.

Emission rate	The rate at which refrigerant is lost to the atmosphere, including emissions from leaks during operation and servicing events.
Ozone Depleting Substances (ODS)	Ozone depleting substances are substances known to deplete the stratospheric ozone layer. The ODS controlled under the Montreal Protocol and its Amendments are chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC), halons, methyl bromide (CH_3Br), carbon tetrachloride (CCl_4), methyl chloroform (CH_3CCl_3), hydrobromofluorocarbons (HBFC) and bromochloromethane (CHBrCl).
Recovery efficiency	The percent of total ODS blowing agent that is recovered during the process of ODS blowing agent extraction.
Recharge	Replenishment of refrigerant agent (using reclaimed or virgin material) into equipment that is below its full capacity because of leakage or because it has been evacuated for servicing or other maintenance.
Reclaim	Reprocessing and upgrading of a recovered ozone depleting substance through mechanisms such as filtering, drying, distillation and chemical treatment in order to restore the ODS to a specified standard of performance. Chemical analysis is required to determine that appropriate product specifications are met. Reclaiming and the associated chemical analysis often involve processing off-site at a central facility.
Recovery	The removal of ozone depleting substances from machinery, equipment, containment vessels, etc., during servicing or prior to disposal without testing or processing it in any way.
Reuse/recycle	Reuse of a recovered ozone depleting substance following a basic cleaning process such as filtering and drying. For refrigerants, recycling normally involves recharge back into equipment and it often occurs ‘on-site’.
Startup, shutdown, and malfunction plan	A plan, as specified under 40 CFR 63.1206, that includes a description of potential causes of malfunctions, including releases from emergency

	safety vents, that may result in significant releases of hazardous air pollutants, and actions the source is taking to minimize the frequency and severity of those malfunctions.
Stockpile	ODS stored for future use or disposal in bulk quantities at a single location. These quantities may be composed of many small containers or a single large container.
Substitute refrigerant	Those refrigerants that will be used to fulfill the function that would have been filled by the destroyed ODS refrigerants. These refrigerants may be drop-in replacements used in equipment that previously used the type of ODS destroyed or may be used in new equipment that fulfills the same market function.
Substitute emissions	A term used in this protocol to describe the greenhouse gases emitted from the use of substitute refrigerants in technologies that are used to replace the ODS destroyed in a project.
Transportation system	A term used to encompass the entirety of the system that moves the ODS from the point of aggregation to the destruction facility.

10 References

CAR (2010) U.S. Ozone Depleting Substances Project Protocol Version 1.0. February 3, 2010. http://www.climateactionreserve.org/how/protocols/adopted/ods/current/ (accessed August 30, 2010)

CAR (2010) U.S. Ozone Depleting Substances Project Protocol Errata and Clarifications. May 7, 2010. http://www.climateactionreserve.org/how/protocols/adopted/ods/current/ (accessed August 30, 2010)

Appendix A Foam Recovery Efficiency and Calculations – Quantification Methodology

The following methodology calculates the site- or process-specific recovery efficiency for blowing agent recovery projects, and uses this value for calculation of GHG emission reductions in Section 5. Determination of accurate recovery efficiency allows project baseline emissions and project emissions to be calculated in reference to the initial quantity of foam blowing agent diverted from project baseline treatment.

A.1 Calculating Recovery Efficiency

All appliance foam projects must calculate a recovery efficiency based on a run of a minimum ten appliances. Basing this analysis on a number of appliances greater than ten will likely result in a higher calculated recovery efficiency due to the 90% upper confidence limit used for calculating the concentration of ODS blowing agent in the foam. A larger sample size will decrease uncertainty and thus lower the estimated blowing agent concentration and increase recovery efficiency; however, sampling of additional appliances will also increase testing costs.

The procedures below shall be used to calculate recovery efficiency.

Estimate initial blowing agent concentration

The concentration of ODS blowing agent in the PU foam prior to any appliance treatment shall either be assumed to equal to 14.9% or calculated according to the steps below. Calculating a sample-specific value allows the Offset Project Operators or Authorized Project Designees to document a lower ODS blowing agent concentration, which will result in a higher estimated recovery efficiency.

The following steps shall be followed to document a sample-specific ODS blowing agent concentration:

1. Cut four PU foam samples from each appliance (left side, right side, top, bottom) using a reciprocating saw. Samples must be at least four inches square and the full thickness of the insulation.
2. Seal the cut edges of each foam sample using aluminum tape or similar product that prevents off-gassing.
3. Individually label each sample to record appliance model, and site of sample (left, right, top, or bottom)
4. Analyze samples according to the procedures dictated for building foam in Section 6.3. Samples may be analyzed individually (four analyses per appliance), or a single analysis may be done using equal masses of foam from each sample (one analysis per appliance).
5. Based on the average of the samples for each appliance, calculate the 90% upper confidence limit of the concentration. The 90% upper confidence limit shall be used as the parameter BA_{conc} in the equations below.

Extract the ODS blowing agent and separate foam residual

The ODS blowing agent from the sampled appliances must be collected and quantified according to the steps below.

1. Begin processing with all equipment shut down and emptied of all materials.
2. Process all sample appliances.
3. Extract and collect concentrated BA. The mass of the recovered blowing agent shall be determined by comparison of the mass of the fully evacuated receiving containers to their mass when filled. This value shall be used as the parameter BA_{post} in the equations below.

Separate foam residual

The quantity of foam in the processed appliances must be established either through use of a default value of 12.9 pounds per appliance, or according to the following steps. If the value of 12.9 pounds per appliance is used, it shall be multiplied by the number of appliances processed to determine $Foam_{res}$ in the calculation of recovery efficiency.

1. Separate and collect all foam residual, which may be in a fluff, powder, or pelletized form. Processes must be documented to demonstrate that no significant quantity of foam residual is lost in the air or other waste streams.
2. If desired, manually separate non-foam components in the residual (e.g., plastic) to determine a percent of foam in residual. If performed, this analysis must be conducted on at least one kilogram of residual, and results may be no lower than 90%.
3. Weigh the total recovered foam residual, and, if performed, multiply by the percent foam in residual, to calculate total mass of foam recovered. This value shall be used as the parameter $Foam_{res}$.

Calculate recovery efficiency

To calculate the recovery efficiency, apply the calculated values to the equations below. The recovery efficiency (RE) calculated below shall be used in the calculations of Section 5.

$$BA_{init} = \frac{Foam_{res}}{(1 - BA_{conc})} \times BA_{conc}$$

Where,

			Units
$Foam_{res}$	=	Mass of foam recovered	lbs foam
BA_{conc}	=	Initial concentration of blowing agent in PU foam	lbs BA / lbs PU
BA_{init}	=	Initial quantity of blowing agent in appliances prior to treatment	lbs BA

$$RE = \frac{BA_{post}}{BA_{init}}$$

Where,			Units

			Units
RE	=	Recovery efficiency	%
BA_{post}	=	Quantity of recovered blowing agent in concentrated form	lbs BA
BA_{init}	=	Initial quantity of blowing agent in appliances prior to treatment	lbs BA

Appendix B Emission Factor Tables

Table B.1. CO_2 Emission Factors for Fossil Fuel Use

Fuel Type	Heat Content	Carbon Content (Per Unit Energy)	Fraction Oxidized	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Coal and Coke	**MMBtu / Short ton**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / Short ton**
Anthracite Coal	25.09	28.26	1.00	103.62	2,599.83
Bituminous Coal	24.93	25.49	1.00	93.46	2,330.04
Sub-bituminous Coal	17.25	26.48	1.00	97.09	1,674.86
Lignite	14.21	26.30	1.00	96.43	1,370.32
Unspecified (Residential/ Commercial)	22.05	26.00	1.00	95.33	2,102.29
Unspecified (Industrial Coking)	26.27	25.56	1.00	93.72	2,462.12
Unspecified (Other Industrial)	22.05	25.63	1.00	93.98	2,072.19
Unspecified (Electric Utility)	19.95	25.76	1.00	94.45	1,884.53
Coke	24.80	31.00	1.00	113.67	2,818.93
Natural Gas (By Heat Content)	**Btu / Standard cubic foot**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / Standard cub. ft.**
975 to 1,000 Btu / Std cubic foot	975 – 1,000	14.73	1.00	54.01	Varies
1,000 to 1,025 Btu / Std cubic foot	1,000 – 1,025	14.43	1.00	52.91	Varies
1,025 to 1,050 Btu / Std cubic foot	1,025 – 1,050	14.47	1.00	53.06	Varies
1,050 to 1,075 Btu / Std cubic foot	1,050 – 1,075	14.58	1.00	53.46	Varies
1,075 to 1,100 Btu / Std cubic foot	1,075 – 1,100	14.65	1.00	53.72	Varies
Greater than 1,100 Btu / Std cubic foot	> 1,100	14.92	1.00	54.71	Varies
Weighted U.S. Average	1,029	14.47	1.00	53.06	0.0546
Petroleum Products	**MMBtu / Barrel**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / gallon**
Asphalt & Road Oil	6.636	20.62	1.00	75.61	11.95
Aviation Gasoline	5.048	18.87	1.00	69.19	8.32
Distillate Fuel Oil (#1, 2 & 4)	5.825	19.95	1.00	73.15	10.15
Jet Fuel	5.670	19.33	1.00	70.88	9.57
Kerosene	5.670	19.72	1.00	72.31	9.76
LPG (average for fuel use)	3.849	17.23	1.00	63.16	5.79
Propane	3.824	17.20	1.00	63.07	5.74
Ethane	2.916	16.25	1.00	59.58	4.14
Isobutene	4.162	17.75	1.00	65.08	6.45
n-Butane	4.328	17.72	1.00	64.97	6.70
Lubricants	6.065	20.24	1.00	74.21	10.72
Motor Gasoline	5.218	19.33	1.00	70.88	8.81
Residual Fuel Oil (#5 & 6)	6.287	21.49	1.00	78.80	11.80
Crude Oil	5.800	20.33	1.00	74.54	10.29
Naphtha (<401 deg. F)	5.248	18.14	1.00	66.51	8.31
Natural Gasoline	4.620	18.24	1.00	66.88	7.36
Other Oil (>401 deg. F)	5.825	19.95	1.00	73.15	10.15
Pentanes Plus	4.620	18.24	1.00	66.88	7.36
Petrochemical Feedstocks	5.428	19.37	1.00	71.02	9.18
Petroleum Coke	6.024	27.85	1.00	102.12	14.65
Still Gas	6.000	17.51	1.00	64.20	9.17
Special Naphtha	5.248	19.86	1.00	72.82	9.10
Unfinished Oils	5.825	20.33	1.00	74.54	10.34
Waxes	5.537	19.81	1.00	72.64	9.58

Default CO_2 emission factors (per unit energy) are calculated as: Carbon Content × Fraction Oxidized × 44/12.
Default CO_2 emission factors (per unit mass or volume) are calculated as: Heat Content x Carbon Content × Fraction Oxidized × 44/12× Conversion Factor (if applicable).
Heat content factors are based on higher heating values (HHV).

Table B.2. CO_2 Electricity Emission Factors

eGRID subregion acronym	eGRID subregion name	Annual output emission rates	
		(lb CO_2/MWh)	(metric ton CO_2/MWh)*
AKGD	ASCC Alaska Grid	1,232.36	0.559
AKMS	ASCC Miscellaneous	498.86	0.226
AZNM	WECC Southwest	1,311.05	0.595
CAMX	WECC California	724.12	0.328
ERCT	ERCOT All	1,324.35	0.601
FRCC	FRCC All	1,318.57	0.598
HIMS	HICC Miscellaneous	1,514.92	0.687
HIOA	HICC Oahu	1,811.98	0.822
MROE	MRO East	1,834.72	0.832
MROW	MRO West	1,821.84	0.826
NEWE	NPCC New England	927.68	0.421
NWPP	WECC Northwest	902.24	0.409
NYCW	NPCC NYC/Westchester	815.45	0.370
NYLI	NPCC Long Island	1,536.80	0.697
NYUP	NPCC Upstate NY	720.80	0.327
RFCE	RFC East	1,139.07	0.517
RFCM	RFC Michigan	1,563.28	0.709
RFCW	RFC West	1,537.82	0.698
RMPA	WECC Rockies	1,883.08	0.854
SPNO	SPP North	1,960.94	0.889
SPSO	SPP South	1,658.14	0.752
SRMV	SERC Mississippi Valley	1,019.74	0.463
SRMW	SERC Midwest	1,830.51	0.830
SRSO	SERC South	1,489.54	0.676
SRTV	SERC Tennessee Valley	1,510.44	0.685
SRVC	SERC Virginia/Carolina	1,134.88	0.515

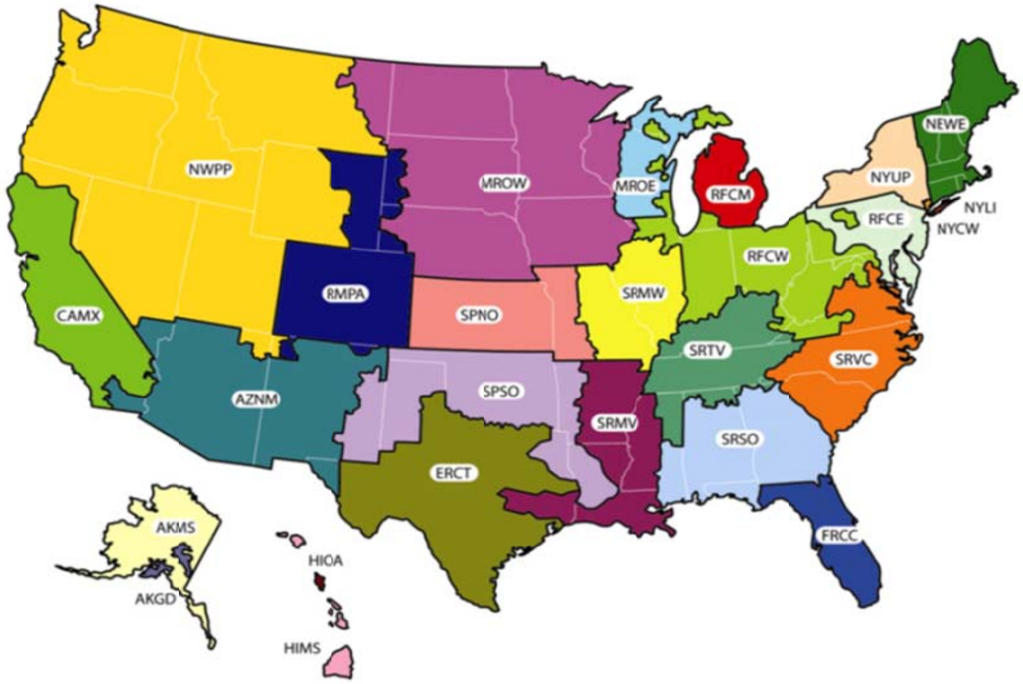


Figure B.1. Map of eGRID2007 Subregions

Appendix C Offset Project Listing Information

1. Offset project Name
2. Offset Project Operator or Authorized Project Designee
3. Technical Consultants
4. Other parties with a material interest
5. Date of form completion
6. Form completed by (name, organization)
7. Offset project Description: 1-2 paragraphs
8. List all points of origin by US state for ODS sourced for this project
9. All ODS sources that will be destroyed under this project:
   Refrigerant Destruction: CFC-11, CFC-12, CFC-113, CFC-114, or CFC-115
   Destruction of ODS Blowing agent in intact building foam: CFC-11, CFC-12, HCFC-22, HCFC-141b
   Destruction of concentrated ODS blowing agent in appliance foam: CFC-11, CFC-12, HCFC-22, HCFC-141b
10. Name of destruction facility
11. Address of destruction facility
12. Is the destruction facility a RCRA permitted hazardous waste combustor (HWC)?
13. If the destruction facility is not a RCRA-permitted HWC, has it met the TEAP requirements for ODS destruction?
14. Offset project commencement date
15. Reporting period
16. Have any GHG reductions associated with the offset project ever been registered with or claimed by another registry or program, or sold to a third party prior to our listing? If yes, identify the registry or program (Vintage and reporting period)
17. Is this offset project being implemented and conducted as the result of any law, statute, regulation, court order, or other legally binding mandate? If yes, explain.
18. Has an Offset Project Data Report been developed? If not, what date will it be in place?
19. Has the offset project-specific recovery efficiency been determined (for appliance foam projects only)? If not, when will this factor be established? If yes, what is the factor?
20. Was, or will, any of the destroyed ODS be sources from the US government? If yes, how much?
21. Was, or will, any of the destroyed ODS be considered hazardous waste under US, state or local law? If yes, how much and explain.

Appendix D Offset Data Report Information

1. Offset project name
2. Offset Project Operator or Authorized Project Designee
3. Report date
4. Contact information for Offset Project Operator or Authorize Project Designee
    a. Address, email, phone number
5. Name of individual completing report
6. Reporting Period
7. Does offset project meet all local, state, or federal regulatory requirements?
8. Date(s) of ODS destruction
9. Destruction facility name and location
10. Type of ODS destroyed
11. Mass and composition of ODS as determined by the process outlined in Section 6.6 of the Protocol.
12. Names of all parties and their contact information included in the chain of custody documentation
13. Is all the information in the offset project listing still accurate? If not provided updates.
14. Project baseline emissions
15. Project emissions
16. Total GHG reductions

California Environmental Protection Agency

AIR RESOURCES BOARD

Compliance Offset Protocol Urban Forest Projects

Adopted: October 20, 2011

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Abbreviations and Acronyms

ARB	California Air Resources Board
C	Carbon
CAR	Climate Action Reserve
CH_4	Methane
CO_2	Carbon dioxide
dbh	Diameter at breast height
GHG	Greenhouse gas
lb	Pound
N_2O	Nitrous oxide
NTG	Net tree gain
Regulation	Cap-and-Trade Regulation, title 17, California Code of Regulations, sections 95800 et seq.
TMP	Tree maintenance plan
USFS	United States Forest Service

1 Introduction

The Compliance Offset Protocol Urban Forest Projects provides methods to quantify and report greenhouse gas (GHG) removal enhancements associated with a planned set of tree planting and maintenance activities to permanently increase carbon storage in trees. This protocol is based on The Climate Action Reserve's Urban Forest Project Protocol Version 1.1[1] (CAR 2010).

Offset Project Operators or Authorized Project Designees that implement tree-planting programs must use this protocol to quantify and report GHG removal enhancements. The protocol provides eligibility rules, methods to quantify GHG removal enhancements, offset project-monitoring instructions, and procedures for reporting Offset Project Data Reports. Additionally, all offset projects must submit to independent verification by ARB-accredited verification bodies at least once every six years. Requirements for verification bodies to verify offset project emissions data reports are provided in the Cap-and-Trade Regulation (Regulation).

To register urban forest project GHG removal enhancements, Offset Project Operators and Authorized Project Designees are not required to prepare and submit an annual municipal, campus, or utility-level GHG inventory.

This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification of GHG emission reductions associated with urban forest projects. The protocol is comprised of both quantification methodologies and regulatory program requirements to develop an urban forest project and generate ARB or registry offset credits.

AB 32 exempts quantification methodologies from the Administrative Procedure Act (APA)[2]; however those elements of the protocol are still regulatory. The exemption allows future updates to the quantification methodologies to be made through a public review and Board adoption process but without the need for rulemaking documents. Each protocol identifies sections that are considered quantification and exempt from APA requirements. Any changes to the non-quantification elements of the offset protocols would be considered a regulatory update subject to the full regulatory development process. Those sections that are considered to be a quantification methodology are clearly indicated in the title of the chapter or subchapter if only a portion of that chapter is considered part of the quantification methodology of the protocol.

[1] Climate Action Reserve (2010) Urban Forest Project Protocol Version 1.1 March 10, 2010 http://www.climateactionreserve.org/how/protocols/adopted/urban-forest/current-urban-forest-project-protocol/ (accessed May 20, 2011).
[2] Health and Safety Code section 38571.

2 The GHG Reduction Project

2.1 Project Definition – Quantification Methodology

For the purpose of this protocol, the GHG reduction ("removal enhancement") project is defined as a planned set of tree planting and maintenance activities that permanently increase carbon storage, taking into account GHG emissions associated with planting and maintenance of project trees.

While project trees are planted for the purposes of the urban forest GHG project, tree sites are the primary unit of analysis. A tree site contains one tree at a time, however, the tree may be replaced over time and the site itself may be moved. This is because project trees are subject to mortality and other types of losses and therefore may need to be replaced and/or relocated during the offset project life (see Section 6 for details).

This protocol is not applicable for forest management and conservation activities that occur on large natural forested tracts within cities (≥ 100 acres contiguously forested and containing dead downed woody material).

An Offset Project Operator or Authorized Project Designee can assemble several smaller offset projects into a single offset project for the purposes of achieving economies of scale and more efficient reporting. However, reporting, monitoring, and verification practices must follow the requirements set forth in this protocol and the Regulation.

This protocol is applicable to three specific project types: urban forest GHG projects undertaken (1) in municipalities[3], (2) on educational campuses[4], and (3) by utilities. An offset project is defined by a specific number of project tree sites, determined a priori, that will be planted and maintained within one of the above types of entities over the offset project life. If the Offset Project Operator or Authorized Project Designee intends to plant more project tree sites than the number defined under the original offset project, this constitutes a second, distinct urban tree project. Offset Project Operators or Authorized Project Designees can undertake as many urban tree projects as desired in the future as long as they each, separately, meet the eligibility criteria and reporting requirements in this protocol and set forth in the Regulation.

2.2 Offset Project Operator or Authorized Project Designee

The Offset Project Operator or Authorized Project Designee is responsible for offset project listing, monitoring, reporting and verification. The Offset Project Operator or Authorized Project Designee must have legal authority to implement the offset project. For the purpose of this protocol, an Offset Project Operator or Authorized Project

[3] Including cities, counties, and other local agencies or special districts.
[4] As noted in Section 4, the physical area owned and/or controlled by the municipality, educational campus, or utility determines municipal, campus, or utility service area boundaries. In the case of educational campuses, the Offset Project Operator or Authorized Project Designee may define the entity as a single campus or a system of campuses, as long as the definition is clearly stated and the entity can demonstrate that it has ownership and/or control over the physical area.

Designee must represent a municipality, educational institution, or utility. The Offset Project Operator or Authorized Project Designee must submit the information in Appendix C along with the listing requirements in the Regulation. Responsibility for tree planting, care, and maintenance activities may reside with either the Offset Project Operator or Authorized Project Designee.

3 Eligibility Rules

General eligibility requirements for offset projects are set forth in the Regulation. The Offset Project Operator or Authorized Project Designee using this protocol must also satisfy the following rules to be eligible to receive ARB or registry offset credit.

3.1 Location

Only offset projects located in the United States and its territories are eligible under this protocol. In addition, offset projects situated on the following categories of land are only eligible under this protocol if they meet the requirements of this protocol and the Regulation, including the waiver of sovereign immunity requirements of section 95975(l) in the Regulation:

1. Land that is owned by, or subject to an ownership or possessory interest of a Tribe;
2. Land that is “Indian lands” of a Tribe, as defined by 25 U.S.C. §81(a)(1); or
3. Land that is owned by any person, entity, or Tribe, within the external borders of such Indian lands.

Project tree sites must be located according to the requirements in Section 4 (average spacing of no less than 5 meters and placement along streets, in parks and parking lots, etc.) Thus, urban forest projects must take place in urban or other types of developed areas.

3.2 Offset Project Commencement

Offset Project Commencement for an urban forest project is defined as the date at which the Offset Project Operator or Authorized Project Designee implements a planned set of tree planting activities and becomes operational. For the purposes of this protocol, the commencement of operation means when trees are planted and regular maintenance begins. Offset projects may always be submitted for listing prior to their commencement date.

3.3 Project Crediting Period

The crediting period for this project type is 25 years. Requirements for renewal of offset project crediting periods are set forth in the Regulation.

3.4 Additionality

Offset projects must meet the additionality requirements in the Regulation, in addition to the requirements below.

3.4.1 Net Tree Gain – Quantification Method

The offset project must demonstrate a priori that it will exceed the business-as-usual threshold, and information confirming this, in accordance with the requirements below, must be provided in the documentation for applying for offset project listing as set forth in Appendix C.

The business-as-usual threshold comparison for municipalities, educational campuses, and utilities is based on information within the area the offset project will take place. If a partner organization/individual working with a municipality, educational campus, or utility plants trees outside the offset project boundary, these activities should not be included in the comparison.

Municipalities and Educational Campuses

The business-as-usual thresholds for municipalities and educational campuses are measured in terms of net tree gain (NTG), i.e., the annual number of trees planted by a municipality or educational campus minus the annual number of trees removed by a municipality or educational campus. Only project activities that exceed this threshold are eligible.

The threshold for municipalities and educational campuses is set at maintaining a stable urban forest population (i.e. a NTG of 0). In other words, municipalities and educational campuses must plant at least as many trees as they remove.

In addition to the requirements for offset project listing, the Offset Project Operator or Authorized Project Designee must demonstrate a priori that an offset project will exceed the threshold, by calculating the anticipated NTG of the municipality, or educational campus, based on recent activities and anticipated project activities. Specifically, the calculation must be based on:

1. The annual average number of urban trees planted and removed in the municipality or educational campus over no more than the most recent five year period preceding the offset project commencement date, or using data from a single year occurring at some point during the past most recent five year period.
2. The expected average annual number of GHG project tree sites to be planted by the offset project.
3. Where urban trees include trees under municipality or educational campus ownership or control and are open-grown in managed landscapes.

In addition to the general requirements for monitoring, reporting, and record retention set forth in the Regulation, for each year of the offset project the Offset Project Operator or Authorized Project Designee is required to report an annual average NTG (number of urban trees planted minus removed) for the municipality, or educational campus, including regular activities (planting of “non-project” trees) and project activities (planting of “project” trees). The annual average NTG must be based on a five-year rolling average (i.e. the most recent previous five years including the reporting year), except in the first five years of the offset project when the average may be based on less than five years of data (i.e. one-year average in the first year of the offset project, two-year average in the second year). When the average annual NTG for the municipality or educational campus is positive (more trees are planted than removed), the number of trees planted in excess of the number removed determines how many eligible project trees can be designated that year. Specific eligible project trees are identified each year by the Offset Project Operator or Authorized Project Designee and tracked individually for the duration of the offset project. Carbon sequestration and GHG emissions from tree care, monitoring, and maintenance of the eligible project trees are the basis for calculating offset project GHG reductions.

If the municipality or educational campus reports a negative NTG in any given year, no new trees planted that year can be considered eligible project trees and no ARB or registry offset credits can be issued. When the municipality or educational campus returns to an average annual NTG of zero or greater, ARB or registry offset credits for GHG reductions from project trees during the intervening years (up to a maximum of five years) can be issued ex-post upon verification, as long as the criteria in this protocol for project trees were met during those years.

Utilities

Most utilities do not have tree planting programs that go beyond replacing trees removed during line clearance operations. While some have programs specifically aimed at storing carbon and conserving energy in residential households, on average utilities are planting fewer than 400 trees annually in these types of programs. All trees planted under these types of programs are considered additional and therefore are designated as eligible project trees. These trees may be used to generate GHG reductions, provided all criteria in this protocol and the regulation are met.

3.5 Regulatory Compliance

Offset Project Operators or Authorized Project Designees must fulfill all applicable local, regional and national requirements for environmental impact assessments that apply based on the offset project location. Offset projects must also meet all other local, regional, and national requirements that might apply. Offset projects are not eligible to receive ARB or registry offset credits for GHG emission reductions or GHG removal enhancements that occur as the result of activities that are not in compliance with regulatory requirements.

4 Offset Project Boundary – Quantification Methodology[5]

The Offset Project Boundary delineates the GHG sources, GHG sinks, and GHG reservoirs that are considered significantly affected by the project activity and must be included in the calculation of GHG reductions.

In this protocol, the Offset Project Boundary is defined as the carbon stored in standing trees and GHG emissions from motor vehicles and equipment used in tree care activities.

Required GHG source and GHG sink categories for reporting are as follows:

- Carbon stored in standing trees
- CO_2 emissions from motor vehicles related to tree planting, care, and monitoring
- CO_2 emissions from equipment related to tree planting and care

CO_2 is the primary GHG to report for urban forest projects.

The Offset Project Boundary includes the components of the project operations that are impacted by the project activity, including the physical area covered by the offset project as well as the specific equipment used by the offset project. This includes:

- The number of eligible project tree sites (determined in Section 3)
- Equipment used to plant and maintain the trees

Tree sites must be located within the boundary of a municipality, educational institution, or utility. Boundaries are determined by the physical area owned and/or controlled by a municipality or educational campus, or the service area covered by a utility.

For each offset project, eligible project trees must be planted:

- Along streets, in parks, city golf courses, cemeteries, near city buildings, greenbelts, city parking lots, and other public open space, or on private property in municipalities
- Along streets, near classrooms, dorms, office buildings, near recreational fields and other facilities, in parking lots, arboretums, and other open space on educational campuses
- In parks, streets, parking lots, private property, and open spaces by utilities

Tree plantings must have an average spacing of no less than 5 meters. Biomass equations for estimating carbon stock changes are for open-growing urban trees and assume relatively intensive management. The spatial location of all project tree sites must be known and recorded using GPS or GIS.

[5] The entirety of Chapter 4 is considered a quantification method.

4.1 Leakage

Leakage is an increase in GHG emissions or decrease in sequestration caused by the offset project but not accounted for within the offset project boundary. In the case of urban forest projects, the most likely form of leakage is the shifting of funds and maintenance from non-project tree resources (i.e. trees within the municipality, educational campus, or utility service area that are not part of the project) to project trees within a municipality, educational campus, or utility service area. For example, if funding is reduced for pruning existing trees to fund a GHG tree planting project, there may be an overall decline in the health of the urban forest within a municipality, educational campus, or utility service area and a long-term increase in mortality. A tree maintenance plan (TMP) is used to assess whether this type of activity-shifting leakage is occurring. Details on the TMP requirements are provided in Section 8.1. If annual expenditures of the municipality, educational campus, or utility (separate from offset project expenditures) in one or more program areas decrease by more than 10% from amounts in the initial TMP or from amounts in the previous year TMP, and these changes cannot be explained by the Offset Project Operator or Authorized Project Designee to the verifier, leakage will be assumed and if confirmed, no ARB or registry offset credits can be issued in that year.

5 GHG Calculation Methods – Quantification Methodology[6]

This section provides the detailed methods for calculating GHG emissions and GHG removals enhancements from the required GHG sources and GHG sinks:

- Carbon storage in standing trees: *Project Tree CO_2 Sequestration*
- GHG emissions from motor vehicles related to tree planting, care, and monitoring: *Vehicle CO_2 Emissions*
- GHG emissions from equipment related to tree planting and care: *Equipment CO_2 Emissions*

Project GHG reductions (removal enhancements) are based on the amount of carbon sequestered in eligible project trees minus GHG emissions from the planting, care and maintenance of those trees over the reporting period. Below is the general formula for determining project GHG reductions.

$$\text{Project GHG Reductions} = \text{Project Tree } CO_2 \text{ Sequestration} - \text{Vehicle } CO_2 \text{ Emissions} - \text{Equipment } CO_2 \text{ Emissions}$$

5.1 Quantifying Project Tree CO_2 Sequestration

For each crediting period, the Offset Project Operator or Authorized Project Designee estimates the amount of carbon contained in eligible project trees (carbon stocks) and then uses these data to calculate an incremental carbon stock change (carbon sequestration). Carbon stock changes are reported in final units of carbon dioxide equivalent (metric tons CO_2e). The change in carbon stocks (in kilograms) is the basis for estimating project tree carbon sequestration, and is calculated using the equation below. The factor 3.67 is the molecular weight ratio of CO_2 to carbon and is used to convert carbon stock change to CO_2. The factor 0.001 is used to convert the result from kilograms to metric tons.

$$\text{Project Tree } CO_2 \text{ Sequestration} = (Cstock_{year\ x} - Cstock_{year\ x-n}) \times (3.67) \times 0.001$$

5.1.1 Quantifying Tree Carbon Stocks

Quantifying the carbon stocks in eligible project trees is based on direct measurements of trees and approved urban tree carbon models (“allometric equations”). Consult Appendix A and Appendix B for detailed requirements.

Appendix A covers how to design tree measurement programs (inventories), including required tree measurement data and sampling techniques, design, and error. Appendix B describes how to estimate tree carbon from tree measurement data using allometric equations.

[6] The entirety of Chapter 5 is considered a quantification method.

Approved approaches for quantifying carbon stocks:

1. Measure all trees in project tree sites during a single year (census). Use the measurement data with approved allometric equations (Appendix B) to estimate tree volume, biomass, and carbon stocks. Data from direct tree measurements (i.e. tree dbh, diameter at breast height, and height if applicable) can be input directly into approved allometric equations.

2. Measure a sample of trees in the project tree population each year (Appendix A), use the measurement data with approved allometric equations to estimate carbon stocks in the samples (Appendix B), and extrapolate the carbon stock estimates to the entire tree population (Appendix A). As described above in Approach 1, direct measurement must be used to estimate tree carbon stock.

5.1.2 Requirements for Tree Monitoring and Acceptable Levels of Uncertainty

In addition to the general requirements for monitoring, reporting, and record retention set forth in the Regulation, a tree monitoring plan must be included as part of the offset project documents (see Section 7.2 for details). The tree monitoring plan must describe in detail the approach the offset project plans to use to quantify carbon stocks. The document will serve as evidence for the Offset Project Operator or Authorized Project Designee and will communicate the methodology to the verification body.

Approach 2 involves statistical extrapolation from sample data. The sampling method must be stratified by like-species and age classes (not to exceed groupings of five-year age classes). The combinations of species and age classes create independent sampling populations, or strata. Appendix A provides further details on stratified sampling design.

The resulting estimates must meet a minimum confidence level of 90% to report all of the estimated carbon stocks. If the project sampling design results in lower levels of confidence, the carbon stock estimates will be discounted according to the method below. See Appendix A for details on sampling programs.

Descriptive statistics must be produced at the time of verification if a sampling methodology is incorporated. The estimate of carbon stock change in project trees is adjusted based on the level of confidence in the carbon stock estimate according to the table below. The table provides sampling error ranges (where sampling error is on either side of the mean estimate at the 90% confidence level), calculated with the following equation:

Sampling Error (90% confidence interval) =	*[(1 Standard Error *1.645)/(Sample mean)] x 100*

Table 5.1. Sampling Error and Carbon Stock Change Adjustment

Sampling Error*	Carbon Stock Change Adjustment (deduction by)
0 to 5%	0%
5.1 to 10%	10%
10.1 to 15%	20%
15.1 to 20%	30%
> 20%	100%

* Minimum confidence interval at 90% confidence limits.

5.2 Quantifying GHG Emissions from Motor Vehicles Related to Tree Planting and Care

Vehicle emissions are those associated with transport of personnel, supplies, and trees to and from eligible project tree sites.

Calculations of CO_2 emissions from vehicles are based on actual fuel use (gallons per year) and an emission factor (kg CO_2 per gallon) for fuel.

$$C_{vehicle\ emis} = TC \times EF$$

Where,

TC	=	Total annual fuel consumption (gallons)
EF	=	Emission factor by fuel type. Divide by 1,000 to convert kilograms into metric tons (t).

See the CO_2 emission factors for fuel combustion in the table below.

Table 5.2. Carbon Dioxide Emission Factors for Fuels

Fuel	CO_2 Emission Factor (kg CO_2/gallon)
Aviation Gasoline	8.31
Biodiesel (B100)	9.45
Crude Oil	10.28
Diesel 1 Diesel 2 Diesel 4	10.18 10.21 10.96
Ethane	6.01
Ethanol (E100)	5.75
Isobutane	6.29
Jet Fuel (Jet A or A-1)	9.75
Kerosene	10.15
Liquefied Petroleum Gas (LPG)	5.79
Methanol	4.15

Motor Gasoline	8.78
n-Butane	6.58
Propane	5.59
Residual Fuel Oil (#5,6)	10.21, 11.27
	(kg CO_2/therm)
Natural Gas	5.30

Source: Federal Register, Vol. 74, No. 209 (October 30, 2009)

The volume of fuel consumed during the crediting period can be derived from fuel records data (including bulk fuel purchase records, collected fuel receipts, official logs of vehicle fuel gauges or storage tanks). Where actual fuel use (TC) is not available, it can be estimated using vehicle information (make, model, model year, and fuel type) and annual mileage estimates by vehicle type. For each vehicle, convert annual mileage to fuel consumption using EPA's fuel economy formula below. In this equation, DP_c and DP_h are the proportion of miles traveled spent in city and highway driving conditions, respectively. A DP_c value of 0.55 and a DP_h value of 0.45 may be used as a default value, or a fleet specific number may be substituted if known.

Total Fuel Use (gallons)	=	Total Mileage (miles)	/	(	Fuel Economy City (mpg)	x	DP_c	+	Fuel Economy Highway (mpg)	x	DP_h	)

Alternatively, the amount of fuel used for the eligible project trees can be estimated by prorating total fuel usage for all tree maintenance and monitoring activities of the municipality, educational campus, or utility by the number of eligible project tree sites relative to total trees managed by the municipality, educational campus, or utility.

5.3 Quantifying GHG Emissions from Equipment Related to Tree Planting and Care

Equipment emissions are associated with back hoes used in planting, and chain saws, aerial lifts, and chippers used during tree removal and pruning activities.

If the total amount of fuel consumed by equipment on GHG project-related activities is known, CO_2 emissions can be calculated using fuel-specific emission factors in Table 5.2:

$$C_{equip\ emis} = TC \times EF$$

In many cases, equipment use is tracked in hours. If the hours are known, the emissions can be calculated for each piece of equipment based on the following formula and then summed:

$$C_{equip\ emis} = HRS \times LF \times HP \times EF$$

Where,

HRS	=	Hours used
LF	=	Typical load factor
HP	=	Maximum horsepower
EF	=	Average CO_2 emissions per unit of use (kg/hr)

Typical load factors, horsepower, average emissions, and EFs for equipment are given in Table 5.3. Typical hours required for pruning and removal activities are given for maintenance equipment in Table 5.4.

Table 5.3. Typical Load Factors (LF) and Average CO_2 Emissions (EF) for Maintenance Equipment

Equipment	HP range[b]	LF[a]	EF (kg/hp/hr)[b]
Aerial lift (45 hp)	25<HP≤50	0.505	0.783
Backhoe	HP≤120	0.465	0.775
Chain saw (2 hp)	HP≤2	0.500	0.429
Chain saw (7 hp)	2<HP≤7	0.500	0.429
Chipper (50 hp)	HP≤50	0.370	0.783

[a] Climate Action Reserve 2010, Section 6.3 pg 16.
[b] California Air Resources Board 2008

Table 5.4. Total Hours of Equipment Run-Time for Tree Pruning and Removal

Pruning					Removal				
dbh	2.3-hp saw	3.7-hp saw	Bucket truck[a]	Chipper[b]	2.3-hp saw	3.7-hp saw	7.5-hp saw	Bucket truck	Chipper
1-6	0.05	NA	NA	0.05	0.3	NA	NA	0.2	0.1
7-12	0.1	NA	0.2	0.1	0.3	0.2	NA	0.4	0.25
13-18	0.2	NA	0.5	0.2	0.5	0.5	0.1	0.75	0.4
19-24	0.5	NA	1.0	0.3	1.5	1.0	0.5	2.2	0.75
25-30	1.0	NA	2.0	0.35	1.8	1.5	0.8	3.0	1.0
31-36	1.5	0.2	3.0	0.4	2.2	1.8	1.0	5.5	2.0
36+	1.5	0.2	4.0	0.4	2.2	2.3	1.5	7.5	2.5

[a] Mean HP = 43
[b] Mean HP = 99

Note: Values by dbh classes (inches) and assume crews work efficiently and equipment is not run idle.

Source: see references in CAR 2010.

5.4 Quantifying GHG Emissions from Vehicles and Equipment for Municipalities with Insufficient Data

In some instances, municipalities may not have the data necessary to calculate GHG emissions for tree planting and maintenance activities as required in Sections 5.2 and 5.3 (if, for instance, tree maintenance activities are contracted out to private entities). If data required to calculate CO_2 emissions from tree planting and maintenance activities is not obtainable, municipal projects may use a default emission factor equal to 4.17 kg CO_2 per project tree per year to calculate the annual CO_2 emissions from all, or a portion of, the tree planting and maintenance activities associated with a municipal urban forest project.[7] However, all offset projects must use the methods described in Sections 5.2 and 5.3 to assess CO_2 emissions from vehicles and equipment if there is sufficient data to do so. The metric listed above is based on survey results from municipal tree planting programs, and is thus only applicable to municipal urban forest projects.

[7] The default emission factor was derived from survey responses detailing annual fuel usage for the tree planting and maintenance activities of 30 municipal urban forest programs nation-wide. The default value is equal to one standard deviation above the mean of the data set.

6 Permanence

The Regulation requires that credited GHG reductions and GHG removal enhancements be "permanent." GHG offset projects involving biological carbon sequestration must address the potential reversibility of sequestered carbon, which is the loss of stored carbon after ARB or registry offset credits have been issued. Consistent with guidance from the Intergovernmental Panel on Climate Change, permanence is defined as 100 years - the biological carbon should remain stored for 100 years (e.g. a reduction of carbon created in 2010 will remain stored until 2110 and if it is reversed, e.g. through mortality, it must be replaced).

Project Life is defined as the period of time between offset project commencement and a period of 100 years following the issuance of any ARB or registry offset credit for GHG reductions or GHG removal enhancements achieved by the offset project. Urban forest offset projects must continue to monitor, verify and report project data for a period of 100 years following any ARB or registry offset credit issuance. For example, if ARB or registry offset credits are issued to an urban forest project in year 25 following offset project commencement, monitoring and verification activities must be maintained until year 125. Offset Project Operators and Authorized Project Designees must take steps to maximize the likelihood that the carbon gains of urban forest projects are preserved for the project life. To this end, the following are requirements of this protocol:

1. All offset projects must monitor onsite carbon stocks, submit annual Offset Project Data Reports, and undergo third-party verification of those reports with site visits at least once every six years for the duration of the Project Life.
2. Continuous replacement of dead project trees at all tree sites during the Project Life (i.e. projects must have an average net tree gain of no less than zero). Prior to removal, dead trees must be measured for dbh (and height, if applicable) and their carbon content calculated and recorded using procedures in Appendix B. Dead trees must be replaced within one year from when they were removed. This timeframe allows for planting to occur at the appropriate time of year (e.g. loss and removal may occur in the fall and replanting occurs in the spring). Each tree site may have one or more replacement trees over time. Also, the location of some GHG project tree sites may change due to disturbances that unexpectedly eliminate tree sites. It is the Offset Project Operator's or Authorized Project Designee's responsibility to promptly locate and plant replacement sites so that there is no reduction in the total number of treed project sites.
3. If reversals are not compensated for with replacement trees, ARB requires that GHG offset credits be retired in proportion to any reversals (i.e. the carbon lost, in CO_2 equivalents, from removed trees), such that the total number of issued ARB offset credits does not exceed the total quantity of carbon stored (in CO_2 equivalents) by a project since its commencement date.

7 Offset Project Monitoring – Quantification Methodology[8]

General requirements for monitoring, reporting, and record retention are provided in the Regulation. Offset Project Operators and Authorized Project Designees are responsible for monitoring the performance of the offset project and maintaining records of monitoring data in accordance with the Regulation as well as the requirements stipulated in Section 8 and Appendix D. Monitoring is required for the Project Life (a period of 100 years following the issuance of ARB or registry offset credits for quantified GHG reductions or GHG removal enhancements).

Monitoring requirements are divided into these categories:

- Tree maintenance plan
- Project tree monitoring plan
- GHG emissions and sequestration activity data

The tree maintenance plan (TMP) is used to assess the potential of leakage and other aspects of offset project performance. The tree monitoring plan and GHG emissions and sequestration activity data are used to verify GHG emissions and sequestration estimates.

7.1 Tree Maintenance Plan

Reporting planting and maintenance activities and expenditures is critical to assessing leakage and GHG tree project compliance. At the level of the municipality, campus, or utility, by comparing reported annual tree care expenditures for different years a verifier can assess if a boost in project activity coincides with a drop in the level of care non-project trees are receiving. At the project level, information about tree maintenance and expenditures helps assess the strength of the project and its likelihood of success. In addition, all tree planting and removal practices by the municipality, campus, or utility must be reported each year to determine the number of eligible project trees.

To standardize annual reporting of tree planting and maintenance operations, activities are grouped into five program areas: tree planting, young tree care (< 5 years), mature tree care (> 5 years), tree removal, and administration/other (e.g. clerical, training, outreach). Annual expenditures and the level of service provided are indicators for each program area. Level of service is a quantifiable measure of tree care activities performed during a year. Higher levels of service indicate greater amounts of work performed. Reporting municipalities, educational campuses, or utilities must provide a TMP that describes municipal, educational campus, or utility-level expenditures for a 10- to 20-year period and project level activities for the reporting period.

Below are the specific TMP requirements. All information is for GHG project activities and expenditures (i.e. those related to project trees), except where noted. In some cases, information about the municipality, educational campus, or utility is also required to assess leakage potential (i.e. activities and expenditures related to non-project trees).

[8] The entirety of Section 7 is considered a quantification method.

Where both project and municipal, educational campus, or utility-level information is required, this is denoted in parentheses. Otherwise the information pertains to the project only.

Note that the Offset Project Operator or Authorized Project Designee~~s~~ must report on the most recent annual levels and expenditures and estimate the anticipated annual levels and expenditures for each of the criteria below in the project listing form and maintain records on actual levels and expenditures each year for the Project Life.

Tree planting:

- Number of trees planted in new tree sites each year, not including replacement trees (total for the municipality, educational campus, or utility, including project and non-project trees).
- Number of trees planted to replace removed trees each year (“replacement trees”), including replacement trees planted in relocated tree sites (separately for non-project and project trees).
- Species, size, and location[9] of project trees planted in new tree sites each year.
- Species, size, and location9 of project replacement trees planted in existing or relocated tree sites each year.
- Number and location[9] of relocated project tree sites each year.
- Reasons for relocations and, if applicable, modifications made to the project to reduce the chance of future relocations.
- Project tree resource: percentage of total project tree sites now planted.
- Annual tree planting expenditure (separately for the project and for the municipality, educational campus, or utility).

Young tree care:

- Number of young project trees inspected/pruned each year.
- Inspection/pruning cycle (total number of project trees / number treated per year).
- Annual expenditure (separately for the project and for the municipality, educational campus, or utility).

Mature tree care:

- Number of mature project trees inspected/pruned each year.
- Inspection/pruning cycle (total number of project trees / number treated per year).
- Annual expenditure (separately for the project and for the municipality, educational campus, or utility).

Tree removal:

- Number of trees removed from existing tree sites each year (separately for non-project and project trees).
- Species, size, and location[9] of project trees removed each year.
- Reasons for removals and, if applicable, modifications made to the project to reduce the chance of future removals.

[9] Tree site location must be designated on a map of the project physical boundaries.

- Removal cycle (total number of project trees to remove / number removed per year).
- Annual expenditure (separately for the project and for the municipality, educational campus, or utility).

Administration/other:
- Average $/tree site expenditure (total $ on admin and other / total tree numbers) (separately for the project and municipality, educational campus, or utility).
- Annual expenditure (separately for the project and for the municipality, educational campus, or utility).

If the potential for leakage is determined, the Offset Project Operator or Authorized Project Designee must explain to the verifier the changes in expenditures. Additional information on municipal, educational campus, or utility-level tree planting activities may be requested by the verification body.

7.2 Project Tree Monitoring Plan

A Project Tree Monitoring Plan is important for several reasons. The plan provides sufficient and transparent information on tree measurement and monitoring. This information is used to ensure the quantification methods meet the standards of this protocol. In addition, the plan informs the offset project about the status of tree sites, helping to ensure that lost trees are replaced and risks of reversals are minimized. The items below must be included in a project tree monitoring plan. For further technical information on urban forest inventory and monitoring, consult Appendix A.

- Choice of method from the options in Section 5.1.
- Detailed description of procedures to census (or sample, if applicable), measure, and report information on the project trees, including the survey method, sample sizes, and method for choosing samples.
- Methods used to measure and record tree size.
- Methods used and information collected on tree survival and health.
- Statistical methods used to extrapolate sample data to the total project tree population, if applicable.
- Estimated sampling error, if applicable.

7.3 GHG Emissions and Sequestration Activity Data

The data below are required inputs for estimating project GHG reductions. Transparent reporting of this information assists with verification of the project.

- Data on the species, dimensions (including dbh), date of measurement, and location of measured trees.
- Specific equations used to calculate tree volume, biomass and carbon content.
- Make and model year, annual amount and type of fuel used by tree planting and care vehicles (or the vehicle miles traveled and average fuel economy).

- Equipment type, horsepower rating, annual amount and type of fuel consumed in tree maintenance equipment (or the number of hours equipment is used).

8 Reporting Parameters

General requirements for monitoring, reporting, and record retention are included in the Regulation. This section provides requirements on additional reporting and procedures specific to this protocol.

8.1 Annual Reporting Requirements

The Offset Project Operator or Authorized Project Designee~~s~~ must submit an Offset Project Data Report according to the requirements in the Regulation. The Offset Project Data Report must include the information listed in the Regulation and this protocol and cover a single reporting period. See the Regulation and Appendix D for specific requirements.

All reports must be submitted after a review by a Professional Urban Forester. If the offset project is located in a jurisdiction without a Professional Urban Forester law or regulation, then a Professional Urban Forester must either have a Certified Forester credential managed by the Society of American Foresters, or any one of the following: California Certified Urban Forester credential managed by the California Urban Forests Council, Certified Arborist credential managed by the International Society of Arboriculture, Registered Consulting Arborist credential managed by the American Society of Consulting Arborists, or any other valid professional Forester, Arborist, Landscape Contractor, Landscape Architect, or Planner license or credential, approved by a government agency in the jurisdiction where the project is located.

8.2 Document Retention

The Offset Project Operator or Authorized Project Designee is required to retain all documentation and information outlined in the Regulation and in this protocol. Record retention requirements can be found in the Regulation.

Specific types of information the Offset Project Operator or Authorized Project Designee must retain includes but is not limited to:

- All data inputs for the calculation of vehicle and equipment fuel consumption and CO_2 emissions, tree carbon stocks, and project GHG reductions
- CO_2e tonnage calculations
- Initial and subsequent verification records and results
- Tree monitoring plan, and all tree maintenance plans and records relevant to the urban forest project

8.3 Verification Cycle

Offset project verification schedules are set forth in the Regulation.

9 Regulatory Verification Requirements

Regulatory verification requirements are set forth in the Regulation. In addition, each urban forest offset project verification team must include the following:

1. At least one Professional Urban Forester that takes an active role in reviewing the urban forest offset project tree biomass and carbon inventory, tree maintenance plan, tree monitoring plan, and conducting the site visit.
2. An ARB-accredited Forest or Urban Forest Offset Project Specialist.

An explanation demonstrating that the verification team includes individuals with the required experience and expertise must be included in the Notice of Verification Services submittal. The required experience and expertise may be demonstrated by a single individual, or by a combination of individuals.

During initial verification, the verification body must determine if the methodology in the Project Tree Monitoring Plan is acceptable and if it has sufficient detail for analysis during verification of the project.

10 Glossary of Terms[10]

GHG reservoir	GHG reservoir is defined in the Regulation. For urban forest projects, GHG reservoirs include above-ground or below-ground biomass or roots, litter, soil, bole, branches and leaves, among others.
Carbon sequestration	The removal and storage of carbon from the atmosphere in greenhouse gas sinks or greenhouse gas reservoirs through physical or biological processes The process by which trees remove carbon dioxide from the atmosphere and transform it into biomass.
Carbon stock	The quantity of carbon contained in a GHG reservoir. For this protocol, urban trees are carbon stocks.
Dry weight (DW) biomass	The weight of aboveground tree biomass when dried to 0% moisture content. Also known as oven-dry and bone-dry biomass. Convert from green biomass to dry weight biomass by multiplying by 0.56 for hardwoods or 0.48 for softwoods.
Freshweight or green biomass	The weight of aboveground tree biomass when fresh (or green), which includes the moisture present at the time the tree was cut. The moisture content of green timber varies greatly among different species. This protocol assumes that the moisture content of freshweight biomass is 30%.
Inherent uncertainty	For this protocol, the scientific uncertainty associated with calculating carbon stocks and greenhouse gas emissions.
Leakage	Increased GHG emissions or decreased GHG removals that result from the displacement of activities or resources from inside the offset project's boundary to locations outside the offset project's boundary as a result of the offset project activity. For this protocol, shifting of activities or resources *from* other parts of the

[10] For terms not defined in this section, the definitions in the Regulation apply.

	municipality, educational campus, or utility *to* the project, causing unanticipated increases in GHG emissions outside the project boundary.
Net tree gain (NTG)	Number of trees planted minus the number removed annually. NTG can be measured at the entity or project level.
Professional Urban Forester	A professional engaged in the science and profession of urban forestry. A Professional Urban Forester is defined as having any one of the following: Certified Forester credential managed by the Society of American Foresters; California Certified Urban Forester credential managed by the California Urban Forests Council; Certified Arborist credential managed by the International Society of Arboriculture; Registered Consulting Arborist credential managed by the American Society of Consulting Arborists; any other valid Forester, Arborist, Landscape Contractor, Landscape Architect, or Planner professional license or credential approved by a government agency in the jurisdiction where the project is located.
Project activity	The atmospheric CO_2 removal, carbon storage, GHG emission reductions and GHG emissions due to an urban forest tree project.
Project Life	Refers to the duration of an urban forest project and its associated monitoring and verification activities, as defined in Section 6.
Reporting uncertainty	The level of uncertainty associated with an entity's chosen method of sampling and/or inventorying carbon stock and calculation methodologies. Contrast with inherent uncertainty.
Tree Biomass	The amount of organic material comprising the above-ground (bole, stems and leaves) and below-ground (roots) components of a tree.
Tree maintenance plan (TMP)	Describes annual tree maintenance levels of service and associated expenditures.
Tree residue	Above-ground biomass from urban trees (as distinguished from construction debris) that can be salvaged for reuse, such as mulch, wood products, or fuel.
Tree resource	All trees planted and maintained by an entity.

11 References

Health and Safety Code, section 38571.

California Air Resources Board. 2008. *Off-road mobile sources emission reduction program*. http://www.arb.ca.gov/msprog/offroad/offroad.htm. (May 25, 2008).

Climate Action Reserve. 2010, Urban Forest Project Protocol, version 1.1. Climate Action Reserve, March 10, 2010. www.climateactionreserve.org (accessed March 16, 2010).

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Appendix A Urban Forest Inventories and Sampling – Quantification Methodology[11]

The Compliance Offset Protocol Urban Forest Projects requires collecting information about trees over time. This can be accomplished through field surveys, where it may not be practical to perform a complete inventory of every tree in the overall population. However, it is still possible to obtain reliable information about the overall population by collecting data from a representative subset or sample. Sampling is the technique used to choose representative units for study from a larger population. This appendix provides basic information about field survey and remote-sensing approaches, inventories and sampling, and lists additional resources.

A.1 Options for Data Collection

A.1.1 Field Surveys

Field or ground surveys can provide high quality data on individual trees if inspectors are well-trained and motivated. For example, tree dbh can be directly measured for use in biomass equations. Urban tree inventory includes locating the tree using a Global Positioning System (GPS), collecting relevant data, delivery of a database, and reporting findings. During a field survey information on the condition and management needs of each tree can be collected. These data may trigger actions that will improve tree growth and survival.

A.2 Complete Inventory

A complete inventory will always provide the most accurate assessment of the tree population. Typically the only bias introduced is from measurement inaccuracies. Establishing measurement protocols, training data collectors, and performing regular quality control assessments should limit this error.

The primary questions to answer when conducting both complete inventories and sampling are 1) what data are necessary to collect, 2) how should these data be recorded – on paper or electronically, and 3) what margin of error is acceptable for samples? The first two questions are data collection issues and are addressed in this section. The third question is a data analysis issue and will be addressed in the sampling section of this appendix.

A.2.1 Inventory Systems

There are numerous urban tree inventory systems available to consumers ranging from freeware to software packages requiring fee-for-service support. See the Climate Action Reserve Urban Forest Project Protocol, version 1.1, 2010 for guidance on inventory systems.

A.2.2 What to Record

For assessing and monitoring carbon stocks, any database associated with an inventory system must be capable of producing the reports required for project reporting. Table A.1 shows an example list of key data fields, drawn from the i-Tree software suite developed by the USDA

[11] The entirety of Appendix A is considered a quantification method.

Forest Service as an inventory and reporting tool. More detailed components are listed in the users guide available at http://www.itreetools.org.

Table A.1. Example of Common Data Fields for Tree Inventorying

Data Field	Description	Purpose
Tree Id	unique tree identifier	tree location
Zone	alphanumeric code/name showing management area or zone where tree is located	area/zone comparisons or sampling areas
Street Segment	numeric code used with STRATUM sampling program	used in sampling to predict population by dbh classes
City Managed	numeric code showing city or private tree ownership	asset value, structure
Species Code	alphanumeric code denoting genus and species	species and tree count,
Land Use	numeric code for landuse types (e.g., single family residential, commercial, park)	may assist in stratified sampling
Loc Site	numeric code for tree site (e.g., front lawn, planting strip, median, cutout)	tree location info, stratified sampling, energy benefits
DBH	numeric code for diameter-at-breast-height	growth, structure, age, carbon storage, annualization, costs
Mtce Recommendation	numeric code for recommended mtce (e.g., young tree, mature tree)	tree health,mortality, pruning needs assessments
Priority Task	numeric code for highest priority task to perform on tree	tree health,mortality, pruning needs assessments
Sidewalk Damage	numeric code describing extent of damage	costs, size and species associated with damage
Wire Conflict	numeric code describing utility line conflicts	costs, size and species associated with conflicts
Condition Wood	numeric code describing wood (structural) health of tree	asset value, structure
Condition Leaves	numeric code describing foliar (functional) health of tree	asset value, structure
OtherOne, Two, Three	numeric data field with up to 10 variables to be described by user	3 fields in STRATUM to be defined by user
Setback	distance between tree and nearest air-conditioned/heated space	energy analysis use/energy conservation projects
Tree Orient	numeric data listing 1 of 8 azimuth orientations of tree in reference to building	energy analysis use/energy conservation projects

Source: i-Tree program.

Essentially, the data to be collected will depend upon the project needs. To estimate carbon stocks, information on tree species and ‘diameter at breast height’ (dbh) are the minimum requirements.

A.2.3 Measuring Method and Allowable Error for Primary Measurements

This section describes the minimum data collection fields and allowable measurement error necessary to report under this protocol.

Species

The most common method for identifying species in an inventory is the use of species code – usually a four-letter code taken from first two letters of genus and species names, or four letters plus one number when genus and species letters are duplicated in study. Use species coding lists in i-Tree Manual 2.2 as guide. (Example: *Acer saccharum* = ACSA and *Acer saccharinum* (in same study) would be ACSA1).

Diameter at Breast Height (dbh in cm)

Measure the diameter at breast height (1.37m) to nearest 0.1 cm using a dbh tape (available from most forestry suppliers). Where possible for multi-stemmed trees forking below 1.37 m measure above the butt flare and below the point where the stem begins forking. When this is not possible, measure diameter at root collar (DRC) as described below. Saplings (dbh/DRC 2.54 - 12.5 cm) will be measured at 1.37 m unless falling under multi-stemmed/unusual stem categories requiring DRC measurements (per FHM Field Methods Guide [see reference in CAR 2010]).

Diameter at Root Collar (DRC in cm)

The method for measuring diameter at the root collar is adapted from the FHM Field Methods Guide. For species requiring diameter at the root collar, measure the diameter at the ground line or at the stem root collar, whichever is higher. For these trees, treat clumps of stems having a unified crown and common root stock as a single tree; examples include mesquite, juniper, and mountain mahogany. For multi-stemmed trees, compute and record a cumulative DRC (see below); record individual stem diameters and a stem status (live or dead) on a separate form or menu as required.

Measuring DRC: Before measuring DRC, remove the loose material on the ground (e.g. litter) but not mineral soil. Measure just above any swells present, and in a location so that the diameter measurements are reflective of the volume above the stems (especially when trees are extremely deformed at the base).

Stems must be at least 1.0 ft in length and 1.0 inch in diameter to qualify for measurement; stems that are missing due to cutting or damage must have previously been at least 1.0 ft in length (estimate by checking diameter of wound and compare with diameter and length of other stems – checking taper).

Whenever DRC is impossible or extremely difficult to measure with a diameter tape (e.g. due to thorns, extreme number of limbs), stems may be estimated and recorded to the nearest 1.0 inch class.

Additional instructions for DRC measurements are illustrated in Figure A.1. Do not measure cut stems as shown in Diagram 5 of Figure A.1; measure only complete stems.

Computing and Recording DRC: For all trees requiring DRC, with at least one stem 1.0 inch in diameter or larger at the root collar, DRC is computed as the square root of the sum of the squared stem diameters. For a single-stemmed DRC tree, the computed DRC is equal to the single diameter measured and rounded to the nearest 0.1 inch.

Use the following formula to compute DRC:

$$\text{DRC} = \text{SQRT [SUM (stem diameter}^2)]$$

For example, a multi-stemmed woodland tree with stems of 12.2, 13.2, 3.8, and 22.1 would be calculated as:

$$\begin{aligned}\text{DRC} &= \text{SQRT } [12.2^2 + 13.2^2 + 3.8^2 + 22.1^2] \\ &= \text{SQRT } [825.93] \\ &= 28.74 \\ &= 28.7\end{aligned}$$

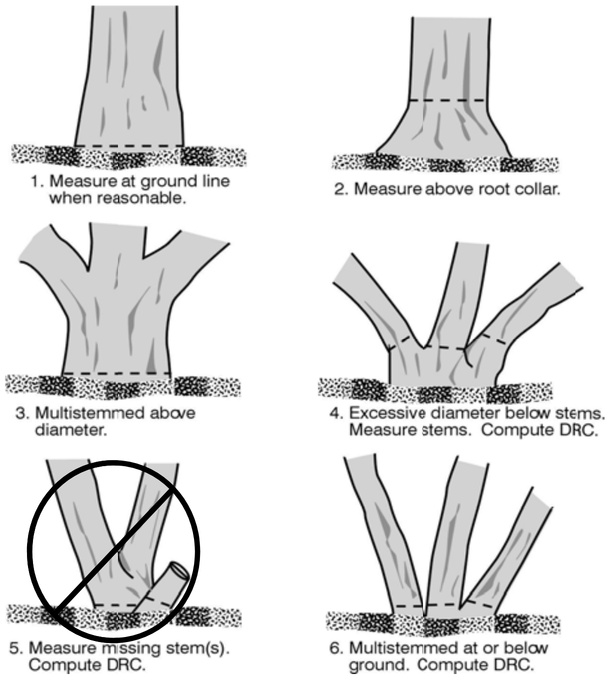
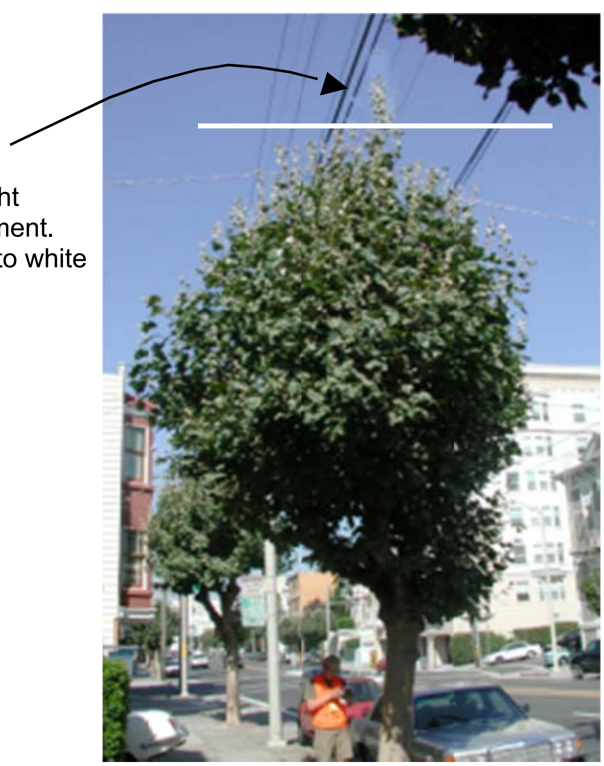


Figure A.1. Measuring DRC in Various Situations

Tree Height

From ground level to tree top to nearest 0.5 m (omit erratic leader as shown in Figure A.2) with range pole, altimeter or clinometer.



Tree height measurement. Measure to white line.

Figure A.2. Example of Tree with Erratic Leader

A.3 Sampling from Populations

As previously mentioned, sampling involves measuring only a portion of the trees on the offset project and using the data to estimate parameters of interest for the overall population.

A.3.1 Statistical Bias

The reason for using statistically sound sampling methods is to avoid bias in the estimates of the parameter(s) measured. Although the value of any single estimate (biased or not) is unlikely to equal the true population value, the mean of a large number of unbiased estimates will approximate the true value. In contrast, the mean of a large number of biased estimates will either be higher or lower than the true population value, depending on the direction of the bias. If the project developer is interested in knowing the actual value of a parameter from the population (e.g. actual tree dbh), they generally want to use an unbiased estimator of that parameter. In some situations, a small bias (e.g. a tendency to slightly over- or underestimate cover) can be tolerated if the bias is small relative to the standard deviation of the estimation errors (perhaps 10% to 15% or less).

Bias in estimates can come from various sources. For instance, if tree shadows are counted as canopy in aerial photo interpretation (misclassification bias), the canopy cover estimate will be biased upward. Many types of bias can be avoided through good sampling design and the careful implementation of appropriate evaluation techniques.

A.3.2 Random Sampling and Random Numbers

Most statistical methods used in environmental areas are based on the assumption of random sampling. This means that every unit in the population has an equal chance (or known probability) of being chosen for the sample. Furthermore, the selection of random units should be independent of other units that have been sampled. If a sample unit is rejected because it is too close to one already chosen, the sample will not be random and independent. A relatively simple and reliable method for randomization is to use random numbers. Most spreadsheet, database, and statistical programs have functions that generate random numbers, or random numbers can be found on-line or chosen from printed tables.

Several techniques can be used to draw a random sample from a population that consists of individual objects or records (e.g. street addresses or tree numbers). Many spreadsheet programs include tools that can produce a random sample of a specified size from a range of cells. Alternatively, a unique random number can be assigned to each unit or record, sorting the list based on the random number, and picking the required number of units from the top of the sorted database.

In some cases, it is necessary to take random samples across a geographic area, such as part or all of a city or forested area. In such a situation, random sample points can be assigned by randomly sampling from a coordinate grid that has been established for the area in question. This may either be an existing set of map-based coordinates, such as UTM or State Plane grids, or an arbitrary grid based on units measured on a map or aerial photograph (e.g. distances measured from the bottom and left edge of the map or photo). After the range of X and Y coordinates have been determined within the area to be sampled, X and Y coordinates can be selected randomly to generate random sample points. This is simple random sampling, one of five common random sampling techniques. The other four include systematic sampling, stratified sampling, cluster sampling, and multi-stage sampling.

A.3.3 Systematic Sampling

Systematic sampling means that the sample units are selected at equally spaced intervals over a population. Examples include selecting every tenth tree from a list of trees or selecting sample plots at equally spaced distances over a project area. In carefully planned forest surveys, systematic sampling can yield more precise results than simple random sampling. Systematic sampling is unbiased if the first unit is randomly selected. One advantage to systematic sampling is that it is simpler to select one random number and then collect data on every 5th, 10th or 15th (project developer chooses the interval) tree on the list, than to select as many random numbers as the sample size (although these numbers can be generated by any spreadsheet program). It also provides a good spread across a tree population. A disadvantage is that a list is needed to start with to be able to know total sample size and to calculate a sampling interval. The only advantage of systematic sampling over simple random sampling is the simplicity of needing to choose only one random number.

A.3.4 Stratified Sampling

In many urban forest applications, it is desirable to have samples distributed throughout the population. For instance, the project developer may want to ensure that trees from each of several different land use zones are included in the sample because it has been determined that trees are growing differently in different land use areas due to differences in care and maintenance. In such situations, stratified random sampling will be the most efficient and meaningful method for selecting samples. In this method, the population to be sampled is first divided into meaningful subunits or strata. These may be large subdivisions, planning sectors, maintenance districts, or any other convenient management or planning unit.

If strata are assigned so that each is more or less homogeneous with respect to the characters being measured, fewer samples will be needed to adequately characterize each stratum. For instance, if tree cover is to be assessed in different portions of a city, visual estimates of the tree canopy cover could be used to help demarcate zones where canopy cover is relatively uniform. A sample of street trees might be stratified by tree species, size, and/or age, depending on the purpose of the evaluation. If these trees were classified in a municipal street tree database, stratification might be accomplished relatively simply from existing tree data. However, if such data are lacking, it may be necessary to conduct a preliminary sample to delineate the population before sampling occurs.

Once strata are assigned and delineated, samples are drawn at random from within each stratum. If the number of samples selected from each stratum is not proportional to the size of the stratum, the averages from each will have to be weighted to obtain an overall population average. Given prior knowledge about the population, stratified sampling is a commonly used probability method that is superior to random sampling because it reduces error.

A.3.5 Sampling Size

Optimal sample size will vary somewhat with the characteristics being rated or tallied.

In general:

- Up to a point, the reliability of estimates will increase as sample size increases

- The more variable the population is with respect to the characteristic(s) being rated, the larger the sample should be
- A large sample is required to accurately estimate the frequencies of relatively rare events or characteristics
- Larger sample sizes are needed to detect relatively small differences between means or proportions; smaller sample sizes may suffice if the differences are relatively large

The optimum sample size represents a compromise between cost and accuracy, since both generally increase with increasing sample size. An optimum sample size can be determined by identifying the point of diminishing returns beyond which further increases in accuracy are not worth the additional costs of data collection. Optimum sample size will vary with the type of data being collected, so it is not possible to set a single number for all applications.

However, certain statistical formulas can be used to estimate the minimum sample size needed for a specific purpose. A number of statistics web sites include on-line interactive calculators that allow required sample sizes to be estimated. Before these sample size calculators can be used, several things must be known about the data that will be collected and how it will be analyzed.

Type of Data

Main types include:

1. Continuous – variables can take any value, e.g. tree diameters
2. Discrete – variables can only have certain discrete values
    a. Types of discrete data include:
        i. Ranks – ordered ratings, e.g. low, moderate, high
        ii. Counts – e.g. number of trees by species or dbh class
        iii. Binary – variable has only two outcomes, e.g. present/absent. Binary data is typically expressed as proportions or percents, such as the percent canopy cover determined from dot grid counts (canopy is rated as present or absent for each dot)

Type of Analysis

Continuous data are typically analyzed using linear models, including linear regression and analysis of variance techniques. Discrete data may be analyzed in various ways, including contingency table analysis, logistic regression, and survival analysis. Different formulas are used to estimate sample sizes for various analysis methods.

Expected Values

To estimate sample sizes for analyses of continuous data, estimates of expected population means (the Greek letter mu may be used for this term) and standard deviations or variances (the Greek letter sigma symbolizes the population standard deviation; variance is the square of the standard deviation) will have to be specified. For proportions, estimates of the expected proportions are needed; margins of error (as percents) may also be needed.

Data Structure

If data are paired or arranged in blocks or other more complex designs, the structure of the statistical model should be specified.

Confidence Level

Also abbreviated as the Greek letter alpha, this is the probability of Type I error, the chance that a difference is significant when it really is not (i.e. the probability of rejecting the null hypothesis when it is true). This is typically set at a low level, often 5% (alpha=0.05), meaning that there would only be a 5% (1 in 20) chance of deciding that a spurious difference is real (i.e. a 95% chance of avoiding Type I error).

Power

This parameter is expressed as (1-beta) where beta is the probability of Type II error. Power is the probability of detecting a real difference (i.e. the probability of rejecting the null hypothesis when it is false). When detecting real differences, the power of a test should be high, generally at least 80% (0.8) or greater.

A.3.6 Sampling Design and Monitoring Frequency

The frequency of monitoring is related to the rate and magnitude of change in tree growth, removal rates, planting rates and so forth – the smaller the expected change, the greater the potential that frequent monitoring will not detect a significant change. Frequency of monitoring should be determined by the magnitude of expected change – less frequent monitoring is applicable if only small changes are expected (see reference in CAR 2010).

All sampling designs should incorporate some form of random sampling to quantify the carbon stocks within established project boundaries using statistically accepted methods for inferring the urban forest biomass based on sample plots. There are multiple ways one can design a sampling plan. Although a few examples are provided here, it is important to remember that the specific sampling method used should be determined after evaluating project size, monitoring frequency and acceptable level of sampling error. Four basic designs are addressed here.

1. ***Rolling Sample***
   A percentage of the complete inventory is sampled annually, with results used to infer biomass or volume for the complete inventory.

   Example: during year 1 a non-profit tree group plants 3,000 new tree sites along a greenway, with a variety of species mixed throughout the area. Each year, 10% of the tree sites are sampled, until, at the end of 10 years, 100% of the inventory has been sampled. The annual 10% samples are fixed samples proportional to representation. Thus, the complete inventory is divided into 10 samples at the outset of the project. These 10% samples may be based on stratified random sampling with species type and frequency (number of trees planted per species) as the strata, or to reduce data collection costs, trees could be clustered into 10 cohorts based on geographic proximity. Other forms of random sampling, including cluster sampling for obtaining the 10% sample may also be suitable.

2. ***Periodic Sampling***
   All trees are re-inventoried but not annually. A sampling period is determined at the outset. For example, all trees are re-inventoried every 6 years.

3. ***Fixed Plot Sampling***
   All trees in a geographical area are never completely inventoried. A set of plots of fixed size and number are established and used to extrapolate volume or biomass on an area basis. Example: the city of San Francisco establishes a new 30-mile long multi-use

greenway along a former railroad corridor. They employ the UFORE plot sampling method (see references in CAR 2010) and establish thirty 10-m radius permanent plots based on land use stratification. The plots are sampled annually. Biomass or volume for the greenway is extrapolated based on sample plots to area relationship.

4. ***Variable Plot***
   Variable plot is similar to fixed plot sampling except the area sampled varies to coincide w/ logistical requirements, such as property boundaries where permission to access private property is required. Area of the plot is measured and used to infer to the total area based on plot area to total area ratio.

Note that items 1 and 2 can be applied to items 3 and 4; they are potentially at different levels or scales within a sampling design.

A.3.7 Minimum Required Sampling Criteria

All sampling methodologies and measurement standards must be statistically sound and reviewed by verification bodies. All sample plots should be permanently benchmarked for auditing and monitoring purposes. Plot centers, street segments, or individual trees (in the case of some forms of rolling samples) should be referenced on maps, preferably using GPS coordinates or using GIS. The methods utilized shall be documented and made available for verification and public review. The design of the sampling methodology and measurement standards must include the requirements stated in Table A.2.

Table A.2. Minimum Required Sampling Criteria

GHG Reservoir	Required?	Name of Requirement	Description of Requirement
Tree Biomass	Yes	Diameter (breast height) Measurements	Stated minimum diameter in methodology not to be greater than 7.6 cm (3 in.)
		Measurement Tools	Description of tools used for height, diameter, and plot measurement.
		Measurement Standards	The methodology shall include a set of standards for height and diameter measurements and describe compliance with allowable measurement error.
		Stratification Design	A description of the rules used to stratify the trees.
		Plot Layout	A description of the plot layout.
		Allometric Equations used for Estimating Biomass	The methodology shall include a description of the allometric equations used to estimate the whole tree biomass (bole, branches, and roots) from bole diameter measurements. This includes a description of how equations were assigned and implemented. Use only the equations provided in this protocol.

A.3.8 Sampling Error

All estimates of reported GHG reservoirs must have a high level of statistical confidence. Measurement standards are established by ARB for the estimate of metric tons of carbon in the required pools derived from sampling. Confidence in the estimate of metric tons of carbon from sampling can be measured statistically in terms of the size of the standard error relative to the estimate of the mean. This establishes confidence limits and can be expressed as a percentage of the mean. Larger confidence intervals indicate that there is less confidence in the mean estimate than smaller confidence intervals. For all GHG reservoirs reported, the standard error must be within 20% of the estimate of the mean for the estimate to be accepted. However, estimates are adjusted based on the statistical level of confidence, such that only estimates with a standard error within 5% or less receive no deduction. Most spreadsheet software packages provide users the ability to run descriptive statistics on a set of data, and results include the mean, standard error, standard deviation and confidence level. Table A.3 provides an example of summary results for each plot in a measured stratum. Note that standard deviation quantifies the scatter, how much the measured values differ from one another, whereas, standard error quantifies how accurately the true mean of the population is known. Standard error gets smaller as the sample gets larger, but standard deviation does not change predictably since it only quantifies scatter.

Table A.3. Summary Results for Each Plot in a Stratum

Plot #	Carbon Tons per Hectare	Plot #	Carbon Tons per Hectare	Plot #	Carbon Tons per Hectare
1	337	8	367	15	342
2	296	9	260	16	366
3	308	10	260	17	355
4	271	11	322	18	423
5	289	12	323	19	437
6	228	13	439	20	156
7	144	14	309		
Average Carbon Tons per Hectare					312
Standard error (must be <20% of mean)					17.85

Note: Confidence level is less than 10% of the mean as required by ARB.

Appendix B Calculating Biomass and Carbon – Quantification Methodology[12]

This appendix describes how measured tree size data are used with biomass equations to calculate tree volume and carbon content. Equations are presented for 26 open-grown urban tree species. To be consistent with biomass equations used in the Compliance Offset Protocol U.S. Forest Projects, foliar biomass is not included in the formulations. Additional biomass equations have been adapted from the literature on natural and native forest biomass for use in urban settings. The urban species equations have also been used to develop two general equations for broadleaf trees and conifers. Complete listings of equations are available in Table B.1 and Table B.2 at the end of this appendix. Table B.1 lists equations based on measurements of dbh and height or dbh only, derived from data collected on open-grown trees. Additional information can be found in CAR 2010 section B.5 pg 67-68.

B.1 Estimating Biomass and Carbon Using Volumetric Equations

Estimating biomass and carbon using volumetric equations is a two-step process that entails 1) calculating green volume, and 2) converting green volume to dry weight biomass and then carbon content (C). Table B.1 and Table B.2 provide examples of volumetric equations and biomass conversion factors for common urban species. Table B.1 equations estimate volume (m^3/tree) from diameter at breast height (dbh in centimeters) and height (in meters) measurements.

1. Use equations for dbh and height (or equations for dbh only if necessary) to calculate volume.

   Example:
   Volume in cubic meters (V) for a 15.6 m tall hackberry (*Celtis occidentalis*) with a 40.4 cm dbh is calculated as:

$$V = 0.002245 \times (40.4)^{2.118} \times (15.6)^{-0447}$$
$$= 1.66\ m^3$$

[Eq. 1]

2. Determine freshweight (FW) biomass, dry weight (DW) biomass and carbon content by applying biomass conversion factors in Table B.1, incorporating belowground biomass, and calculating carbon.

   a. Convert from volume to FW biomass by multiplying V by the species-specific density factor.

      For hackberry, FW would be calculated as:

$$FW = 1.66 \times 801$$
$$= 1329.66\ kg$$

[Eq. 2]

[12]The entirety of Appendix B is considered a quantification method.

b. The equations given here only calculate volume (and hence biomass) for the *aboveground* portion of the tree. Add the biomass stored belowground by multiplying the FW biomass by 1.28. For total FW biomass, including belowground roots calculate:

$$\text{Total FW} = 1329.66 \times 1.28 = 1704.62 \text{ kg} \quad \text{[Eq. 3]}$$

c. Convert FW biomass into DW biomass by multiplying by the constant 0.56 for hardwoods and 0.48 for conifers (see reference in CAR 2010). For our hackberry example:

$$\text{DW} = 1704.62 \times 0.56 = 954.59 \text{ kg} \quad \text{[Eq. 4]}$$

d. Convert DW biomass into kilograms of carbon (C) by multiplying by the constant 0.50:

$$\text{C} = 954.59 \times 0.5 = 477.30 \text{ kg} \quad \text{[Eq. 5]}$$

e. Tree carbon stock is to be reported in metric tons. Therefore, results calculated in kilograms must be multiplied by 0.001 to convert to metric tons.

B.1.1 Estimating Biomass and Carbon Using Forest-Derived Equations

Biomass calculated using equations derived from native or natural forest trees (Table B.2) must be adjusted by a factor of 0.80 when applied to open-grown, urban trees because of differences in biomass allocation between the tree populations.

Unlike the equations used above, the forest equations listed produce DW biomass rather than FW biomass. Therefore the step involving the species-specific density factor (step 2a above) does not need to be incorporated. The calculation for carbon content (kg) is:

$$\text{C} = \text{DW} \times 1.28 \times 0.5 \quad \text{[Eq. 7]}$$

B.1.2 Estimating Tree Biomass for Standing Dead or Dying Trees

Unlike trees in forest settings, dead or dying trees in urban areas are usually removed immediately due to safety concerns in public and private areas. Typically, the only difference between biomass in a live tree and that in a dead tree is the absence of foliage for the latter.

Because foliar biomass is not included in these formulations, dead and dying tree biomass should be calculated just as for live tree biomass.

B.1.3 Estimating Carbon in Lying (Dead/Downed) Tree Biomass

As discussed in Section B.1.2 above, it is assumed in nearly all urban applications that dead/dying trees are removed almost immediately and that lying tree biomass will rarely, if ever exist. It is most likely to exist in natural settings within cities like riparian or nature areas. In that case, sampling, measurement and carbon estimation procedures should follow the Compliance Offset Protocol U.S. Forest Projects rather than this protocol.

B.2 Error in Estimating Carbon and Biomass

The volume equations used in this protocol were developed from trees that may differ in size from the trees in a specific sample or inventory. The dbh ranges for trees sampled to develop the volume and biomass equations are listed where known at the end of the appendix (Table B.1 and Table B.2). Applying the equations to trees with dbh outside of this range may increase the error in estimates.

B.3 Reporting Uncertainty versus Inherent Uncertainty

Reporting uncertainty is the level of uncertainty associated with an entity's chosen carbon stock sampling and calculation methodologies. Inherent uncertainty refers to the scientific uncertainty associated with calculating carbon stocks and GHG emissions.

There is an inherent scientific uncertainty in quantifying carbon stocks of entities. However, determining scientific accuracy is not the focus of this protocol. Instead, the verification process is designed to identify and assess reporting uncertainty. Therefore, when assessing if the estimate of the carbon content in project trees meets ARB's minimum quality standard, only quantification differences that result from reporting uncertainty should be considered, not inherent uncertainty. Therefore, it is not necessary to attempt to quantify error for biomass equations accepted by ARB. Any statistical error associated with these equations falls under the category of inherent uncertainty.

Table B.1. Volume Equations for 26 Urban Tree Species

				Vol to FW Conversion
	Species	**DBH Range (cm)**	**Volume (m^3)**	**kg/m3**
	Acacia longifolia	15.0 - 57.2	$=0.0283168466(0.048490 * (dbh/2.54)^{2.347250})$	1121
	Acer platanoides	9.7 - 102.1	$=0.0019421 * dbh^{1.785}$	737
	Acer saccharinum	13.2 - 134.9	$=0.000363 * dbh^{2.292}$	721
	Celtis occidentalis	10.9 - 119.4	$=0.0014159 * dbh^{1.928}$	801
	Ceratonia siliqua	15.5 - 71.4	$=0.0283168466(0.066256 * (dbh/2.54)^{2.128861})$	961
D	Cinnamomum camphora	12.7 - 68.8	$=0.0283168466(0.031449 * (dbh/2.54)^{2.534660})$	817
B	Cupressus macrocarpa	15.7 - 146.6	$=0.0283168466(0.035598 * (dbh/2.54)^{2.495263})$	577
H	Eucalyptus globulus	15.5 - 130.0	$=0.0283168466(0.055113 * (dbh/2.54)^{2.436970})$	1121
	Fraxinus pennsylvanica	14.7 - 122.7	$=0.0005885 * dbh^{2.206}$	785
O	Fraxinus velutina 'Modesto'	14.5 - 84.8	$=0.0283168466(0.022227 * (dbh/2.54)^{2.633462})$	769
N	Gleditsia triancanthos	9.1 - 98.3	$=0.0005055 * dbh^{2.220}$	977
L	Gymnocladus dioicus	10.2 - 36.8	$=0.0004159 * dbh^{2.059}$	929
Y	Jacaranda mimosifolia	17.3 - 59.7	$=0.0283168466(0.036147 * (dbh/2.54)^{2.486248})$	609
	Liquidambar styraciflua	14.0 - 54.4	$=0.0283168466(0.030684 * (dbh/2.54)^{2.560469})$	801
	Magnolia grandiflora	14.5 - 74.2	$=0.0283168466(0.022744 * (dbh/2.54)^{2.622015})$	945
	Pinus radiata	16.8 - 105.4	$=0.0283168466(0.019874 * (dbh/2.54)^{2.666079})$	705
	Pistacia chinensis	12.7 - 51.3	$=0.0283168466(0.019003 * (dbh/2.54)^{2.808625})$	657
	Platanus acerifolia	15.5 - 73.9	$=0.0283168466(0.025170 * (dbh/2.54)^{2.673578})$	833
	Populus sargentii	6.4 - 136.7	$=0.0020891 * dbh^{1.873}$	753
	Quercus ilex	12.7 - 52.1	$=0.0283168466(0.025169 * (dbh/2.54)^{2.607285})$	1186
	Quercus macrocarpa	10.9 - 100.1	$=0.0002431 * dbh^{2.415}$	993
	Tilia cordata	11.2 - 64.5	$=0.0009359 * dbh^{2.042}$	673
	Ulmus americana	17.5 - 114.3	$=0.0018 * dbh^{1.869}$	865
	Ulmus parvifolia chinensis	17.3 - 55.9	$=0.0283168466(0.028530 * (dbh/2.54)^{2.639347})$	865
	Ulmus pumila	15.5 - 131.6	$=0.0048879 * dbh^{1.613}$	865
	Zelkova serrata	14.5 - 86.4	$=0.0283168466(0.021472 * (dbh/2.54)^{2.674757})$	865
	General Broadleaf	6.4 - 136.7	=0.280285*(dbhcm)^2.310647	Eqtn produces FW
	General Conifer	6.4 - 136.7	=0.05654*(dbhcm)^2.580671	Eqtn produces FW
	Acacia longifolia	15.0 - 57.2	$=0.0283168466(0.01406 * (dbh/2.54)^{2.18649} * (3.28*ht)^{0.46736})$	1121
	Acer platanoides	9.7 - 102.1	$=0.001011 * dbh^{1.533} * ht^{0.657}$	737
	Acer saccharinum	13.2 - 134.9	$=0.000238 * dbh^{1.998} * ht^{0.596}$	721
D	Celtis occidentalis	10.9 - 119.4	$=0.002245 * dbh^{2.118} * ht^{-0.447}$	801
B	Ceratonia siliqua	15.5 - 71.4	$=0.0283168466(0.00857 * (dbh/2.54)^{1.79584} * (3.28*ht)^{0.93967})$	961
H	Cinnamomum camphora	12.7 - 68.8	$=0.0283168466(0.00982 * (dbh/2.54)^{2.13480} * (3.28*ht)^{0.63404})$	817
	Cupressus macrocarpa	15.7 - 146.6	$=0.0283168466(0.00576 * (dbh/2.54)^{2.26035} * (3.28*ht)^{0.63013})$	577
a	Eucalyptus globulus	15.5 - 130.0	$=0.0283168466(0.00309 * (dbh/2.54)^{2.15182} * (3.28*ht)^{0.83573})$	1121
n	Fraxinus pennsylvanica	14.7 - 122.7	$=0.000414 * dbh^{1.847} * ht^{0.646}$	785
d	Fraxinus velutina 'Modesto'	14.5 - 84.8	$=0.0283168466(0.00129 * (dbh/2.54)^{1.76296} * (3.28*ht)^{1.42782})$	769
	Gleditsia triancanthos	9.1 - 98.3	$=0.000489 * dbh^{2.132} * ht^{0.142}$	977
H	Gymnocladus dioicus	10.2 - 36.8	$=0.000463 * dbh^{1.545} * ht^{0.792}$	929
E	Jacaranda mimosifolia	17.3 - 59.7	$=0.0283168466(0.01131 * (dbh/2.54)^{2.18578} * (3.28*ht)^{0.54805})$	609
I	Liquidambar styraciflua	14.0 - 54.4	$=0.0283168466(0.01177 * (dbh/2.54)^{2.31582} * (3.28*ht)^{0.41571})$	801
G	Magnolia grandiflora	14.5 - 74.2	$=0.0283168466(0.00449 * (dbh/2.54)^{2.07041} * (3.28*ht)^{0.84563})$	945
H	Pinus radiata	16.8 - 105.4	$=0.0283168466(0.00533 * (dbh/2.54)^{2.22681} * (3.28*ht)^{0.66899})$	705
T	Pistacia chinensis	12.7 - 51.3	$=0.0283168466(0.00292 * (dbh/2.54)^{2.19157} * (3.28*ht)^{0.94367})$	657
	Platanus acerifolia	15.5 - 73.9	$=0.0283168466(0.01043 * (dbh/2.54)^{2.43642} * (3.28*ht)^{0.39168})$	833
	Populus sargentii	6.4 - 136.7	$=0.001906 * dbh^{1.806} * ht^{0.134}$	753
	Quercus ilex	12.7 - 52.1	$=0.0283168466(0.00431 * (dbh/2.54)^{1.82158} * (3.28*ht)^{1.06269})$	1186
	Quercus macrocarpa	10.9 - 100.1	$=0.000169 * dbh^{1.956} * ht^{0.842}$	993
	Tilia cordata	11.2 - 64.5	$=0.000945 * dbh^{1.617} * ht^{0.59}$	673
	Ulmus americana	17.5 - 114.3	$=0.0012 * dbh^{1.696} * ht^{0.405}$	865
	Ulmus parvifolia chinensis	17.3 - 55.9	$=0.0283168466(0.01046 * (dbh/2.54)^{2.32481} * (3.28*ht)^{0.49317})$	865
	Ulmus pumila	15.5 - 131.6	$=0.000338 * dbh^{0.855} * ht^{2.041}$	865
	Zelkova serrata	14.5 - 86.4	$=0.0283168466(0.00666 * (dbh/2.54)^{2.36318} * (3.28*ht)^{0.55190})$	865

Note: Equations require dbh (cm) only or dbh (cm) and height (m) measurements to calculate volume. Factors are listed for converting volume to freshweight (FW), and two FW general biomass equations derived from these species are also listed.

Source: Climate Action Reserve (2010) Urban Forest Project Protocol Version 1.1 March 10, 2010.

Table B.2. Dry Weight Biomass Equations

Spcode	Botanic	Common	Model	Source and DBH Range
ACRU	Acer rubrum	Red maple	$=(0.1970*(dbh^{2.1933}))*0.80$	Ter-Mikaelian, Nova Scotia 0-35 cm red maple
ACSA2	Acer saccharum	Sugar maple	$=(0.1791*(dbh^{2.3329}))*0.80$	Ter-Mikaelian, Maine 3-66 cm sugar maple
PRSE2	Prunus serotina	Black cherry	$=((0.0716*dbh^{2.6174}))*0.80$	Ter-Mikaelian, West VA 5-50 cm black cherry
QURU	Quercus rubra	Northern red oak	$=(0.1130*(dbh^{2.4572}))*0.80$	TerMikaelian, West VA 5-50 cm red oak
FRAM	Fraxinus americana	White ash	$=(0.1063*(dbh^{2.4798}))*0.80$	Ter-Mikaelian, West VA 5-50 cm white ash
TIAM	Tilia americana	American basswood	$=((0.0617*dbh^{2.5328}))*0.80$	Ter-Mikaelian, West VA 5-50 cm basswood
BENI	Betula nigra	River birch	$=(0.0692*(dbh^{2.6606}))*0.80$	Ter-Mikaelian, West VA 5-50 cm black birch
Palms	General palms	General palms	=(6.0*ht(m)+0.8)+(0.8*ht(m)+0.9)	Frangi and Lugo, 1985
Hardwoods	General hardwoods	General hardwoods	=((EXP(-2.437+2.418*(LN(dbh)))+EXP(-3.188 + 2.226*(LN(dbh)))))*0.8	Tritton and Hornbeck, Northeast, 10-50 cm

Note: Use constants to add roots, convert to carbon. Biomass is reduced to 80% of original predicted value to account for less biomass in urban trees.

Appendix C Offset Project Listing Information

Section 1: General Information

1. Date of form completion:
2. Form completed by (name):
3. Project listing as a:
   - Municipal Project
   - Educational Campus Project
   - Utility Project
4. Name and contact information of the Offset Project Operator:
5. Name and contact information of Authorized Project Designee (if applicable):
6. Offset project commencement date:
7. Date of initial reporting period:
8. Location of offset project (including approximate latitude/longitude):

Section 2: Offset Project Summary

1. Describe the goals of the offset project.
2. Name of the person or entity that is responsible for planning, implementation, and reporting of project activity. List and explain the involvement of Authorized Project Designees, if applicable.
3. Briefly describe implementation of the offset project. Include general information on the number of project tree sites and trees that will be planted (including replacements), types of species, where they will be planted, tree maintenance and monitoring plans (Note: Some of this information is also required in the Tree Maintenance Plan [separate document]):
4. Confirm that the trees will be planted in maintained landscapes and spaced at least 5 m (16 ft) apart so as to be open-growing (Y/N):

Section 3: Offset Project Boundaries

1. Physical Boundary: Describe and include a map of the physical boundary of the offset project, including planned tree sites, an outline of the geographical boundary of the municipality, educational campus, or utility service area, and tree care facilities (location where vehicles and equipment are housed):
2. GHG Offset Project Boundary: List the GHG sources and GHG sinks that will be included in the Offset Project Boundary.

Section 4: Offset Project Eligibility

1. State the expected average annual net number of project tree sites created over the Project Life (this is the project NTG):
2. State the average annual NTG prior to offset project commencement (for municipalities and educational campuses only):

3. State the total number of trees prior to the start of the offset project (for municipalities and educational campuses only):
4. Is any portion of the project activity required by any local, state, regional, or federal regulation? (Y/N)
5. Describe tree planting requirements outside of the project activity that are mandated by law and are planned to be undertaken by the entity:

Section 5: Tree Maintenance Plan

This initial Tree Maintenance Plan constitutes a description of planned maintenance activities. Per Section 8 of the protocol, approved offset projects must annually submit a Tree Maintenance Plan for each year of project duration, reporting activities ex post. This initial Tree Maintenance Plan must address the following requirements:

1. Document the most recent and anticipated future levels of service and expenditures for all criteria in the Tree Maintenance Plan (for details, see protocol Section 9: Project Monitoring).
2. Describe how project tree planting sites will be identified and prioritized.
3. Provide estimates for tree mortality rates for newly planted and established project trees, and explain how these estimates were derived.
4. Describe how project trees that need replacing will be identified, the timing of replacement, and the species and size of replacement trees.
5. Identify the personnel who will implement and manage the project, their roles and responsibilities, and funds required for salary, operations, training, and overhead over the duration of the project. Other activities that may be included here are public relations, accounting, fund raising, and outreach.

Section 6: Project Tree Monitoring Plan

Per Section 8.2 of the protocol, the Project Tree Monitoring Plan must address the following requirements:

Provide a detailed description of:

1. Method chosen from the options in Section 5.1.
2. Procedures that will be used to census, measure, and report information on the project trees, including survey method, sample sizes, and method for choosing samples.
3. Methods that will be used to measure and record tree dimensions.
4. Methods that will be used and information collected on tree survival and health.
5. Statistical methods that will be used to extrapolate sample data to the total project tree population, if applicable.
6. Estimating sampling error, if applicable.

Appendix D Offset Project Data Report

Each Offset Project Data Report must contain the following:

1. Offset Project Operator or Authorized Project Designee
2. Offset Project Name
3. Name of Individual Completing the Report
4. Date
5. Verification Period
6. Project personnel
7. Personnel names(s)
8. Organization and title(s)
9. Responsibilities

10. Equations and calculations

    a. Project tree volume, biomass, and carbon stocks (for measured trees and for the project tree population, if sampling and extrapolation are used) at project commencement (or renewal) and annually thereafter.

    b. For (a) above, standard error and sampling error at the 90% confidence interval must be met, if applicable.

    c. Amount and type of fuel consumed by project vehicles and equipment.

    d. Project tree carbon stock change and adjusted carbon stock change, if applicable.

    e. Tree planting
        i. Number of trees planted in new tree sites each year, not including replacement trees (total for the municipality, educational campus, or utility service area, including project and non-project trees).
        ii. Number of trees planted to replace removed trees each year ("replacement trees"), including replacement trees planted in relocated tree sites (separately for non-project and project trees).
        iii. Species, size, and location of project trees planted in new tree sites each year.
        iv. Species, size, and location of project replacement trees planted in existing or relocated tree sites each year.
        v. Number and location of relocated project tree sites each year.
        vi. Reasons for relocations and, if applicable, modifications made to the project to reduce the chance of future relocations.
        vii. Project tree resource: Percentage of total project trees planted.

viii. Annual tree planting expenditure (separately for the project and the municipality, educational campus, or utility).

f. Young tree care
   i. Number of young project trees inspected/pruned each year.
   ii. Inspection/pruning cycle (total number of project trees / number treated per year).
   iii. Annual expenditure (separately for the project and the municipality, educational campus, or utility).

g. Mature tree care
   i. Number of mature project trees inspected/pruned each year.
   ii. Inspection/pruning cycle (total number of project trees / number treated per year).
   iii. Annual expenditure (Reported annually, separately for the project and for the municipality, educational campus, or utility).

g. Tree removal
   i. Number of trees removed from existing tree sites each year (separately for non-project and project trees).
      xiii. Species, size, and location[13] of project trees removed each year.
   ii. Reasons for removals and, if applicable, modifications made to the project to reduce the chance of future removals.
   iii. Removal cycle (total number of project trees to remove / number removed per year).
   iv. Annual expenditure (separately for the project and for the municipality, educational campus, or utility).

h. Administration/other
   i. Average $/tree site expenditure (total $ on administration and other / total tree numbers) (separately for the project and municipality, educational campus, or utility).
   ii. Annual expenditure (separately for the project and for the municipality, educational campus, or utility).

j. Net Tree Gain for each year and annual averages (Section 3.4.2) at the level of the municipality or educational campus.

k. Net Tree Gain for each year at the project level.

11. Project Tree Monitoring Plan
    a. Choice of method from the options in Section 5.1.

[13] Tree site location must be designated on a map of the project physical boundaries.

b. Detailed description of procedures to census (or sample, if applicable), measure, and report information on the project trees, including the survey method, sample sizes, and method for choosing samples.
c. Methods used to measure and record tree size.
d. Methods used and information collected on tree survival and health.
e. Statistical methods used to extrapolate sample data to the total project tree population, if applicable.
f. Estimated sampling error, if applicable.

12. Calculated project GHG reductions (removal enhancements, by year):
    a. Project tree CO_2 sequestration (adjusted for sampling error, if applicable)
    b. Project vehicle CO_2 emissions
    c. Project equipment CO_2 emissions
    d. Project GHG reductions (removal enhancements)

California Environmental Protection Agency

AIR RESOURCES BOARD

Compliance Offset Protocol U.S. Forest Projects

Adopted: October 20, 2011

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Abbreviations and Acronyms

ARB	Air Resources Board
C	Carbon
CAR	Climate Action Reserve
CH_4	Methane
CO_2	Carbon dioxide
FIA	Forest Inventory and Analysis Program of the U.S. Forest Service
GHG	Greenhouse gas
lb	Pound
IFM	Improved Forest Management
N_2O	Nitrous oxide
Regulation	Cap-and-Trade Regulation, title 17, California Code of Regulations, sections 95800 et seq.
SSR	GHG Sources, GHG Sinks, and GHG Reservoirs
USFS	United States Forest Service

1 Introduction

The Compliance Offset Protocol U.S. Forest Projects (Forest Offset Protocol) provides requirements and methods for quantifying the net climate benefits of activities that sequester carbon on forestland. The protocol provides offset project eligibility rules; methods to calculate an offset project's net effects on greenhouse gas (GHG) emissions and removals of CO_2 from the atmosphere (removals); procedures for assessing the risk that carbon sequestered by a project may be reversed (i.e. released back to the atmosphere); and approaches for long term project monitoring and reporting. The goal of this protocol is to ensure that the net GHG reductions and GHG removal enhancements caused by an offset project are accounted for in a complete, consistent, transparent, accurate, and conservative manner and may therefore be reported as the basis for issuing ARB or registry offset credits. The protocol is built off of The Climate Action Reserve's Forest Project Protocol Version 3.2.[1]

Offset Project Operators or Authorized Project Designees must use this protocol to quantify and report GHG reductions and GHG removal enhancements. The protocol provides eligibility rules, methods to quantify GHG reductions, project-monitoring instructions, and procedures for reporting Offset Project Data Reports. Additionally, all offset projects must submit to independent verification by ARB-accredited verification bodies. Requirements for verification bodies to verify Offset Project Data Reports are provided in the Cap-and-Trade Regulation (Regulation).

AB 32 exempts quantification methodologies from the Administrative Procedure Act (APA)[2]; however those elements of the protocol are still regulatory. The exemption allows future updates to the quantification methodologies to be made through a public review and Board adoption process but without the need for rulemaking documents. Each protocol identifies sections that are considered to be quantification methodologies and exempt from APA requirements. Any changes to the non-quantification elements of the offset protocols would be considered a regulatory update subject to the full regulatory development process. Those sections that are considered to be quantification methodologies are clearly indicated in the title of the chapter or subchapter if only a portion of that chapter is considered part of the quantification methodology.

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[1] Climate Action Reserve (CAR 2010) Forest Project Project Protocol Version 3.2. August 31, 2010. http://www.climateactionreserve.org/wpcontent/uploads/2009/03/Forest_Project_Protocol_Version_3.2.pdft/ (accessed September 9, 2010)

[2] Health and Safety Code section 38571.

1.1 About Forests, Carbon Dioxide, and Climate Change

Forests have the capacity to both emit and sequester carbon dioxide (CO_2), a leading greenhouse gas that contributes to climate change. Trees, through the process of photosynthesis, naturally absorb CO_2 from the atmosphere and store the gas as carbon in their biomass, i.e. trunk (bole), leaves, branches, and roots. Carbon is also stored in the soils that support the forest, as well as the understory plants and litter on the forest floor. Wood products that are harvested from forests can also provide long term storage of carbon.

When trees are disturbed, through events like fire, disease, pests or harvest, some of their stored carbon may oxidize or decay over time releasing CO_2 into the atmosphere. The quantity and rate of CO_2 that is emitted may vary, depending on the particular circumstances of the disturbance. Forests function as reservoirs in storing CO_2. Depending on how forests are managed or impacted by natural events, they can be a net source of emissions, resulting in a decrease to the reservoir, or a net sink, resulting in an increase of CO_2 to the reservoir. In other words, forests may have a net negative or net positive impact on the climate.

Through sustainable management and protection, forests can also play a positive and significant role to help address global climate change. The Forest Offset Protocol is designed to address the forest sector's unique capacity to sequester, store, and emit CO_2 and to facilitate the positive role that forests can play to address climate change.

2 Forest Project Definitions and Requirements

For the purposes of this protocol, a Forest Project is a planned set of activities designed to increase removals of CO_2 from the atmosphere, or reduce or prevent emissions of CO_2 to the atmosphere, through increasing and/or conserving forest carbon stocks.

A glossary of terms related to Forest Projects is provided in Section 11 of this protocol. Throughout the protocol, important defined terms are capitalized (e.g. "Reforestation Project"). For terms not defined in Section 11, the definitions in the Regulation apply.

2.1 Project Types

The following types of Forest Project activities are eligible:

2.1.1 Reforestation

A Reforestation Project involves restoring tree cover on land that is not at optimal stocking levels and has minimal short-term (30-years) commercial opportunities. A Reforestation Project is only eligible if it can fully satisfy the eligibility rules in the Regulation and:

1. The project involves tree planting or removal of impediments to natural reforestation, on land that:
    a. Has had less than 10 percent tree canopy cover for a minimum of 10 years; or
    b. Has been subject to a Significant Disturbance that has removed at least 20 percent of the land's above-ground live biomass in trees.
2. No rotational harvesting of reforested trees or any harvesting of pre-existing carbon in live trees occurs during the first 30 years after offset project commencement unless such harvesting is needed to prevent or reduce an imminent threat of disease. Such harvesting may only occur if the Offset Project Operator or Authorized Project Designee provides a written statement from the government agency in charge of forestry regulation in the state where the project is located stipulating that the harvesting is necessary to prevent or mitigate disease.
3. The tree planting, or removal of impediments to natural reforestation, does not follow a commercial harvest of healthy live trees that has occurred in the Project Area within the past 10 years, or since the occurrence of a Significant Disturbance, whichever period is shorter.
4. The offset project does *not* employ broadcast fertilization.
5. The offset project does not take place on land that was part of a previously listed and verified Forest Project, unless the previous Forest Project was terminated due to an Unintentional Reversal (see Section 7) or is an early action offset project transitioning to this protocol according to the provisions of the Regulation and this protocol.
6. If the offset project was an offset project in a voluntary offset program, the offset project can demonstrate it has met all legal and contractual requirements to allow it to terminate its project relationship with the voluntary offset program and be listed using this compliance offset protocol.

Reforestation Projects on both private and public lands, excluding federal lands that are not included in the categories of land listed in section 3.6 of this protocol, are eligible.

2.1.2 Improved Forest Management

An Improved Forest Management Project involves management activities that maintain or increase carbon stocks on forested land relative to baseline levels of carbon stocks, as defined in Section 6.2 of this protocol. An Improved Forest Management Project is only eligible if it can fully satisfy the eligibility rules in the Regulation and:

1. The offset project takes place on land that has greater than 10 percent tree canopy cover.
2. The offset project employs natural forest management practices, as defined in Section 3.8.2 of this protocol.
3. The offset project does *not* employ broadcast fertilization.
4. The offset project does not take place on land that was part of a previously listed and verified Forest Project, unless the previous Forest Project was terminated due to an Unintentional Reversal (see Section 7) or is an early action offset project transitioning to this protocol according to the provisions of the Regulation and this protocol.
5. If the offset project was an offset project in a voluntary offset program, the offset project can demonstrate it has met all legal and contractual requirements to allow it to terminate its project relationship with the voluntary offset program and be listed using this compliance offset protocol.

Eligible management activities may include, but are not limited to:

- Increasing the overall age of the forest by increasing rotation ages.
- Increasing the forest productivity by thinning, diseased, and suppressed trees.
- Managing competing brush and short-lived forest species.
- Increasing the stocking of trees on understocked areas.
- Maintaining stocks at a high level.

Improved Forest Management Projects on both private and public lands, excluding federal lands that are not included in the categories of land listed in section 3.6 of this protocol, are eligible.

2.1.3 Avoided Conversion

An Avoided Conversion Project involves preventing the conversion of forestland to a non-forest land use by dedicating the land to continuous forest cover through a Qualified Conservation Easement or transfer to public ownership, excluding transfer to federal ownership. An Avoided Conversion Project is only eligible if it can fully satisfy the eligibility rules in the Regulation and:

1. It can be demonstrated that there is a significant threat of conversion of project land to a non-forest land use by following the requirements for establishing the project's baseline in Section 6.3 of this protocol.
2. The offset project does *not* employ broadcast fertilization.
3. The offset project does not take place on land that was part of a previously listed and verified Forest Project, unless the previous Forest Project was terminated due to an Unintentional Reversal (see Section 7) or is an early action offset project transitioning to this protocol according to the provisions of the Regulation and this protocol.
4. If the offset project was an offset project in a voluntary offset program, the offset project can demonstrate it has met all legal and contractual requirements to allow it to terminate its project relationship with the voluntary offset program and be listed using this compliance offset protocol.

An Avoided Conversion Project may involve tree planting and harvesting as part of the project activity.

Avoided Conversion Projects are eligible only on lands that are privately owned prior to offset project commencement.

2.2 Forest Owners

A Forest Owner is the owner of any interest in the real (as opposed to personal) property involved in a Forest Project, excluding government agency third party beneficiaries of conservation easements. Generally, a Forest Owner is the owner in fee of the real property involved in a Forest Project. In some cases, one entity may own the land while another entity may have an interest in the trees or the timber on the property, in which case all entities or individuals with interest in the real property are collectively considered Forest Owners, however, a single Forest Owner must be identified as the Offset Project Operator.

The Offset Project Operator is responsible for undertaking, listing, and verifying a Forest Project, however, all Forest Owner(s) are ultimately responsible for all Forest Project commitments. The Offset Project Operator may identify an Authorized Project Designee pursuant to §95974 of the Regulation, to assist or consult with implementation of the Forest Project. All information submitted to ARB or an Offset Project Registry shall reference the Offset Project Operator and all Forest Owner(s) who are ultimately responsible for the accuracy and completeness of the information submitted.

3 Eligibility Rules and Other Requirements

In addition to the definitions and requirements described in Section 2, Forest Projects must meet several other criteria and conditions to be eligible for listing, and must adhere to requirements in the Regulation and requirements related to duration and crediting periods.

3.1 Additionality

ARB and registry offsets credits must be generated by projects that yield surplus GHG emission reductions or removal enhancements that exceed any GHG reductions or removals otherwise required by law or regulation, or any GHG reduction or removal that would otherwise occur in a conservative Business-As-Usual Scenario. Forest Projects must satisfy the following to be considered additional:

1. Forest Projects must achieve GHG reductions or GHG removal enhancements above and beyond any GHG reductions or GHG removal enhancements that would result from compliance with any federal, state, or local law, regulation or ordinance. Forest Projects must also achieve GHG reductions and GHG removal enhancements above and beyond any GHG reductions or GHG removal enhancements that would result from compliance with any court order or other legally binding mandates, including management plans (such as Timber Harvest Plans) that are required for government agency approval of harvest activities. Legally binding mandates also include conservation easements or deed restrictions, except where such conservation easements have been enacted in support of the Forest Project, as described in Section 3.5. This requirement is assessed through the Legal Requirement Test in 3.1.1.
2. Forest Projects must achieve GHG reductions or GHG removal enhancements above and beyond any GHG reductions or GHG removal enhancements that would result from engaging in Business-As-Usual activities, as defined by the Regulation and the requirements described and assessed through the Performance Test in Section 3.1.2.

3.1.1 Legal Requirement Test

To meet additionality requirements, the following legal requirement test must be met, specific to each type of Forest Project.

3.1.1.1 Reforestation Projects

Reforestation Project activities cannot be legally required (as defined in 3.1 above) at the time of offset project commencement. Modeling of the Forest Project's baseline carbon stocks must reflect all legal constraints, as required in Section 6.1 of this protocol.

3.1.1.2 Improved Forest Management Projects

Improved Forest Management Project activities (defined as management activities intended to maintain or increase carbon stocks relative to baseline levels) cannot be legally required (as defined in 3.1 above) at the time of offset project commencement. Modeling of the Forest Project's baseline carbon stocks must reflect all legal constraints, as required in Section 6.2 of this protocol.

3.1.1.3 Avoided Conversion Projects

Avoided Conversion Project activities cannot be legally required (as defined in 3.1 above) at the time of offset project commencement. Modeling of the Forest Project's baseline carbon stocks must reflect all legal constraints, as required in Section 6.3 of this protocol.

Official documentation must be submitted demonstrating that the type of anticipated land use conversion is legally permissible. Such documentation must fall into at least one of the following categories:

1. Documentation indicating that the current land use policies, including zoning and general plan ordinances, and other local and state statutes and regulations, permit the anticipated type of conversion.
2. Documentation indicating that the Forest Owner(s) obtained all necessary approvals from the governing county to convert the Project Area to the proposed type of non-forest land use (including, for instance, certificates of compliance, subdivision approvals, timber conversion permits, other rezoning, major or minor use permits, etc.).
3. Documentation indicating that similarly situated forestlands within the project's Assessment Area were recently able to obtain all necessary approvals from the governing county, state, or other governing agency to convert to a non-forest land use (including, for instance, certificates of compliance, subdivision approvals, timber conversion permits, other rezoning, major or minor use permits, etc.).

3.1.2 Performance Test

The Performance Test is satisfied if the following requirements are met, depending on the type of Forest Project.

3.1.2.1 Reforestation Projects

A Reforestation Project that occurs on land that has had less than 10 percent tree canopy cover for at least 10 years automatically satisfies the Performance Test.

A Reforestation Project that occurs on land that has undergone a Significant Disturbance satisfies the Performance Test if:

1. The Forest Project corresponds to a scenario in Appendix E, Table E.1, indicating that it is "eligible" (as determined by the requirements and methods in Appendix E); or
2. The Forest Project occurs on a type of land for which the Forest Owner has not historically engaged in or allowed timber harvesting. (Examples of such land include municipal or state parks.)

3.1.2.2 Improved Forest Management Projects

An Improved Forest Management Project automatically satisfies the Performance Test. Project activities are considered additional to the extent they produce GHG reductions and/or GHG removal enhancements in excess of those that would have occurred under a conservative Business-As-Usual Scenario, as defined by the baseline estimation requirements in Section 6.2.1.

3.1.2.3 Avoided Conversion Projects

An Avoided Conversion Project satisfies the Performance Test if a real estate appraisal for the Project Area (as defined in Section 4) is submitted indicating the following:

1. *The Project Area is suitable for conversion*. The appraisal must clearly identify the highest value alternative land use for the Project Area and indicate how the physical characteristics of the Project Area are suitable for the alternative land use.
    a. At a minimum, where conversion to commercial, residential, or agricultural land uses is anticipated, the appraisal must indicate that the slope of Project Area land does not exceed 40 percent.

   b. Where conversion to agricultural land use is anticipated, the appraisal must provide:
      i. Evidence of soil suitability for the type of expected agricultural land use.
      ii. Evidence of water availability for the type of expected agricultural land use.
   c. Where conversion to mining land use is anticipated, the appraisal must provide evidence of the extent and amount of mineral resources existing in the Project Area, and the commercial viability of mineral extraction.
   d. The appraisal must identify specific portions of the Project Area suitable for the identified alternative land use. For example, an appraisal that identified a golf course as an alternative land use must specify the approximate acres suitable for fairways, greens, clubhouses, and outbuildings.
2. *The alternative land use for the Project Area has a higher market value than forestland*. The appraisal for the property must demonstrate that the fair market value of the anticipated alternative land use for the Project Area is at least 40 percent greater than the value of the current forested land use.

Where conversion to residential, commercial, or recreational land uses is anticipated, the appraisal must also describe the following information:
1. The proximity of the Project Area to metropolitan areas.
2. The proximity of the Project Area to grocery and fuel services and accessibility of those services.
3. Population growth within 180 miles of the Project Area.

The appraisal must be conducted in accordance with the Uniform Standards of Professional Appraisal Practice[3] and the appraiser must meet the qualification standards outlined in Internal Revenue Code, Section 170 (f)(11)(E)(ii).[4]

3.2 Offset Project Commencement

The date of offset project commencement for a Forest Project is the date on which an activity is first implemented that will lead to increased GHG reductions or GHG removal enhancements relative to the Forest Project's baseline. The following actions identify offset project commencement for each project type:
- For a Reforestation Project, the action is the planting of trees, the removal of impediments to natural regeneration, or site preparation for the planting of trees, whichever comes first.
- For an Improved Forest Management Project, the action is initiating forest management activities that increase sequestration and/or decrease emissions relative to the baseline, or transferring the Project Area to public ownership.
- For an Avoided Conversion Project, the action is committing the Project Area to continued forest management and protection through recording a conservation

[3] Uniform Standards of Professional Appraisal Practice. http://www.uspap.org/2010USPAP/toc.htm. (Accessed October 1, 2010).
[4] Section 170 (f)(11)(E)(ii) of the Internal Revenue Code defines a qualified appraiser as
"an individual who -
(I) has earned an appraisal designation from a recognized professional appraiser organization or has otherwise met minimum education and experience requirements set forth in regulations prescribed by the Secretary,
(II) regularly performs appraisals for which the individual receives compensation, and
(III) meets such other requirements as may be prescribed by the Secretary in regulations or other guidance."

easement with a provision to maintain the Project Area in forest cover or transferring the Project Area to public ownership.

An Improved Forest Management project's offset project commencement date must be linked to a discrete, verifiable action that delineates a change in practice relative to the Forest Project's baseline. Any one of the following actions denotes an Improved Forest Management project's offset project commencement date:

- Recordation of a conservation easement on the Project Area. The date the easement was recorded is the Forest Project's offset project commencement date.
- Transferring of property ownership (to a public or private entity). The offset project commencement date is the date of property transfer.
- Submitting the offset project listing information specified in Section 9.1.1. Offset project commencement is the date of submittal of listing information, provided that the offset project completes verification within 30 months of being submitted. If the offset project does not meet this deadline, the listing information must be resubmitted under the latest version of the protocol.

Adequate documentation denoting the offset project commencement date must include where applicable, deeds of trust, title reports, conservation easement documentation, dated forest management plans, and/or other relevant contracts or agreements.

3.3 Project Crediting Period

The crediting period for offset projects using this protocol is 25 years. This means that after a successful initial verification, a Forest Project will be eligible to receive Offset Credits for GHG reductions and/or removals quantified using this protocol, and verified by ARB-approved verification bodies, for a period of 25 years following the offset project's commencement date. A project may be renewed for subsequent crediting periods, subject to approval at that time and use of the quantification methods in the most recent approved version of the Forest Offset Protocol at the time of renewal.

The baseline for any Forest Project under this version of the Forest Offset Protocol is valid for the duration of the Project Life following a successful initial verification where the offset project receives a Positive Verification Statement.

3.4 Project Life and Minimum Time Commitment

Project Life is defined as the period of time between offset project commencement and a period of 100 years following the issuance of any ARB or registry offset credit for GHG reductions or GHG removal enhancements achieved by the offset project. Forest Projects must continue to monitor, verify and report offset project data for a period of 100 years following any ARB or registry offset credit issuance. For example, if ARB or registry offset credits are issued to a Forest Project in year 25 following offset project commencement, monitoring and verification activities must be maintained until year 125.

There are three possible exceptions to this minimum time commitment:

1. A Forest Project automatically terminates if a Significant Disturbance occurs leading to an Unintentional Reversal that reduces the Forest Project's Standing Live Carbon Stocks below the Forest Project's baseline Standing Live Carbon Stocks. If this occurs, the requirements of section 95983(d) of the Regulation shall apply.

2. A Forest Project automatically terminates if Project Lands or timber rights are sold to an entity that does not elect to take over the Forest Project responsibilities and commitments. Such a termination will require a quantity of ARB Offset Credits to be retired, as specified under 'Retiring Compliance Instruments Following Project Termination,' below.
3. A Forest Project may be voluntarily terminated prior to the end of its minimum time commitment if the required quantities of Compliance Instruments are retired, as specified under 'Retiring Compliance Instruments Following Project Termination,' below.

Retiring Compliance Instruments Following Project Termination

If a Forest Project is terminated for any reason except an unintentional reversal, the Forest Owner must replace any ARB Offset Credits that have previously been issued based on the requirements in the Regulation and the following provisions:

a. For a Reforestation or Avoided Conversion Project, a quantity of Compliance Instruments equal to the total number of ARB Offset Credits issued, and where applicable, all Early Action Offset Credits issued pursuant to section 95990(i) of the Regulation, to the project over the preceding 100 years must be retired.
b. For an Improved Forest Management Project, a quantity of Compliance Instruments equal to the total number of ARB Offset Credits issued, and where applicable, all Early Action Offset Credits issued pursuant to section 95990(i) of the Regulation, to the project over the preceding 100 years, multiplied by the appropriate compensation rate indicated in Table 3.1 must be retired.

Table 3.1. Compensation Rate for Terminated Improved Forest Management Projects

Number of years that have elapsed between offset project commencement and the date of termination	Compensation Rate
0-5	1.40
6-10	1.20
11-20	1.15
21-25	1.10
31-50	1.05
>50	1.00

3.5 Use of Qualified Conservation Easements

For Avoided Conversion Projects on private land, the Forest Owner must record a Qualified Conservation Easement against the offset project's property in order for the Forest Project to be eligible. Any Forest Project that records a Qualified Conservation Easement may reduce its risk rating and required contribution to the Forest Buffer Account in Appendix D. To be "qualified" for purposes of ARB's compliance offset program, the conservation easement must:

a. Be granted by the owner of the fee to a qualified holder of a conservation easement in accordance with the conservation easement enabling statute of the state in which the project is located;
b. Be perpetual in duration;

c. Expressly acknowledge that ARB is a third party beneficiary of the conservation easement with the right to enforce all obligations under the easement and all other rights and remedies conveyed to the holder of the easement. These rights include standing as an interested party in any proceeding affecting the easement.

Qualified Conservation Easements must be recorded no earlier than one year before the offset project's commencement date. If a Qualified Conservation Easement was recorded more than one year prior to the offset project commencement date, the limits imposed by the easement on forest management activities must be considered a legal mandate for the purpose of satisfying the legal requirement test for additionality (Section 3.1.1) and in determining the Forest Project's baseline (Section 0).

As indicated in Section 3.2, an offset project commencement date must be linked to a discrete, verifiable action. The recordation of a conservation easement may be used to denote the commencement date of pre-existing projects between December 31, 2006 and December 31, 2010. Any previously recorded conservation easement may only be considered a Qualified Conservation Easement if it was recorded within one year prior to the identified project commencement date. Any previously recorded conservation easement must still meet, or be modified to meet, all of the requirements of this section (i.e. expressly acknowledging ARB as a third-party beneficiary) in order to be considered "qualified."

The conservation easement may be amended to exclude ARB as a third party beneficiary upon termination of the Forest Project or once all legal requirements for monitoring and verification of carbon stocks under this Compliance Offset Protocol have been met.

3.6 Project Location

All Forest Projects must be located in the United States of America. Reforestation Projects and Improved Forest Management Projects may be located on private land, or on state or municipal public land. Avoided Conversion Projects must be implemented on private land, unless the land is transferred to public ownership as part of the project.

All Forest Projects on public lands must be approved by the government agency or agencies responsible for management activities on the land. This approval must include an explicit approval of the Forest Project's baseline, as determined in Section 0, and must involve any public vetting processes necessary to evaluate management and policy decisions concerning the project activity. Offset projects on federal lands that are not included in the categories of land in the following paragraph are not eligible at this time.

Forest Projects situated on the following categories of land are only eligible under this protocol if they meet the requirements of this protocol and the Regulation, including the waiver of sovereign immunity requirements of section 95975(l) in the Regulation:

1. Land that is owned by, or subject to an ownership or possessory interest of a Tribe;
2. Land that is "Indian lands" of a Tribe, as defined by 25 U.S.C. §81(a)(1); or
3. Land that is owned by any person, entity, or Tribe, within the external borders of such Indian lands.

The Forest Offset Protocol contains data tables, equations, and benchmark data applicable to projects located in the United States. The methods required by this protocol for estimating baseline carbon stocks for Forest Projects cannot currently be applied outside the United

States, as they rely on U.S.-specific data sets and models. Forest Projects in Alaska and Hawaii are not eligible at this time due to lack of region-specific data.

3.7 Regulatory Compliance

As stated in the Regulation, Project Lands must fulfill all applicable local, regional and national requirements on environment impact assessments that apply based on the offset project location. Offset projects must also meet any other local, regional, and national requirements that might apply.

Each time the Forest Project is verified, the Offset Project Operator or Authorized Project Designee must attest that the Forest Owner and Project Lands are in compliance with all applicable laws and regulations. The Offset Project Operator or Authorized Project Designee are required to disclose in writing to the verifier any and all instances of non-compliance associated with the Project Lands with any legal requirement. If a verifier finds that an offset project is in a state of non-compliance with any environmental law or regulation, then ARB or registry offset credits will not be issued for GHG reductions or GHG removal enhancements that occurred during any reporting period of non-compliance.

3.8 Sustainable Harvesting and Natural Forest Management Practices

Forest Projects can create long-term climate benefits as well as provide other environmental benefits, including the sustaining of natural ecosystem processes. This protocol requires eligible offset projects to employ both sustainable long-term harvesting practices and Natural Forest Management practices over time, as described below. Any non-conformance with the sustainable harvesting and Natural Forest Management requirements in this section will result in an adverse offset verification statement during the reporting periods that the Forest Project was out of conformance.

3.8.1 Sustainable Harvesting Practices

At the time commercial harvesting is either planned or initiated within the Project Area, the Offset Project Operator or Authorized Project Designee must demonstrate that the Forest Owner(s) employs and demonstrates sustainable long-term harvesting practices on all of its forest landholdings, including the Project Area, using one of the following options:

1. The Forest Owner must be certified under the Forest Stewardship Council, Sustainable Forestry Initiative, or Tree Farm System certification programs. Regardless of the program, the terms of certification must require adherence to and verification of harvest levels which can be permanently sustained over time.
2. The Forest Owner must adhere to a renewable long-term management plan that demonstrates harvest levels which can be permanently sustained over time and that is sanctioned and monitored by a state or federal agency.
3. The Forest Owner must employ uneven-aged silvicultural practices (if harvesting occurs) and must maintain canopy cover averaging at least 40 percent across the entire forestland owned by the Forest Owner in the same Assessment Areas covered by the Project Area, as measured on any 20 acres within the Forest Owner’s landholdings found in any of these Assessment Areas, including land within and outside of the Project Area (areas impacted by Significant Disturbance may be excluded from this test).

Forest Owners who acquire new forest landholdings within their entity have up to 5 years to incorporate such acquisitions under their certification or management plan, whether or not such land is contiguous with the Project Area.

3.8.2 Natural Forest Management

All Forest Projects must promote and maintain a diversity of native species and utilize management practices that promote and maintain native forests comprised of multiple ages and mixed native species within the Project Area and at multiple landscape scales ("Natural Forest Management").

All Forest Projects are required to establish and/or maintain forest types that are native to the Project Area. For the purposes of this protocol, native forests are defined as those forests occurring naturally in an area, as neither a direct nor indirect consequence of human activity post-dating European settlement.

The Forest Offset Protocol Resources section of ARB's webpage provides required references by Assessment Area for the definition of native forests (see Appendix F). If a state/regional reference is unavailable or inadequate, documentation from a state botanist or other qualified independent resource, recognized as expert by academic, private and government organizations, must be submitted indicating that the project promotes and maintains native forests per the definition above. Where supported by scientific peer-reviewed research, the planting of native species outside of their current distribution is allowed as an adaptation strategy due to climate change. Such planting must be done in accordance with a state or federally approved adaptation plan, or a local plan that has gone through a transparent public review process. A written statement must be submitted from the government agency in charge of forestry regulation in the state where the project is located stipulating that the planting of native trees outside their current range is appropriate as an adaptation to climate change.

The following requirements shall apply to all Forest Projects regardless of the silvicultural or regeneration methods that are used to manage or maintain the forest:

1. Forest Projects must maintain or increase standing live carbon stocks over the project life, as described in Section 3.8.3.
2. Forest Projects must show verified progress (verified at scheduled site-visits) towards native tree species composition and distribution consistent with the forest type and forest soils native to the Assessment Area.
3. Forest Projects must manage the distribution of habitat/age classes and structural elements to support functional habitat for locally native plant and wildlife species naturally occurring in the Project Area, as specified in Table 3.2 and Section 3.8.4 below.

Forest Projects that initially engage in Natural Forest Management must continue to do so for as long as monitoring and verification of the Forest Project are required by this protocol (i.e. for the duration of the Project Life). Forest Projects that do not initially meet Natural Forest Management criteria but can demonstrate progress towards meeting these criteria at the times identified in Table 3.2 are still eligible.

The evaluation criteria provided in Table 3.2 shall be used to determine if the Forest Project meets the criteria for engaging in Natural Forest Management. The following evaluation must be completed and verified at a Forest Project's first verification and at all subsequent verifications. Forest Project carbon stock inventories (requirements for which are contained in Appendix A) should be used as the basis of these assessments where applicable.

Table 3.2. Evaluation criteria to test if a Forest Project meets the requirement for the establishment and maintenance of native species and natural forest management

<table>
<tr><th>Criteria</th><th>When Assessed</th><th>Results of not passing criteria</th><th>Application Rules</th></tr>
<tr><td colspan="4">Native Species</td></tr>
<tr><td rowspan="2">Project consists of at least 95% native species based on the sum of carbon in the standing live carbon pool. The assessment shall be conducted using estimates of stems per acre for Reforestation Projects and basal area per acre for Improved Forest Management and Avoided Conversion Projects.</td><td>Assessed at initial verification from inventory data.</td><td>Forest Project is not eligible unless demonstrated that management will achieve this goal over the project life.</td><td rowspan="2">Applies to all project types throughout the project life</td></tr>
<tr><td>Assessment during verification site visits must demonstrate continuous progress toward goal. This criterion must be met within 25 years.</td><td>Project is not in conformance with protocol requirements.</td></tr>
<tr><td colspan="4">Composition of Native Species</td></tr>
<tr><td rowspan="2">Improved Forest Management and Avoided Conversion Projects

Where the Project Area naturally consists of a mixed species distribution, no single species' prevalence, measured as the percent of the basal area of all live trees in the Project Area, exceeds the percentage value of standing live carbon shown under the heading 'Species Diversity Index' in the Forest Offset Protocol Resources section of ARB's website. Where the Project Area does not naturally consist of a mixed species distribution, a written statement from the government agency in charge of forestry regulation in the state where the project is located stipulating that the project area does not naturally consist of a mixed species distribution must be submitted.

Reforestation

To the extent seed is available, and/or physical site characteristics permit, Reforestation Projects that involve planting of seedlings must plant a mixture of species such that no single species' prevalence, measured as the percent of all live tree stems in the Project Area, exceeds the percentage value shown under the heading 'Species Diversity Index' in the Assessment Area table in the Forest Offset Protocol Resources section of ARB's website. Where seed is unavailable, the Reforestation Project is based on natural regeneration, or physical site characteristics are limiting, a written statement from the government agency in charge of forestry regulation in the state where the project is located stipulating that seed is unavailable, the Reforestation Project is based on natural regeneration, or physical site characteristics are limiting must be submitted.</td><td>Species composition is assessed at project initiation from inventory data.</td><td>Project is not eligible, unless it is demonstrated that management activities will enable this goal to be achieved over the project life.</td><td rowspan="2">Applies to all project types throughout the project life

Some project sites may not be capable of meeting the requirement. In these cases, a written statement from the government agency in charge of forestry regulation in the state where the project is located must be submitted as described under "Criteria"</td></tr>
<tr><td>Species composition is assessed at initial verification from inventory data.

Project must show continuous progress toward criteria. These criteria must be met within 25 years.</td><td>Project is not in conformance with protocol requirements.</td></tr>
<tr><td colspan="4">Distribution of Age Classes/Sustainable Management</td></tr>
<tr><td>All forest landholdings owned or controlled by the Forest Owner are currently under one of the following:

1. Third party certification under the Forest Stewardship Council, Sustainable Forestry Initiative, or Tree Farm System, whose certification standards require adherence to and verification of harvest levels which can be permanently sustained over time, or</td><td>Condition shall be met at all times during project and is assessed during each verification.</td><td>Project is not in conformance with protocol requirements.</td><td>Applies to all project types at first regeneration harvest</td></tr>
</table>

2. Operating under a renewable long-term management plan that demonstrates harvest levels which can be permanently sustained over time and that is sanctioned and monitored by a state or federal agency, or 3. The Forest Owner must employ uneven-aged silvicultural practices and canopy retention averaging at least 40 percent across the forest, as measured on any 20 acres within the entire forestland owned by the Forest Owner, including land within and outside of the Project Area. (Areas impacted by Significant Disturbance may be excluded from this test.)			
On a watershed scale up to 10,000 acres (or the project area, whichever is smaller), all projects must maintain, or make progress toward maintaining, no more than 40 percent of their forested acres in ages less than 20 years. (Areas impacted by Significant Disturbance may be excluded from this test.)	Age classes (if even age management is used) are assessed at project initiation and each verification site visit.	NA	
	Project must show continuous progress toward criteria. This criterion must be met within 25 years.	Project is not in conformance with protocol requirements.	
Structural Elements (Standing and Lying Dead Wood)			
Lying dead wood must be retained in sufficient quantities, as described below. **For portions of the Project Area that have not recently undergone salvage harvesting:** If a verifier determines that the quantity of lying dead wood is commensurate with recruitment from standing dead trees (i.e. there is no evidence that lying dead wood has been actively removed), the project must maintain (or demonstrate ongoing progress toward) an average of at least: ▪ one (1) metric ton of carbon (C) per acre; or ▪ 1% of standing live carbon stocks, in *standing* dead wood, whichever is higher, If a verifier determines that the quantity of lying dead wood is **not** commensurate with recruitment from standing dead trees (i.e. it appears lying dead wood has been actively removed), the project must maintain (or demonstrate ongoing progress toward) an average of at least: ▪ two (2) metric tons of carbon (C) per acre; or ▪ 1% of standing live carbon stocks, in *standing* dead wood, whichever is higher, Standing dead wood may be evenly or unevenly distributed throughout the portion of the Project Area unaffected by salvage harvesting, as long as the appropriate minimum average tonnage per acre requirement is met. **For portions of the Project Area that have undergone salvage harvesting within the previous year:*** If a verifier determines that the quantity of lying dead wood following salvage harvest is commensurate with recruitment from standing dead trees, the project must maintain (or demonstrate ongoing progress toward) an average of at least	Assessed during project at each verification audit.	Project is not in conformance with protocol requirements.	Applies to all project types throughout the project life

two (2) metric tons of carbon (C) per acre in *standing* dead wood, If a verifier determines that the quantity of lying dead wood following harvest is **not** commensurate with recruitment from standing dead trees, the project must maintain (or demonstrate ongoing progress toward) an average of at least four (4) metric tons of carbon (C) per acre in *standing* dead wood, Standing dead wood may be evenly or unevenly distributed throughout the portion of the Project Area subject to salvage harvesting, as long as the appropriate minimum average tonnage per acre requirement is met. This requirement must be met for a period of 30 years following the salvage harvest. After 30 years, the portion of the Project Area subject to salvage harvesting must meet the requirements for portions that have not recently undergone salvage harvesting (described above).			

3.8.3 Promotion of the Onsite Standing Live Carbon Stocks

In an effort to promote and maintain the environmental benefits of Forest Projects, the standing live carbon stocks within the Project Area must be maintained and/or increased during the Project Life. Therefore, except as specified below, ARB or registry offset credits will not be issued for quantified GHG reductions and GHG removal enhancements achieved by a Forest Project if a Forest Project's Offset Project Data Reports – over any 10-year consecutive period – indicate a decrease in the standing live carbon stocks.

Exceptions are allowed where reductions in standing live carbon stocks are important for maintaining and enhancing forest health, environmental co-benefits, or the long-term security of all carbon stocks; where reductions are due to non-harvest disturbances; or where reductions are required by law. Note that these exceptions in no way change or affect the requirements related to compensating for reversals, as detailed in Section 7.3.

Forest Projects whose standing live carbon stocks have decreased over a 10-year period are not in conformance with protocol requirements, except if the decrease in standing live carbon stocks is due to one of the following causes:

1. The decrease is demonstrably necessary to substantially improve the Project Area's resistance to wildfire, insect, or disease risks. The actions that will be taken to reduce the risks must be documented. The techniques used to improve resistance must be supported by relevant published peer reviewed research.
2. The decrease is associated with a planned balancing of age classes (regeneration, sub-merchantable, and merchantable) and is detailed in a long-term management plan that demonstrates harvest levels can be permanently sustained over time and that is sanctioned and monitored by a state or federal agency. In this case, documentation must be submitted at the time of the Forest Project's Listing, indicating that a balancing of age classes, resulting in a decrease in the standing live carbon stocks, is planned at the initiation of the Forest Project (Figure 3.1). At no time over the Project Life shall the Forest Project's inventory of standing live carbon stocks fall below the Forest Project's baseline standing live carbon stocks, or 20 percent less than the Forest Project's standing live carbon stocks at the project's initiation, whichever is higher. Over any

consecutive 10-year period, average standing live carbon stocks must be maintained at or above the standing live carbon stocks at the initiation of the project.

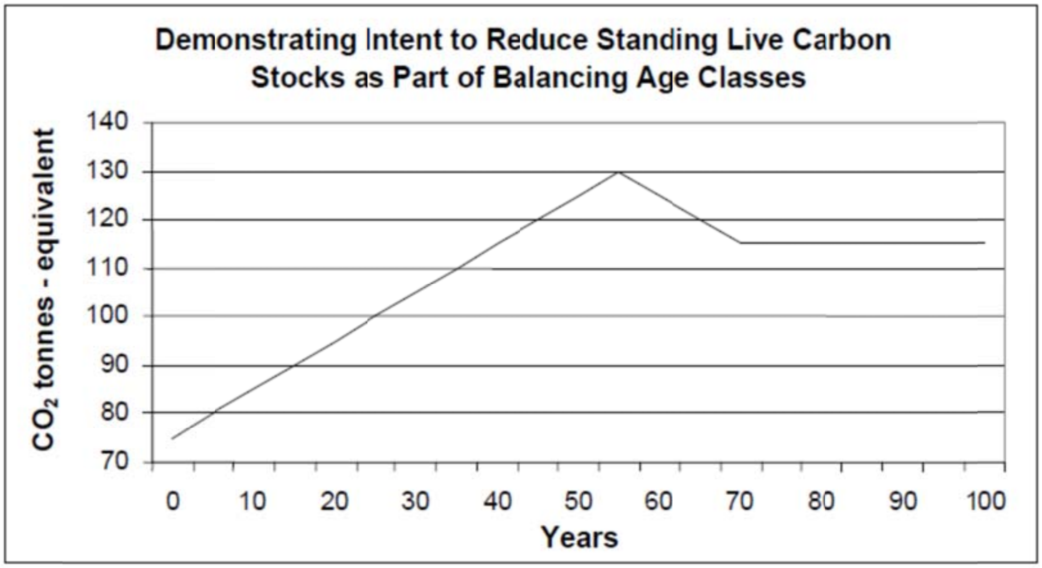


Figure 3.1. Example of Reducing Standing Live Carbon Stocks as Part of Balancing Age Classes

3. The decrease is part of normal silviculture cycles for forest ownerships less than 1,000 acres. Inventory fluctuations are a normal part of silvicultural activities. Periodic harvest may remove more biomass than the biomass growth over the past several years. At no time during the Project Life shall the Forest Project's inventory of standing live carbon stocks fall below the Forest Project's baseline standing live carbon stocks, or 20 percent less than the Forest Project's standing live carbon stocks at the project's initiation, whichever is higher. Over any consecutive 10-year period, average standing live carbon stocks must be maintained at or above the standing live carbon stocks at the initiation of the project. Documentation submitted at the time the Forest Project is Listed must indicate that fluctuations in the Forest Project's standing live carbon stocks are an anticipated silvicultural activity and that the overall trend will be for standing live carbon stocks to increase or stay the same over the life of the offset project (Figure 3.2).

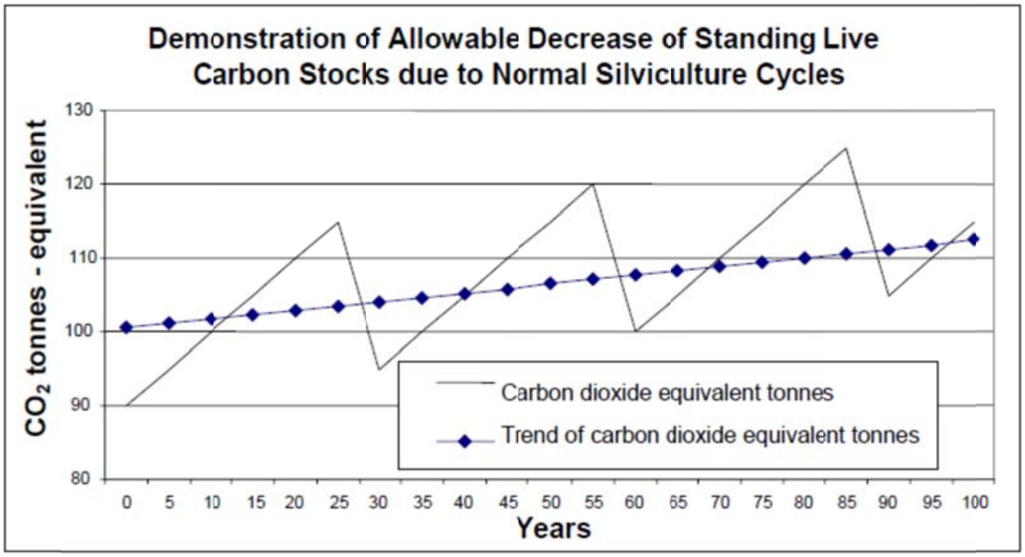


Figure 3.2. Example of Allowable Decrease of Standing Live Carbon Stocks due to Normal Silviculture Cycles

4. The decrease is due to an unintentional reversal such as wildfire, disease, flooding, wind-throw, insect infestation, or landslides.
5. The decrease in standing live carbon stocks occurs after the final crediting period (during the required 100 year monitoring period) as long as the residual live carbon stocks are maintained at a level that assures all credited standing live carbon stocks are permanently maintained.

3.8.4 Balancing Age and Habitat Classes

A variety of silvicultural practices may be employed in the Project Area during the course of a Forest Project though the protocol does not endorse any particular practice. To ensure environmental integrity, Forest Projects must meet a minimum set of standards in the use of any such practices.

For offset projects that employ even-aged management practices, harvesting must be limited to stands no greater than 40 acres. Stands adjacent to recently harvested stands must not be harvested using an even-aged harvest until the average age of the adjacent stand is at least 5-years old, or the average height in the adjacent stand is at least 5 feet. On a watershed scale up to 10,000 acres, all projects must maintain, or make progress toward maintaining, no more than 40 percent of their forested acres in ages less than 20 years. Areas impacted by a Significant Disturbance are exempt from this test until 20 years after reforestation of such areas.

The protocol does not override a landowner's obligation to abide by applicable laws and regulations, including any governing forest practice rules that may be more stringent. Regardless of the silvicultural practice employed, landowners must fulfill their commitment under the protocol to permanently maintain or increase onsite standing live carbon stocks (i.e. the carbon in live trees within the Project Area) as specified in Section 3.8.3.

4 Identifying the Project Area

The geographic boundaries defining the Project Area must be described in detail at the time a Forest Project is Listed. The boundaries must be defined using a map, or maps, that display public and private roads, major watercourses (4th order or greater), topography, towns, and either public land survey townships, ranges, and sections or latitude and longitude. The maps must be of adequate resolution to clearly identify the required features. The Project Area can be contiguous or separated into tracts. The Project Area may also extend across multiple Assessment Areas within an Ecosection or Supersection (see Appendix F) and across no more than two adjacent Ecosections or Supersections.

For Improved Forest Management Projects, the geographic boundaries may be defined such that non-forested areas, or areas not under forest management, are excluded from the Project Area.

For Reforestation Projects, the Project Area must be on land that has had less than 10 percent tree canopy cover for a minimum of ten years, or that have been subject to a Significant Disturbance that resulted in at least 20 percent of the carbon stocks being emitted. A Reforestation Project may defer finalizing the boundaries of the Project Area until the second full verification provided: (1) all lands included in the Project Area were initially included in the Project Area during listing, and (2) the Reforestation Project has elected to defer its initial inventory until the second full verification. This allows Reforestation Projects to initially identify a larger Project Area during project listing that may be revised prior to the completion of the forest inventory and the issuance of any ARB or registry offset credits.

For Avoided Conversion Projects, the Project Area is defined through the required appraisal process. The Project Area must be determined following the boundary definitions in Table 4.1 based on the type of anticipated conversion. All lands in the Project Area must be covered by the Qualified Conservation Easement or transferred to public ownership as part of the program.

Table 4.1. Project Area Definition for Avoided Conversion Projects

Conversion Type	Project Area Definition
Residential	The boundary of the parcel or parcels that have been appraised as having a ‘higher and better use’ in residential development.
Agricultural Conversion or Mining	The boundary of the parcel or parcels that have been appraised as having a ‘higher and better use’ in agricultural production or mining.
Golf Course	The boundary of the parcel or parcels that have been appraised as having a ‘higher and better use’ as a golf course. This is to include forested areas within 200’ of fairways, greens, and buildings.
Commercial Buildings	The boundary of the parcel or parcels that have been appraised as having a ‘higher and better use’ in commercial buildings. This is to include forested areas with 200’ of suitable building sites.

5 Offset Project Boundary

The Offset Project Boundary defines all the GHG emission sources, GHG sinks, and GHG reservoirs (SSR's) that must be accounted for in quantifying a Forest Project's GHG reductions and GHG removal enhancements (Section 0). The Offset Project Boundary encompasses all the GHG emission SSR's that may be significantly affected by Forest Project activities, such as forest carbon stocks and harvested wood products. For accounting purposes, the GHG sources, GHG sinks, and GHG reservoirs included in the Offset Project Boundary are organized according to whether they are predominantly associated with a Forest Project's "Primary Effect" (i.e. the Forest Project's intended changes in carbon stocks, GHG emissions, or GHG removal enhancements) or its "Secondary Effects" (i.e. unintended changes in carbon stocks, GHG emissions, or GHG removal enhancements caused by the Forest Project). Secondary effects may include increases in mobile combustion CO_2 emissions associated with site preparation, as well as increased CO_2 emissions caused by the shifting of harvesting activities from the Project Area to other forestlands (referred to as "Leakage"). Offset projects are required to account for Secondary Effects following the methods described in Section 6.

The following tables provide a comprehensive list of the SSRs that may be affected by a Forest Project, and indicate which SSRs must be included in the Offset Project Boundary for each type of Forest Project. If a SSR is designated as a "reservoir/pool," this means that GHG reductions and GHG removal enhancements are accounted for by quantifying changes in carbon stock levels. For SSRs designated as GHG sources or GHG sinks, GHG reductions and GHG removal enhancements are accounted for by quantifying changes in GHG emission or GHG removal enhancement rates, as described in the tables.

5.1 Reforestation Projects

Table 5.1. Offset Project Boundary – Reforestation Projects

SSR	Description	Type	Gas	Included or Excluded?	Quantification Method
Primary Effect Sources, Sinks, and Reservoirs					
RF-1	Standing live carbon (carbon in all portions of living trees)	Reservoir / Pool	CO_2	Included	**Baseline:** Modeled based on initial field inventory measurements **Project:** Measured by field measurements and updating forest carbon inventory
RF-2	Shrubs and herbaceous understory carbon	Reservoir / Pool	CO_2	Included	**Baseline:** Modeled based on initial field inventory measurements **Project:** Measured by updating forest carbon inventory
RF-3	Standing dead carbon (carbon in all portions of dead, standing trees)	Reservoir / Pool	CO_2	Included	**Baseline:** Modeled based on initial field inventory measurements **Project:** Measured by updating forest carbon inventory
RF-4	Lying dead wood carbon	Reservoir / Pool	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
RF-5	Litter and duff carbon (carbon in	Reservoir / Pool	CO_2	Excluded	**Baseline:** N/A

SSR	Description	Type	Gas	Included or Excluded?	Quantification Method
	dead plant material)				**Project:** N/A
RF-6	Soil carbon	Reservoir / Pool	CO_2	*Included/excluded: Soil carbon must be included in the Offset Project Boundary if any of the following occur: ▪ Site preparation activities involve deep ripping, furrowing, or plowing where soil disturbance exceeds (or is expected to exceed from the baseline characterization and modeling) 25 percent of the Project Area over the Project Life, or ▪ Mechanical site preparation activities are not conducted on contours.	**Baseline:** Modeled based on initial field inventory measurements **Project:** Measured by updating forest carbon inventory
RF-7	Carbon in in-use forest products	Reservoir / Pool	CO_2	Included	**Baseline:** Estimated from modeled harvesting volumes **Project:** Estimated from measured harvesting volumes
RF-8	Forest product carbon in landfills	Reservoir / Pool	CO_2	Excluded when project harvesting exceeds baseline Included when project harvesting is below baseline	**Baseline:** Estimated from modeled harvesting volumes **Project:** Estimated from measured harvesting volumes
Secondary Effect Sources, Sinks, and Reservoirs					
RF-9	Biological emissions from site preparation activities	Source	CO_2	*Included: Biological emissions from site preparation are not quantified separately, but rather are captured by measuring changes in included carbon reservoirs	**Baseline:** N/A **Project:** Quantified based on measured carbon stock changes in included reservoirs (SSRs #RF-2 and #RF-6)
RF-10	Mobile combustion emissions from site preparation activities	Source	CO_2	Included	**Baseline:** N/A **Project:** Estimated using default emission factors
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
RF-11	Mobile combustion emissions from ongoing project operation & maintenance	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
RF-12	Stationary combustion emissions from	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A

SSR	Description	Type	Gas	Included or Excluded?	Quantification Method
	ongoing project operation & maintenance				
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
RF-13	Biological emissions from clearing of forestland outside the Project Area	Source	CO_2	Included	**Baseline:** N/A **Project:** Estimated using default land-use conversion factors for non-project land
RF-14	Biological emissions/ removals from changes in harvesting on forestland outside the Project Area	Source / Sink	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
RF-15	Combustion emissions from production, transportation, and disposal of forest products	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A -
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
RF-16	Combustion emissions from production, transportation, and disposal of alternative materials to forest products	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
RF-17	Biological emissions from decomposition of forest products	Source	CO_2	Included	**Baseline:** Quantified as a component of calculating carbon stored for 100 years in wood products (SSR #RF-7) and landfills (SSR #RF-8) **Project:** Quantified as a component of calculating carbon stored for 100 years in wood products (SSR #RF-7) and landfills (SSR #RF-8)
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A

5.2 Improved Forest Management Projects

Table 5.2. Offset Project Boundary – Improved Forest Management Projects

SSR	Description	Type*	Gas	Included or Excluded?	Quantification Method
Primary Effect Sources, Sinks, and Reservoirs					
IFM-1	Standing live carbon (carbon in all portions of living trees)	Reservoir / Pool	CO_2	Included	**Baseline:** Modeled based on initial field inventory measurements **Project:** Measured by field measurements and updating forest carbon inventory
IFM-2	Shrubs and herbaceous understory carbon	Reservoir / Pool	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
IFM-3	Standing dead carbon (carbon in all portions of dead, standing trees)	Reservoir / Pool	CO_2	Included	**Baseline:** Modeled based on initial field inventory measurements **Project:** Measured by updating forest carbon inventory
IFM-4	Lying dead wood carbon	Reservoir / Pool	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
IFM-5	Litter and duff carbon (carbon in dead plant material)	Reservoir / Pool	CO_2	Excluded	**Baseline:** Modeled based on initial field inventory measurements **Project:** Measured by updating forest carbon inventory
IFM-6	Soil carbon	Reservoir / Pool	CO_2	*Included/ Excluded Soil carbon must be included in the Offset Project Boundary, if any of the following activities occur: ▪ Site preparation activities involve deep ripping, furrowing, or plowing where soil disturbance exceeds (or is expected to exceed from the baseline characterization and modeling) 25 percent of the Project Area over the Project Life, or ▪ Mechanical site preparation activities are not conducted on contours.	**Baseline:** Modeled based on initial field inventory measurements **Project:** Measured by updating forest carbon inventory
IFM-7	Carbon in in-use forest products	Reservoir / Pool	CO_2	Included	**Baseline:** Estimated from modeled harvesting volumes **Project:** Estimated from measured harvesting volumes
IFM-8	Forest product carbon in landfills	Reservoir / Pool	CO_2	Excluded when project harvesting exceeds baseline Included when project harvesting is below baseline	**Baseline:** Estimated from modeled harvesting volumes **Project:** Estimated from measured harvesting volumes
Secondary Effect Sources, Sinks, and Reservoirs					
IFM-9	Biological	Source	CO_2	*Included	**Baseline:** N/A

SSR	Description	Type*	Gas	Included or Excluded?	Quantification Method
	emissions from site preparation activities			Biological emissions from site preparation are not quantified separately, but rather are captured by measuring changes in included carbon reservoirs	**Project:** Quantified based on measured carbon stock changes in included reservoirs (SSR #IFM-6, where applicable)
IFM-10	Mobile combustion emissions from site preparation activities	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
IFM-11	Mobile combustion emissions from ongoing project operation & maintenance	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A .
IFM-12	Stationary combustion emissions from ongoing project operation & maintenance	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
IFM-13	Biological emissions from clearing of forestland outside the Project Area	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
IFM-14	Biological emissions/ removals from changes in harvesting on forestland outside the Project Area	Source / Sink	CO_2	Included / Excluded	**Baseline:** N/A **Project:** Estimated using a default 20% "leakage" factor applied to the difference in harvest volume relative to baseline
IFM-15	Combustion emissions from production, transportation, and disposal of forest products	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A

SSR	Description	Type*	Gas	Included or Excluded?	Quantification Method
IFM-16	Combustion emissions from production, transportation, and disposal of alternative materials to forest products	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
IFM-17	Biological emissions from decomposition of forest products	Source	CO_2	*Included	**Baseline:** Quantified as a component of calculating carbon stored for 100 years in wood products (SSR #IFM-7) and landfills (SSR #IFM-8) **Project:** Quantified as a component of calculating carbon stored for 100 years in wood products (SSR #IFM-7) and landfills (SSR #IFM-8)
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A

5.3 Avoided Conversion Projects

Table 5.3. Offset Project Boundary – Avoided Conversion Projects

SSR	Description	Type*	Gas	Included or Excluded?	Quantification Method
Primary Effect Sources, Sinks, and Reservoirs					
AC-1	Standing live carbon (carbon in all portions of living trees)	Reservoir / Pool	CO_2	Included	**Baseline:** Modeled based on initial field inventory measurements and expected land-use conversion rates **Project:** Measured by field measurements and updating forest carbon inventory
AC-2	Shrubs and herbaceous understory carbon	Reservoir / Pool	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
AC-3	Standing dead carbon (carbon in all portions of dead, standing trees)	Reservoir / Pool	CO_2	Included	**Baseline:** Modeled based on initial field inventory measurements and expected land-use conversion rates **Project:** Measured by updating forest carbon inventory
AC-4	Lying dead wood carbon	Reservoir / Pool	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
AC-5	Litter and duff carbon (carbon	Reservoir / Pool	CO_2	Excluded	**Baseline:** N/A

SSR	Description	Type*	Gas	Included or Excluded?	Quantification Method
	in dead plant material)				**Project:** N/A
AC-6	Soil carbon	Reservoir / Pool	CO_2	*Included/ Excluded Soil carbon must be included in the Offset Project Boundary, if any of the following activities occur: ▪ Site preparation activities involve deep ripping, furrowing, or plowing where soil disturbance exceeds (or is expected to exceed from the baseline characterization and modeling) 25 percent of the Project Area over the Project Life, or Mechanical site preparation activities are not conducted on contours.	**Baseline:** Modeled based on initial field inventory measurements and expected land-use conversion rates **Project:** Measured by updating forest carbon inventory
AC-7	Carbon in in-use forest products	Reservoir / Pool	CO_2	Included	**Baseline:** Estimated from modeled harvesting volumes **Project:** Estimated from measured harvesting volumes
AC-8	Forest product carbon in landfills	Reservoir / Pool	CO_2	Excluded when project harvesting exceeds baseline Included when project harvesting is below baseline	**Baseline:** Estimated from modeled harvesting volumes **Project:** Estimated from measured harvesting volumes
Secondary Effect Sources, Sinks, and Reservoirs					
AC-9	Biological emissions from site preparation activities	Source	CO_2	*Included Biological emissions from site preparation are not quantified separately, but rather are captured by measuring changes in included carbon reservoirs	**Baseline:** N/A **Project:** Quantified based on measured carbon stock changes in included reservoirs (SSR #AC-6, where applicable)
AC-10	Mobile combustion emissions from site preparation activities	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
AC-11	Mobile combustion emissions from ongoing project operation & maintenance	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
AC-12	Stationary combustion emissions from	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A

SSR	Description	Type*	Gas	Included or Excluded?	Quantification Method
	ongoing project operation & maintenance				
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
AC-13	Biological emissions from clearing of forestland outside the Project Area	Source	CO_2	Included	**Baseline:** N/A **Project:** Estimated using default forestland conversion factors
AC-14	Biological emissions/ removals from changes in harvesting on forestland outside the Project Area	Source / Sink	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
AC-15	Combustion emissions from production, transportation, and disposal of forest products	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
AC-16	Combustion emissions from production, transportation, and disposal of alternative materials to forest products	Source	CO_2	Excluded	**Baseline:** N/A **Project:** N/A
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A
AC-17	Biological emissions from decomposition of forest products	Source	CO_2	Included	**Baseline:** Quantified as a component of calculating carbon stored for 100 years in wood products (SSR #AC-7) and landfills (SSR #AC-8) **Project:** Quantified as a component of calculating carbon stored for 100 years in wood products (SSR #AC-7) and landfills (SSR #AC-8)
			CH_4	Excluded	**Baseline:** N/A **Project:** N/A
			N_2O	Excluded	**Baseline:** N/A **Project:** N/A Decomposition of forest is not expected to be a significant source of N_2O emissions.

6 Quantifying Net GHG Reductions and GHG Removal Enhancements

This section provides requirements and methods for quantifying a Forest Project's net GHG reductions and GHG removal enhancements.

Quantification Methodology:
For each type of Forest Project, quantification proceeds in seven steps:

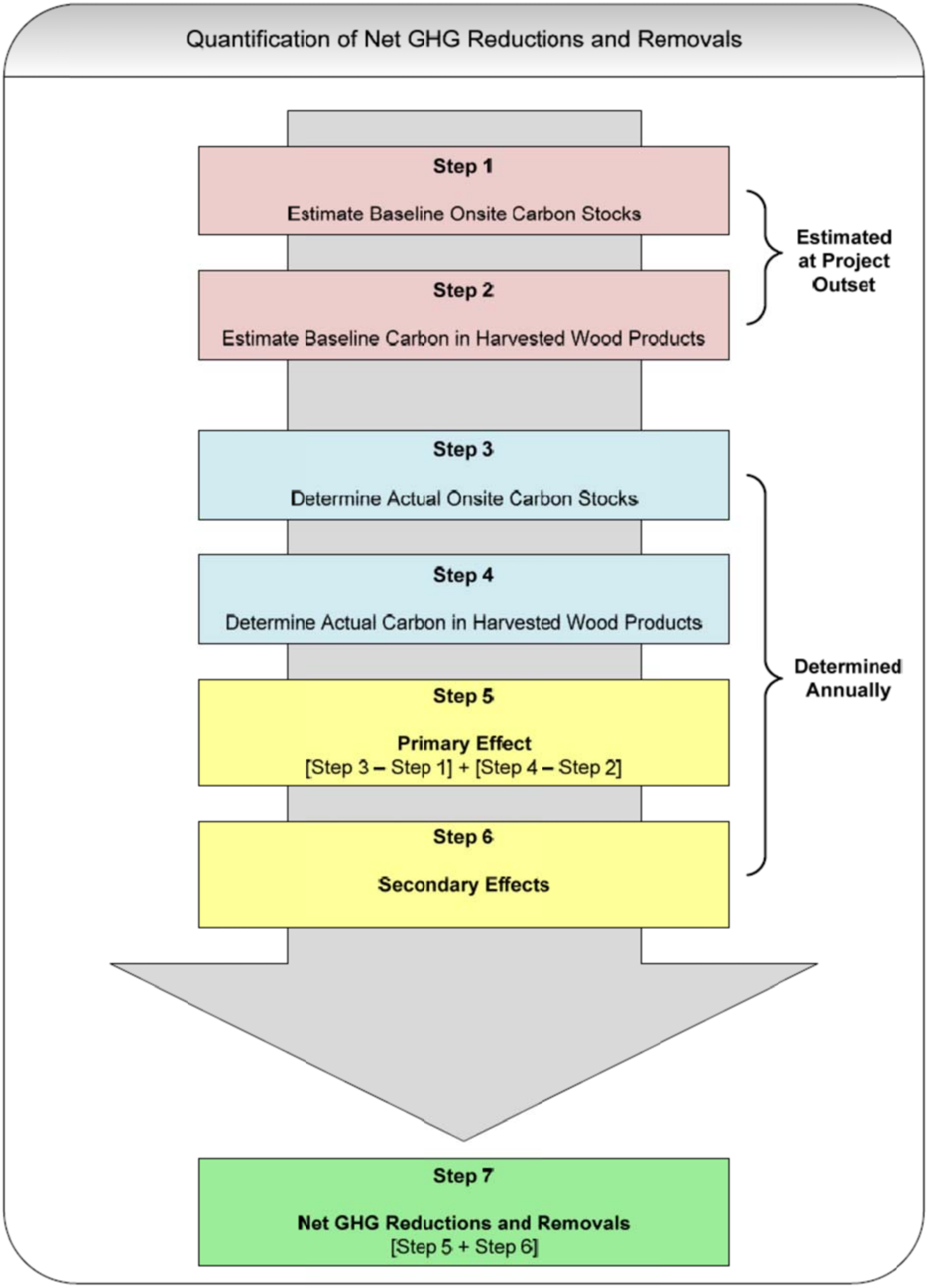
1. **Estimating baseline onsite carbon stocks.** The baseline is an estimate of what would have occurred in the absence of a Forest Project. To establish baseline onsite carbon stocks, the carbon stock changes in each of the Forest Project's required onsite carbon pools (identified in Sections 5.1 to 5.3) must be modeled over 100 years. Modeling must be based on inventoried carbon stocks at the time of the Forest Project's offset project commencement (or when first inventoried as is allowed for Reforestation Projects), following the applicable requirements in this section. Onsite carbon stocks are inventoried following the requirements in Appendix A; modeling of onsite carbon stocks over time must be conducted following the requirements in this section and the requirements and methods in Appendix B. Baseline onsite carbon stocks are estimated over 100 years at the time of the Forest Project's commencement.
2. **Estimating baseline carbon in harvested wood products.** In conjunction with modeling baseline onsite carbon stocks, a forecast of any harvesting that would have occurred in the baseline must be developed and converted to an average annual harvesting volume. From this, the amount of carbon that would have been transferred each year (on average) to long-term storage in wood products can be determined. Baseline harvesting is forecasted following the requirements in this section and carbon stored in wood products must be calculated following the requirements and methods in Appendix C.
3. **Determining actual onsite carbon stocks.** Each year, the Forest Project's actual onsite carbon stocks must be determined. This must be done by updating the Forest Project's forest carbon inventory for the current year, following the requirements and methods in this section and in Appendices A and B. The estimate of actual onsite carbon stocks must be adjusted by an appropriate confidence deduction, as described in Appendix A, Section A.4.
4. **Determining actual carbon in harvested wood products.** Each year, any harvesting in the Project Area must be reported and from this, the amount of carbon transferred to long-term storage in wood products must be calculated following the requirements and methods in Appendix C.
5. **Calculating the offset project's Primary Effect.** Each year, the actual change in GHG emissions or GHG removal enhancements associated with the Forest Project's intended ("Primary") effect must be quantified, as defined in Section 5. For any given year, the Primary Effect is calculated by:
    a. Taking the difference between actual onsite carbon stocks for the current year and actual onsite carbon stocks for the prior year
    b. Subtracting from (a) the difference between baseline onsite carbon stocks for the current year and baseline onsite carbon stocks for the prior year
    c. Adding to (b) the calculated difference between actual and baseline carbon in harvested wood products for the current year (see Equation 6.1.)
6. **Quantifying the offset project's Secondary Effects.** Each year, the actual change in GHG emissions or GHG removal enhancements associated with the Forest Project's unintended ("Secondary") effects must be quantified as defined in Section 5.

Requirements and methods for quantifying Secondary Effects are provided below for each type of Forest Project. Secondary Effects will almost always be negative (i.e. they will reflect an increase in GHG emissions caused by the offset project).

7. **Calculating total net GHG reductions and GHG removal enhancements.** For each year, total net GHG reductions and GHG removal enhancements are calculated by summing a Forest Project's Primary and Secondary Effects. If the result is positive, then the Forest Project has generated GHG reductions and/or GHG removal enhancements in the current year. If the result is negative, this indicates a reversal has occurred except as specified below (see Section 7).

Requirements for how to perform quantification steps 1 to 4 for each Forest Project type are presented in the remainder of this section. The required formula for quantifying annual net GHG reductions and GHG removal enhancements is presented in Equation 6.1. Net GHG reductions and GHG removal enhancements must be quantified and reported in units of carbon dioxide-equivalent (CO_2e) metric tons.

A reversal occurs only if: (1) total net GHG reductions and GHG removal enhancements for the year are negative; and (2) ARB or registry offset credits have previously been issued to the Forest Project. If calculated GHG reductions and GHG removal enhancements are negative and no ARB or registry offset credits have been issued to the project since its commencement date then the result should be treated as a "negative carryover" to GHG reduction calculations in subsequent years (variable N_{y-1} in Equation 6.1). This may happen, for example, because the confidence deduction applied to actual onsite carbon stocks can result in actual values being less than baseline values in a Forest Project's initial years.


Quantification of Net GHG Reductions and Removals
Step 1
Estimate Baseline Onsite Carbon Stocks
Step 2
Estimate Baseline Carbon in Harvested Wood Products
Estimated at Project Outset
Step 3
Determine Actual Onsite Carbon Stocks
Step 4
Determine Actual Carbon in Harvested Wood Products
Step 5
Primary Effect
[Step 3 – Step 1] + [Step 4 – Step 2]
Step 6
Secondary Effects
Determined Annually
Step 7
Net GHG Reductions and Removals
[Step 5 + Step 6]

Quantification Methodology

Equation 6.1.

$$QR_y = [(\Delta AC_{onsite} - \Delta BC_{onsite}) + (AC_{wp,\,y} - BC_{wp,\,y}) * 80\% + SE_y] * (1 - ACD) + N_{y-1}$$

Where,

QR_y = Quantified GHG reductions and GHG removal enhancements for year y

ΔAC_{onsite} = $(AC_{onsite,\,y})(1 - CD_y) - (AC_{onsite,\,y-1})(1 - CD_{y-1})$

Where,

$AC_{onsite,\,y}$ = Actual onsite carbon (CO_2e) as inventoried for year y

$AC_{onsite,\,y-1}$ = Actual onsite carbon (CO_2e) as inventoried for year y-1 (if y is the first year of the offset project, then the value for $AC_{onsite,\,y-1}$ will be zero)

CD_y = Appropriate confidence deduction for year y, as determined in Appendix A, Section A.4.

CD_{y-1} = Appropriate confidence deduction for year y-1, as determined in Appendix A, Section A.4.

ΔBC_{onsite} = $BC_{onsite,\,y} - BC_{onsite,\,y-1}$

Where,

$BC_{onsite,\,y}$ = Baseline onsite carbon (CO_2e) as estimated for year y

$BC_{onsite,\,y-1}$ = Baseline onsite carbon (CO_2e) as estimated for year y-1 (if y is the first year of the offset project, then the value for $BC_{onsite,\,y-1}$ will be zero)[5]

$AC_{wp,\,y}$ = Actual carbon in wood products produced in year y that is projected to remain stored for at least 100 years (i.e. $WP_{total,\,y}$ derived for actual harvest volumes following the requirements and methods in Appendix C)

$BC_{wp,y}$ = Averaged annual baseline carbon in wood products that would have remained stored for at least 100 years (i.e. $WP_{total,\,y}$ derived for baseline harvest volumes following the requirements and methods in Appendix C)

SE_y = Secondary Effect GHG emissions caused by the project activity in year y

ACD = Avoided Conversion Project discount factor, determined in Section 6.3.1

N_{y-1} = Any negative carryover from the prior year (occurs when total quantified GHG reductions are negative prior to the issuance of any CRTs for the project)

Note: The net change in carbon in harvested wood products, $(AC_{wp,\,y} - BC_{wp,\,y})$, is multiplied by 80 percent in Equation 6.1 to reflect market responses to changes in wood product production. The general assumption in this protocol is that for every ton of reduced harvesting caused by a

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[5] For Improved Forest Management projects, where baseline onsite carbon stocks are averaged across all years, the value for ΔBC_{onsite} will be zero in all years except the first year of the project.

Forest Project, the market will compensate with an increase in harvesting of 0.2 tons on other lands (see Section 6.2.6).

6.1 Reforestation Projects

6.1.1 Estimating Baseline Onsite Carbon Stocks

Quantification Methodology

To estimate baseline carbon stocks for a Reforestation Project:

1. Provide a qualitative characterization of the likely vegetative conditions and activities that would have occurred without the project, taking into consideration any laws, statutes, regulations, or other legal mandates that would encourage or require reforestation on the Project Area. The qualitative assessment shall include an assessment of the commercial value of trees within the Project Area over the next 30 years. The qualitative assessment must be used as the basis for modeling baseline carbon stocks (Step 3).
2. Inventory the carbon stocks in each of the Forest Project's required carbon pools, following the requirements in Appendix A of this protocol.[6] For carbon pools that will be affected by site preparation, the inventory must be conducted prior to any site preparation activities. For those carbon pools that are affected by site preparation, provide an estimate of initial carbon stocks using one of the following alternatives:
    - Measuring carbon stocks using 20 sample plots located in the portion of the Project Area containing the greatest amount of biomass in the pool that will be affected.
    - Stratifying (classifying) the Project Area into similar densities and measuring stocks within the affected carbon pools using 20 sample plots per density class.
    - Measuring the affected carbon stocks based on a grid system across the Project Area.

For other carbon stocks, the inventory may be deferred, as described below.

3. Once a full inventory is obtained, perform a computer simulation that models the carbon stocks for 100 years following the forest project's commencement date, based on the qualitative characterization of what would have occurred without the offset project. The modeling must follow the requirements and methods for modeling contained in Appendix B, Section B.3, incorporating any conditions and constraints specified in the qualitative characterization of the baseline (Step 1, above). The computer simulation must model the expected growth in carbon stocks associated with pre-existing trees in the Project Area (i.e. those not planted as part of the Forest Project).

Deferral of Initial Inventory for Carbon Stocks Not Affected by Site Preparation

The inventory of carbon stocks that are not affected by site preparation may be deferred until a Reforestation Project's second verification. At the time of the second verification, an estimated inventory of the all required carbon stocks at the time of the Forest Project's offset project commencement date must prepared by:

1. Assuming standing dead carbon stocks at the time of the Forest Project's offset project commencement date were equal to the standing dead carbon stocks measured and verified at the second verification.

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[6] Initial carbon stocks could be zero if the Project Area has no quantifiable forest cover or required carbon pools.

2. Using an approved growth model or a stand table projection methodology, as described in Appendix B, Section B.1, to derive an estimate of standing live carbon stocks in pre-existing trees (i.e. those not planted as part of the Forest Project) at the time of the Forest Project's offset project commencement date. The approved growth model or stand table projection used for the estimate must produce a result within 5 percent of current inventory data for pre-existing trees.

If the inventory of these carbon pools is deferred, the timing of the second verification is at the discretion of the Offset Project Operator or Authorized Project Designee (but must occur within 12 years of the initial verification). Reforestation Projects for which an initial inventory is deferred are not eligible to receive ARB or registry offset credits until after the second verification.

6.1.2 Estimating Baseline Carbon in Harvested Wood Products

Quantification Methodology

If harvesting of the pre-existing trees would be expected to occur in the baseline, the following steps must be performed:

1. Use a model (see Appendix B) to determine the *average* amount of carbon in standing live carbon stocks (prior to delivery to a mill) that would have been harvested in each year of the baseline over 100 years. The result will be a uniform estimate of harvested carbon in each year of the baseline. This estimate is determined at offset project commencement using the same biomass equations used to calculate biomass in live trees, and will not change over the course of the offset project crediting period.
2. On an annual basis, determine the amount of harvested carbon that would have remained stored in wood products, averaged over 100 years, following the requirements and methods in Appendix C.

6.1.3 Determining Actual Onsite Carbon Stocks

Quantification Methodology

Actual carbon stocks for Reforestation Projects must be determined by updating the Project Area's forest carbon inventory. This is done by:

1. Incorporating any new forest inventory data obtained during the previous year into the inventory estimate. Any plots sampled during the previous year must be incorporated into the inventory estimate.
2. Using an approved model to "grow" (project forward) prior-year data from existing forest inventory plots to the current reporting year. Approved growth models and requirements and methods for projecting forest inventory plot data using models is provided in Appendix B.
3. Updating the forest inventory estimate for harvests and/or disturbances that have occurred during the previous year.
4. Applying an appropriate confidence deduction for the inventory based on its statistical uncertainty, following the requirements and methods in Appendix A, Section A.4.

6.1.4 Determining Actual Carbon in Harvested Wood Products

Quantification Methodology

Perform the following steps to determine actual carbon in harvested wood products:

1. Determine the actual amount of carbon in standing live carbon stocks (prior to delivery to a mill) harvested in the current year (based on harvest volumes determined in Section 6.1.3).

2. Determine the amount of actual harvested carbon that will remain stored in wood products, averaged over 100 years, following the requirements and methods in Appendix C.

6.1.5 Quantifying Secondary Effects

Quantification Methodology

For Reforestation Projects, significant Secondary Effects can arise from two sources:

1. One-time combustion emissions associated with machinery used in site preparation; and
2. The shifting of cropland or grazing activities to forestland outside the Project Area (which may be both a market and/or physical response to the project activity), which is accounted for over the Project Life.

To quantify combustion emissions associated with site preparation, use the appropriate standard emission factor from Table 6.1 corresponding to the level of brush cover on the Project Area, multiplied by the number of acres in the Project Area (Equation 6.2).

Mobile combustion emissions must be added to Secondary Effect emissions (SE_y in Equation 6.1) in the first year of an offset project. If this results in a negative amount for total net quantified GHG reductions and GHG removal enhancements in year one (QR_1), the negative amount must be carried over into future years (N_{y-1} in Equation 6.1) until sufficient GHG reductions and GHG removal enhancements are accrued to achieve a positive balance. Negative GHG reductions and GHG removal enhancements due to site preparation emissions are *not* considered a reversal (Section 7.1).

Equation 6.2. Combustion Emissions Associated with Site Preparation

$$MC_y = (-1) \times (EF_{mc} \times PA)$$

Where,

MC_y	=	Secondary Effect CO_2e emissions due to mobile combustion from site preparation
EF_{mc}	=	Mobile combustion emission factor from Table 6.1
PA	=	The size of the Project Area, in acres

Table 6.1. Mobile Combustion Emissions for Reforestation Projects

SITE PREP - REFORESTATION PROJECTS		
Emissions Associated with Mobile Combustion		
Average Metric Tons CO_2e Per Acre		
Light	Medium	Heavy
25% Brush Cover	50% Dense Brush Cover	> 50% Brush Cover, stump removal
0.090	**0.202**	**0.429**

To quantify GHG emissions from the shifting of cropland and grazing activities each year, determine the appropriate "leakage" risk percentage for the project following the decision tree in Figure 6.3. The leakage risk percentage is only determined once, at offset project commencement. Each year, this percentage must be applied to the net increase in onsite carbon stocks to determine the annual Secondary Effects due to shifting of cropland or grazing activities (Equation 6.3).

Equation 6.3. Emissions from Shifting Cropland and Grazing Activities

$$AS_y = (-1) \times L \times (\Delta AC_{onsite} - \Delta BC_{onsite})$$

Where,

AS_y	=	Secondary Effect CO_2e emissions due to shifting of cropland or grazing activities
L	=	Leakage risk percentage, as determined from Figure 6.3
ΔAC_{onsite}	=	Annual difference in actual onsite carbon (CO_2e) as defined in Equation 6.1.
ΔBC_{onsite}	=	Annual difference in baseline onsite carbon (CO_2e) as defined in Equation 6.1.

Total Secondary Effect emissions for Reforestation Projects are calculated as follows (Equation 6.4). The value for Secondary Effect emissions will always be negative or zero.

Equation 6.4. Total Secondary Effect Emissions

$SE_y = (AS_y + MC_y)$ *or* **0**, whichever is lower

Where,

SE_y	=	Secondary Effect GHG emissions caused by the project activity in year y (Equation 6.1)
AS_y	=	Secondary Effect CO_2e emissions due to shifting of cropland or grazing activities
MC_y	=	Secondary Effect CO_2e emissions due to mobile combustion from site preparation*

*Only occurs in year 1.

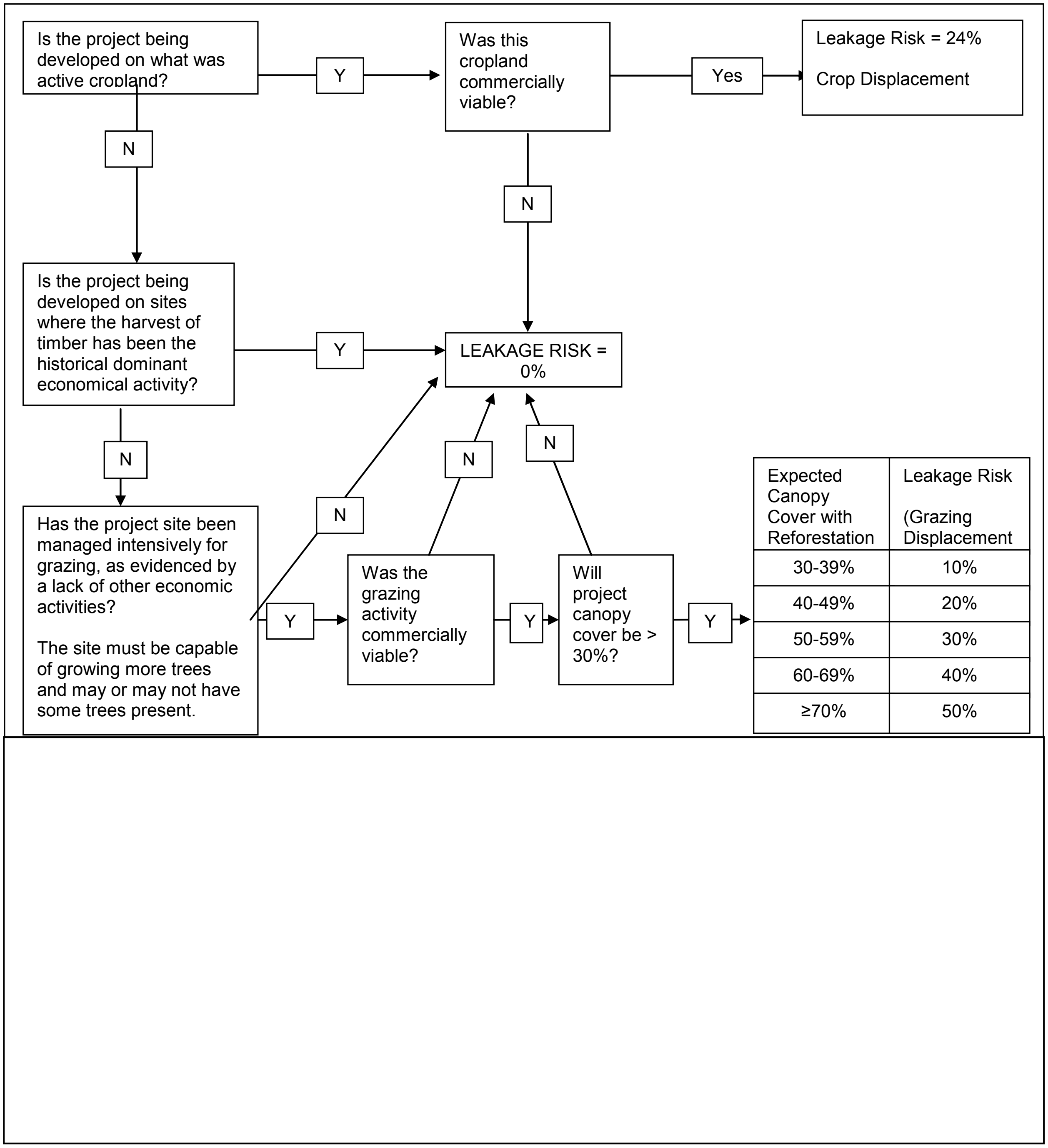

Figure 6.3. Activity Shifting ("Leakage") Risk Assessment for Reforestation Projects

6.2 Improved Forest Management Projects

Improved Forest Management Projects that take place on private land – or on land that is transferred to public ownership at the time the project is initiated – must estimate baseline onsite carbon stocks following the requirements and procedures in Section 6.2.1. Improved Forest Management Projects that take place on land that was publicly owned prior to the offset project commencement date must estimate baseline onsite carbon stocks following the requirements and procedures in Section 6.2.2. Requirements for determining baseline carbon in harvested wood products, determining actual onsite carbon stocks, determining actual carbon in harvested wood products, and quantifying Secondary Effects are the same for all Improved Forest Management Projects.

6.2.1 Estimating Baseline Onsite Carbon Stocks – Private Lands

Quantification Methodology

The baseline approach for Improved Forest Management Projects on private lands applies a standardized set of assumptions to offset project-specific conditions. A key assumption is that baseline carbon stocks will depend on how a project's initial standing live carbon stocks compare to "Common Practice," defined as the average standing live carbon stocks on similar lands within the Forest Project's Assessment Area. In addition, baseline carbon stocks must be adjusted to reflect management practice on the Forest Owner's other landholdings in instances where Project Area carbon stocks are more than 20 percent below the carbon stocks on land within the same logical management unit. Finally, the baseline must be modeled to reflect all legal and economic constraints affecting the Project Area.

The following steps must be followed to estimate baseline carbon stocks:

1. Determine the Common Practice level of above-ground standing live carbon stocks applicable to the Project Area.
2. Determine if the Project Area's initial above-ground standing live carbon stocks are above or below Common Practice.
3. Estimate baseline above-ground standing live carbon stocks, taking into account financial and legal constraints on harvesting in the Project Area, as well as the minimum baseline level applicable to the Project Area, as defined in the requirements for Step 3, below. The minimum baseline level will depend on whether initial above-ground standing live carbon stocks are above or below Common Practice.
4. Determine the baseline carbon stocks over 100 years for all required carbon pools in the Project Area.

For all calculations in this section, all values for "carbon stocks" should be expressed in metric tons of CO_2-equivalent.

Step 1 – Determine the Common Practice Carbon Stocks for the Project's Assessment Area

As defined in this protocol, Common Practice refers to the average stocks of above-ground standing live carbon associated with the Assessment Area(s) covered by the Project Area. Common Practice is used as a reference point for baseline estimation. To determine a value for Common Practice, see Appendix F and the data available in the Forest Offset Protocol Resources section of ARB's website.

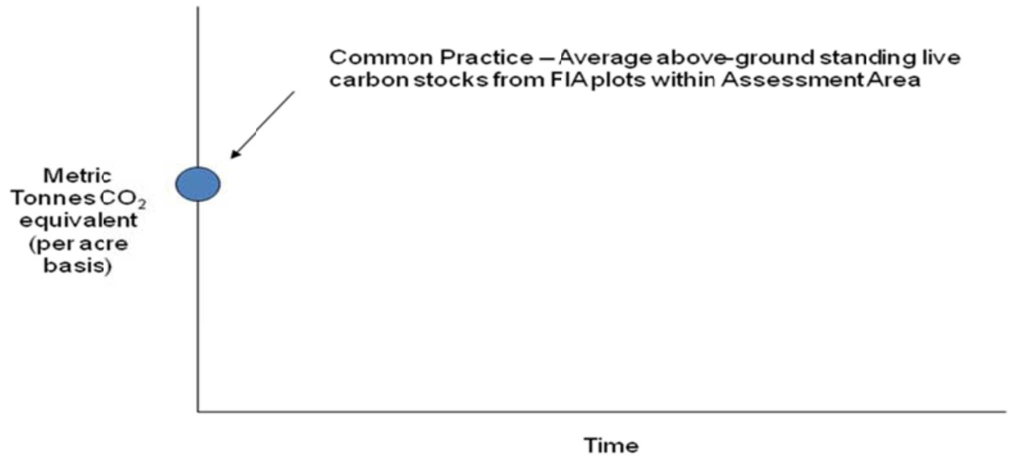

Figure 6.4. Common Practice as a Reference Point for Baseline Estimation

Step 2 – Determine if Initial Above-Ground Standing Live Carbon Stocks Are Above or Below Common Practice

To determine if initial above-ground standing live carbon stocks are above or below Common Practice, perform the following steps:

1. From the initial forest carbon inventory for the Project Area (conducted following the requirements in Appendix A), identify the metric tons of carbon contained in the *above-ground portion* of standing live carbon stocks.
2. Divide this amount by the number of acres in the Project Area.
3. Compare the result with the Common Practice value identified in Step 1.

Step 3 – Determine Baseline Above-Ground Standing Live Carbon Stocks

The baseline above-ground standing live carbon stocks must be determined by: (1) Modeling above-ground standing live carbon stocks through a series of growth and harvesting scenarios over 100 years; and (2) averaging the model results over the 100-year timeframe, so that the baseline is expressed as a single (average) value for above-ground standing live carbon stocks per acre in every year. The modeling must be performed following the requirements and methods in Appendix B and must meet the following conditions:

1. Growth and harvesting scenarios must reflect all legal constraints, following the requirements in Section 6.2.1.2.
2. Growth and harvesting scenarios must reflect any financial constraints, following the requirements in Section 6.2.1.3.
3. The averaged model results, expressed as above-ground standing live carbon stocks per acre, must not fall below a minimum baseline level (MBL). If initial above-ground standing live carbon stocks are above Common Practice, the MBL must be determined using the formula in Equation 6.5. If initial above-ground standing live carbon stocks are below Common Practice, then MBL must be determined using the formula in Equation 6.6.

A graphical example of a baseline meeting these conditions is provided in Figure 6.5 and Figure 6.6. Figure 6.5 shows the baseline before averaging; Figure 6.6 shows the baseline after averaging.

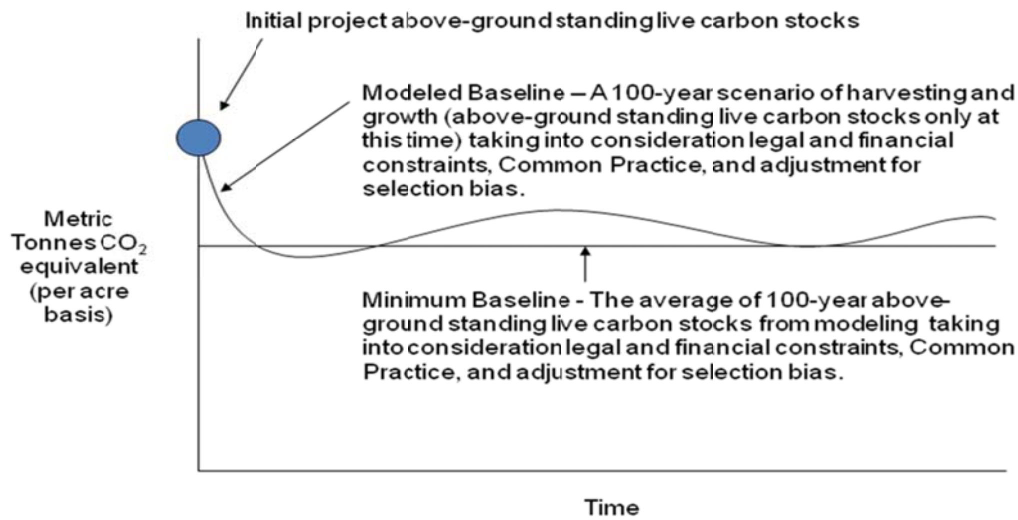

Figure 6.5. Modeling Standing Live Carbon Stocks Where Initial Stocks Are Above Common Practice

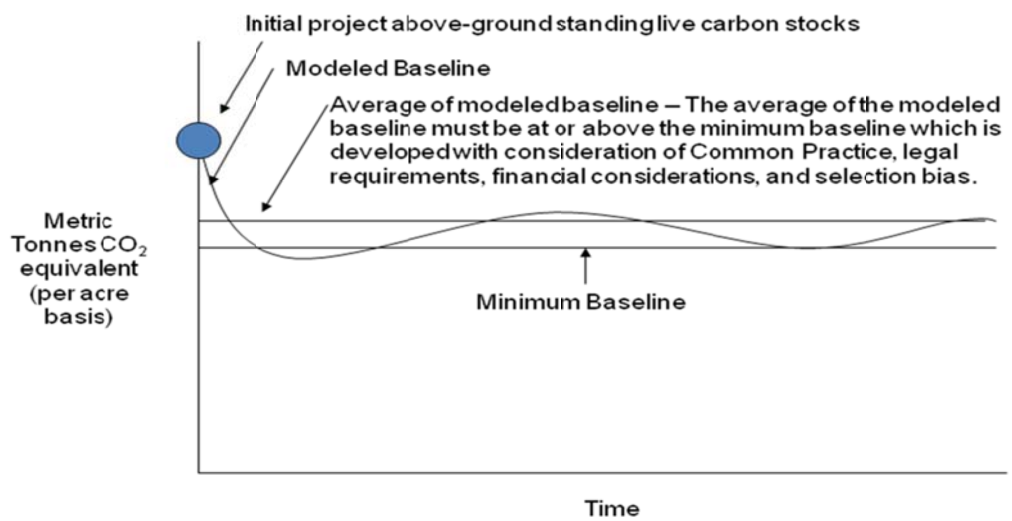

Figure 6.6. Averaging the Modeled Standing Live Carbon Stocks Where Initial Stocks Are Above Common Practice

Equation 6.5. Determining the Minimum Baseline Level Where Initial Stocks Are Above Common Practice

MBL = CP

Where,

MBL	=	Minimum baseline level (above-ground standing live carbon stocks)
CP	=	Common Practice (as determined in Step 1)

Equation 6.6. Determining the Minimum Baseline Level Where Initial Stocks Are Below Common Practice

MBL = MAX (MAX (HSR, ICS), MIN (CP, WCS))

Where,

MAX	=	The highest value in the set of values being evaluated.
MIN	=	The lowest value in the set of values being evaluated.
MBL	=	Minimum baseline level (above-ground standing live carbon stocks)
HSR	=	The "High Stocking Reference" for the Project Area. The High Stocking Reference is defined as 80 percent of the highest value for above-ground standing live carbon stocks per acre within the Project Area during the preceding 10-year period. To determine the High Stocking Reference, the Offset Project Operator or Authorized Project Designee must document changes in the Project Area's above-ground standing live carbon stocks over the preceding 10 years. Figure 6.7 presents a graphical portrayal of a High Stocking Reference determination.
CP	=	Common Practice (as determined in Step 1)
ICS	=	Initial above-ground standing live carbon stocks per acre within the Project Area (as determined in Step 2)
WCS	=	The weighted average above-ground standing live carbon stocks per acre for all Forest Owner (and affiliate) landholdings within the same logical management unit as the Project Area. See Section 6.2.1.1 for requirements and methods for calculating WCS.

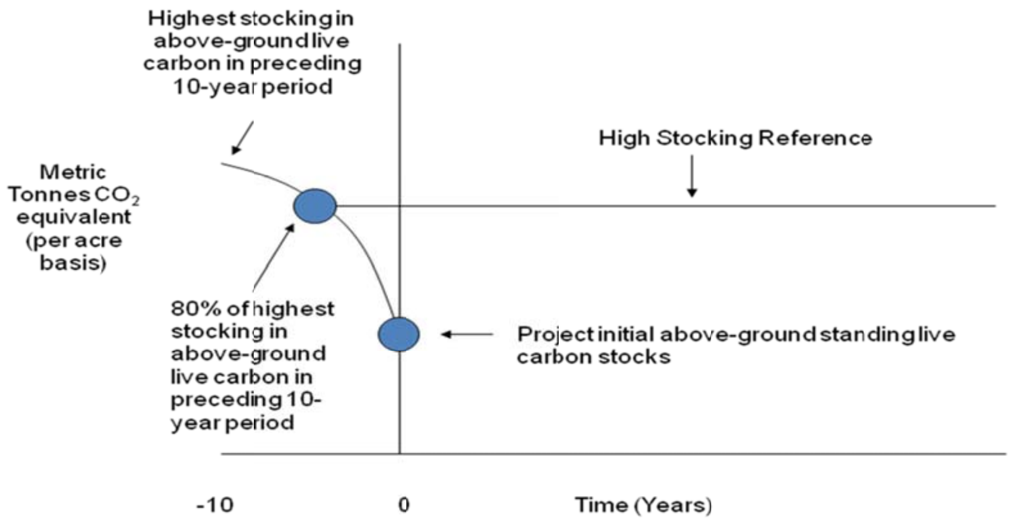

Figure 6.7. Determining a Project Area's High Stocking Reference
Note: It is possible for the High Stocking Reference to be higher than Common Practice, even where initial live-tree carbon stocks for the project are below Common Practice.

Step 4 – Determine the Baseline for All Carbon Pools

Once the baseline for above-ground standing live carbon stocks has been determined, perform the following steps:

1. Estimate baseline carbon stocks for all other required carbon pools identified for the offset project (including below-ground carbon stocks, as well as standing dead carbon stocks where applicable). These carbon stocks must be modeled or estimated following the requirements and methods in Appendix A and Appendix B.
2. Average the results, so that the baseline for other carbon pools contains the same (average) value for carbon stocks in every year.
3. Sum the above-ground standing live carbon stock baseline and the baseline for all other carbon stocks to produce a final baseline for all carbon pools (see Figure 6.8).

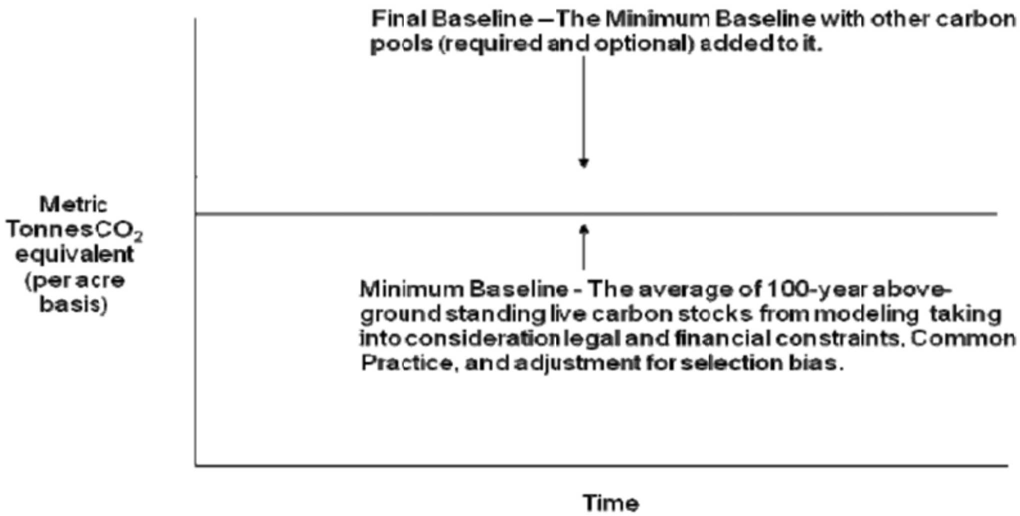

Figure 6.8. Final Baseline Incorporating All Required Carbon Stocks

6.2.1.1 Determining Weighted Average Carbon Stocks (WCS) on Lands in the Same Logical Management Unit as the Project Area

Quantification Methodology

Determining the minimum baseline level (MBL) for an Improved Forest Management project requires a comparison to carbon stocking levels on other lands within the same logical management unit (LMU) as the Project Area. The carbon stocking level within the LMU (expressed as the weighted average above-ground standing live carbon stocks per acre for all lands in the same LMU) is used as a parameter (WCS) for determining the MBL in Equation 6.6.

A “logical management unit” or “LMU” is defined as all land that the Forest Owner and its affiliate(s) (as defined below) either own in fee or hold timber rights on, and which it or they manage as an explicitly defined planning subunit. LMUs are generally characterized by unique biological, geographical, and/or geological conditions, are generally delimited by watershed boundaries and/or elevational zones, and contain unique road networks. In addition, an LMU must:

- Be a sustainable planning subunit as demonstrated by inventory reports and growth and harvest projections for the LMU or;
- Where even aged management is utilized, have a uniform distribution (by area) of 10-year age classes that extend to the normal rotation age (variation of any 10-year age class not to exceed 20%) or;
- Where uneven aged management is utilized, have between 33% and 66% of the forested stands exceeding the retention standards identified in the growth and harvest projections by a minimum of 25% (basal area).

An “affiliate” is defined as any person or entity that, directly or indirectly, through one or more intermediaries, controls or is controlled by or is under common control with the Forest Owner, including any general or limited partnership in which the Forest Owner is a partner and any limited liability company in which the Forest Owner is a member. For the purposes of this definition, "control" means the possession, direct or indirect, of the power to direct or cause the direction of the management and policies of a person, whether through the ownership of voting securities, by contract or otherwise, and "person" means an individual or a general partnership, limited partnership, corporation, professional corporation, limited liability company, limited liability partnership, joint venture, trust, business trust, cooperative or association or any other legally-recognized entity.

If an explicit, existing LMU containing the Project Area cannot be identified, the LMU must be defined by identifying all lands where the Forest Owner and its affiliate(s) (as defined above) either own in fee or hold timber rights within the same Assessment Area(s) covered by the Project Area. Assessment Areas covered by the Project Area are identified in Step 1, above, using the information in Appendix F.

To calculate WCS, estimate the above-ground standing live carbon stocks per acre for the entire LMU containing the Project Area (including the Project Area itself). This can be done using either existing inventory data, or a stratified vegetation-type analysis.

6.2.1.1.1 Calculating WCS Using Inventory Data

Quantification Methodology
If sufficient inventory data for LMU lands exist to quantify above-ground standing live carbon stocks for the entire LMU, then the formula in Equation 6.7 must be used to calculate WCS.

Equation 6.7. Formula for WCS Using Inventory Data

$$If \ \left|\left(1-\frac{ECS}{ICS}\right)\right| \leq 0.2, then\ WCS = ICS$$

$$If \ \left|\left(1-\frac{ECS}{ICS}\right)\right| > 0.2, then\ WCS = \frac{ICS \cdot PA + ECS \cdot EA}{PA + EA}$$

Where,

WCS	=	The weighted average above-ground standing live carbon stocks per acre within the LMU containing the Project Area
ICS	=	Initial above-ground standing live carbon stocks per acre within the Project Area
PA	=	Size of the Project Area in acres
ECS	=	Above-ground standing live carbon stocks per acre within the LMU *but excluding the Project Area* (EA), as determined from existing inventory data
EA	=	Size of the LMU in acres, e*xcluding the Project Area*

6.2.1.1.2 Calculating WCS Using Stratified Vegetation-Type Analysis

Quantification Methodology
If sufficient inventory data is not available for the LMU, a stratified vegetation-type analysis must be used to calculate WCS. To conduct this analysis, all landholdings within the LMU – including the Project Area – must be divided into vegetation types and size class/canopy cover categories as delimited in Table 6.2 with a resolution for classification no greater than 40 acres. Each vegetation class has a "carbon rating" provided in Table 6.2. WCS must be calculated using the

ratio of average carbon stocking on LMU lands relative to carbon stocking on Project Area lands (referred to as the "stratified carbon weighting factor" or SWF). The required formulas are specified in Equation 6.8 and Equation 6.9.

Equation 6.8. Formula for WCS Using Stratified Vegetation-Type Analysis

$$If\ \left|\left(1-\frac{ECS}{ICS}\right)\right| \le 0.2, then\ WCS = ICS$$

$$If\ \left|\left(1-\frac{ECS}{ICS}\right)\right| > 0.2, then\ WCS = \frac{ICS \cdot PA + SWF \cdot ICS \cdot EA}{PA + EA}$$

Where,

WCS = The weighted average above-ground standing live carbon stocks per acre within the LMU containing the Project Area

ECS = Above-ground standing live carbon stocks per acre within the LMU, but excluding the Project Area (EA), as determined from existing inventory data

ICS = Initial above-ground standing live carbon stocks per acre within the Project Area

PA = Size of the Project Area in acres

SWF = The stratified carbon weighting factor for the LMU (from Equation 6.9 below)

EA = Size of the LMU in acres, e*xcluding the Project Area*

Equation 6.9. Formula for LMU Stratified Carbon Weighting Factor

$$SWF = \frac{\sum_i (PA_i \cdot CR_i)}{\sum_i PA_i} \div \frac{\sum_i (EA_i \cdot CR_i)}{\sum_i EA_i}$$

Where,

PA_i = Acres of the Project Area in forest vegetation type *i* (from Table 6.2)

EA_i = Acres of the LMU, e*xcluding the Project Area,* in forest vegetation type *i* (from Table 6.2)

CR_i = Carbon rating for forest vegetation type *i* (from Table 6.2)

Table 6.2. Vegetation Classes for Stratification

Forest Vegetation Description	Average Diameter (Breast Height)	Average Canopy Cover	Carbon Rating (metric tons CO_2e)
Brush	0"	NA	0
Regeneration	3"	NA	0.5
Pole-sized trees	6" - 12"	< 33%	2
Pole-sized trees	6" - 12"	33% - 66%	4
Pole-sized trees	6" - 12"	>66%	6
Small Sawlogs	12" - 20"	< 33%	4
Small Sawlogs	12" - 20"	33% - 66%	8
Small Sawlogs	12" - 20"	>66%	12
Large Sawlogs	20" - 36"	< 33%	8
Large Sawlogs	20" - 36"	33% - 66%	16
Large Sawlogs	20" - 36"	>66%	24
Very Large Trees	>36"	< 33%	16
Very Large Trees	>36"	33% - 66%	32
Very Large Trees	>36"	>66%	48

6.2.1.2 Consideration of Legal Constraints

In modeling the baseline for standing live carbon stocks, all legal constraints that could affect baseline growth and harvesting scenarios must be incorporated. The standing live carbon stock baseline must represent a growth and harvesting regime that fulfills all legal requirements. Voluntary agreements that can be rescinded, such as rental contracts and forest certifications, are not legal constraints. Habitat Conservation Plans (HCPs) and Safe Harbor Agreements (SHAs) that are in place more than one year prior to the offset project commencement date shall be modeled as legal constraints. HCPs and SHAs that are approved after the date one year prior to the offset project's commencement date are not considered legal constraints for the purpose of baseline modeling and may be disregarded from the baseline modeling.

Legal constraints include all laws, regulations, and legally-binding commitments applicable to the Project Area at the time of offset project commencement that could affect standing live carbon stocks. Legal constraints include:

1. Federal, state, or local government regulations that are required and might reasonably be anticipated to influence carbon stocking over time including, but not limited to:
    a. Zones with harvest restrictions (e.g. buffers, streamside protection zones, wildlife protection zones)
    b. Harvest adjacency restrictions
    c. Minimum stocking standards
2. Forest practice rules, or applicable Best Management Practices established by federal, state, or local government that relate to forest management.
3. Other legally binding requirements affecting carbon stocks including, but not limited to, covenants, conditions and restrictions, and other title restrictions in place prior to or at the time of project initiation, including pre-existing conservation easements, Habitat Conservation Plans, Safe Harbor Agreements, and deed restrictions, excepting an

encumbrance that was put in place and/or recorded less than one year prior to the offset project commencement date, as defined in Section 3.5.

For forest projects located in California, the baseline must be modeled to reflect all silvicultural treatments associated with any submitted, active, or approved timber harvest plans (THPs) at the time of offset project commencement that would affect harvesting and management within the Project Area during the Project Life. All legally enforceable silvicultural and operational provisions of a THP – including those operational provisions designed to meet California Forest Practice Rules requirements for achieving Maximum Sustained Production of High Quality Wood Products [14 CCR 913.11 (933.11, 953.11)] – are considered legal constraints and must be reflected in baseline modeling for as long as the THP will remain active. For portions of the Project Area not subject to THPs (or over time periods for which THPs will not be active), baseline carbon stocks must be modeled by taking into account any applicable requirements of the California Forest Practice Rules and all other applicable laws, regulations, and legally binding commitments that could affect onsite carbon stocks. On a case-by-case basis, the California Department of Forestry and Fire Protection (Cal FIRE) may assist in identifying minimum carbon stocking levels that would be effectively required under California Forest Practice Rules.

6.2.1.3 Consideration of Financial Constraints

In modeling the baseline for standing live carbon stocks, financial constraints that could affect baseline growth and harvesting scenarios must be included. It must be demonstrated that the growth and harvesting regime assumed for the baseline is financially feasible through one of the following means:

1. A financial analysis of the anticipated growth and harvesting regime that captures all relevant costs and returns, taking into consideration all legal, physical, and biological constraints. Cost and revenue variables in the financial analysis may be based on regional norms or on documented costs and returns for the Project Area or other properties in the Forest Project's Assessment Area.
2. Providing evidence that activities similar to the proposed baseline growth and harvesting regime have taken place on other properties within the Forest Project's Assessment Area within the past 15 years. The evidence must demonstrate that harvesting activities have taken place on at least one other comparable site with:
    a. Slopes that do not exceed slopes in the Project Area by more than 10 percent
    b. An equivalent zoning class to the Project Area
    c. Comparable species composition to the Project Area (i.e. within 20 percent of project species composition based on trees per acre)

6.2.2 Estimating Baseline Onsite Carbon Stocks – Public Lands

Quantification Methodology

For Improved Forest Management Projects on lands owned or controlled by public agencies, the baseline must be estimated by:

1. Conducting an initial forest carbon inventory for the Project Area
2. Projecting future changes to Project Area forest carbon stocks by:
    a. Extrapolating from historical trends
    b. Anticipating how current and future public policy will affect onsite carbon stocks

The method that results in the highest estimated carbon stock levels must be used to determine the baseline.

To extrapolate from historical trends:

- For Project Areas that have a ten-year history of declining carbon stocks, the baseline must be defined by the average of the carbon stocks over the past ten years and considered static for the project life (i.e. the same level of carbon stocks is assumed in every year).
- For Project Areas that demonstrate an increasing inventory of carbon stocks over the past ten years, the growth trajectory of the baseline shall continue until the forest (under the baseline stocks) achieves a stand composition consistent with comparable forested areas that have been relatively free of harvest over the past 60 years.

To anticipate how current and future public policy will affect onsite carbon stocks, the baseline must be modeled following the requirements and methods in Appendix B incorporating constraints imposed by all applicable statutes, regulations, policies, plans and Activity-Based Funding.

6.2.3 Estimating Baseline Carbon in Harvested Wood Products

Quantification Methodology

To estimate the amount of baseline carbon transferred to long-term storage in wood products each year, the following steps must be performed:

1. Determine the *average* amount of carbon in standing live carbon stocks (prior to delivery to a mill) that would have been harvested in each year of the baseline over 100 years. The result will be a uniform estimate of harvested carbon in each year of the baseline. This estimate is determined at offset project commencement, using the same biomass equations used to calculate biomass in live trees, and will not change over the course of the project.
    a. For offset projects on private lands, the amount of harvested carbon must be derived from the growth and harvesting regime used to develop the baseline for onsite carbon stocks in Section 6.2.1.
    b. For offset projects on public lands, the amount of harvested carbon must be derived from the growth and harvesting regime assumed in the baseline for onsite carbon stocks derived in Section 6.2.2.
2. On an annual basis, determine the amount of harvested carbon that would have remained stored in wood products, averaged over 100 years, following the requirements and methods in Appendix C.

6.2.4 Determining Actual Onsite Carbon Stocks

Quantification Methodology

Actual carbon stocks for Improved Forest Management projects must be determined by updating the Project Area's forest carbon inventory. This is done by:

1. Incorporating any new forest inventory data obtained during the previous year into the inventory estimate. Any plots sampled during the previous year must be incorporated into the inventory estimate.
2. Using an approved model to "grow" (project forward) prior-year data from existing forest inventory plots to the current reporting year. Approved growth models and requirements and methods for projecting forest inventory plot data using models are provided in Appendix B.
3. Updating the forest inventory estimate for harvests and/or disturbances that have occurred during the previous year.
4. Applying an appropriate confidence deduction for the inventory based on its statistical uncertainty, following the requirements and methods in Appendix A, Section A.4.

6.2.5 Determining Actual Carbon in Harvested Wood Products

Quantification Methodology

Perform the following steps to determine actual carbon in harvested wood products:

1. Determine the actual amount of carbon in standing live carbon stocks (prior to delivery to a mill) harvested in the current year (based on harvest volumes determined in Section 6.2.4).
2. Determine the amount of actual harvested carbon that will remain stored in wood products, averaged over 100 years, following the requirements and methods in Appendix C.

6.2.6 Quantifying Secondary Effects

Quantification Methodology

For Improved Forest Management Projects, significant Secondary Effects can occur if a project reduces harvesting in the Project Area, resulting in an increase in harvesting on other properties. Equation 6.10 must be used to estimate Secondary Effects for Improved Forest Management projects:

Equation 6.10. Secondary Effects Emissions

$$If \sum_{n=1}^{y} (AC_{hv,n} - BC_{hv,n}) > 0, then \ SE_y = 0$$

$$If \sum_{n=1}^{y} (AC_{hv,n} - BC_{hv,n}) < 0, then \ SE_y = (AC_{hv,y} - BC_{hv,y}) \times 20\%$$

Where,

SE_y	=	Estimated annual Secondary Effects (used in Equation 6.1.)
$AC_{hv,\,n}$	=	Actual amount of onsite carbon harvested in reporting period n (prior to delivery to a mill), expressed in CO_2-equivalent tons
$BC_{hv,\,n}$	=	Estimated average baseline amount of onsite carbon harvested in reporting period n (prior to delivery to a mill), expressed in CO_2-equivalent tons, as determined in Step 1 of Section 6.2.3
Y	=	The current year or reporting period

6.3 Avoided Conversion Projects

6.3.1 Estimating Baseline Onsite Carbon Stocks

Quantification Methodology

The baseline for Avoided Conversion Projects is a projection of onsite forest carbon stock losses that would have occurred over time due to the conversion of the Project Area to a non-forest land use. Estimating the baseline for Avoided Conversion Projects involves two steps:

1. Characterizing and projecting the baseline; and
2. Discount for the uncertainty of conversion probability.

Step 1 - Characterizing and Projecting the Baseline

The project baseline must be characterized by:

1. Clearly specifying an alternative highest-value land use for the Project Area, as identified by an appraisal (required in Section 3.1.2.3).
2. Estimating the rate of conversion and removal of onsite carbon stocks, taking into consideration any laws, statutes, regulations, or other legal mandates that affect land use conversion or removal of onsite carbon stocks. The rate of conversion and removal of onsite carbon stocks must be estimated by either:
    a. Referencing planning documentation for the Project Area (e.g. construction documents or plans) that specifies the timeframe of the conversion and intended removal of forest cover on the Project Area; or
    b. In the absence of specific documentation, identifying default Total Conversion Impact and Annual Conversion values from Table 6.3.
3. Using a computer simulation to project changes in onsite carbon stocks over 100 years, reflecting the rate of conversion estimated in (2). The simulation must model changes in onsite carbon stocks for all required carbon pools, as identified in Section 5.3.

Table 6.3. Default Avoided Conversion

Type of Conversion Identified in Appraisal	**Total Conversion Impact** This is the assumed total effect over time of the conversion activity. (The total conversion impact is amortized over a 10-year period to determine the annual conversion in the next column.)	**Annual Conversion** This is the assumed annual conversion activity. The percentages below are multiplied by the initial onsite carbon stocks for the project on an annual basis for the first 10 years of the project.
Residential	Estimate using the following formula: TC = min(100, (P*3 / PA)*100) *Where:* TC = % total conversion (TC cannot exceed 100%) PA = the Project Area (acres) identified in the appraisal P = the number of unique parcels that would be formed on the project area as identified in the appraisal *Each parcel is assumed to deforest 3 acres of forest vegetation.	Estimate using the following formula: AC = TC / 10 *Where:* AC = % annualized conversion TC = % total conversion
Mining and agricultural conversion, including pasture or crops	90%	9.0%
Golf course	80%	8.0%
Commercial buildings	95%	9.5%

The computer simulation of the baseline must apply the identified rate of conversion over time to estimate changes in onsite carbon stocks, beginning with the Project Area's initial onsite carbon stocks.

If the projected conversion rate does not result in a complete removal of onsite forest carbon stocks, the baseline projection should account for any residual forest carbon value as a steady condition for the balance of a 100-year projection.

Step 2 - Discount for Uncertainty of Conversion Probability

If the fair market value of the anticipated alternative land use for the Project Area (as determined by the appraisal required in Section 3.1.2.3) is *not more than 80 percent greater* than the value of the current forested land use, then a discount must be applied each year to the offset project's quantified GHG reductions and GHG removal enhancements. If quantified GHG reductions and GHG removal enhancements for the year are positive (i.e. $[(\Delta AC_{onsite} - \Delta BC_{onsite}) + (AC_{wp, y} – BC_{wp, y}) * 80\% + SE_y] > 0$ in Equation 6.1) then use the following formula (Equation 6.11) to calculate the appropriate Avoided Conversion Discount factor, ACD. If quantified GHG reductions and removals for the year are negative, then ACD must equal zero.

Equation 6.11. Avoided Conversion Discount Factor

If $0.4 < ((VA / VP) – 1) < 0.8$, **then** $ACD = [80\% – ((VA / VP) – 1)] \times 2.5$
If $((VA / VP) – 1) > 0.8$, **then** $ACD = 0\%$
If $((VA / VP) – 1) < 0.4$, **then** $ACD = 100\%$

Where,

ACD	=	The Avoided Conversion Project discount factor (used in Equation 6.1).
VA	=	The appraised fair market value of the anticipated alternative land use for the Project Area
VP	=	The appraised fair market value of the current forested land use for the Project Area

6.3.2 Estimating Baseline Carbon in Harvested Wood Products

Quantification Methodology

Harvesting is assumed to occur in the baseline over time as the Project Area is converted to another land use. To estimate the baseline carbon transferred to long-term storage in harvested wood products each year:

1. Determine the amount of carbon in standing live carbon stocks (prior to delivery to a mill) that would have been harvested in each year, consistent with the rate of reduction in baseline standing live carbon stocks determined in Section 6.3.1. This projection is determined at offset project commencement, using the same biomass equations used to calculate biomass in live trees, and will not change over the course of the offset project.
2. On an annual basis, determine the amount of harvested carbon that would have remained stored in wood products, averaged over 100 years, following the requirements and methods in Appendix C.

6.3.3 Determining Actual Onsite Carbon Stocks

Quantification Methodology

Actual carbon stocks for Avoided Conversion Projects must be determined by updating the Project Area's forest carbon inventory. This is done by:

1. Incorporating any new forest inventory data obtained during the previous year into the inventory estimate. Any plots sampled during the previous year must be incorporated into the inventory estimate.
2. Using an approved model to "grow" (project forward) prior-year data from existing forest inventory plots to the current reporting year. Approved growth models are identified in Appendix B. Methods for projecting forest inventory plot data using models is also provided in Appendix B.
3. Updating the forest inventory estimate for harvests and/or disturbances that have occurred during the previous year.
4. Applying an appropriate confidence deduction for the inventory based on its statistical uncertainty, following the requirements and methods in Appendix A, Section A.4.

6.3.4 Determining Actual Carbon in Harvested Wood Products

Quantification Methodology

Perform the following steps to determine actual carbon in harvested wood products:

1. Determine the actual amount of carbon in standing live carbon stocks (prior to delivery to a mill) harvested in the current year (based on harvest volumes determined in Section 6.3.3).
2. Determine the amount of actual harvested carbon that will remain stored in wood products, averaged over 100 years, following the requirements and methods in Appendix C.

6.3.5 Quantifying Secondary Effects

Quantification Methodology

Significant Secondary Effects for Avoided Conversion projects can arise if the type of land use conversion that would have happened on the Project Area is shifted to other forest land.

To quantify Secondary Effects for Avoided Conversion projects, use Equation 6.12.

The value for Secondary Effect emissions will always be negative or zero.

Equation 6.12. Secondary Effects Emissions

$$SE_y = (-1) \times CDR\% \times (\Delta AC_{onsite} - \Delta BC_{onsite}) \text{ or } 0\text{, whichever is lower}$$

Where,

SE_y	=	Secondary Effect GHG emissions caused by the project activity in year y (Equation 6.1)
CDR	=	Conversion displacement risk value, assumed to be 3.6% for all forest lands
ΔAC_{onsite}	=	Annual difference in actual onsite carbon (CO_2e) as defined in Equation 6.1
ΔBC_{onsite}	=	Annual difference in baseline onsite carbon (CO_2e) as defined in Equation 6.1

7 Ensuring the Permanence of Credited GHG Reductions and GHG Removal Enhancements

The Regulation requires that credited GHG reductions and GHG removal enhancements be "permanent." Permanence of Forest project GHG reductions and removals is addressed through three mechanisms:

1. The requirement for all offset projects to monitor onsite carbon stocks, submit annual Offset Project Data Reports, and undergo third-party verification of those reports with site visits at least every six years for the duration of the Project Life.
2. The regulatory obligation for all intentional reversals of GHG reductions and GHG removal enhancements to be compensated for through retirement of other Compliance Instruments.
3. The maintenance of a Forest Buffer Account by ARB to provide insurance against reversals of GHG reductions and GHG removal enhancements due to unintentional causes (including natural disturbances such a fires, pest infestations, or disease outbreaks).

GHG reductions and GHG removal enhancements can be "reversed" if the stored carbon associated with them is released (back) to the atmosphere. Many biological and non-biological agents, both natural and human-induced, can cause reversals. Some of these agents cannot completely be controlled and may therefore result in an unintentional reversal, such as natural agents like fire, insects, and wind. Other agents can be controlled, such as the human activities like land conversion and over-harvesting. Under this protocol, reversals due to controllable agents are considered intentional as defined in the Regulation. The Offset Project Operator or Authorized Project Designee is required to identify and quantify the risk of reversals from different agents based on offset project-specific circumstances. The resulting risk rating determines the quantity of ARB offset credits that the project must contribute to the Forest Buffer Account to insure against unintentional reversals.

7.1 Identifying a Reversal

The Offset Project Operator or Authorized Project Designee must demonstrate, through annual reporting and periodic verification, that stocks associated with credited GHG reductions and GHG removal enhancements are maintained for a period of time considered to be permanent. For purposes of this protocol 100 years is considered permanent. If the quantified GHG reductions and GHG removal enhancements (i.e. QR_y in Equation 6.1) in a given year are negative, and ARB offset credits were issued to the Forest Project in any previous year, it is considered a reversal, regardless of the cause of the decrease. Planned thinning or harvesting activities, for example, may cause a reversal if they result in a negative value for QR_y.

7.2 Insuring Against Reversals

Unintentional reversals are insured against by contributing a percentage of ARB offset credits to a Forest Buffer Account. The amount of the contribution is based on a project-specific risk evaluation.

7.2.1 About the Forest Buffer Account

A Forest Buffer Account is a holding account for ARB offset credits issued to Forest Project, which is administered by ARB. All Forest Projects must contribute a percentage of ARB offset credits to the Forest Buffer Account any time ARB offset credits are issued by ARB for verified GHG reductions and GHG removal enhancements. Each Forest Project's contribution is determined by a project-specific risk rating, as described in Section 7.2.2. If a Forest Project experiences an unintentional reversal of credited GHG reductions and GHG removal enhancements (as defined in Section 7.3), ARB offset credits from the Forest Buffer Account will be retired in an amount equal to the total amount of carbon that was reversed (measured in metric tons of CO_2-equivalent) according to the process identified in the Regulation. A Forest Buffer Account therefore acts as a general insurance mechanism against unintentional reversals for ARB offset credits issued to Forest Projects.

7.2.2 Contributions to the Forest Buffer Account

ARB offset credits will be contributed to the Forest Buffer Account pursuant to the Regulation based on the reversal risk rating for a project as determined by the requirements and methods in Appendix D. The risk rating must be determined prior to listing, and recalculated in every year the project undergoes verification. Forest Owners who record a Qualified Conservation Easement in conjunction with implementing a Forest Project will receive a lower risk rating (see Appendix D).

7.3 Compensating for Reversals

The Regulation defines reversals and establishes how reversals will be compensated.

7.3.1 Unintentional Reversals

The Regulation defines unintentional reversals. Requirements for compensating unintentional reversals are set forth in the Regulation.

7.3.2 Intentional Reversals

The Regulation defines intentional reversals. Requirements for intentional reversals are set forth in the Regulation.

7.4 Disposition of Forest Projects after a Reversal

Provisions related to the disposition of a Forest Project after a reversal are set forth in the Regulation. These provisions dictate under what circumstances a Forest Project that undergoes an intentional or unintentional reversal would be terminated and under what circumstances the Forest Project may continue without termination.

8 Offset Project Monitoring

General requirements for monitoring, reporting, and record retention are provided in the Regulation. The Offset Project Operator or Authorized Project Designee must conduct monitoring activities and submit Offset Project Data Reports in accordance with the Regulation and this protocol. Monitoring is required for a period of 100 years following the final issuance of any ARB or registry offset credits to an offset project.

For Forest Projects, monitoring activities consist primarily of updating a project's forest carbon inventory. ARB requires a complete inventory of carbon stocks to be reported each year. This complete inventory must be maintained and updated throughout the Project Life.

8.1 Forest Carbon Inventory Program

Prior to a Forest Project's first verification, a documented forest carbon inventory program, including an inventory monitoring plan and a modeling plan, must be established detailing the specific methods that will be used to update the project's forest carbon inventory on an annual basis. The forest carbon inventory program must adhere to the requirements and methods in Appendices A and B, which establish the equations for computing biomass and limits to which computer models can be used in the inventory update process.

8.2 Annual Monitoring Requirements

The Offset Project Operator or Authorized Project Designee is required to report the Forest Project's onsite carbon stocks each year in an Offset Project Data Report. The Offset Project Data Report must include an estimate of carbon stocks in all required carbon pools. The estimate must reflect the appropriate confidence deduction as determined by the steps in Appendix A, Section A.4. Annual onsite carbon stock estimates are computed from inventory data. Inventory data are updated annually by:

1. Incorporating any new forest inventory data obtained during the previous year.
2. Modeling growth in sample plots using approved growth models and stand table projection methods (see Appendix B regarding growth models and stand table projections).
3. Updating the forest inventory data for harvests and/or disturbances that have occurred during the previous year.

Specific methods used to update the forest inventory must follow the inventory methodologies approved at the time the project is initially verified. Modifications to inventory methodologies must be approved in advance by a third-party verification body and by ARB, and documented in the change log.

9 Reporting Requirements

This section provides supplemental requirements for reporting in addition to requirements contained in the Regulation. Offset Project Data Reports must be submitted at the conclusion of every Reporting Period.

9.1 Offset Project Documentation

In order for the offset project to be Listed, all of the information specified in the Project Listing Requirements in Section 9.1.1 must be submitted, along with any additional information specified in the Regulation. Reporting deadlines and record retention requirements are contained in the Regulation.

All reports that reference carbon stocks must be submitted with the oversight of a Professional Forester. If the offset project is located in a jurisdiction without a Professional Forester law or regulation, then a Professional Forester must either have the Certified Forester credentials managed by the Society of American Foresters, or other valid professional forester license or credential approved by a government agency in a different jurisdiction.

9.1.1 Offset Project Listing Requirements

The listing information in this section must be submitted by the Offset Project Operator or Authorized Project Designee prior to the Listing of the offset project. This information is also submitted as part of the first Offset Project Data Report, and is subject to verification at the initial offset project verification. The following listing information must be submitted no later than the date at which the Offset Project Operator or Authorized Project Designee submits the first Offset Project Data Report:

9.1.1.1 All Offset Projects[7]

1. Offset project name.
2. Offset project contact information, including name, phone number, address, and email address for:
    a. Offset Project Operator
    b. Authorized Project Designee (if applicable);
3. Whether the Offset Project Operator is the owner in fee for the project area.
    a. If yes, provide documentation (e.g. deed of trust, title report) showing the Offset Project Operator's ownership interest in the property and its interest in the trees and standing timber on the property.
    b. If no, explain how the entity identified as the Offset Project Operator has the right to undertake and list the project and provide documentation supporting the explanation.
4. Offset project type (reforestation, improved forest management, or avoided conversion).
5. A description of the management activities that will lead to increased carbon stocks in the Project Area, compared to the baseline.

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[7] Reforestation projects as qualified in section 6.1 can defer the items that are marked with an asterisk until the second site-visit verification.

6. Indicate if the offset project occurs on public or private lands, and further specify if the offset project occurs on any of the following categories of land:
   a. Land that is owned by, or subject to an ownership or possessory interest of a Tribe;
   b. Land that is "Indian lands" of a Tribe, as defined by 25 U.S.C. §81(a)(1); or
   c. Land that is owned by any person, entity, or Tribe, within the external borders of such Indian lands.
7. Offset project commencement date, with an explanation and justification of the commencement date.
   a. Specify the action(s) that identify the offset project commencement date.
8. A statement as to whether any GHG reductions or GHG removal enhancements associated with the Project Lands have ever been listed or registered with, or otherwise claimed by, another registry or program, or sold to a third party prior to listing, including;
   a. Have any lands within the Project Area ever been listed or registered with an offset project registry or program in the past?
   b. Have greenhouse gas emission reductions or removal enhancements associated with lands within the Project Area been credited or claimed for the purpose of greenhouse gas mitigation or reduction goals, whether in a voluntary or regulatory context?
   c. If yes, identify the registry or program (include vintages and reporting period).
9. A statement as to whether the project is being implemented and conducted as the result of any law, statute, regulation, court order, or other legally binding mandate? If yes, explain.
10. Declaration that the offset project does *not* employ broadcast fertilization.
11. If the Forest Project is located on public land, a description and copies of the documentation demonstrating explicit approval of the offset project's management activities and baseline including any public vetting processes necessary to evaluate management and policy decisions concerning the offset project.
12. If the Forest Project is located on the following categories of land, a description and copies of documentation demonstrating that the land within the Project Area is owned by a tribe or private entities:
   a. Land that is owned by, or subject to an ownership or possessory interest of a Tribe;
   b. Land that is "Indian lands" of a Tribe, as defined by 25 U.S.C. §81(a)(1); or
   c. Land that is owned by any person, entity, or Tribe, within the external borders of such Indian lands.
13. If commercial harvesting is either planned or ongoing within the Project Area, a description of how the Forest Owner satisfies one of the three requirements for employing and demonstrating sustainable long-term harvesting practices on all of its forest landholdings (refer to Section 3.8.1).
14. A description of how the offset project meets (or will meet) the definition of "Natural Forest Management" (refer to Section 3.8.2), including:
   a. Composition of native species;
   b. Distribution of age classes / sustainable management;
   c. Structural elements (standing and lying dead wood);
15. Descriptions and maps of the Project Area boundaries that include:
   a. Governing jurisdictions, and latitude/longitude coordinates
   b. Public and private roads (map)
   c. Towns (map)

   d. Major watercourses (4th order or greater), water bodies, and watershed description (map)
   e. Topography (map)
   f. Townships, ranges, and sections or latitude and longitude (map)
   g. Existing land cover and land use (description with optional map)
   h. Forest vegetation types (description with optional map)
   i. Site classes (description with optional map)
   j. Land pressures and climate zone/classification (description with optional map)
   k. Historical land uses, current zoning, and projected land use within project area and surrounding areas (description with optional map)
   l. A georeferenced shape file (or other electronic file that can be read in a geographic information system) that clearly identifies the project area and boundaries. This file may constitute the required map if it includes the required map information listed above.
16. Identify what assessment area or areas contain lands within the Project Area.
   a. Include how many acres of project lands fall within each assessment area.
   b. Include a value for total project area acreage.
17. General description of the forest conditions within the Project Area:
   a. Species (tree) composition;
   b. Age class distribution;
   c. Management history;
18. Indicate whether the project will employ a Qualified Conservation Easement.
   a. If yes, include the date the Qualified Conservation Easement was or will be recorded, the terms that affect forest management within the easement, and provide a copy of the Qualified Conservation Easement to ARB.
19. *A description of the inventory methodology for each of the carbon pools included in the Forest Project's Offset Project Boundary. The inventory methodology must describe the information required in Appendix A.3.
20. *A description of the calculation methodologies for determining metric tons per acre for each of the carbon pools included in the Offset Project Data Report.
21. *A modeling plan, following the requirements and methods in Appendix B, Section B.3.
22. *A diagram of the final baseline incorporating all required carbon stocks.
23. *A summary of the inventory of carbon stocks for each carbon pool.
24. *A summary of inventory confidence statistics.
25. *A description and estimate of the Forest Project's baseline onsite carbon stocks. Baseline onsite carbon stocks must be portrayed in a graph depicting time in the x-axis and metric tons CO_2-equivalent in the y-axis. The graph should be supported with written characterizations that explain any annual changes in baseline carbon stocks over time.
26. *An estimate of carbon that will be stored long-term in harvested wood products in the baseline.
27. *Calculation of the offset project's reversal risk rating and contribution to the Forest Buffer Account.

9.1.1.2 Reforestation Projects

In addition to the information in Section 9.1.1.1, the following information must be provided for Reforestation projects:

1. An explanation of how the Project Lands, at the time of offset project commencement, meets the eligibility requirements of a) less than 10 percent tree canopy cover for a

minimum of 10 years; or b) subject to a significant disturbance that has removed at least 20 percent of the land's above-ground live biomass. The explanation should include why the forest was out of forest cover or a description of the disturbance if a natural significant disturbance occurred.
2. For a Reforestation Project that occurs on land that has undergone a recent Significant Disturbance, indicate the eligibility scenario pertaining to the project site as identified in Appendix E, or a description of how the Forest Project occurs on a type of land for which the Forest Owner has not historically engaged in or allowed timber harvesting.
3. A qualitative characterization of baseline conditions, including an assessment of the likely vegetative conditions and activities that would have occurred in the absence of the project, taking into consideration any laws, statutes, regulations, or other legal mandates that would encourage or require reforestation on the Project Area. The qualitative assessment shall include an assessment of the commercial value of trees within the project area over the next 30 years.
4. List any laws, statutes, regulations or other legal mandates that would encourage or require reforestation on the project area.

9.1.1.3 Improved Forest Management Projects on Private Lands

In addition to the information in Section 9.1.1.1, the following information must be provided for Improved Forest Management projects on private lands:

1. Documentation that the Project Area has greater than 10 percent tree canopy cover.
2. A determination of how the Forest Project's initial standing live carbon stocks compare to Common Practice, as required in Section 6.2.1.
3. If the Forest Project's initial standing live carbon stocks are below Common Practice, a determination of the "High Stocking Reference" for the Project Area. To determine the High Stocking Reference, changes in the Project Area's live-tree carbon stocks over the preceding 10 years must be documented.
    a. Include an affidavit testifying that the inventory depicted over the past 10 years is reasonably accurate.
    b. Include a summary of volume harvested over the past 10 years.
4. Documentation of any and all legal constraints affecting forest management activities on the Project Area. The documentation of legal constraints must include:
    a. A description of each constraint (refer to Section 6.2.1.2).
    b. A narrative that describes the effect of the constraint on forest management.
    c. A description of the modeling techniques used to simulate the effects of the constraint.
5. A demonstration that the growth and harvesting regime assumed for the baseline is financially feasible following the requirements of Section 6.2.1.3.

9.1.1.4 Improved Forest Management Projects on Public Lands

In addition to the information in Section 9.1.1.1, the following information must be provided for Improved Forest Management projects on public lands:

1. Documentation demonstrating that the offset project takes place on land that has greater than 10 percent tree canopy cover.
2. A projection of future changes to Project Area forest carbon stocks by extrapolating from historical trends; and anticipating how current and future public policy will affect onsite carbon stocks per the requirements of Section 6.2.2.

3. An explanation of how current and future public policy will affect onsite carbon stocks and how, the baseline modeling incorporates constraints imposed by all applicable statutes, regulations, policies, plans and Activity-Based Funding.

9.1.1.5 Avoided Conversion Projects

In addition to the information in Section 9.1.1.1, the following information must be provided for Avoided Conversion projects:

1. Documentation demonstrating the planned or completed dedicating of the land in the Project Area to continuous forest cover through a Qualified Conservation Easement or transfer to public ownership.
2. Documentation demonstrating that the type of anticipated land use conversion is legally permissible per the requirements of Section 3.1.1.3.
3. A description of how the Project Area was determined, following the requirements in Section 4.
4. A full copy of the appraisal that was prepared for the Project Area per the requirements of Section 3.2.1.3.
5. A description of the highest value alternative land use identified in the appraisal.
6. An estimate the rate of conversion and removal of onsite carbon stocks per the requirements in Section 6.3.1.
7. A comparison of the fair market value of the anticipated alternative land use for the Project Area with the value of the current forested land use, and the calculation of an appropriate uncertainty discount (following the requirements in Section 6.3.1).
8. Where the anticipated alternative land use is commercial, residential or agricultural use, indicate the maximum slope of the project area.
9. Where the anticipated alternative land use is mining, describe the extent of mineral resources existing in the Project Area.
10. Where the anticipated alternative land use is commercial, residential or recreational use, indicate:
    a. The proximity of the Project Area to metropolitan areas;
    b. The proximity of the Project Area to grocery and fuel services and accessibility of those services;
    c. Population growth (people per year) within 180 miles of the Project Area.

9.2 Offset Project Data Report

Offset Project Operators or Authorized Project Designees must submit an Offset Project Data Report each year according to the reporting schedule in the Regulation. The listing information in Section 9.1.1 must be included in the initial Offset Project Data Report, and is subject to verifier review during the initial verification. All Offset Project Data Reports must include the information in section 9.2.1.

9.2.1 Annual Reporting

An Offset Project Data Report must be prepared for each reporting period during the Project Life. Offset Project Data Reports must be provided to verification bodies whenever a Forest Project undergoes verification. Offset Project Data Reports must contain an annual update of the project's forest carbon inventory (Section 8.2). Each report must also contain the following information. Reforestation Projects, as qualified in Section 6.1, can defer the items that are marked with an asterisk until submitting the offset project data report that will undergo the second verification.

1. Offset project name.
2. Offset project contact information, including name, phone number, address, and email address for:
    a. Offset Project Operator
    b. Authorized Project Designee (if applicable);
3. Reporting Period.
4. A statement as to whether the Forest Project and associated Project Lands have met and been in compliance with all local, state, or federal regulatory requirements during the reporting period. If not, an explanation of the non-compliance must be provided.
5. A statement as to whether all the information submitted for project Listing is still accurate. If not provided updates to the relevant listing information.
6. An updated estimate of the reporting period's carbon stocks in all required carbon pools.
7. *The appropriate confidence deduction for the forest carbon inventory following the requirements and methods in Appendix A, Section A.4)
8. *An explanation of any decrease over any 10-year consecutive period in the standing live carbon pool.
9. Any changes in the status of the Forest Owner including, if applicable per Section 3.8.1, the acquisition of new forest landholdings.
10. A description of how the project meets (or will meet) the definition of "Natural Forest Management" (refer to Section 3.8.2), including progress on criteria that have not been fully met in previous years.
11. *An estimate of reporting-year harvest volumes and associated carbon in harvested wood products.
12. *Estimated mill efficiency, as determined following the method in Appendix C, Section C.2.
13. The baseline carbon stock estimates for all required carbon pools for the reporting period, as determined following the requirements in Section 0 and approved at the time of the project's registration.
14. An estimate of Secondary Effects, following calculation steps and/or factors provided in Section 0 and approved at the time of the offset project listing.
15. The uncertainty discount for avoided conversion projects, as determined following the requirements of Section 6.3 and approved at offset project listing. (After the initial verification, the uncertainty discount does not change.)
16. A calculation of total net GHG reductions and GHG removal enhancements (QR_y) for the reporting period, following the requirements in Section 0.
17. If a reversal has occurred during the previous reporting period, the report must include a written description and explanation of the reversal, whether the reversal has been classified as intentional or unintentional, and the status of compensation for the reversal.
18. *The offset project's reversal risk rating, as determined following the requirements in Section 7 and Appendix D.
19. *A calculation of the offset project's Forest Buffer Account contribution.
20. For the initial Offset Project Data Report: Projections of baseline and actual harvesting volumes from the Project Area over 100 years.

9.2.2 Additional Reporting for Verification Years

Forest Projects must be verified at least every six years. If verification is less frequent than annual, Offset Project Data Reports must include the following additional information on aggregated GHG emission reductions or removal enhancements since the last verification:

1. Annual estimates of carbon stocks for all required carbon pools reported during each year since the last verification.
2. Confidence deduction for the forest carbon inventory applied for each year since the last verification for the project, if applicable.
3. Baseline carbon stock estimates for all required carbon pools reported during each year since the last verification.
4. Estimate of Secondary Effects reported during each year since the last verification.
5. If a reversal has occurred during the previous six years, the report must provide a written description and explanation of the reversal, whether the reversal has been classified as intentional or unintentional, and the status of compensation for the reversal.
6. Calculation of the offset project's Forest Buffer Account contribution for each year since the last verification.
7. Calculation of total net GHG reductions and GHG removal enhancements (QR_y) reported for each reporting period since the last verification.

9.3 Reporting and Verification Cycle

Upon completion of a reporting period, the Offset Project Operator or Authorized Project Designee must annually submit an Offset Project Data Report according to the schedule specified in the Regulation for each reporting period. Reporting periods are defined in the Regulation. Offset Project Data Reports must be verified (including a site visit) by an ARB-accredited verification body according to the schedule and requirements in the Regulation and Section 10.

A Forest Project is considered automatically terminated (see Section 3.4) if the Offset Project Operator or Authorized Project Designee chooses not to report data and undergo verification at required intervals.

Reforestation Projects for which an initial inventory is deferred are not eligible to receive ARB or registry offset credits until after the second verification.

10 Verification

10.1 Regulatory Verification Requirements

Offset Project Data Reports must be verified in accordance with the regulatory verification requirements in Subarticle 13 of the Regulation and this protocol. Failure to conform to any requirements in this protocol or the Regulation, as applicable, will result in an adverse verification statement. Forest Projects are not eligible to receive a qualified positive offset verification statement.

10.2 Additional Verification Requirements

In addition to the offset project verification requirements in the Regulation, verification of Offset Project Data Reports for Forest Projects must include the following:

10.2.1 Initial Verification

During the initial full verification, the following is required:

1. A detailed review of all required Listing Information during the initial verification.
    a. Include a thorough review of documentation and maps to verify the acreage of the Project Area enrolled in a Forest Project.

10.2.2 Full Verification

During every full verification, including the initial verification, the following is required of the offset verifier:

1. A detailed review of the forest carbon inventory, including:
    a. Inventory methodology and sampling design;
    b. Inventory update processes;
    c. Measurement of sample plots and sample plot locations;
    d. Lifetime and updating of sample plots, as applicable;
    e. Stratification methods, if applicable;
    f. Biomass equations and calculations;
    g. Incorporation of growth and harvest modeling and data;
    h. Documentation of inventory methods and procedures, including procedures for data quality assurance and quality control.
2. Identification and re-measurement of a selection of sample plots, along with a comparison with inventory data to have reasonable assurance that sample plots are measured accurately using the methods required in this section.

    The following paragraphs use specific terms that may not always have the same meanings in varying contexts. For the purposes of this verification the following terms and definitions apply:

- Stand: An individual unit or polygon that is relatively homogeneous in terms of the carbon stocking within its borders. For live and dead trees, the determination of stand boundaries is usually based on forest vegetation attributes, such as species, size (age), and density characteristics. For soils, the determination of soil stand boundaries is made on similar soil types.
- Stratum: A group of stands that contain a similar attribute, such as vegetation or soils attributes.
- Strata: Plural of stratum. The set of different groupings for a specific attribute, such as vegetation or soil.

The offset verifier will sample plots consistent with the objectives of a random, risk-based and efficient approach. In doing so, the offset verifier may weight the probability of selecting strata and plots based on appropriate criteria such as carbon stocking, access difficulty, and vegetation heterogeneity. Verifiers may choose to sample project plots within strata with a cluster design. The selection of a stratum may use probability proportional to carbon stocks or probability proportional to error risk.

The verification procedures described below must be applied independently for each applicable carbon pool/applicable combination of pools that is included in the Offset Project Boundary:

- Standing live and dead trees;
- Soil;
- Lying dead wood; and
- Shrubs and herbaceous understory.

Sequential statistical methods are used to minimize the verification effort when verification and project sample data agree. Sequential approaches have stopping rules rather than fixed sample sizes. With each successive plot, or series of plots, analyzed by the offset verifier, the stopping rules indicate to the offset verifier a) to continue to the next plot(s) since the results do not indicate either a bias or an agreement and further testing is required, b) stop as the testing indicates a bias, or c) stop as the testing indicates agreement. When a stopping rule is met then the result is evaluated. Verification of sample plots is successful after a minimum number of successive plots in a sequence indicate agreement. Where the stopping rules indicate the presence of a bias, additional verification plots may be collected after that time if it is felt that random chance may have caused the test to fail and a convergence towards agreement is expected with additional samples. For effective application of the sequential statistics in the field, the determination of when the stopping rule is met is determined at the end of each sampling day, which will include the full set of plots measured in that day.

Stands of a given stratum must be independently selected using a random selection design. Plots, or clusters, must be independently selected within a stand using a random or systematic design. No more than 6 plots or clusters can be assigned to a stand, unless the groups of plots required for verification exceed the number of stands that exist for the offset project. If the offset project is not stratified for each applicable pool, the offset verifier shall allocate the plots or clusters on a randomized basis. If the offset verifier uses a cluster design, the mean of the cluster accounts for one observation (plot). Plots may be measured and assessed one at a time or in reasonable batches that correspond to logistical realities such as crew-days of effort. Verification sampling may be conducted using clustering or systematic approaches to facilitate efficiency.

When the project area has been stratified for the purposes of estimating the Forest Project's inventory based on common characteristics for each carbon pool, the offset verifier shall select three strata for each applicable carbon pool based on the offset verifier's evaluation of risk. Consideration of risk should be based on the overall importance of a given stratum to the project's total stocks and the presumption that any given stratum is inaccurately measured. The selection of stands to verify within a given stratum must be random. The minimum number of sample plots varies by project size and number of strata verified. (Table 10.1).

Table 10.1. Minimum number of sample plots in sequence, as a function of project size.

Test	Number of Strata Verified	Project Acres				
		<100	100 - 500	501 - 5,000	5,000 - 10,000	> 10,000
Paired/Unpaired	3	2	3	4	5	6
	2	4	6	8	10	12
	1	8	12	16	20	24

There are two possible statistical procedures that can be applied to the stratum-level verifications. A paired test can be applied when plot locations can be found and it is statistically appropriate (i.e. plot measurements can be replicated) to use a paired test. An unpaired test can be applied when plots cannot be relocated. The range of acceptable error (δ, delta) is fixed at 10 percent.

Assigning Risk to Strata: The offset verifier must determine for each applicable pool or combination of pools if the Offset Project Operator or Authorized Project Designee has stratified the project area into strata that reflect common characteristics that influence carbon stocks. The offset verifier may presume risk exists in the highest stocked strata, strata that are unique or difficult to access due to topographical, vegetative, or other physical barrier, strata that represent a large portion of the project's inventory due to the area they represent, or any other risk perceived by the offset verifier. The determination of risk must be applied to the stratum as a unit and not individual stands of a given stratum.

Selecting Strata based on Risk: Based on the assessment of risk, the offset verifier will query, or request that the Offset Project Operator or Authorized Project Designee query, the set of stands that are associated with the strata selected. The queried stands must have an identifier which can be based on the Offset Project Operator or Authorized Project Designee's identification convention or one assigned by the offset verifier. Three strata must be selected, or the maximum number of strata stratified by the Offset Project Operator or Authorized Project Designee for each pool. Table 10.2 displays an example of ordered strata for standing live and dead trees selected by stratum with random numbers assignments.

Table 10.2. Stands selected by vegetation strata and risk class with random number assignments.

Stand Number	Stratum (from Forest Owner or Verifier)	Risk Class	Order of Random Selection
2	Dense Intermediate Conifers	High Stocking	5
3	Dense Intermediate Conifers	High Stocking	3
4	Dense Intermediate Conifers	High Stocking	1
8	Dense Intermediate Conifers	High Stocking	8
9	Dense Intermediate Conifers	High Stocking	2
10	Dense Intermediate Conifers	High Stocking	1
15	Dense Intermediate Conifers	High Stocking	4
18	Dense Intermediate Conifers	High Stocking	7
Stand Number	**Stratum (from Forest Owner or Verifier)**	**Risk Class**	**Order of Random Selection**
8	Dense Mature Conifers	High Stocking	4
9	Dense Mature Conifers	High Stocking	3
10	Dense Mature Conifers	High Stocking	5
15	Dense Mature Conifers	High Stocking	2
18	Dense Mature Conifers	High Stocking	1
Stand Number	**Stratum (from Forest Owner or Verifier)**	**Risk Class**	**Order of Random Selection**
13	Medium Dense Mature Riparian	Difficult Access	2
14	Medium Dense Mature Riparian	Difficult Access	1
17	Medium Dense Mature Riparian	Difficult Access	3

Planning and Implementing Field Verification Sampling: The selected stands should be mapped and labeled with the random number to assist in developing a strategy to perform field sampling activities. Up to 6 plots or clusters may be re-measured in a stand (if plots are monumented) or installed (if plots are not monumented) in each stand. If the project area has not been stratified or there are less than 3 strata, the offset verifier shall locate the plots or clusters using a random process of their own design. For efficiency, it is acceptable for the offset verifier to relocate to a new area at the beginning of a day without having completed all the plots in the previous day.

Determination if the Stopping Rules have been met: The offset verifier must determine if the stopping rules have been met for each stratum after the measurement of each plot, unless the offset verifier determines it is appropriate to defer the determination until no later than the end of each day of sampling. The offset verifier must conduct the appropriate calculation for a paired or unpaired test. It is required that the offset verifier apply the random order selection in the sampling process. For efficiency purposes, the offset verifier may skip the random order on a temporal basis as long as the sequential analysis includes the ordered set of stands. This may provide significant efficiencies when selected stands and/or plots are in close geographic proximity and it is hypothesized that the stopping rules will require the full number of plots. An example is displayed in Table 10.3.

Table 10.3. The table displays a sampling schedule planned by the offset verifier and the verification results. In this example, the sequential sampling is conditionally satisfied

after Day 3 but requires the full set of randomly selected stands to be sampled up to the point of satisfying the sequential statistics, which is met after sampling Stand 3 on Day 4.

Stand	Stratum (from Forest Owner)	Risk Class	Order of Random Selection	Sampling Schedule (Planned)	Verification Effort	Verification Results
4	Dense Intermediate Conifers	High Stocking	1	Day 3	Day 1	Inconclusive. Stand 9 sampled. Sequential sampling criteria not satisfied - More plots are needed
9	Dense Intermediate Conifers	High Stocking	2	Day 1	Day 2	Inconclusive. Stand 15 sampled. Sequential sampling criteria not satisfied - More plots are needed
3	Dense Intermediate Conifers	High Stocking	3	Day 4	Day 3	Inconclusive. Stand 4 sampled. Sequential sampling criteria satisfied but stand order must be satisfied. Stand 3 must be sampled.
15	Dense Intermediate Conifers	High Stocking	4	Day 2	Day 4	Conclusive. Stand 3 sampled. Sequential sampling criteria is met and adherence to random selection is maintained
2	Dense Intermediate Conifers	High Stocking	5	Day 6		
10	Dense Intermediate Conifers	High Stocking	6	Day 5	Further Verification Effort not Necessary	
18	Dense Intermediate Conifers	High Stocking	7	Day 7		
8	Dense Intermediate Conifers	High Stocking	8	Day 8		

Paired Plots: The statistical test is based on a comparison of the offset verifier's measurements of plots within a selected stratum, calculated as CO_2-equivalent compared to the Offset Project Operator's or Authorized Project Designee's measurements of plots, which may include any adjustments for growth. The offset verifier must use α=0.05 and β=0.20 to control for error. The null hypothesis (H_0) is that the verification and project plots are equal.

1) Sample and measure at least the minimum number of plots required in Table 10.1.
2) If $n \geq ((Z_\alpha + Z_\beta)^2 \times S_n^2) / D^2$ then stop and evaluate. Otherwise take another sample.

   n = Number of verification plots measured,
   Z_α = α/2% N(0,1) = 1.645,
   Z_β = β/2% N(0,1) = 0.8416,
   S_n^2 = sample variance of the differences,
   D = δ × project average estimate.

3) If stopped, then evaluate.

   If $\bar{X}_N \leq K$ then accept H_0,
   If $\bar{X}_N > K$ then reject H_0.

   $\bar{X}_N$ = sample mean of the differences,
   N = total number of plots measured,

   $K = (Z_\alpha \times D) / (Z_\alpha + Z_\beta)$.

4) If H_0 was rejected then additional samples may be taken as long as the offset verifier is of the opinion that there is a chance that H_0 may be accepted based on the variability and trend observed.

Unpaired Plots: The statistical test is based on comparing the average CO_2-e estimates for each stratum from the verifier plots to the Offset Project Operator's or Authorized Project Designee's plots.

The offset verifier must use α=0.05 to control for error; the β is not specified because the method is constructing a confidence interval not a test. The null hypothesis (H_0) is that the verification and stratum averages are equal. The following procedure is appropriate for the unpaired test.

1) Sample and measure at least the minimum number of plots required in Table 10.1. Calculate n as the sum of the number of plots from both the stratum and the verification.
2) Calculate the following:

   $T_n = \bar{X}_P - \bar{X}_n$ where,
   $\bar{X}_P$ = stratum mean,
   $\bar{X}_n$ = verification mean after sample n.
   S_n^2 = sample variance of the verification plots,
   S_P^2 = sample variance of the stratum plots,
   D = δ × stratum average estimate.
   a = the percentile from a standard normal distribution for one half of alpha; is equal to 1.96 for α=0.05

3) If $n \geq (a^2/D^2) \times (S_n^2 + S_P^2)$ then stop and evaluate. (Note: $n = n = n_P + n_V$). Otherwise take another sample.
4) If stopped, then evaluate. Construct a confidence interval $T_n \pm D$.

   If the confidence interval includes zero then accept H_0,
   Otherwise reject H_0.

5) If H_0 was rejected then additional samples may be taken until as long as the verifier is of the opinion that there is a chance that H_0 may be accepted based on the variability and trend observed.

If the stopping rule in step (3) above cannot be attained within 100 plots then apply a standard unpaired t-test comparison using alpha of 0.05 and beta of 0.80.

3. Application of appropriate confidence deductions, if applicable.
4. Review reversal risk rating calculation.
5. Review of conformance with natural forest management and sustainable harvesting requirements.

10.2.3 Less-Intensive Verification

Less intensive verification refers to offset verification services that may be provided in interim years between full verifications. In the case of Forest Projects, full verification is required once every six years. Less intensive verification services may be provided in interim years between full verification at the discretion of the Offset Project Operator or Authorized Project Designee, subject to the concurrence of the accredited verification body that conducted the last full verification. Less intensive verification is not allowed if (1) there have been significant changes in methodologies or updates to the forest carbon inventory program, or (2) there has been a change in verification body since the previous verification.

Less intensive verification of an Offset Project Data Report only requires data checks and document reviews of an Offset Project Data Report based on the analysis and risk assessment in the most current sampling plan developed as part of the most recent full offset verification services. A site visit is not required. This level of verification may only be used if the verification team can provide findings with a reasonable level of assurance.

During less intensive verification of Forest Projects, the verification team must:

- Conduct data checks and carefully review data and calculations contained within the Offset Project Data Report, and
- At a minimum, review documentation supporting the data and calculations in the Offset Project Data Report, including the data used to update the forest carbon inventory and any new sample plot measurements, updates in growth and yield models, timber harvest plans and other regulatory documentation related to timber harvest, documentation of timber sales.

10.2.4 Verification of Multiple Reporting Years

If verification is less frequently than annual, the verification team must separately review and evaluate each reporting period of reported data specified in Section 9.2.2.

1. Each reporting period of quantified GHG reductions or GHG removal enhancements (QR_y) is separately evaluated for offset material misstatement.

10.2.5 Verification Team

Each verification team must include the following:

1. At least one Professional Forester that takes an active role in reviewing the forest carbon inventory program and conducting the site visit.
2. At least one individual with demonstrated competence in forest biometrics through:

   a. A master's degree in statistics or forest biometrics, or another closely related science that includes 12 semester or 16 quarter hours of forest biometrics, sampling design and/or statistics coursework; or
   b. University coursework that includes 12 semester or 16 quarter hours of forest biometrics, sampling design and/or statistics coursework, and at least two years of experience sampling, developing, implementing and analyzing forest biomass or carbon inventories
3. At least one individual with demonstrated knowledge of and competence in the use of forest growth and yield models, and demonstrated experience working with the model used in the forest carbon inventory being verified. Such experience should include university or other professional coursework, and/or project experience demonstrating competency in the use of the model.
4. An ARB-accredited Forest Offset Project Specialist.

An explanation demonstrating that the verification team includes individuals with the required experience and expertise must be included in the Notice of Verification Services submittal. The required experience and expertise may be demonstrated by a single individual, or by a combination of individuals.

10.2.6 Minimum Required Verification Schedule

Except as allowed for the second verification of Reforestation Projects, ARB requires that an ARB-accredited third-party verification body review and assess all reported data and information for a Forest Project and conduct a site visit at least once every six years. Verification is also required anytime new confidence deductions and/or reversal risk ratings are established.

For Reforestation Projects, the second verification may be deferred up to 12 years at the discretion of the Offset Project Operator or Authorized Project Designee.

11 Glossary of Terms[8]

Above-Ground Live Biomass	The total mass of biomass in live trees including the stem, branches, and leaves or needles, brush and other woody live plants above ground.
Activity-Based Funding	The budget line items that are dedicated to agency accomplishments in vegetation management, including pre-commercial thinning, commercial thinning, harvest, hazard tree removal, hazardous fuel reductions, and other management activities designed to achieve forest sustainability health objectives.
Additional	Additional is defined in the Regulation. Under this protocol, GHG reductions or removals from Forest Projects are demonstrated to be addition when they pass a legal requirement test and a performance test, as described in Section 3.1, and by achieving GHG reductions and removals quantified against an approved baseline, determined according to the requirements in Section 0.
Allometric Equation	An equation that utilizes the genotypical relationship among tree components to estimate characteristics of one tree component from another. Allometric equations allow the below ground root volume to be estimated using the above-ground bole volume.
Assessment Area	A distinct forest community within geographically identified ecoregions that consists of common regulatory and political boundaries that affect forest management. The size of an Assessment Area is determined by efforts to achieve optimal statistical confidence across multiple scales using U.S. Forest Service Forest Inventory and Analysis Program (FIA) plots for biomass. Maps of the Assessment Areas and the associated data may be found on ARB's website.
Avoided Conversion Project	A type of Forest Project consisting of specific actions that prevent the conversion of privately owned forestland to a non-forest land use by dedicating the land to continuous forest cover through a conservation easement or transfer to public ownership.

[8] For terms not defined in this section, the definitions in the Regulation apply.

Best Management Practices	Management practices determined by a state or designated planning agency to be the most effective and practicable means (including technological, economic, and institutional considerations) of controlling point and nonpoint source pollutants at levels compatible with environmental quality goals.
Biological Emissions	For the purposes of the Forest Offset Protocol, biological emissions are GHG emissions that are released directly from forest biomass, both live and dead, including forest soils. For Forest Projects, biological emissions are deemed to occur when the reported tonnage of onsite carbon stocks, relative to baseline levels, declines from one year to the next.
Biomass	Biomass is defined in the Regulation.
Bole	A trunk or main stem of a tree.
Broadcast Fertilization	A fertilizer application technique where fertilizer is spread across the soil surface.
Carbon Pool	A greenhouse gas reservoir.
Common Practice	The average stocks of the standing live carbon pool from within the Forest Project's Assessment Area, derived from FIA plots on all private lands within the defined Assessment Area.
Even-Aged Management	Management where the trees in individual forest stands have only small differences in their ages (a single age class). By convention, the spread of ages does not differ by more than 20 percent of the intended rotation.
FIA	USDA Forest Service Forest Inventory and Analysis program. FIA is managed by the Research and Development organization within the USDA Forest Service in cooperation with State and Private Forestry and National Forest Systems. FIA has been in operation under various names (Forest Survey, Forest Inventory and Analysis) for 70 years.
Forest Buffer Account	Forest Buffer Account is defined in the Regulation as a holding account for Forest Project ARB offset credits administered by ARB. It is used as a general insurance mechanism against unintentional reversals for all forest offset projects listed under a Compliance Offset Protocol.

Forest Management	The commercial or noncommercial growing and harvesting of forests.
Forest Owner	A Forest Owner is defined in the Regulation as the owner of any interest in the real (as opposed to personal) property involved in a forest offset project. Generally, a Forest Owner is the owner in fee of the real property involved in a forest offset project. In some cases, one entity may be the owner in fee while another entity may have an interest in the trees or the timber on the property, in which case all entities or individuals with interest in the real property are collectively considered the Forest Owners, however, a single Forest Owner must be identified as the Offset Project Operator.
Forest Project	A planned set of activities designed to increase removals of CO_2 from the atmosphere, or reduce or prevent emissions of CO_2 to the atmosphere, through increasing and/or conserving forest carbon stocks.
Forestland	Land that supports, or can support, at least 10 percent tree canopy cover and that allows for management of one or more forest resources, including timber, fish and wildlife, biodiversity, water quality, recreation, aesthetics and other public benefits.
GHG Removal Enhancement	GHG removal enhancement is defined in the Regulation. GHG removal enhancements are calculated as gains in carbon stocks over time relative to a Forest Project's baseline.
Greenhouse Gas (GHG) Reservoir	Greenhouse Gas Reservoir is defined in the Regulation. For Forest Projects, GHG reservoirs may include above-ground or below-ground biomass or harvested wood products, among others.
Improved Forest Management Project	A type of Forest Project involving management activities that increase carbon stocks on forested land relative to baseline levels of carbon stocks.
Listed	A Forest Project is considered "listed" when an the Offset Project Operator or Authorized Project Designee is registered with ARB or an approved offset project registry, submits all required documentation for project listing in the Regulation and this protocol, and the project has been approved by ARB or an approved offset project registry for listing.
Litter	Any piece(s) of dead woody material from a tree,

	e.g. dead boles, limbs, and large root masses, on the ground in forest stands that is smaller than material identified as lying dead wood.
Lying Dead Wood	Any piece(s) of dead woody material from a tree, e.g. dead boles, limbs, and large root masses, on the ground in forest stands. Lying dead wood is all dead tree material with a minimum average diameter of 5" and a minimum length of 8'. Anything not meeting the measurement criteria for lying dead wood will be considered litter. Stumps are not considered lying dead wood.
Metric ton (MT) or "ton"	A common international measurement for the quantity of GHG emissions, equivalent to about 2204.6 pounds or 1.1023 short tons.
Native Forest	For the purposes of this protocol native forests shall be defined as those occurring naturally in an area, as neither a direct nor indirect consequence of human activity post-dating European settlement.
Natural Forest Management	Forest management practices that promote and maintain native forests comprised of multiple ages and mixed native species at multiple landscape scales. The application of this definition, its principles, detailed definition, and implementation are discussed further in the Section 3.8.2.
Non-Forest Cover	Land with a tree canopy cover of less than 10 percent.
Non-Forest Land Use	An area managed for residential, commercial, or agricultural uses other than for the production of timber and other forest products, or for the maintenance of woody vegetation for such indirect benefits as protection of catchment areas, wildlife habitat, or recreation.
Non-Harvest Disturbance	Reduction in forest cover that is not a direct result of harvest, such as wildfire and insect disturbances.
Onsite Carbon Stocks	Carbon Stock as defined in the Regulation means "the quantity of carbon contained in an identified GHG reservoir." For Forest Projects onsite carbon stocks include the carbon stocks in the required carbon pools indicated in Table A.1 within the Project Area.
Primary Effect	The Forest Project's intended changes in carbon stocks, GHG emissions, or GHG removals.

Professional Forester	A professional engaged in the science and profession of forestry. For forest projects that occur in a jurisdiction that has professional forester licensing laws and regulations, a Professional Forester must be credentialed in that jurisdiction. Where a jurisdiction does not have a professional forester law or regulation, then a Professional Forester is defined as either having the Certified Forester credentials managed by the Society of American Foresters, or other valid professional forester license or credential approved by a government agency in a different jurisdiction.
Project Area	The area inscribed by the geographic boundaries of a Forest Project, as defined following the requirements in Section 4 of this protocol. Also, the property associated with this area.
Project Life	Refers to the duration of a Forest Project and its associated monitoring and verification activities, as defined in Section 3.4.
Public Lands	Lands that are owned by a public governmental body such as a municipality, county, state, or country.
Qualified Conservation Easement	A qualified conservation easement must explicitly refer to the requirements of the regulation and this protocol and apply to current and all subsequent Forest Owners for the full duration of the Forest Project's minimum time commitment, as defined in Section 3.4 of this protocol.
Reforestation Project	A type of Forest Project involving the restoration of tree cover on land that currently has no, or minimal, tree cover.
Reversal	A reversal as defined in the Regulation. Under this protocol, a reversal is deemed to have occurred if the quantified GHG reductions and removal enhancements in a given year are negative and offset credits were issued to the Forest Project in any previous year, regardless of the cause of the decrease.
Secondary Effects	Unintended changes in carbon stocks, GHG emissions, or GHG removals caused by the Forest Project.
Significant Disturbance	Any natural impact that results in a loss of at least 20 percent of the above-ground live biomass that is not the result of intentional or grossly negligent acts of the Forest Owner.

Standing Dead Carbon Stocks	The carbon in standing dead trees. Standing dead trees include the stem, branches, roots, or section thereof, regardless of species, with a minimum diameter at breast height of five inches and a minimum height of 15 feet. Stumps are not considered standing dead stocks.
Standing Live Carbon Stocks	The carbon in the live tree biomass. Live trees include the stem, branches, roots, and leaves or needles of all live biomass, regardless of species, with a minimum diameter at breast height of five inches and a minimum height of 15 feet.
Stocks (or Carbon Stocks)	The quantity of carbon contained in an identified GHG reservoir (or carbon pool).
Submitted	A Forest Project is “submitted” when all of the appropriate forms have been uploaded and submitted.
Tree	A woody perennial plant, typically large and with a well-defined stem or stems carrying a more or less definite crown with the capacity to attain a minimum diameter at breast height of 5 inches and a minimum height of 15 feet with no branches within 3 feet from the ground at maturity.
Unintentional Reversal	An unintentional reversal as defined in the Regulation is any reversal not due to the Forest Owner’s negligence, gross negligence or willful intent, including wildfires or disease that are not the result of the Forest Owner's negligence, gross negligence or willful intent.
Uneven-Aged Management	Management that leads to forest stand conditions where the trees differ markedly in their ages, with trees of three or more distinct age classes either mixed or in small groups.

Appendix A Developing an Inventory of Forest Project Carbon Stocks

Quantification Methodology

This appendix provides requirements for quantifying a Forest Project's forest carbon stocks. It explains how to identify the required forest carbon pools measured in a Forest Project, as well as the steps necessary for quantifying the existing carbon stocks in the selected pools within the Project Area. Carbon inventory information serves two purposes:

1. It is used as the basis for modeling and estimating carbon stocks in a Forest Project's baseline (following the requirements of Section 0).
2. It is used to quantify actual carbon stocks during the course of a project.

This appendix explains the essential steps and requirements for completing a carbon inventory for all required onsite carbon pools associated with a Forest Project.

A.1 Provide Background Information on Forest Area

To begin the inventory process, develop a general description of the activities and land use patterns that influence carbon stocks in the Project Area, including all the information required in Section 9.1.1.1. This information will help inform the initial design of the forest inventory, as well as the estimations of carbon stocks. This information will be reviewed during verification.

A.2 Measure Carbon Pools in the Project Area

Forest carbon pools are broadly grouped into the following categories:

1. Living biomass
2. Onsite dead biomass
3. Soil

Values for some of these categories of carbon will be determined through direct sampling. Table A.1 indicates the categories with their associated carbon pools and identifies which pools must be quantified for all offset projects versus those are excluded depending on the project. It also shows how the value for the pool is determined.

Table A.1. Requirements of carbon pool categories and determination of value for pool

Category	Carbon Pool	Improved Forest Management	Reforestation	Avoided Conversion	Determination of Value
Living biomass	Standing Live	Required	Required*	Required	Sampled in Project
	Shrubs and Herbaceous Understory	Excluded	Required	Excluded	Sampled in Project
Onsite dead biomass	Standing Dead	Required	Required	Required	Sampled in Project
Soil	Soil**	Required/ Excluded**	Required/ Excluded**	Required/ Excluded**	Sampled in project

* Pre-existing trees must be distinguished from planted trees. Since pre-existing and new trees are easy to distinguish for several decades after tree planting, pre-existing trees do not need to be inventoried until the offset project first seeks verification of GHG reductions and GHG removal enhancements.
** Soil carbon is not anticipated to change significantly as a result of most Forest Project activities. Soil carbon is excluded except when specified in Section 5.

A.3 Developing Onsite Forest Carbon Inventories

To develop estimates of carbon stocks in the carbon pools identified in Table A.1, a forest inventory must first be conducted. Standard forest inventories require the establishment of sample plots and provide inventory estimates in terms of cubic or board foot volume. These measurements are based on the species, trunk or bole diameter, form and height of the tree.

Each Offset Project Operator or Authorized Project Designee must develop and document a forest carbon inventory methodology. The inventory method must be capable of quantifying carbon stocks for required carbon pools to a high degree of accuracy. A complete inventory methodology must include:

1. A description of the Offset Project Boundary, including a list of all carbon pools included in the Offset Project Boundary.
2. For each carbon pool, include a detailed description of the inventory sampling methodology used to quantify that carbon pool, with references clearly documented. This documentation must include:
   a. Standard procedures for the collecting of field measurements. These procedures must be detailed enough so that any qualified forester would be able to accurately repeat the previous measurements. These procedures must include a description of the types of sample plots, location of plots, and frequency for updating or replacing sample plots as well as the forest carbon inventory as a whole;
   b. Standard procedures for where and how to measure parameters used in biomass calculations such as dbh and height (including for irregular trees), how to classify dead wood, and for any other aspects of sampling where a consistent method needs to be documented; and
   c. Stratification rules (pre and post sampling), if applicable, that include a map of vegetation strata, results of stratification (area by strata), tools for application

(such as GIS, aerial photos), and a discussion of how boundaries were determined.

3. Documentation of all analytic methods and biomass equations used to translate field measurements into volume or biomass carbon estimates;
4. A documented quality assurance / quality control (QA/QC) plan including procedures for internal review to ensure that standard operating procedures are being followed. The QA/QC plan must include procedures for assessing and ensuring the quality of collection, transfer and archiving of field data; procedures for data entry and analysis, and data maintenance and archiving; and any other relevant procedures to ensure quality and consistency in the collection and maintenance of data used to compile the offset project data reports.
5. Description of data management systems and processes, including the collection, storage and analysis of inventory related data analytical methods to translate field measurements into volume and/or biomass estimates.
6. A change log documenting any changes in the inventory methods or equations used to calculate carbon stocks.
7. Standard procedures for updating the forest carbon inventory, including documented procedures to account for:
    a. Harvest;
    b. Growth;
    c. Disturbance;
    d. Incorporating new inventory and plot data, and retiring older sample plots;
    e. Modeling, as allowed under Appendix B; and
    f. Application of appropriate confidence deduction.

Inventory methods and sampling procedures, once established, must be consistent over the life of the project. Any changes to inventory methods or calculations must be documented and justified in the change log.

Allometric Equations and Biomass/Carbon Mass Estimates

The equations in this appendix and in the Forest Offset Protocol Resources section of ARB's webpage must be used for biomass and carbon mass estimations using the bole diameter and total height for live trees and sound standing dead trees. Estimates of standing dead tree (for non-sound trees) biomass must be computed in terms of cubic volume and subsequently converted to biomass/carbon mass estimates.

Sample Plots

Any plot data used for deriving the forest carbon inventory estimates must have been sampled within the last 12 years. The scheduling of plot sampling may occur in one time period or be distributed over several time periods. Either approach is acceptable so long as an inventory of the entire Project Area (its required carbon pools and corresponding sample plots) is completed within 12-year intervals.

Steps for Developing a Complete Forest Carbon Inventory

The steps that follow provide more detail on establishing and maintaining a complete inventory and estimating carbon stocks. Results must be summarized in a table when submitting required data in an Offset Project Data Report (see Section 9).

Step 1 – Developing Inventory Methodology and Sample Plots

The Offset Project Operator or Authorized Project Designee must develop and describe a methodology to sample for biomass or volume of all required carbon pools. If a pre-existing forest inventory is used to develop a forest carbon inventory, all steps here must be followed to ensure the existing inventory meets the requirements of this protocol.

Sampling methodology and measurement standards should be consistent throughout the duration of the Forest Project. If new methodologies are adopted, they must achieve an equal or greater accuracy relative to the original sampling design. All sampling methodologies and measurement standards must be statistically sound and must be approved during verification.

Stratification is not required, but it may simplify verification. Temporary flagging of plot center, as is customary to allow for check cruising, is required to ensure ongoing inventory quality and allow for offset verifiers to visit plots when verifying inventory procedures. If permanent plots are used, which are statistically efficient for stock change estimates, permanent plot monumenting must be sufficient for relocation. Plot centers should be referenced on maps, preferably with GPS coordinates. The methodologies utilized must be documented and made available for verification and public review. The design of the sampling methodology and measurement standards must incorporate the requirements in the following table. All tree species within the Project Area must be measured regardless of the merchantability of the trees.

Table A.2. Minimum required sampling criteria for estimated pools

Carbon Pool	Name of Requirement	Description of Requirement
Standing Live Carbon Stocks (above-ground portion)	Diameter (breast height) Measurements	The minimum diameter (at breast height) must be stated in the methodology, and this minimum diameter must not be greater than 5 inches (inventory must include all trees 5 inches and greater in diameter). Height must be measured as required in appropriate biomass equations.
	Measurement Tools	Description of tools used for height measurement, diameter measurement, and plot measurement.
	Measurement Standards	The methodology shall include a set of standards for tree and plot size measurements.
	Plot Layout	A description of plot layout.
	Merchantability of Trees	The methodology shall include all trees regardless of current merchantability to be included in the sampling design.
	Allometric Equation used for Estimating Biomass	The methodology must include a description of the allometric equation used to estimate the whole tree biomass (bole, branches, and leaves) from bole diameter measurements. The use of functions other than those provided in the protocol will need to be approved by ARB and the verification body.
Standing Live Carbon Stocks (below-ground portion)	Plot-level Allometric Equation used for Estimating Biomass	Apply model (Cairns, Brown, Helmer, & Baumgardner, 1997) to estimate below-ground biomass density. This model equation is based on above-ground biomass density in tons per hectare. The use of a function other than that provided in the protocol will need to be approved by ARB and the verification body.
Herbaceous Understory	Sampling Methodology	The sampling methodology prepared by Brown, Shoch, Pearson, & Delaney (2004). Alternative methodologies need to be reviewed and approved by ARB and the verification body.
Standing Dead Trees	Diameter (breast height) and top Diameter Measurements	The minimum diameter (at breast height) must be stated in the methodology, and this diameter must not be greater than 5 inches. The minimum height of standing dead trees is 15'. The method must include how volume is derived where a total height does not exist (i.e. where the tree is broken).
	Measurement Tools	Description of tools used for height, diameter and plot measurement.
	Measurement Standards	The methodology shall include a set of standards for height and diameter measurements.
	Plot Layout	A description of plot layout (may be the same layout as for live tree biomass).
	Merchantability of Trees	The methodology shall include all trees regardless of current merchantability to be including in the sampling design.

Step 2 – Estimating Carbon in Live Trees from Sample Plots

Standing live tree carbon estimates are required for all offset projects. The standing live tree estimate includes carbon in all portions of the tree, including the bole, stump, bark, branches, leaves, and roots. The Offset Project Operator or Authorized Project Designee is responsible for determining appropriate methodologies for sampling to determine standing live tree carbon stocks. The estimate of above-ground live tree biomass must be combined with the estimates of biomass from other carbon pools to determine a mean estimate of the included pools derived from sampling, along with a summary that describes the statistical confidence of the estimate.

All biomass estimates must be converted to carbon estimates. The derived estimate of biomass must be multiplied by 0.5 to calculate the mass (kg) in carbon. This product must be multiplied by 0.001 tons/kg to convert the mass to metric tons of carbon.

Approved biomass equations will be available in the Forest Offset Protocol Resources section of ARB's website.

Step 3 – Estimating Carbon Standing Dead Tree Carbon from Sample Plots

An inventory of carbon stocks in standing dead tree carbon is required for all Forest Projects. The Offset Project Operator or Authorized Project Designee must provide a sampling methodology for standing dead tree carbon as part of an overall sampling strategy (discussed in Step 1). Sound dead trees can be computed using the equations provided for standing live carbon in Step 2. The estimate of standing dead tree carbon for highly decayed trees (broken tops, missing branches, etc.), must be calculated first volumetrically and subsequently converted to biomass and carbon tons.

For those trees where volume is computed, the volume will need to be converted to biomass density by applying conversion factors based on decay class. The methodology developed must include a description of the calculation techniques used to determine biomass density by decay class. The estimate of biomass density must be computed in terms of metric tons of carbon on a per acre basis. The density factors by decay class from Harmon et al (2008) may be used to estimate density in standing dead carbon stocks.

Step 4– Estimate Carbon in Shrubs and Herbaceous Understory from Sample Plots

Any methodology developed for measuring carbon in shrubs must be reviewed during verification. The most applicable biomass estimation methods may be used, including photo series, the estimation functions from published papers, direct sampling, or combinations of approaches.

Step 5 – Estimate of Carbon Tons in Soil

Changes in total soil carbon are a challenge to measure over short timeframes, as this pool changes slowly and is usually dependent on the rate of biomass input relative to soil decomposition. The sampling methodology and protocols for deriving carbon estimates in soil must be developed as part of an overall sampling strategy (discussed in Step 2). Use the soil sampling methodology prepared by Brown, Shoch, Pearson, & Delaney (2004).

Step 6 – Sum Carbon Pools

The metric tons of carbon in each carbon pool, as derived from the preceding steps, must be entered in the following table. For the purpose of quantifying GHG reductions and GHG removal enhancements, all numbers must be converted to metric tons of CO_2-equivalent by multiplying by 3.664.

Table A.3. Summarizing Carbon Pools and Calculating Total Carbon

Carbon Pool	Source	Gross CO_2-equivalent Tons per Acre
Step 2 Live Carbon Stocks	From sampling results of trees.	
Steps 3 Standing Dead Carbon Stocks	From sampling results of standing dead biomass.	
Step 4 Shrubs and Herbaceous Understory	From sampling results of shrubs and herbaceous understory.	
Step 5 Soil	From sampling results of soil.	
Sum of CO_2-equivalent Tons from Required Pools		

A.4 Applying a Confidence Deduction

Any forest carbon inventory estimate will be subject to statistical uncertainty. Where statistical confidence is low, there is a higher risk of overestimating a project's actual carbon stocks and therefore a higher risk of over-quantifying GHG reductions and GHG removal enhancements. To help ensure that estimates of GHG reductions and GHG removal enhancements are conservative, a confidence deduction must be applied each year to the inventory of actual onsite carbon stocks. A confidence deduction is *not* applied to the forest carbon inventory when it is used to model baseline carbon stocks.

To determine the appropriate confidence deduction, perform the following:

1. Compute the standard error of the inventory estimate (based on the carbon in all carbon pools included in the forest carbon inventory).
2. Multiply the standard error by 1.645.
3. Divide the result in (2) by the total inventory estimate and multiply by 100. This establishes the sampling error (expressed as a percentage of the mean inventory estimate from field sampling) for a 90 percent confidence interval.
4. Consult Table A.5 to identify the percent confidence deduction that must be applied to the inventory estimate for the purpose of calculating GHG reductions and removals (i.e. variable CD_y in Equation 6.1 in Section 0).

Table A.4. Forest carbon inventory confidence deductions based on level of confidence in the estimate derived from field sampling.

Sampling Error (% of Inventory Estimate)	Confidence Deduction
0 to 5%	0%
5.1 to 19.9%	(Sampling Error – 5.0%) to the nearest 1/10th percentage
20% or greater	100%

The confidence deduction must be updated each time the offset project is subject to verification, but must remain unchanged between verifications. If increased sampling over time results in a lower confidence deduction at the time of verification, the lower deduction must be applied to inventory estimates in the most recent reporting period subject to verification at that time. ARB or registry offset credits may be issued in the most recent reporting period for any verified increase in quantified GHG reductions and GHG removal enhancements associated with the new (lower) confidence deduction. Conversely, if a loss of qualified sampling plots results in a higher confidence deduction, this higher deduction is applied to the inventory estimates in the most recent reporting period subject to verification at that time. Any resulting decrease in quantified GHG reductions and GHG removal enhancements from prior years as a result of the increased confidence deduction will be treated as an intentional reversal, and must be compensated pursuant to the Regulation.

Appendix B Modeling Carbon Stocks

Quantification Methodology

This protocol requires the use of certain empirical-based models to estimate the baseline carbon stocks and project stocks of selected carbon pools within the Project Area. These models may also be used to supplement assessments of actual changes in carbon stocks resulting from the Forest Project.

B.1 About Models and Their Eligibility for Use with Forest Projects

Empirical-based models are used for estimating existing values where direct sampling is not possible or cost-effective. They are also used to forecast the estimations derived from direct sampling into the future. Field measurements provide the basis for inferring value through the use of these models.

The models that simulate growth projections have two basic functions in the development and management of a forest project. Models project the results of direct sampling through simulated forest management activity. These models, often referred to as growth and yield simulation models, may project information regarding tree growth, harvesting, and mortality over time – values that must ultimately be converted into carbon in an additional step. Other models may combine steps and estimate tree growth and mortality, as well as changes in other carbon pools and conversions to carbon, to create estimated projections of carbon stocks over time.

Models are also used to assist in updating inventory plots so that the plots can represent a reporting year subsequent to their actual sample date. The model simulates the diameter and height increment of sampled trees for the length of time between their sampled date and the reporting year. The limit to the use of models for updating plot data is described in Appendix A.

The following growth models have been approved:

- CACTOS: California Conifer Timber Output Simulator
- CRYPTOS: Cooperative Redwood Yield and Timber Output Simulator
- FVS: Forest Vegetation Simulator
- SPS: Stand Projection System
- FPS: Forest Projection System
- FREIGHTS: Forest Resource Inventory, Growth, and Harvest Tracking System
- CRYPTOS Emulator
- FORESEE

Inventory plot data may be updated for estimating diameter and height growth by incorporating data obtained from sample plots, as in a stand table projection. To qualify for this method:

- The Project Area shall be stratified into even-age management and uneven-age management.
- Diameter increment shall be based on the average annual increment of a minimum of 20 samples of radial growth for diameter increment for each 8” DBH (diameter at breast height) class, beginning at 0 – 8” DBH for each management (even-age or uneven-age) type. The average annual increment shall be added for each year according to the plot’s sample date.
- Height increment shall be based on regression curves for each management type (even-age or uneven-age) developed from height measurements from the same trees the

diameter increment data was obtained. The estimated height shall be determined using the regression estimators for the 'grown' diameters as described above.

Additional models will be allowed following approval of a state forestry authority (i.e. a state agency responsible for oversight of forests) who will acknowledge in writing that the model:
- Has been peer reviewed in a process that: 1) primarily involved reviewers with necessary technical expertise (e.g. modeling specialists in relevant fields of biology, forestry, ecology, etc.), and 2) was open and rigorous
- Is parameterized for the specific conditions of the Project Area
- Limits use to the scope for which the model was developed and evaluated
- Is clearly documented with respect to the scope of the model, assumptions, known limitations, embedded hypotheses, assessment of uncertainties, and sources for equations, data sets, factors or parameters, etc.
- Underwent a sensitivity analysis to assess model behavior for the range of parameters for which the model is applied
- Is reviewed at least every 10 years

B.2 Using models to forecast carbon stocks

The use of simulation models is required for estimating a Forest Project's baseline carbon stocks. Models may also be required to forecast actual carbon stocks expected under the Forest Project (e.g. in conjunction with determining expected harvesting volumes or in updating forest carbon inventories).

Inventory information from Appendix A must be incorporated into the simulation models to project carbon stocks over time. If a model has the ability to convert biomass to carbon, it must include all the carbon pools required by this protocol.

Projected baseline or actual carbon stocks must be portrayed in a graph depicting time in the x-axis and carbon tons in the y-axis. Baseline carbon stocks must be projected forward from the date of the Forest Project's offset project commencement. The graph should be supported with written characterizations that explain any annual changes in baseline carbon stocks over time. These characterizations must be consistent with the baseline analysis required in Section 0.

B.3 Modeling Requirements

A modeling plan must be prepared that addresses all required forecasting or updating of baseline and actual carbon stocks for the Forest Project. The modeling plan shall contain the following elements:

1. A description of all silviculture methods modeled. The description of each silviculture method will include:
    a. A description of the trees retained (by species groups if appropriate) at harvest.
    b. The harvest frequency (years between harvests).
    c. Regeneration assumptions.
2. A list of all legal constraints that affect management activities on the Project Area. This list must identify and describe the constraint and discuss the silviculture methods that will be modeled to ensure the constraint is respected.
3. A description of the site indexes used for each species and an explanation of the source of the site index values used.
4. A description of the model used and an explanation of how the model was calibrated for local use, if applicable.

Modeling outputs must include:

1. Periodic harvest, inventory, and growth estimates for the entire Project Area presented as total carbon tons and carbon tons per acre.
2. Harvest yield streams on modeled stands, averaged by silviculture method and constraints, which must include the period over which the harvest occurred and the estimated volume of wood removed.

Appendix C Estimating Carbon in Wood Products

Quantification Methodology

Wood products may constitute a reservoir for storing carbon over the long term. Projects that increase wood product production can receive credit for the resulting incremental carbon storage. By the same token, projects that reduce wood product production must account for the incremental *reduction* in stored wood product carbon. As indicated in Section 7, GHG reductions and GHG removal enhancements must be effectively "permanent," meaning that sequestered carbon associated with GHG reductions and removals must remain stored for at least 100 years. Wood product carbon is estimated by calculating the average amount of carbon that is likely to remain stored in wood products over a 100-year period.

The processes described here are adapted from the 1605(b) methodology (U.S. Department of Energy, 2007) for accounting for the long-term storage of wood products. Please see Smith, Heath, Skog, & Birdsey (2006) for a more detailed description since the 1605(b) procedure was adapted from this publication.

Because of the significant uncertainties associated with predicting wood product carbon storage over 100 years, the accounting requirements in this appendix are designed to err on the side of conservativeness. This means the calculations are designed to reduce the risk of overestimating the GHG reductions and GHG removal enhancements achieved by a Forest Project. One of the largest sources of uncertainty is predicting the amount of wood product carbon likely to be stored in landfills. To accommodate this uncertainty, and ensure that Forest Project GHG reductions and GHG removal enhancements are accounted for conservatively:

1. Landfill carbon storage is *excluded* from calculations of wood-product carbon in years where a Forest Project's actual harvesting volumes exceed estimated baseline harvesting volumes, as determined in Section 6.
2. Landfill carbon storage is *included* in calculations of wood-product carbon in years where a Forest Project's actual harvesting volumes are below estimated baseline harvesting volumes, as determined in Section 6.

Accounting for wood product carbon must be applied only to actual or baseline volumes of wood harvested from within the Project Area. Trees harvested outside of the Project Area are not part of the Forest Project and must be excluded from any calculations.

There are five steps required to determine carbon stored in wood products:

1. Determining the amount of carbon in harvested wood that is delivered to mills.
2. Accounting for mill efficiencies.
3. Estimating average carbon storage over 100 years in in-use wood products.
4. Estimating average carbon storage over 100 years in wood products in landfills (when applicable).
5. Summing the results to determine total average carbon storage over 100 years.

C.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:

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 volumes and species are derived from modeling a baseline harvesting scenario, following the requirements in Section 6.
   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.
2. If a volume measurement is used, multiply the cubic foot volume by the appropriate wood density factor in Table C.1 (for projects located in the Pacific Southwest) or from the USFS Wood Handbook (other regions).[9] This results in pounds of biomass with zero moisture content.
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. Sum the dry weights for each harvested species to get a total dry weight for all harvested wood.
5. Multiply this total value by 0.5 pounds of carbon/pound of wood to compute the total carbon weight.
6. Divide the total carbon weight by 2,204.6 pounds/metric ton to convert to metric tons of carbon. This value is used in the next step, accounting for mill efficiencies.

Table C.1. Specific gravity and Wood Density of green softwoods and hardwoods by forest type for the Pacific Southwest from Table 1.4.

Forest Type	Specific Gravity of Softwoods	Specific Gravity of Hardwoods	Wood Density of Softwoods (lbs/ft^3)	Wood Density of Hardwoods (lbs/ft^3)
Mixed conifer	0.394	0.521	24.59	32.51
Douglas-fir	0.429	0.483	26.77	30.14
Fir-spruce-hemlock	0.372	0.510	23.21	31.82
Ponderosa pine	0.380	0.510	23.71	31.82
Redwood	0.376	0.449	23.46	28.02

C.2 Account for Mill Efficiencies

Multiply the total carbon weight (metric tons of carbon) derived in C.1 by the mill efficiency identified for the project's Assessment Area in the Forest Offset Protocol Resources section of ARB's website. This is the total carbon transferred into wood products. The remainder of the harvested carbon is considered to be immediately emitted to the atmosphere for accounting purposes in this protocol.

C.3 Estimate the Average Carbon Storage Over 100 Years in In-Use Wood Products

The amount of carbon that will remain stored in in-use wood products for at least 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

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[9] The Wood Handbook (USFS, 2010) contains specific gravities for tree species in other regions. Multiply the specific gravity by the density of water (62.43 lbs/ft^3) to get wood density.

decomposition of harvested wood over time, a decay rate is applied to wood products according to their product class. To approximate the climate benefits of carbon storage, this protocol accounts for the average amount of carbon stored over 100 years. Thus, decay rates for each wood product class have been converted into "average storage factors" in

Table C.2, below.

To determine the average carbon storage in in-use wood products over 100 years, the first step is to determine what percentage of a Project Area's harvest will end up in each wood product class (Columns A-G in

Table C.2). This must be done by either:

1. 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
2. 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 Forest Offset Protocol Resources section of ARB's website.

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

Once the breakdown of in-use wood product categories is determined, use the worksheet in

Table C.2 to estimate the average amount of carbon stored in in-use wood products over 100 years:

1. Assign a percentage to each product class (columns A-G) according to mill data or default values for the project.
2. Multiply the total carbon transferred into wood products (determined in Section C.2) by the percentages in each column and insert the resulting values into boxes 3A through 3G.
3. Multiply the values in 3A-3G by the 100-year average storage factor and insert the results into boxes 4A through 4G.
4. Use Equation C.1 to calculate the average carbon stored in in-use wood products over 100 years (in units of CO_2-equivalent metric tons).

Equation C.1. Average Carbon Stored in In-Use Wood Products

$$WP_{in\text{-}use, y} = \sum(\text{Table C.2, Row 4}) \times 3.67$$

Where,

$WP_{in\text{-}use, y}$	=	Average carbon stored in in-use wood products over 100 years from wood harvested in year y (actual or baseline)

Table C.2. Worksheet to Estimate Long-Term Carbon Storage In In-Use Wood Products

	A	B	C	D	E	F	G
Wood Product Class	Softwood Lumber	Hardwood lumber	Softwood Plywood	Oriented Strandboard	Non Structural Panels	Miscellaneous Products	Paper
% in each class	(X%)	(X%)	(X%)	(X%)	(X%)	(X%)	(X%)
Metric tons C in each class	(3A)	(3B)	(3C)	(3D)	(3E)	(3F)	(3G)
100-year average storage factor (in-use)	0.463	0.250	0.484	0.582	0.380	0.176	0.058
Average C stored in in-use wood products (metric tons)	(4A)	(4B)	(4C)	(4D)	(4E)	(4F)	(4G)

C.4 Estimate the Average Carbon Storage Over 100 Years for Wood Products in Landfills

Wood product carbon in landfills is only calculated for years in which a Forest Project's actual harvesting volumes are below estimated baseline harvesting levels, as determined in Section 6. To determine the appropriate value for average landfill carbon storage, perform the following steps:

Step 1 – Calculate the average carbon storage over 100 years for wood products in landfills

Use the worksheet in

Table C.3 to estimate the average amount of wood product carbon stored in landfills over 100 years:

1. Assign a percentage to each product class (columns A-G) according to mill data or default values for the project (as determined in Section C.3).
2. Multiply the total carbon transferred into wood products (determined in Section C.2) by the percentages in each column and insert the resulting values into boxes 3A through 3G.
3. Multiply the values in 3A-3G by the 100-year average storage factor for landfill carbon and insert the results into boxes 4A through 4G.

Table C.3. Worksheet to Estimate Long-Term Carbon Storage in Wood Products in Landfills

	A	B	C	D	E	F	G
Wood Product Class	Softwood Lumber	Hardwood lumber	Softwood Plywood	Oriented Strandboard	Non Structural Panels	Miscellaneous Products	Paper
% in each class	(X%)	(X%)	(X%)	(X%)	(X%)	(X%)	(X%)
Metric tons C in each class	(3A)	(3B)	(3C)	(3D)	(3E)	(3F)	(3G)
100-year average storage factor (landfills)	0.298	0.414	0.287	0.233	0.344	0.454	0.178
Average C stored in landfills (metric tons)	(4A)	(4B)	(4C)	(4D)	(4E)	(4F)	(4G)

Step 2 – Determine the appropriate value to use for wood product carbon in landfills

Use Equation C.2. Average Wood Product Carbon Stored in Landfills to determine the appropriate value for the average wood product carbon stored in landfills over 100 years (in units of CO_2-equivalent metric tons).

Equation C.2. Average Wood Product Carbon Stored in Landfills

$$If \sum_{n=1}^{y}(AC_{hv,n} - BC_{hv,n}) < 0, then\, WP_{landfill,y} = \sum(Table\ \text{C.3}, Row\ 4) \times 3.67$$

$$If \sum_{n=1}^{y}(AC_{hv,n} - BC_{hv,n}) > 0, then\ WP_{landfill,y} = 0$$

Where,

$WP_{\mathbf{landfill,\ y}}$	=	Average carbon stored in wood products in landfills over 100 years from wood harvested in the current year/reporting period (actual or baseline)
$AC_{hv,\ n}$	=	Actual amount of onsite carbon harvested in reporting period n (prior to delivery to a mill), expressed in CO_2-equivalent tons
$BC_{hv,\ n}$	=	Estimated average baseline amount of onsite carbon harvested in reporting period n (prior to delivery to a mill), expressed in CO_2-equivalent tons
y	=	The current year or reporting period

C.5 Determine Total Average Carbon Storage in Wood Products Over 100 Years

The total average carbon storage in wood products over 100 years for a given harvest volume (as determined in Section C.1) must be calculated and reported as follows (Equation C.3). The value derived for WP_{total} must be used for actual and baseline wood product carbon estimates ($AC_{wp,y}$ or $BC_{wp,y}$ in Equation 6.1) as appropriate, following the guidance in Section 6.

Equation C.3.

$$WP_{total,\,y} = WP_{in\text{-}use,\,y} + WP_{landfill,\,y}$$

Where,

$WP_{total,\,y}$	=	Average carbon stored over 100 years from wood harvested in year y (actual or baseline)
$WP_{in\text{-}use,\,y}$	=	Average carbon stored in in-use wood products over 100 years from wood harvested in year y (actual or baseline)
$WP_{landfill,\,y}$	=	Average carbon stored in wood products in landfills over 100 years from wood harvested in year y (actual or baseline)

Appendix D Determination of a Forest Project's Reversal Risk Rating

A reversal risk rating must be determined for the Forest Project using the worksheets in this section. The worksheets are designed to identify and quantify the specific types of risks that may lead to a reversal, based on project-specific factors.

This risk assessment must be updated every time the Forest Project undergoes a verification site visit. Therefore, a Forest Project's risk profile and its assessment are dynamic. If estimated risk values and associated mitigation measures are updated as improvements in quantifying risks or changes in risks are determined, any adjustments to the risk ratings will affect only current and future year contributions to the Forest Buffer Account.

Risks that may lead to reversals are classified into the categories identified in Table D.1.

Table D.1. Forest Project Risk Types

Risk Category	Risk Type	Description	How managed in this protocol
Financial	Financial Failure Leading to Bankruptcy	Financial failure can lead to bankruptcy and/or alternative management decisions to generate income that result in reversals through over-harvesting or conversion	Default Risk
Management	Illegal Harvesting	Loss of project stocks due to timber theft	Default by Area
	Conversion to Non-Forest Uses	Alternative land uses are exercised at project carbon expense	Default Risk
	Over-Harvesting	Exercising timber value at expense of project carbon	Default Risk
Social	Social Risks	Changing government policies, regulations, and general economic conditions	Default Risk
Natural Disturbance	Wildfire	Loss of project carbon through wildfire	Default Risk
	Disease/Insects	Loss of project carbon through disease and/or insects	Default Risk
	Other Episodic Catastrophic Events	Loss of project carbon from wind, snow and ice, or flooding events	Default Risk

D.1 Financial Risk

Financial failure of an organization resulting in bankruptcy can lead to dissolution of agreements and forest management activities to recover losses that result in reversals. Forest Projects that employ a Qualified Conservation Easement, or that occur on public lands, have lower risk.

Table D.2. Financial Risk Identification

Applies to all projects		
Identification of Risk	**Contribution to Reversal Risk Rating**	
	Forest Project not on public lands or without a Qualified Conservation Easement	**Forest Project on public lands or with a Qualified Conservation Easement**
Default Financial Risk	5%	1%

D.2 Management Risk

Management failure is the risk of management activities that directly or indirectly could lead to a reversal. Forest Projects that occur on public lands, or employ a Qualified Conservation Easement are exempt from this risk category.

Management Risk I – Illegal Removals of Forest Biomass

Illegal logging occurs when biomass is removed either by trespass or outside of a planned set of management activities that are controlled by regulation. Illegal logging is exacerbated by lack of controls and enforcement activities.

Table D.3. Risk of Illegal Removals of Forest Biomass

Applies to all projects	
Identification of Risk	**Contribution to Reversal Risk Rating**
United States Default Harvesting Risk	0%

Management Risk II – Conversion of Project Area to Alternative Land Uses

High values for development of housing and/or agriculture may compete with timber and carbon values and lead to a change in land use that affects carbon stocks. The risk of conversion of any Project Area to other non-forest uses is related to the probability of alternative uses, which are affected by many variables, including population growth, topography, proximity to provisions and metropolitan areas, availability of water and power, and quality of access to the Project Area.

Table D.4. Risk of Conversion to Alternative Land Use

Applies to all projects	
Identification of Risk	**Contribution to Reversal Risk Rating**
With Qualified Conservation Easement that explicitly encumbers all development rights	0%
Without Qualified Conservation Easement	2%

Management Risk III – Over-Harvesting

Favorable timber values, among other reasons, may motivate an Offset Project Operator or Authorized Project Designee to realize timber values at the expense of managing carbon stocks for which ARB or registry offset credits have been issued. Additionally, reversals can occur as the result of harvest associated with fuels treatments.

Table D.5. Risk of Over-Harvesting

Applies to all projects	
Identification of Risk	**Contribution to Reversal Risk Rating**
With Qualified Conservation Easement that explicitly encumbers timber harvesting associated with project stocks	0%
Without Qualified Conservation Easement	2%

D.3 Social Risk

Social risks exist due to changing government policies, regulations, and general economic conditions. The risks of social or political actions leading to reversals are low, but could be significant.

Table D.6. Social Risk Identification

Applies to all projects	
Identification of Risk	**Contribution to Reversal Risk Rating**
United States Default Social Risk	2%

D.4 Natural Disturbance Risk

Natural disturbances can pose a significant risk to the permanence of the GHG reductions and GHG removal enhancements. Natural disturbance risks are only partially controllable by management activities. Management activities that improve resiliency to wildfire, insects, and disease can reduce these risks. Management activities that shift harvesting practices from live sequestering trees to trees that have succumbed to natural disturbances reduce or negate the reversal depending on the size and location of the disturbance.

Natural Disturbance Risk I – Wildfire

A wildfire has the potential to cause significant reversals, especially in certain carbon pools. These risks can be reduced by certain techniques including reducing surface fuel loads, removing ladder fuels, adding fuel breaks, and reducing stand density. However, these techniques cannot reduce emission risk to zero because all landowners will not undertake fuel treatments, nor can they prevent wildfire from occurring.

Table D.7. Natural Disturbance Risk I – Wildfire

Applies to all projects	
Identification of Risk	**Contribution to Reversal Risk Rating**
United States Default Fire Risk	4%
If fuel treatments have been implemented for the Project Area, reduce the value above by the appropriate Y% as indicated below.*	(4%) x Y%

* Depending on the level of fuel treatments, the Y% is set as follows:

- high level of fuel treatments = 50%,
- medium level of fuel treatments = 66.3%,
- low level of fuel treatments = 82.6%,
- no fuel treatments = 100%.

Natural Disturbance Risk II - Disease or Insect Outbreak

A disease or insect outbreak has the potential to cause a reversal, especially in certain carbon pools.

Table D.8. Natural Disturbance Risk II – Disease or Insect Outbreak

Applies to all projects	
Identification of Risk	**Contribution to Reversal Risk Rating**
Default Risk Contribution from Disease or Insect Outbreak	3%

Natural Disturbance Risk III - Other Episodic Catastrophic Events

A major wind-throw event (hurricane, tornado, high wind event) has the potential to cause a reversal, especially in certain carbon pools.

Table D.9. Natural Disturbance Risk III – Other Episodic Catastrophic Events.

Applies to all projects	
Identification of Risk	**Contribution to Reversal Risk Rating**
Default Risk Contribution from Other Catastrophic Events	3%

D.5 Summarizing the Risk Analysis and Contribution to Buffer Account

Use table D.10 to summarize the Forest Project's reversal risk rating. As indicated above, projects that employ a Qualified Conservation Easement, or that occur on public lands, are exempt from certain risk categories. Such Qualified Conservation Easements must clearly identify the goals and objectives of the Forest Project according to the terms of this protocol.

Table D.10. Project Contribution to the Buffer Account Based on Risk.

Risk Category	**Contribution from Risk Descriptions Above**		
	Source	Forest Project without a Qualified Conservation Easement and/or Public Ownership	Forest Projects with a Qualified Conservation Easement and/or Public Ownership
Financial Failure	Default Risk	5%	1%
Illegal Forest Biomass Removal	Default Risk	0%	0%
Conversion	Default Risk	2%	0%
Over-Harvesting	Default Risk	2%	0%
Social	Default Risk	2%	2%
Wildfire	Calculated Risk from worksheet	X%	X%
Disease or Insect Outbreak	Calculated Risk from worksheet	3%	3%
Other Catastrophic Events	Calculated Risk from worksheet	3%	3%

Completing the Risk Rating Analysis:

The Forest Project's reversal risk rating is calculated as follows:

$$100\% - \begin{pmatrix} (1 - FinancialFailure\%) \times (1 - IllegalForestBiomassRemoval\%) \times (1 - Conversion\%) \\ \times (1 - OverHarvesting\%) \times (1 - SocialRisk\%) \times (1 - Wildfire\%) \times (1 - Disease/InsectOutbreak\%) \\ \times (1 - OtherCatastrophicEvents\%) \end{pmatrix}$$

Appendix E Reforestation Project Eligibility

This appendix presents a standardized approach to determine whether reforestation activities on lands that have undergone a Significant Disturbance are likely to be "business as usual," and therefore not eligible for registration based on the net present value for the timber expected to be produced from reforestation. A reforestation project is considered "business as usual" if the net present value for expected timber is $0 or more according to standard assumptions underlying Table E.1.

To determine whether a reforestation project is eligible, perform the following steps:

1. Identify whether site preparation costs[10] are High or Low:
    a. Site preparation costs are High if:
        i. Competing species management (including mechanical removal and/or use of herbicides) has been or will be conducted on 50 percent or more of the Project Area; or
        ii. Soil ripping has occurred on more than 50 percent of the Project Area.
    b. Site preparation costs are Low for all other projects.
2. Identify the value of harvested products (High, Medium, Low, or Very Low) corresponding to the project's Assessment Area, from the lookup table in the Forest Offset Protocol Resources section of ARB's website.
3. Identify the standard Rotation Age for the project's Assessment Area, from the lookup table in the Forest Offset Protocol Resources section of ARB's website.
4. Identify the site class category for the Project Area. The category must be consistent with the stated site productivity in the project's submission form. Projects with mixed site classes must round to the nearest site class category based on a weighted average.
    a. Site Classes I and II are classified as 'Higher'.
    b. Site Classes III, IV, and V are classified as 'Lower'.
5. Determine whether the Forest Project is "eligible" or "not eligible" according to the identified site preparation costs, value of harvested products, rotation age, and site class, as indicated in Table E.1.

[10] All Forest Projects are assumed to have similar costs related to the cost of seedlings and planting; site preparation costs, however, can vary depending on circumstances.

Table E.1. Determination of Reforestation Project Eligibility

Site Preparation Costs	Value of Harvested Products	Rotation Age (Length)	Site Class	Eligibility	Scenario #
High Site Preparation	High	Short, Medium, Long	Higher	Not Eligible	1
			Lower	Not Eligible	2
		Extremely Long	Higher	Eligible	3
			Lower	Eligible	4
	Medium	Short, Medium	Higher	Not Eligible	5
			Lower	Not Eligible	6
		Long	Higher	Not Eligible	7
			Lower	Eligible	8
		Extremely Long	Higher	Eligible	9
			Lower	Eligible	10
	Low	Short	Higher	Not Eligible	11
			Lower	Eligible	12
		Medium, Long, Extremely Long	Higher	Eligible	13
			Lower	Eligible	14
	Very Low	Short, Medium, Long, Extremely Long	Higher	Eligible	15
			Lower	Eligible	16
Low Site Preparation	High	Short, Medium	Higher	Not Eligible	17
			Lower	Not Eligible	18
		Long, Extremely Long	Higher	Not Eligible	19
			Lower	Eligible	20
	Medium	Short, Medium	Higher	Not Eligible	21
			Lower	Not Eligible	22
		Long	Higher	Not Eligible	23
			Lower	Eligible	24
		Extremely Long	Higher	Eligible	25
			Lower	Eligible	26
	Low	Short	Higher	Not Eligible	27
			Lower	Not Eligible	28
		Medium	Higher	Not Eligible	29
			Lower	Eligible	30
		Long, Extremely Long	Higher	Eligible	31
			Lower	Eligible	32
	Very Low	Medium, Long, Extremely Long	Higher	Eligible	33
			Lower	Eligible	34
		Short	Higher	Not Eligible	35
			Lower	Not Eligible	36

Appendix F Determining a Value for Common Practice

Quantification Methodology

Forest Assessment Areas Introduction
Assessment areas are used to provide standardized regional data for offset project development. An assessment area is generally defined as a forest vegetation community that shares common environmental, economical, and regulatory attributes. The Forest Offset Protocol Resources section of ARB's website provides data, by assessment area, necessary to calibrate and/or implement project accounting, including:

- Common Practice – The average carbon stocks (metric tons) of the above ground portion of live trees on private lands. The average carbon stock is the result of the suite of management activities within the assessment area. The common practice value is the extent to which improved forest management projects can receive credit for avoided emissions. (See Section 6.2.)
- Diversity Index – The maximum amount (by carbon percentage) of any one native species allowed within a project. (See Section 3.9.2.)
- The rotation length commonly used in the assessment area and the value of harvest for incorporating in a financial test for reforestation projects (see Appendix E).
- The mill efficiency used for calculating wood products (see Appendix C).
- The wood product classes generated for calculating wood products values (see Appendix C).

Defining Assessment Areas

The U.S. Forest Service Forest Inventory and Analysis Program (FIA) is the basis for development of assessment areas. The FIA program collects data on U.S. forests using an extensive array of coordinated sample plots throughout the nation. Together the plots comprise a national inventory system designed to assess the state of U.S. forests on an ongoing basis. The hierarchical and spatial nature of FIA data make it possible to group sample field plots by geographical location. FIA plots are assigned an attribute referred to as 'forest type' that identifies the dominant vegetation present at the plot. Forest Types were combined into forest communities following a process described further below. An assessment area is a forest community within a defined geographical unit. The geographical units are discussed below.

Ecosections are spatial units and can be mapped. The geographical units that contain assessment areas are based on individual ecosections or combined ecosections (called supersections). Supersections were created in order to stratify the plots into high site class and low site class (where possible) and to increase the statistical reliability of the common practice estimates derived for each assessment area. The combination of ecosections into supersections only occurred where adjacent ecosections share similar environmental, economic, and regulatory attributes. Ecosections are combined into supersections if:

1. The ecosections are adjacent to each other.
2. They share a similar distribution of plots by forest types, which indicates that the ecosections share similar climate, elevation, and other environmental variables.
3. The economics of forest management are similar between the ecosections. The criteria considered to determine economic commonality between ecosections include forest product

generation, transportation networks, forest product mill types, and wood products markets. This was based on professional knowledge of regional timber markets.
4. Regulations between ecosections are relatively homogeneous across ecosection boundaries. Ecosections are not combined into supersections in cases where forest practice regulations between adjoining administrative units are known to be markedly different.

The Forest Service computed the statistics for the combined forest types aggregated at the supersection level and disaggregated at the ecosection level. The statistics are reported on a per acre basis and include board foot volume, basal area (square feet), above ground carbon tons, and the sampling error. Ecosections were not combined into supersections if the aggregation changed average standing carbon stocks of any assessment areas by more than 10%, indicating that there are environmental, economic or regulatory differences affecting the forest stocks within these communities.

The aggregation of forest types into forest communities that define assessment areas is based on the natural forest communities found within the ecosections rather than the presence of a single dominant species as in plantation management. As an example, the Northwest Coast Range contains many forest holdings of intensively managed Douglas-fir forests, yet the natural forest community contains many other species such as western hemlock, Sitka spruce, and red alder, among others. The plots used to define the assessment area, as well as the common practice statistic, are the entire set of plots found in the natural forest community. No effort is made to isolate assessment areas based on the existence of plantations. Successional stage, including the presence of shade tolerance species, and management influence on species prevalence is not a basis for stratifying distinct communities. The Forest Offset Protocol Resources data on ARB's webpage displays the associations of forest species (forest types) and assessment areas for all of the ecosections and supersections. Figure F.1 summarizes conceptually the methodology for delineating assessment areas.

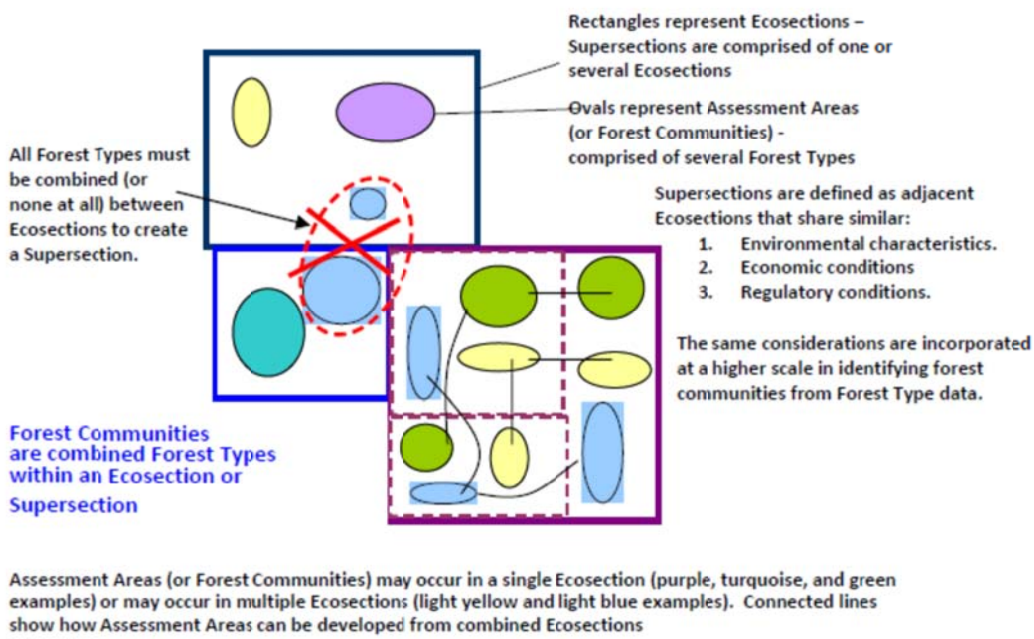

Figure F.1 Schematic of Process to Define Assessment Areas

Determining a Value for Common Practice

The following requirements and methods provide step by step instructions for determining the appropriate Common Practice value for an Improved Forest Management project based on its geographic location and boundaries.

1. **Determine the Geographic Ecosection(s) or Supersection(s) Within Which the Project Area is Located**
   The Offset Project Operator or Authorized Project Designee must determine the geographic Ecosection(s) or Supersection within which the Project Area is located by consulting maps of Supersections. These maps can be downloaded from the Forest Offset Protocol Resources section of ARB's website in either a .pdf format or a Geographical Information System (GIS) shapefile.

2. **Determine the Acreage of the Project Area That Falls Within Each Assessment Area Contained in the Ecosection(s) or Supersection(s)**

   Ecosections and Supersections may consist of one or many Assessment Areas. Assessment Areas are groupings of tree species that are commonly found in association with each other, as in a vegetation community. Assessment Areas are not mapped since the geographic locations of forest communities vary based on highly resolute environmental variables. To determine which Assessment Areas are included within the Project Area, compare the tree species in the Project Area to the species list associated with each Assessment Area in the project's Ecosection(s) or Supersection(s) (identified in Step 1). Tree species information must be looked up using the most current Assessment Area Data File from the Forest Offset Protocol Resources section of ARB's website. The minimum mapping resolution for vegetation communities is 20 acres. Therefore, any contiguous area 20 acres or greater within the Project Area that consists of a separate vegetation community must be independently mapped.

3. **Where Necessary, Stratify Project Area Acres According to Whether They Are High or Low Site Class**

   The Assessment Area Data File on the Forest Offset Protocol Resources section of ARB's website provides data for each Assessment Area by high, low, or all site classes. For Assessment Areas where data are attributed for high and low site classes, the Offset Project Operator or Authorized Project Designee must further stratify the Project Area and identify the acreage that falls within each site class.

   The computation of the statistics in the Assessment Area Data File (on a per acre basis) for board foot volume, basal area (square feet), and CO_2 equivalent was done for high and low site classes wherever the FIA plots were available in adequate quantity to achieve a sampling error of 18 percent or less. The board foot volume and basal area statistics are presented only to elucidate comparisons to the Common Practice (CO_2 equivalent) statistic. Board foot volume and basal area statistics are not used for other purposes in the protocol.

   For stratification purposes, a "high" site class means a Timber Site I or II (Forest Service Types I, II, and III). A low site class means a Timber Site III, IV, or V (Forest Service Types IV – VII). Landowners must determine the portion of the Project Area that is in each site class for each Assessment Area using soils data from a state or federal agency, direct site class data from a state or federal agency, attestation from a state forester, or through field analysis. Whatever method is used, documentation of the analysis must be provided to the verifier at the project's initial verification.

4. **Identify the Common Practice Statistic Associated with Each Assessment Area and Site Class Stratum**

   For each Assessment Area and Site Class within the Project Area, identify the appropriate Common Practice statistic from Assessment Area Data File. The value displayed in the Assessment Area Data File indicates CO_2 equivalent metric tons per acre in the above ground portion (bole, bark, top and branches) of live trees.

   If data for an Assessment Area are provided for both high and low site classes, and a Offset Project Operator or Authorized Project Designee is unable or unwilling to stratify the Project Area into site classes using an acceptable method described above, then the high site-class Common Practice statistic must be used for all acres within the Assessment Area.

5. **Determine a Value for Common Practice for the Entire Project Area**

   Determine a single Common Practice value for the entire Project Area by calculating the average of the Common Practice statistics for each Assessment Area and site class, weighted by the number of acres of each Assessment Area and site class within the Project Area. See Table F1 for an example.

Table F1. Example of Common Practice Statistic Calculation

Ecosection(s) /Supersection(s)	Assessment Area	Site Class	Acres	Common Practice (Metric Tons CO2-e)
Name the Ecosection(s)/Supersection(s) the project is found within.	*Identify the Assessment Areas the project is in. If the project is in more than one site class for an Assessment Area, enter the Assessment Area twice*	*Enter the Site Class Value*	*Acres for each Assessment Area-Site Class Combination*	*Enter the Value from the most current Assessment Area Data File*
Adirondacks & Green Mountains	Adirondacks & Green Mountains Northeast Conifers	High	1,000	91.8
Adirondacks & Green Mountains	Adirondacks & Green Mountains Northeast Conifers	Low	100	84.4
Adirondacks & Green Mountains	Adirondacks & Green Mountains Northern Hardwood	High	50	102.8
Total Acres / Weighted Average Common Practice			**1,150**	**91.6**