GHR005 Methodology for Assessing Emission Reductions from Rice Cultivation

Version 1.0
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GLOBAL HEAT REDUCTION™

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1 Introduction

This Methodology has been developed for use in connection with the Global Heat Reduction (GHR) Registry (the "Registry"), consistent with the requirements of the GHR Registry Standard[1]. It is intended for use in evaluating projects under selected project types and within geographic regions identified herein.

The Methodology uses the standard nomenclature of "shall" or "must" for required clauses and "should" or "may" for suggested clauses. All documentation and reporting under this methodology must be conducted in English, with translations provided where necessary to accommodate local stakeholders.

2 Methodology Overview

2.1 Methodology Description

This methodology enables the quantification of reductions in multiple climate forcers, including methane (CH_4), nitrous oxide (N_2O), and black carbon (BC) that result from sustainable rice cultivation practices such as water management, reduced nitrogen application, and avoided biomass burning thereby enabling a more comprehensive radiative forcing-based climate impact assessment. This methodology is based on the Clean Development Mechanism (CDM) methodology *AMS.III-AU Small Scale Methodology: Methane emission reduction by adjusted water management practice in rice cultivation Version 04.0*[2], Gold standard-GS437[3] and Verra-VCS0051[4] and the Climate Action Reserve's *U.S. Rice Cultivation Project Protocol Version 1.1*[5]*,* and references to the application of the Denitrification-Decomposition (DNDC) biogeochemical process model therein. This GHR Methodology follows the IPCC (2019) Guidelines for Greenhouse Gas Inventories[6], and the DNDC model[7] ensuring methodological consistency with international standards.

This methodology is designed to ensure that credits issued represent additional, permanent, independently verified, and rigorously quantified reductions in rice cultivation. Final approval of a project under this methodology is granted exclusively by the GHR Registry.

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[1] Located at: Documents | Heat Reduction

[2] AMS.III-AU Small Scale Methodology: Methane emission reduction by adjusted water management practice in rice cultivation Version 04.0. Available at: https://cdm.unfccc.int/UserManagement/FileStorage/5IP163JN4RKG2D0XOQZS9T7W8MEYAC

[3] Gold Standard GS437: Appendix A – Guidelines for measuring methane emissions from rice fields

[4] Verra VM0051: Appendix 2 – Guidelines for Field Measurements under Quantification Approach 2

[5] U.S. Rice Cultivation Project Protocol Version 1.1. Available at: https://www.climateactionreserve.org/wp-content/uploads/2023/10/Rice-Protocol-v1.1-combined.pdf

[6] 2019 Refinement to the 2006 IPPCC Guidelines for National Greenhouse Gas Inventories. Available at: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories — IPCC

[7] Li, C. et al. (2010). *Modeling greenhouse gas emissions from rice-based production systems: Sensitivity and upscaling.* Agriculture, Ecosystems & Environment, 136(3–4), 223–231

2.2 Project Type(s) Covered by the Methodology

Projects under this methodology primarily aim to implement agricultural interventions to reduce methane emissions from rice cultivation through switching water management. While the focus of this methodology is on sustainable agricultural practices that result in a reduction in methane emissions, practices that lead to the reduction in CO_2, N_2O and BC are also included. The projects function to promote sustainable agricultural practices and contribute to climate change mitigation by reducing greenhouse gas (GHG) emissions.

2.3 Eligibility Requirements for Projects under the Methodology

To be eligible to register under this methodology, projects must meet all eligibility requirements of the CDM methodology *AMS-III.AU*, Registry Standard, and the following additional criteria:

1. The project proponents must provide proof of legal ownership of the project at the designated site(s) and must have legal rights to the credits generated from the project.
2. The project and project proponents must be in compliance with all applicable local, regional, national, and international regulations and laws.
3. Projects must not lead to a decrease in rice yield that causes significant leakage emissions from production shifts, unless those emissions are quantified and accounted for in accordance with Section 6.3 of this methodology.

2.4 Geographic Scope

Global

3 Materiality, Additionality, Permanence, and Secondary Effects

3.1 Materiality

Materiality refers to information that, if omitted, erroneous, or misstated, would lead to misrepresentation of the radiative forcing (RF) reduction of a project. A materiality assessment is required for projects, with a materiality threshold of ±5% of annual RF reductions in a given monitoring period. Materiality will be assessed by the validation and verification body (VVB) as part of validation and verification process (see Section 7.5).

In this category, errors, omissions, and misrepresentations that could significantly affect the estimation of the RF reduction potential associated with a project include, for example:

- Significant under-estimate or over-estimate of the methane emissions reduced by the operation
- Project is misrepresented in terms of any eligibility or additionality requirements

3.2 Additionality Considerations

The project proponent shall demonstrate additionality for projects that aim to reduce methane emissions from rice cultivation, consistent with the GHR Registry Standard. This involves proving that the project activities lead to GHG reductions that would not have occurred in the absence of the project. The project proponent shall provide clear evidence of additionality in the Project Design Document (see Section 7.1), and ongoing assessments of additionality will be detailed in the Project Monitoring Reports (see Section 7.3).

3.2.1 Regulatory Surplus Test

The project proponent must demonstrate that the project activities are not required by existing laws, regulations, or any legally binding mandates in the project's jurisdiction. If such regulations do exist, the project proponent must provide evidence that the project's scope exceeds the regulatory requirements. This could involve demonstrating that the intervention goes beyond what is mandated or achieves reductions in a more effective or efficient manner.

3.2.2 Common Practice Analysis

The project proponent must show that the project activities are not common practice within the agricultural sector or region. A thorough analysis must be conducted to confirm that the use of sustainable rice farming practices is not widely adopted in the region where the project is implemented. This analysis shall include a review of similar operations in the region surroundings of the project area, supported by reliable data and documented evidence.

3.2.3 Financial Feasibility Test

The project proponent must demonstrate that, without the revenue from carbon credits, the implementation of the project activities would not be financially viable. This can be shown through a financial analysis comparing the project's costs and expected returns with and without the anticipated carbon credit revenue. Additionally, the project proponent must identify and explain any financial barriers, such as high initial costs or lack of access to capital, that would prevent the implementation of the project activities without carbon finance.

3.3 Permanence

The project proponent shall evaluate and report the risk of non-permanence at each monitoring period (see Section 7). By implementing the project activities, the annual methane emissions that would otherwise have been generated shall be permanently reduced. Therefore, there is minimal risk of non-permanence of RF reductions achieved based on the emission reductions achieved through this process.

3.4 Risk of Secondary Effects

If rice yields decrease as a direct result of project activity, to be conservative it is assumed that the decrease in rice production causes a net increase in production elsewhere outside the project boundary. The emissions associated with this shift in production must be estimated if project related yield losses are statistically significant compared to historic and average yields. Secondary effects and leakage must be calculated as detailed in Section 6.3.

4 Baseline and Project Scenario Descriptions

4.1 Baseline Scenario

The baseline scenario represents a business-as-usual situation, representing what would have occurred in the absence of the project activities. In this methodology, the baseline scenario represents the continuation of the current practice e.g. transplanted and continuously flooded rice cultivation in the project fields. Additional GHG emissions resulting from cultivation equipment, fertilizer application, and crop residue burning shall be included in the baseline scenario. The baseline is established based on historical data and standard global emission factors, representing the average methane emissions over at least the three continuous years preceding the project start date based on the number of heads.

The project proponent shall identify and justify the baseline scenario in the Project Design Document[8] (PDD), and monitor and update the scenario as needed in subsequent Project Monitoring Reports.[9]

4.2 Project Scenario

The project scenario is the implementation of rice cultivation practices such as transitioning from continuous flooding to intermittent flooding, using an alternate wetting and drying method or aerobic rice cultivation method, and switching from transplanting to direct seeding, reduction in the usage of nitrogen fertilizers and avoided residue burning. Additional GHG emissions resulting from biomass burning and cultivation equipment are included in the project scenario.

The project proponent shall identify and justify the project scenario in the PDD, and monitor and update the scenario in subsequent Project Monitoring Reports.

4.3 Group Project Scenario

In addition to individual projects, it is possible that multiple operations under one management and ownership system may apply for assessment and credit issuance in an aggregated group. All such individual operations within the aggregated group would be required to meet the requirements of the GHR Registry Standard and this methodology.

[8] Located at: Documents | Heat Reduction
[9] Located at: Documents | Heat Reduction

5 Project Boundaries

5.1 Boundaries for Assessing Radiative Forcing, Radiative Forcing Reduction, Co-benefits, and Trade-offs

The project boundary is the physical, geographical site(s) where applicable rice cultivation practice changes are implemented. The project boundary may include multiple fields which are all undergoing the cultivation method changes as outlined in this methodology as part of the project activity. Stratification of project fields and baseline conditions is encouraged to enhance representativeness of emission estimations. Fields shall be grouped into strata sharing similar cultivation practices and environmental characteristics, including but not limited to water management regime (seasonal and pre-seasonal), type and rate of organic amendment application, soil pH, and soil organic carbon content, as stratification enables the assignment of appropriate baseline emission factors, derived from literature or reference fields to each homogeneous group. The stratification model shall align with guidance provided in Chapter 5.5 of the 2019 Refinement to the 2006 IPCC Guidelines.[10]

The project proponent shall describe the project boundaries in the PDD. Any changes to the project boundaries will be reported in subsequent Project Monitoring Reports.

5.2 Sources, Sinks, and Reservoirs of Radiative Forcing

The project proponent shall account for all significant, project-related climate forcer sources, sinks, and reservoirs (SSRs) within the project boundary. The exclusion of emission sources is permissible, provided the exclusions result in conservatively low crediting and have been tested for their significance to total credit amounts. SSRs (Table 1) that are considered significant and/or have been selected for accounting in the baseline scenario shall also be included in the project scenario.

Table 1. Potential climate forcer sources, sinks, and reservoirs

Project Type: Using sustainable cultivation to reduce methane emissions from rice farming			
Source	Climate Forcer	Included in Calculation	Justification/Explanation
Anaerobic Decay of Soil Organic Carbon	CH_4	Required	Methane emissions which are partially avoided under the project scenario and baseline. Calculated in project and baseline scenarios. Biogenic CO_2 emissions are not included.
Operation of Cultivation Equipment	CO_2, CH_4, N_2O, SF_6, HFCs, CFCs, Black Carbon, Organic	Required	Emissions from the operation of cultivation equipment, such as motors, tractors, tilling equipment etc. The use of grid electricity or

[10] IPCC (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 5: Cropland.

	Carbon, Sulfate Aerosols		burning of fuels to power this equipment results in climate forcer emissions. Calculated in project and baseline scenarios
Biomass Burning	CH_4, N_2O, Black Carbon	Optional	Emissions resulting from biomass burning of agriculture waste/residue. Calculated in project and baseline scenarios.
Nitrogen Soil Emissions and Fertilizer Application	CO_2, CH_4, N_2O	Required	Emissions resulting from the application of nitrogen fertilizers, or due to changes in farming practices applied during the project scenario. Calculated in project and baseline scenarios.
Secondary Effects/Leakage	CO_2, CH_4, N_2O, SF_6, HFCs, CFCs, Black Carbon, Organic Carbon, Sulfate Aerosols	Required	If project activities lead to a reduction in rice yield > RY_{min} calculated below in the first year of implementation, it is conservatively assumed that production will increase outside of the project. Emissions from this increase in production are considered and calculated under the project scenario.

5.3 Guidance for Selecting the Most Suitable Quantification Approach

Table 2. Decision Matrix for Quantification Approach

Step	Question	If YES	If NO
1	Do you have capacity to conduct direct field measurements (e.g., closed chamber sampling for CH_4)?	Use Option 1: Direct Measurement (Tier 3)	Go to step 2
2	Are there national or regional emission factors available from government reports, peer-reviewed literature, or research institutions specific to your project conditions?	Use Option 2: National/Regional Factors (Tier 2)	Reconsider project eligibility or seek technical support

Note: Each option must be supported by evidence in the Project Design Document (PDD), with references or justifications for the choice made. Projects may also shift between options across monitoring periods, provided the data availability conditions change and are transparently documented.

6 Quantification

This methodology offers two pathways for quantifying emission reductions based on the data availability and project capabilities:

Option 1: Direct measurements using field-level data (Tier 3)

Option 2: National or regional emission factors (Tier 2)

Project proponents must follow the most rigorous applicable approach based on the guidance provided in the quantification selection table above.

6.1 Types of Data Required, Accepted Data Sources and Calculation Methods

Information about data and parameters can be found in the calculations and descriptions in sections 6.2 – 6.4, the tools utilized or mandated in this methodology, and in section 7.2. A listing of the monitored and non-monitored data and parameters is available in Appendix A.

6.1.1 OPTION 1: Direct Measurement Approach (Tier 3)

This approach relies on direct field measurements such as closed chamber sampling and is considered the most accurate. Appendices C and D provides the recommended sampling procedures.

The baseline emission factor for continuously flooded fields without organic amendments ($EF_{BL,c}$) shall be either determined ex-ante prior to the start of the project activity (in this case the ex-ante value should be used to calculate emission reduction during the crediting period) or monitored annually (in this case, the ex-post values should be used to calculate emissions reduction during the crediting period). At least three reference fields shall be chosen in the project area. On these fields, measurements shall be carried out using the closed chamber method in accordance with the guidance on methane measurement in Appendix C.

Baseline Scenario Climate Forcer Calculation Methods

For the purpose of defining reference field conditions for baseline and project emission measurements and their comparison with project fields, each project field shall be classified with its specific pattern of cultivation conditions, applying the following parameters under Table 3:

Table 3. Parameters for the definition of cultivation patterns[11]

#	Parameter	Type[a]	Values/categories	Source/method[b]
1	Water regime: on-season[c]	Dynamic	Continuously flooded	Baseline: Farmer's information Project: Monitoring
			Single drainage	
			Multiple drainage	
2	Water regime: pre-season	Dynamic	Flooded (>30 days)	Baseline: Farmer's information Project: Monitoring
			Short drainage (<180 d)	

[11] From CDM AMS-III.AU.

			Long drainage (>180 d)	
3	Organic amendment	Dynamic	Straw on-season[d]	Baseline: Farmer's information Project: Monitoring
			Green manure	
			Straw off-season[d]	
			Farmyard manure	
			Compost	
			No organic amendment	
4	Soil pH	Static	< 4.5	ISRIC-WISE soil property database[e] or national data
			4.5 – 5.5	
			> 5.5	
5	Soil organic carbon	Static	< 1%	ISRIC-WISE soil property database[e] or national data
			1 – 3%	
			> 3%	
6	Climate	Static	[AEZ][f]	Rice Almanac, HarvestChoice[f]

Comments:
(a) Dynamic conditions are those that are connected to the management practice of a field, thus can change over time (no matter whether intended by the project activity or due to other reasons) and shall be monitored in the project fields. Static conditions are site-specific parameters that characterize a soil and do not (relevantly) change over time and thus in principle only have to be determined once for a project and the corresponding fields.
(b) Source/method of data acquisition to determine the applicable value for each parameter.
(c) The values 'upland', 'regular rainfed', 'drought prone', and 'deep water', which are regularly used to differentiate the on-season water regime (see IPCC guidelines), are not mentioned here, because these categories are excluded from a project activity under this methodology (cf. applicability criteria).
(d) Straw on-season means straw applied just before rice season, and straw off-season means straw applied in the previous season. Rice straw that was left on the surface and incorporated into soil just before the rice season is classified as straw on-season.
(e) For these static parameters, refer to appropriate global or national data. The database from ISRIC provides soil data which can be used for this purpose.
(f) Climate zone: use agroecological zones as shown in the Rice Almanac[12] (Third Edition, 2002), or by HarvestChoice[13].

With the help of this field characterization, project fields can be grouped according to their cultivation pattern. All fields with the same cultivation pattern form one group.

** NOTE: Groups of fields within a single project are not the same as a Group Project scenario, described above.*

The project proponent shall calculate the baseline scenario climate forcer emissions using the following:

[12] IRRI (2002). *Rice Almanac: Source Book for the Most Important Economic Activity on Earth*, Third Edition. International Rice Research Institute (IRRI), International Center for Tropical Agriculture (CIAT), and West Africa Rice Development Association (WARDA), Los Baños, Philippines. https://doi.org/10.1093/aob/mcg189

[13] IFPRI and University of Minnesota (2015). *HarvestChoice; International Food Policy Research Institute (IFPRI);* University of Minnesota. (2016). CELL5M: A Multidisciplinary Geospatial Database for Africa South of the Sahara. Harvard Dataverse. https://doi.org/10.7910/DVN/G4TBLF

Total Baseline Emissions (BE_{total})

$$BE_{total,y,f} = \sum_{s} \left(BE_{CE,s,f} + BE_{s,directCH4} + BE_{fert,s,f} + BE_{residue,s,f} \right) \quad \textbf{Eq. 1}$$

Where:

$BE_{total,y,f}$	Total Baseline emissions in year *y* calculated on a seasonal basis and summed for the year, for climate forcer *f* [t *f*]. Forcers are listed in Table 1.
$BE_{CE,s,f}$	Baseline emissions from cultivation equipment in season[14] *s*, for climate forcer *f* [t *f*]
$BE_{s,directCH4}$	Baseline direct methane emissions from project fields in season *s* [t CH_4]
$BE_{fert,s,f}$	Baseline emissions from fertilizer application in season *s*, for climate forcer *f* [t *f*]
$BE_{residue,s,f}$	Baseline emissions from crop residue burning in season *s*, for climate forcer *f* [t *f*]

Baseline Emissions from the Operation of Cultivation Equipment

$$BE_{CE,s,f} = \left(C_{BL,elec,s} \times EF_{elec,f} \right) + \sum_{j}^{n} \left(C_{BL,j,s} \times EF_{j,f} \right) \quad \textbf{Eq. 2}$$

Where:

$BE_{CE,s,f}$	Baseline emissions from cultivation equipment in season *s*, for climate forcer *f* [t *f*]
$C_{BL,elec,s}$	Baseline electricity consumption from cultivation equipment in season *s* [MWh]
$EF_{elec,f}$	Electricity emission factor for climate forcer *f* [t *f* /MWh]
$C_{BL,j,s}$	Baseline consumption of combustion fuel *j* from cultivation equipment in season *s* [fuel unit]
$EF_{j,f}$	Emission factor of climate forcer *f* for fuel *j* [t *f* /fuel unit]

Baseline Direct Methane Emissions from the Project Rice Fields

$$BE_{s,directCH4s} = \sum_{g=1}^{G} EF_{BL,s,g} \times A_{s,g} \times 10^{-3} \quad \textbf{Eq. 3}$$

Where:

$BE_{s,directCH4}$	Baseline emissions from project fields in season *s* [t CH_4]
$EF_{BL,s,g}$	Baseline emission factor of group *g* in season *s* [kg CH_4/ha]

[14] In this methodology, "season" means an entire cropping season (from land preparation until harvest or post season drainage).

$A_{s,g}$	Area of project fields of group *g* in season *s* [ha]
g	Group *g*, covers all project fields with the same cultivation pattern as determined with the help of Table 3 (*G* = total number of groups)
10^{-3}	Conversion factor from kg to tonne

Baseline Emission factor $EF_{BL,s,g}$ on Reference Fields

Baseline reference fields when using Option 1 shall be in a way that they are representative of baseline emissions in the project rice fields. For each group of fields with the same cultivation pattern, as defined with the help of Table 3, at least three reference fields with the same pattern shall be determined in the project area. On these fields, measurements using the closed chamber method shall be carried out, each resulting in an emission factor expressed as kg CH_4/ha per season. The seasonally integrated baseline emission factor $EF_{BL,s,g}$ shall be derived as average value from the three geographically distinct measurements for each reference field (see Appendix C for guidelines on methane measurement).

Baseline Emissions from the Usage of Nitrogen Fertilizers

$$BE_{fert,s,f} = \sum_{i} A_{s,g} \times Rate_{N,s,g} \times EF_{g,N2O,fert} \times \frac{44}{28} \times 10^{-3} \quad \text{Eq. 4}$$

Where:

$BE_{fert,s,f}$	Baseline emissions from nitrogen fertilizer use in season *s* [t N_2O]
$A_{s,i}$	Area under cultivation for group *g* in season *s* [ha]
$Rate_{N,s,i}$	Nitrogen application rate for group *g* for season *s* [kg N ha^{-1}]
$EF_{N2O,fert}$	Emission factor for N_2O emissions from synthetic and organic fertilizer application for group *g* [kg N_2O-N per kg N applied]
44/28	Stochiometric factor for the conversion from N-N_2O to N_2O
10^{-3}	Conversion factor from kg to tonne

Baseline Emissions from Crop/Biomass Residue Burning

$$BE_{residue,s,f} = \sum_{i} A_{s,i} \times RPR_{s,i} \times DM_{s,i} \times B_{s,i} \times EF_{f,i} \times 10^{-3} \quad \text{Eq. 5}$$

Where:

$BE_{residue,s,f}$	Baseline emissions from crop residue burning in season *s* [t of climate forcer *f*]
$A_{s,i}$	Area of harvested crop *i* in season *s* [ha]
$RPR_{s,i}$	Residue-to-product ratio for crop *i* in season *s*
$DM_{s,i}$	Dry matter fraction of the residue crop *i* in season *s* [kg DM/ha]
$B_{s,i}$	Fraction of crop residue that is burned of crop *i* in season *s*

$EF_{f,i}$	Emission factor from crop residue burning of crop *i* for climate forcer *f* [kg f/kg DM]
10^{-3}	Conversion factor from kg to tonne

Project Scenario Climate Forcer Calculation Methods

Project emissions consist of direct CH_4 emissions, which will still be emitted under the changed cultivation practice, emissions from operating cultivation equipment, emissions from fertilizer application, and emissions from secondary effects. While optimized nitrogen fertilizer application is promoted as a sustainable agricultural practice under the project scenario, emissions from fertilizer use are conservatively included in both the baseline and project scenarios to ensure accurate accounting. This approach captures any residual differences and aligns with consistent quantification requirements under the methodology.

Total project scenario climate forcer emissions shall be calculated as follows:

Total Project Emissions (PE_{total})

$$PE_{total,y,f} = \sum_{s}(PE_{CE,s,f} + PE_{s,directCH4} + PE_{fert,s,f} + PE_{residue,s,f} + PE_{SE,s,f}) \quad \textbf{Eq. 6}$$

Where:

$PE_{total,y,f}$	Total Project emissions in year *y* calculated on a seasonal basis and summed for the year, for climate forcer *f* [t *f*]
$PE_{CE,s,f}$	Project emissions from cultivation equipment in season *s*, for climate forcer *f* [t *f*]
$PE_{s,directCH4}$	Project direct methane emissions in season *s* [t CH_4]
$PE_{fert,s,f}$	Project emissions from fertilizer application in season *s*, for climate forcer *f* [t *f*]
$PE_{residue,s,f}$	Project emissions from crop residue burning in season *s*, for climate forcer *f* [t *f*]
$PE_{SE,s,f}$	Project emissions from secondary effect in season *s*, for climate forcer *f* [t *f*]

Project Direct Methane Emissions for Project Rice Fields

$$PE_{s,directCH4} = \sum_{g=1}^{G} EF_{P,s,g} \times A_{s,g} \times 10^{-3} \quad \textbf{Eq. 7}$$

Where:

$PE_{s,directCH4}$	Project direct methane emissions from rice fields in season *s* [t CH_4]
$EF_{P,s,g}$	Project emission factor from project fields of group *g* in season *s* [kg CH_4/ha]
$A_{s,g}$	Area of project fields of group *g* in season *s* [ha]

g	Group *g*, covers all project fields with the same cultivation pattern as determined with the help of Table 3 (*G* = total number of groups)
10^{-3}	Conversion factor from kg to tonne

The seasonally integrated project emission factor $EF_{P,s,g}$ shall be determined using measurements on at least three project reference fields that fulfil the same conditions as the baseline reference fields, with the difference that they are cultivated according to the defined project cultivation practice. Project reference fields shall be established close to the baseline reference fields and begin with the growing season at the same time. $EF_{P,s,g}$ is the average of the measurement results from the three project fields.

Project Emissions from the Operation of Cultivation Equipment

$$PE_{CE,s,f} = \left(C_{PJ,elec,s} \times EF_{elec,f}\right) + \sum_{j}^{n} C_{PJ,j,s} \times EF_{j,f} \qquad \textit{Eq. 8}$$

Where:

$PE_{CE,s,f}$	Project emissions from cultivation equipment in season *s*, for climate forcer *f* [t]
$C_{PJ,elec,s}$	Project electricity consumption from cultivation equipment in season *s* [MWh]
$EF_{elec,f}$	Electricity emission factor for climate forcer *f* [t/MWh]
$C_{PJ,j,s}$	Project consumption of combustion of fuel *j* from cultivation equipment in season *s* [fuel unit]
$EF_{j,f}$	Emission factor of climate forcer *f* for fuel *j* [t/fuel unit]

Project Emissions from the Usage of Nitrogen Fertilizers and Changes in Agricultural Practices

$$PE_{fert,s,f} = \sum_{i} A_{s,g} \times Rate_{N,S,g} \times EF_{N2O,g,fert} \times \frac{44}{28} \times 10^{-3} \qquad \textit{Eq. 9}$$

Where:

$PE_{fert,s,f}$	Project emissions from nitrogen fertilizer use [t N_2O-N]
$A_{s,g}$	Area under cultivation for group *g* [ha]
$Rate_{N,S,g}$	Nitrogen application rate for group *g* for season *s* [kg N ha^{-1}]
$EF_{N2O,g,fert}$	Emission factor for N_2O emissions from synthetic and organic fertilizer application [kg N_2O-N per kg N applied] for group *g*
44/28	Stochiometric factor for the conversion from N-N_2O to N_2O
10^{-3}	Conversion factor from kg to tonne

Project Emissions from Crop/Biomass Residue Burning

$$PE_{residue,s,f} = \sum_{i} A_{s,i} \times RPR_{s,i} \times DM_{s,i} \times B_{PJ,s,i} \times EF_{f,i} \times 10^{-3} \quad \textit{Eq. 10}$$

Where:

$PE_{residue,s,f}$	Project emissions from crop residue burning in season s for climate forcer *f* [t]
$A_{s,i}$	Area of harvested crop *i* in season *s* [ha]
$RPR_{s,i}$	Residue-to-product ratio for crop *i* in season *s*
$DM_{s,i}$	Dry matter fraction of the residue harvested crop *i* in season *s* [kg DM/ha]
$B_{PJ,s,i}$	Fraction of crop residue that is burned during the project of harvested crop *i* in season *s*
$EF_{f,i}$	Emission factor from crop residue burning for climate forcer *f* of crop *I* [kg f/kg DM]
10^{-3}	Conversion factor from kg to tonne

6.1.2 OPTION 2: National/Regional Emission Factor Approach (Tier 2)

This quantification approach follows the same emission categories as Option 1 but estimates them using credible national or regional emission factors instead of direct measurements. Project-specific reference fields are not required. Emission factors for equations equivalent to Eq. 1 through Eq. 10 may be sourced from scientific literature, national GHG inventories, or authorized government publications.

6.2 Secondary Effects

If there is a rice yield decrease that exceeds the threshold RY_{min} calculated in Equation 13 as a direct result of the project activity, to be conservative it is assumed that the decrease in rice production causes a net increase in production elsewhere outside the project boundary. The emissions associated with this shift in production must be estimated if project related yield losses are statistically significant compared to historic and average yields.

If a simple summation of project yield, or in the case of aggregate, the aggregate project area yields, shows that yields did not decrease compared to the average historic rice yield for the same area, then this protocol assumes leakage has not occurred and subsequently emissions associated with shifting production do not need to be estimated (i.e. the remainder of this subsection can be skipped).

In order to determine if rice yields have decreased across the project area during the cultivation cycle as a result of project activity, the annual yield from the project area must be compared to historical yields from the same project area.

The following procedure, adapted from Climate Action Reserve (CAR) U.S. Rice Protocol, must be followed for each cultivation cycle to ensure that the yields from the project area have not declined due to project activity. The following procedure is applicable for a (hypothetical) single field project. All project aggregates must apply the following procedure to the entire project area, defined as the sum of individual fields included in verification activities

Calculate the mean rice yield over the five rice cultivation years prior to the start of the project:

$$RY_{mean} = average(RY_t) \quad \textit{Eq. 11}$$

Where:

RY_{mean}	Mean rice yield of the project area over the three rice cultivation years prior to the start of the project [kg]
RY_t	Rice (paddy) yield in prior cultivation year *t* [kg] normalized to the industrial standard of 14% moisture content
t	Year of rice cultivation. Use five years of prior rice yields in the project area, ignoring any years where the project area was fallow.

Calculate the standard deviation of the rice yield over the five rice cultivation years prior to the start of the project:

$$SD = stdev(RY_t) \quad \textit{Eq. 12}$$

Where:

SD	Standard deviation of the rice yield over the three rice cultivation years prior to the start of the project
RY_t	Rice (paddy) yield in prior cultivation year *t* [kg] normalized to the industrial standard of 14% moisture content
t	Year of rice cultivation. Use five years of prior rice yields in the project area, ignoring any years where the project area was fallow.

Calculate the minimum threshold for the yield to be statistically lower than the historic average:

$$RY_{min} = RY_{mean} - 2.92 \times SD \quad \textit{Eq. 13}$$

Where:

RY_{min}	Minimum yield threshold below which normalized yields are significantly smaller than the historical average [kg]
RY_{mean}	Mean rice yield of the project area over the five rice cultivation years prior to the start of the project [kg]
SD	Standard deviation of the rice yield over the five rice cultivation years prior to the start of the project

The t-distribution value of 2.92 = t(0.05, n – 1), where n is 3, and n - 1 degrees of freedom is 2. There should always be three data points when performing this calculation in the Rice Cultivation Project Protocol (RCPP) version 1.1, as there shall always be 3 years of rice yield data for a given field.

If RY_s is equal to or greater than RY_{min} for season *s*, the yield is not statistically lower than the historical average, and no leakage emissions need to be included. If RY_s is less than RY_{min} for season *s*, the leakage emissions are calculated as follows:

$$PE_{SE,s,f} = (1 - \frac{RY_s}{RY_{min}}) \times (BE_{CE,s,f} + BE_{s,directCH4} + BE_{fert,s,f} + BE_{residue,s,f}) \qquad \textbf{Eq. 14}$$

Where:

$PE_{SE,s,f}$	Total secondary effect emissions by the project activity over project crediting period [t CO_2e]
RY_s	Sum of project rice yields in season *s* [kg]
RY_{min}	Minimum yield threshold below which normalized yields are significantly smaller than the historical average [kg]
$BE_{CE,s,f}$	Baseline emissions from cultivation equipment in season *s*, for climate forcer *f* [t *f*]
$BE_{s,directCH4}$	Baseline direct methane emissions from project fields in season *s* [t CH_4]
$BE_{fert,s,f}$	Baseline emissions from fertilizer application in season *s*, for climate forcer *f* [t *f*]
$BE_{residue,s,f}$	Baseline emissions from crop residue burning in season *s*, for climate forcer *f* [t *f*]

6.3 Determination of the Project's Climate Impact

The climate impact shall be calculated using:

- the annual emission reductions of each climate forcer in tonnes
- the annual emission reductions in CO_2e using GWP100 metrics
- the annual radiative forcing reduction due to the project activity in tonnes of CO_2fe

This methodology takes an emissions inventory approach, where the net emissions (project – baseline) of each climate forcer are determined first, and then that inventory is used to calculate the carbon dioxide equivalence and the radiative forcing equivalence, both on a per-forcer basis and as a total.

GWP100 is the cumulative impact of a climate pollutant over 100 years, relative to CO_2. This is the metric used by the Greenhouse Gas Protocol and within the voluntary carbon markets. The reduction of greenhouse gases in the atmosphere of each climate forcer shall be disclosed in tonnes of CO_2e.

Short-lived pollutants have higher warming potentials over shorter timespans. Radiative forcing (RF) is a metric that is used within the IPCC reports on climate change to calculate the annual impact of all climate forcers over any timespan. In order to provide clarity on the annual impact of the change of all climate forcers including short lived climate pollutants due to the project activity, the radiative forcing impact of each climate forcer shall also be disclosed in tonnes of CO_2fe.

The project proponent shall provide the projected levels of reduction or removal of climate forcers in the Project Design Document and shall provide actual levels of reduction or removal of climate forcers in the Monitoring Report.

6.3.1 Calculating the Project's Total Climate Impact

The project proponent shall determine the net climate forcer reductions as follows:

$$ER_{y,f} = BE_{y,f} - PE_{y,f} \quad \textit{Eq. 15}$$

Where:

$ER_{y,f}$	Emission reductions in year *y*, for climate forcer *f*
$BE_{y,f}$	Baseline emissions in year *y*, for climate forcer *f*
$PE_{y,f}$	Project emissions in year *y*, for climate forcer *f*

For the ex-ante estimation of emission reductions within the PDD, project participants shall either refer to own field experiments or estimate baseline and project emissions with the help of national data or IPCC tier 2 default values for emission. The approach shall be explained and justified in the PDD.

Carbon Dioxide Equivalents (CO_2e) Reductions

$$R_{CO_2e,y} = ER_{y,CO_2} + \sum ER_{y,f} \times GWP_f \quad \textit{Eq. 16}$$

Where:

$R_{CO_2e,y}$	Reduction in CO_2e due to project activities in year *y* [t CO_2e]
ER_{y,CO_2}	Net CO_2 emissions in year *y* [t CO_2]
$ER_{y,f}$	Net emissions in year *y* for climate forcer *f* [t *f*]
GWP_f	Global warming potential over 100 years (GWP 100) for climate forcer *f* [t CO_2e/t *f*], use IPCC values or other values with justification)[15]

The RF Reduction Over Time Horizon *TH*

$$R_{CO_2fe,TH} = \sum_{i=y}^{TH} RF(ER_{y,f}) \quad \textit{Eq. 17}$$

[15] See IPCC AR6 Table 7.SM.7 | Greenhouse gas lifetimes, radiative efficiencies, global warming potentials (GWPs), global temperature potentials (GTPs) and cumulative global temperature potentials (CGTPs). Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter07_SM.pdf.

Where:

$R_{CO_2fe,TH}$	Radiative forcing reduction due to project activities over time horizon *TH* [t CO_2fe]
TH	Time horizon for RF analysis in years (e.g., 20, 50, or 100), depending on project's selected crediting perspective.
$RF(ER_{y,f})$	Radiative forcing of net climate forcer emissions in year *y*, for climate forcer *f*

NOTE: The function for determining Radiative Forcing is described in Appendix A of the GHR Registry Standard.
NOTE: This equation accounts for accumulated GHG reductions over the time horizon.

Additional details for calculating radiative forcing can be found in Appendix A of the GHR Registry Standard. Radiative forcing shall also be calculated in W/m^2 or a derivative unit, as described in Section 4.1.3 of the GHR Registry Standard

6.4 Conservative Assumptions and Estimates

The project proponent may make ex-ante estimations of the direct methane emissions reduction using an IIPCC default values or values from published, peer-reviewed scientific literature (Option 2) as described above.

It is conservatively assumed that a decrease in rice production within the project area leads to an increase in rice production outside the project area (and vice versa, that if production has not decreased then there has been no shift in production).

6.5 Methods of Determining Uncertainty

Uncertainties may originate from estimated values and limitations in the accuracy of the systems used to monitor the methane produced from the rice cultivation process. These uncertainties affect the baseline scenario, the quantification of methane released, and the factors considered in the project emissions calculations. Each parameter used in the quantification (Sections 6.2 - 6.4) must have its uncertainty calculated from calibration checks, determined from relevant peer-reviewed scientific literature, or conservatively estimated with clear documentation, as applicable. Where global, regional or country specific default values are used in Option 2 calculations, a default uncertainty factor of 15% is used on the emission reductions.

The degradation rate of methane in the atmosphere is well established in the literature and will be used for RF calculation purposes. Conservative assumptions listed in Section 6.4 may be used without uncertainty estimation requirements. Credit issuance will be discounted on a conservative basis reflecting on the variability in these parameters, as described in Section 8.

6.6 Potential co-benefits, trade-offs, and SDGs

The project proponent shall, at minimum, make a qualitative assessment of co-benefits and trade-offs associated with the project activities.

The project proponent may make a quantitative assessment of any co-benefits and trade-offs using the *Methodology Standard for Stressor-Effects Life Cycle Assessment (SCS-002)* or an alternative ISO-14044-compliant life cycle assessment standard. Verified claims related to co-benefits, trade-offs, and corresponding UN Sustainable Development Goals (SDGs) are only permissible when the project has undergone a quantitative assessment for the relevant impact category.

Table 4 contains a list of potential co-benefit and trade-off impact categories relevant to this methodology.

Table 5 provides a list of specific SDG targets related to these impact categories.

Table 4. Potential Co-benefits and Trade-offs to Project Scenario

Impact Group	Impact Category	Enter Yes if applicable, No if not applicable	
		Potential Co-benefits	Potential Trade-off
Resource Depletion Group	Non-Renewable Energy Resource Depletion	No	No
	Net Freshwater Consumption	No	No
	Critical Minerals Resource Depletion	No	No
	Biotic Resource Depletion	No	No
Ocean Ecosystem Impacts Group	Ocean Acidification	Yes	No
	Marine Biome Disturbance	No	No
	Marine Eutrophication	No	No
	Key Species Loss	No	No
	Persistent Eco Toxic Chemical Loading	No	No
	Marine Plastic Loading	No	No
Terrestrial Ecosystem Impacts Group (impacts from Emissions)	Regional Acidification	No	No
	Stratospheric Ozone Depletion	No	No
	Freshwater Ecotoxic Exposure Risks	No	No
	Freshwater Eutrophication	No	No
	Terrestrial Eutrophication	No	No
Terrestrial Ecosystem Impacts Group (impacts from Land Use and Land Conversion)	Terrestrial Disturbance	No	No
	Freshwater Disturbance	No	No
	Threatened Species Impacts	No	No
	Soil Degradation and Erosion	No	No
	Noise and Vibration	No	No
Human Health Impacts (from Chronic	Ground Level Ozone Exposure Impacts	Yes	No
	PM2.5 Exposure Impacts	No	No

Exposures to Hazardous Substances)	Hazardous Ambient Air Contaminant Exposure Impacts	Yes	No
	Hazardous Indoor Air Contaminant Exposure Impacts	No	No
	Hazardous Food or Water Contaminant Exposure Impacts including Chemical Pesticides and Fertilizers	No	No
	Hazardous Dermal Contaminant Impacts	No	No
Risks from Hazardous Wastes	Risks from Radioactive Wastes	No	No
	Risks from Untreated Hazardous Wastes	No	No

Table 5. Associated Sustainable Development Goals and Targets

Sustainable Development Goal	Target Numb er	Target	Reason for Inclusion
3. Ensure healthy lives and promote well-being for all at all ages	3.9	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution, and contamination	Methane is a toxic air pollutant and a precursor of tropospheric ozone. Reducing methane will improve air quality, which has major public health benefits, such as preventing respiratory illnesses.
9. Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation	9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	The methodology facilitates the adoption of sustainable rice cultivation practices with low emission technologies that enhance nitrogen and water use efficiency. By reducing greenhouse gas emissions and strengthening climate resilience in the agricultural sector, it contributes to the transition toward sustainable and resource-efficient agro-industrial systems.
13. Take urgent action to combat climate change and its impacts	13.2	Integrate climate change measures into national policies, strategies, and planning	Projects using this methodology reduce their climate forcer emissions compared to baseline.
14. Conserve and sustainably use the oceans, seas, and marine resources for sustainable development	14.3	Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	Methane emissions contribute to ocean acidification. By reducing methane emissions compared to baseline, projects using this methodology minimize the impacts of ocean acidification.

7 Reporting Requirements

7.1 Project Design Document (PDD)

A Project Design Document (PDD) is required to be developed by the project proponent prior to validation and verification. PDDs must meet the requirements of the GHR Registry Standard and this methodology, using GHR's PDD Template.[16] PDDs are subject to approval by GHR prior to registration in the GHR Registry.

The PDD shall be published and publicly available in the GHR Registry. A project proponent may request redactions to some information in the PDD to protect intellectual property and other business confidential information (e.g., proof of eligibility information, the specific terms of legal agreements, and intellectual property detailed in the Life Cycle Assessments (LCA)). Redaction shall be at the sole choice of GHR, but such permission will not be unreasonably withheld. However, all information is subject to validation and verification requirements.

7.2 Documentation and Monitoring

The project proponent shall submit a detailed Project Monitoring Plan as part of the PDD. The Project Monitoring Plan facilitates the gathering of all pertinent data needed for:

- Confirming the fulfilment of the eligibility requirements
- Confirming the climate forcer emissions or amounts associated with the project
- Confirming secondary effect emissions or amounts (i.e., leakage)

The data gathered shall be kept on record for a minimum of five years following the conclusion of the project activity's final crediting period.

Details shall be provided and documented in the Project Monitoring Plan to confirm that best practices are being utilized. In cases where such methods and procedures are not known or accessible, the project will establish, document, and apply standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) processes for inventory tasks, including field data gathering and data management. It is advisable to use or modify SOPs obtained from published manuals.

The PDD shall also contain thorough documentation of the equations, methods, measurements, and instruments used to record and process the data needed to fulfil the requirements of this methodology. The monitoring plan must include the on-site inspections for each of the individual farms included in the project boundary where the project activity is/will be implemented for each monitoring period.

[16] GHR Project Design Document template: Documents | Heat Reduction

In order to determine whether the project fields are cultivated according to the project cultivation practice as defined by the project activity and thus assure that measurements on the reference fields are representative for the emissions from the project fields, a cultivation logbook shall be maintained for all project fields. With the help of the logbook, all parameters that are part of the project cultivation practice, and at least the following, shall be documented by the farmers:

a) Sowing and transplanting (date);
b) Fertilizer, organic amendments, and crop protection application (date and amount);
c) Water regime on the field (e.g. "dry/moist/flooded") and dates where the water regime is changed from one status to another; and
d) Yield.

In addition, farmers shall state whether they have followed fertilization recommendations provided with the introduction of the adjusted water management practice.

The project proponents shall ensure that the project reference fields are cultivated in a way that they represent the ranges of cultivation practice elements on the project fields in a conservative manner with respect to methane emissions. Should farmers relevantly deviate from the defined project cultivation practice, so that their fields cannot be deemed to be represented by the reference fields anymore, those fields shall not be taken into account for the determination of the aggregated project area $A_{s,g}$ of that season. This requirement shall ensure that only those farms are considered for the calculation of emission reductions which comply with the project cultivation practice.

Monitoring Reports for the project must be submitted as specified in Section 7.3, using the GHR Monitoring Report Template. Monitoring Reports must contain updated data, calculations, and attestations as specified in the project monitoring plan and the Monitoring Report Template. Any deviations from the Project Monitoring Plan must be reported and justified within the Monitoring Reports.

7.3 Monitoring Report

The project proponent shall generate a Monitoring Report to describe ongoing project activities addressed in the monitoring plan. Each Monitoring Report must cover the period from the last report of the previous crediting year to present crediting year and will be published and publicly available on the GHR Registry.

The project proponents may request redactions to some information in updated Monitoring Reports to protect intellectual property (IP). Redaction is at the sole discretion of SCS; however, such permission will not be unreasonably withheld. All information is subject to validation and verification requirements.

Content requirements for the Monitoring Reports are provided in the GHR Monitoring Report Template.[17]

[17] Documents | Heat Reduction

7.4 Monitoring Period

The monitoring period is the timespan over which the VVB assesses and confirms the Project's climate mitigation activities and resulting *ex-post* GHG emission reductions/removals and other RF reductions per vintage year.

The monitoring period for projects assessed under this methodology shall be at most 1 year from the project start date or last date of verification.

During the monitoring period, the Project Proponent shall file an Incident Report if changes in processes, materials or activities are observed that could alter the level of RF reduction, describing the nature, timing, scale, and likely permanence of the change. An incident report must also be submitted to the GHR Registry if actual RF reduction levels are shown to fall short of projections, whether due to a known loss event (i.e., a planned or unplanned change in process or activity) or due to any other cause describing the nature, extent, scope and expected permanence of the shortfall, and provide a root cause analysis of the source of the shortfall.

7.5 Project Validation and Verification

The project shall be validated in accordance with the requirements of GHR Registry Standard Section 6.

Each project monitoring period shall undergo verification in accordance with the requirements of the Registry Standard Section 7.4. Project validation and verification reports shall be provided to the GHR Registry by the VVB. Project validation and verification reports shall clearly describe the process of the assessment as well as the findings from the assessment. Specifications for the content of the validation and verification reports can be found in the GHR Validation and Verification Report Template.[18]

[18] GHR Validation and Verification template: *Documents | Heat Reduction*

8 Crediting

8.1 Credit Issuance

Credits shall be issued after independent validation and verification that the requirements of this Methodology have been met. Credit issuance shall be adjusted to reflect inherent uncertainties in measuring and monitoring the Project activities. The adjustment shall be based on the uncertainty assessment conducted as part of the Project's quantification process and reported in the Monitoring Reports. Credit issuance shall be adjusted to reach a 90% or greater certainty in the quantified CO_2e.

Once issued, the credits will be registered and tracked in the GHR Registry. The GHR Registry will record the details of each credit, including the Project for which it was issued, the date it was issued, the retirement date and retirement location, the amount of net CO_2e it represents, CO_2e+ information (e.g., scope of analysis, co-benefit and trade-off information, climate benefits over various time horizons), and associated documentation.

All the GHR Registry credits may be retired for carbon accounting only once, and all retirements are recorded in the GHR Registry.

8.2 Crediting Period

The crediting period for projects under this methodology is 5 years. The project may be renewed up to 3 times and must be re-validated for each crediting period.

8.3 Buffer Pool Requirements

Methane reduction projects are not reversible and therefore are subject to the GHR Registry Standard's lower minimum buffer pool contribution requirement of 2% of the total credits issued. However, this buffer pool contribution percentage is subject to review on a project-by-project basis, based on the parameters identified in Appendix B, and may be increased as warranted.

Glossary

Baseline scenario: The business-as-usual scenario representing the project area environment and emissions in the absence of the project.

Climate forcer: Any external driver of climate change that causes a positive or negative change in RF (e.g., an emission, substance, process, activity or change in state).[19]

Direct seeded rice: A system of cultivating rice in which seeds, either pre-germinated or dry, are broadcast or sown directly in the field under dry- or wetland condition; no transplanting process is involved.

IPCC approach: The most recent version of the applicable IPCC guidance on methane emission from rice cultivation. The applicable version at the time of approval of the (CDM) methodology is chapter 5.5, volume 4 of the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.*[20]

Irrigated: A type of water regime in which fields are flooded for a significant period of time and water regime is fully controlled.

Field/Stratum: A discrete area within the project boundary where rice is cultivated under relatively uniform management and biophysical conditions. The terms *field* and *stratum* are used interchangeably throughout this methodology. Fields or strata may be grouped for sampling and analysis based on shared characteristics such as water management, soil type, or variety used.

Project area: The area within the project boundary where project activities take place. The project area may be contiguous or be comprised of multiple smallholder areas within a larger defined boundary.

Project cultivation practice: A set of elements of a cultivation practice which is adopted under the project activity. This mainly consists of the adjusted irrigation method. Field preparation, fertilization and weed and pest control may also be included.

Project scenario: The implementation of rice cultivation practices such as transitioning from continuous flooding to intermittent flooding, using an alternate wetting and drying method or aerobic rice cultivation method, and switching from transplanting to direct seeding, reduction in the usage of nitrogen fertilizers and avoided residue burning.

Rainfed regime: Water input in rice cultivation system is primarily dependent on precipitation and natural flooding. Rainfed regime is further divided into:

1. Regular rainfed regime: where rice fields depend entirely on rainfall, with water levels typically not exceeding 50 cm, and may include drought-prone conditions.

[19] SCS RF Protocol: ICIMOD_RF_Protocol_V1.1 (2024).pdf
[20] IPCC (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4: Agriculture, Forestry and Other Land Use Chapter 5: Cropland. Table 5.9: Default Parameters for Crop Residue Management and Emissions. Available at: https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch05_Cropland.pdf

2. Deep water regime: where fields are submerged under more than 50 cm of water for a significant portion of the growing season, primarily due to seasonal flooding from rainfall and river overflow.

Residue or Waste: Biomass left after rice harvest, mainly rice straw, that may be incorporated, left on the field, or burned. It excludes non-agricultural waste and is relevant to emissions accounting in this methodology.

Rice yield: Yield refers to harvested paddy and not to milled rice. Reported values must be normalized to the industrial standard of 14% moisture content.

Transplanted rice: A system of planting rice where seeds are raised in a nursery bed for some 20 to 30 days. The young seedlings are then directly transplanted into the flooded rice field.

Upland: A type of water regime in which fields are never flooded for a significant period of time.

Water regime: A combination of rice ecosystem type (e.g., irrigated, rainfed and deep water) and flooding pattern (e.g., continuously flooded, intermittently flooded).

Acronyms and Abbreviations:

CDM: Clean Development Mechanism

BE: Baseline Emissions

CH_4: Methane

CO_2: Carbon Dioxide

CO_2e: Carbon Dioxide Equivalents

CO_2e+: Carbon Dioxide Equivalents with additional heat impact data

EF: Emission Factor

GHG: Greenhouse Gas

GHR: Global Heat Reduction

GWP: Global Warming Potential

IPCC: Intergovernmental Panel on Climate Change

N_2O: Nitrous oxide

PDD: Project Design Document

PE: Project Emissions

QA/QC: Quality Control/Quality Assurance

RF: Radiative forcing

SOP: Standard Operating Procedure

SSR: Sources, Sinks, and Reservoir

t: tonne (metric)

VVB: Validation and Verification Body

UNFCCC: United Nations Framework Convention on Climate Change

Appendix A: Data and Parameters

1. Monitored Data and Parameters

The information provided below is consistent with the GHR Registry Standard, including Normative Appendix A, *Calculating Project-Related Radiative Forcing Values.*

Data/Parameter:	$C_{BL, elec,s}$
Data Unit:	MWh
Description:	Baseline electricity consumption from cultivation equipment in season *s*
Source(s) of data:	Project records / Energy meters
Description of measurement methods and procedures to be applied:	Electricity usage recorded via meters and verified through billing records
Frequency of monitoring/ recording:	Seasonal
QA/QC procedures to be applied:	Regular calibration of energy meters; cross-verification with supplier records
Comments:	Ensure consistent logging for accurate project emissions estimates

Data/Parameter:	$C_{BL,j,s}$
Data Unit:	Fuel unit
Description:	Baseline fuel consumption for fuel *j* in cultivation equipment in season *s*
Source(s) of data:	Fuel purchase records / Equipment logs
Description of measurement methods and procedures to be applied:	Fuel logs from project sites, purchase receipts from suppliers
Frequency of monitoring/ recording:	Seasonal
QA/QC procedures to be applied:	Validation via purchase invoices, fuel logbooks, and supplier reports
Comments:	Multiple fuel types should be tracked separately

Data/Parameter:	$A_{s,g}$
Data Unit:	Hectares (ha)
Description:	Area of project fields for group *g* in season *s*
Source(s) of data:	GIS Mapping / Field Survey
Description of measurement methods and procedures to be applied:	Satellite imagery and land records validation
Frequency of monitoring/ recording:	Annual
QA/QC procedures to be applied:	Verification via GPS tracking and area mapping

Comments:	Consistency in GIS data collection is critical

Data/Parameter:	$A_{s,i}$
Data Unit:	Hectares (ha)
Description:	Area under cultivation for crop *i* in season *s*
Source(s) of data:	GIS Mapping / Satellite Data
Description of measurement methods and procedures to be applied:	Field mapping techniques and remote sensing
Frequency of monitoring/ recording:	Annual
QA/QC procedures to be applied:	Cross-checking with official land registry records
Comments:	NA

Data/Parameter:	$Rate_{N,s,G}$
Data Unit:	kg N ha^{-1} yr^{-1}
Description:	Nitrogen application rate for group *g* in season *s*
Source(s) of data:	Farmer records / Soil testing reports
Description of measurement methods and procedures to be applied:	Sampling-based nitrogen application tracking
Frequency of monitoring/ recording:	Annual
QA/QC procedures to be applied:	Randomized field inspections
Comments:	Standardized application rates should be verified

Data/Parameter:	$RPR_{s,i}$
Data Unit:	Ratio, dimensionless
Description:	Residue-to-product ratio for crop *i* in season *s*
Source(s) of data:	Field surveys if option 1 is chosen. Country-specific data from National agricultural databases/ IPCC 2019 if Option 2 is chosen. Default Rice = 1.3[21]
Description of measurement methods and procedures to be applied:	Estimation based on crop type using literature data
Frequency of monitoring/ recording:	Annual
QA/QC procedures to be applied:	Use country-specific data where available
Comments:	NA

[21] IPCC (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 5: Cropland. Table 5.9: Default Parameters for Crop Residue Management and Emissions. Available at: https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch05_Cropland.pdf

Data/Parameter:	$DM_{s,i}$
Data Unit:	kg DM/ha
Description:	Dry matter fraction of residue for crop *i* in season *s*
Source(s) of data:	Field surveys if option 1 is chosen. Country-specific data from National agricultural databases/ IPCC 2019 if Option 2 is chosen. Typically 0.85 for crop residues.
Description of measurement methods and procedures to be applied:	Sampling of dry matter content in field conditions if field surveys are opted
Frequency of monitoring/ recording:	Annual
QA/QC procedures to be applied:	Ensure consistency with previous studies, with data required to be verifiable
Comments:	NA

Data/Parameter:	$B_{s,i}$
Data Unit:	Fraction, dimensionless (0-1)
Description:	Fraction of crop residue that is burned for crop *i* in season *s*
Source(s) of data:	Field Surveys / Remote Sensing
Description of measurement methods and procedures to be applied:	Survey of farm practices and satellite monitoring. Default IPCC 2019 = 0.25 for global rice paddies if Option 2 is chosen.
Frequency of monitoring/ recording:	Seasonal
QA/QC procedures to be applied:	Comparisons and verification with satellite images and past data
Comments:	Local regulations on residue burning may apply

Data/Parameter:	$C_{PJ,elec,s}$
Data Unit:	MWh
Description:	Project electricity consumption from cultivation equipment in season *s*
Source(s) of data:	Project records / Energy meters
Description of measurement methods and procedures to be applied:	Electricity meters, verified with billing records
Frequency of monitoring/ recording:	Seasonal
QA/QC procedures to be applied:	Regular calibration of energy meters; cross-verification with supplier records
Comments:	Ensure consistent logging for accurate project emissions estimates

Data/Parameter:	$C_{PJ,j,s}$
Data Unit:	Fuel unit

Description:	Project fuel consumption for fuel *j* in cultivation equipment in season *s*
Source(s) of data:	Fuel purchase records / Equipment logs
Description of measurement methods and procedures to be applied:	Fuel logs from project sites, purchase receipts
Frequency of monitoring/ recording:	Seasonal
QA/QC procedures to be applied:	Validation via invoices, supplier reports
Comments:	Multiple fuel types should be tracked separately

Data/Parameter:	$A_{I,y}$
Data Unit:	Hectares (ha)
Description:	The area (in hectares) of each rice cultivation unit *i* in year *y*
Source(s) of data:	Project records, GIS mapping
Description of measurement methods and procedures to be applied:	Measured through GPS mapping and land records
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	Cross-check with official land records and satellite imagery
Comments:	NA

Data/Parameter:	RY_t
Data Unit:	kilograms (kg)
Description:	Rice yield in prior cultivation year *t*
Source(s) of data:	GIS Mapping / Satellite Data
Description of measurement methods and procedures to be applied:	Field mapping techniques and remote sensing
Frequency of monitoring/ recording:	Annual
QA/QC procedures to be applied:	Cross-checking with official land registry records
Comments:	NA

Data/Parameter:	L_y
Data Unit:	Days/year
Description:	Cultivation period of rice in year y
Source(s) of data:	GIS Mapping / Satellite Data
Description of measurement methods and procedures to be applied:	Field mapping techniques and remote sensing
Frequency of monitoring/ recording:	Annual
QA/QC procedures to be applied:	Cross-checking with official land registry records
Comments:	NA

Data/Parameter:	T
Data Unit:	°C
Description:	Air temperature in chamber
Source(s) of data:	Direct measurements
Description of measurement methods and procedures to be applied:	Manufacturer guidelines and sensitivity analyses must be applied
Frequency of monitoring/ recording:	During each sampling period
QA/QC procedures to be applied:	Manufacturer guidelines and sensitivity analyses must be applied.
Comments:	NA

Data/Parameter:	Δt
Data Unit:	days
Description:	Time interval between successive sampling days
Source(s) of data:	Direct measurements
Description of measurement methods and procedures to be applied:	Manufacturer guidelines and sensitivity analyses must be applied
Frequency of monitoring/ recording:	Measurements should be taken at least bi-weekly, increasing to weekly during high-emission periods
QA/QC procedures to be applied:	NA
Comments:	NA

Data/Parameter:	ΔC/Δt
Data Unit:	ppm/hr
Description:	Rate of change in CH_4 concentration
Source(s) of data:	Direct measurements
Description of measurement methods and procedures to be applied:	Manufacturer guidelines and sensitivity analyses must be applied
Frequency of monitoring/ recording:	Each sampling event shall involve at least three gas sample collections
QA/QC procedures to be applied:	As described in the manufacturer guidelines
Comments:	NA

2. Non-Monitored Data and Parameters

Data/Parameter:	$EF_{elec,f}$
Data Unit:	t ƒ/MWh

Description:	Electricity emission factor for climate forcer *f*
Source(s) of data:	IPCC 2019 Guidelines / National Energy Database
QA/QC procedures to be applied:	Cross-verification with national energy statistics and grid factors
Comments:	May vary based on country-specific energy grid emission factors

Data/Parameter:	$EF_{j,f}$
Data Unit:	t *f*/fuel unit
Description:	Emission factor for fuel *j* for climate forcer *f*
Source(s) of data:	IPCC 2019 and National Inventory Reports
QA/QC procedures to be applied:	Comparison with national fuel inventory data and global standards
Comments:	Fuel mix variations must be considered when applying emission factors

Data/Parameter:	$EF_{BL,s,g}$
Data Unit:	kg CH_4/ha per season
Description:	Baseline emission factor from project fields for group *g* in season *s*
Source(s) of data:	Measured data if Option 1 is chosen. IPCC 2019/ Country-specific emission factors from peer-reviewed literature if Option 2 is chosen.
QA/QC procedures to be applied:	Validation against national or regional data
Comments:	NA

Data/Parameter:	$EF_{N2O,fert}$
Data Unit:	kg N_2O-N per kg N applied
Description:	Default emission factor for N_2O emissions from fertilizers
Source(s) of data:	Measured data if Option 1 is chosen. IPCC 2019/ Country-specific emission factors from peer-reviewed literature if Option 2 is chosen. IPCC 2019[22] Guidelines. Default = 0.003 for continuous flooding Default = 0.005 for fields with 1 or more drainage periods
QA/QC procedures to be applied:	IPCC consistency checks
Comments:	National values when available can be used with verifiable citations

[22] Table 11.1, Chapter 11, Volume 4, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019)

Data/Parameter:	$EF_{f,i}$
Data Unit:	kg *f*/kg DM
Description:	Emission factor from crop residue burning for climate forcer *f* for crop *i*
Source(s) of data:	Measured data if Option 1 is chosen. IPCC 2019/ country-specific emission factors from peer-reviewed literature if Option 2 is chosen.
QA/QC procedures to be applied:	Literature sources should be reviewed for updates
Comments:	Literature values vary by location and practice IPCC 2019 and literature values for *f* are as follows: CH_4 (Methane): 0.005 kg CH_4/kg DM burned N_2O (Nitrous Oxide): 0.0007 kg N_2O/kg DM burned BC (Black Carbon): 0.0001 kg BC/kg DM burned[23]

Data/Parameter:	$EF_{P,s,g}$
Data Unit:	kg CH_4/ha per season
Description:	Project emission factor from project fields for rice cultivation for group *g* in season *s*
Source(s) of data:	Measured data if option 1 is chosen. Country-specific data from peer-reviewed literature/ IPCC 2019 if Option 2 is chosen.
QA/QC procedures to be applied:	Validation against national or regional data
Comments:	NA

Data/Parameter:	$EF_{P,c,f}$
Data Unit:	kg *f*/ha
Description:	Project Emission Factor for rice cultivation for climate forcer *f*
Source(s) of data:	Measured data if option 1 is chosen. IPCC 2019 Guidelines or project-specific measurements if Option 2 is chosen.
QA/QC procedures to be applied:	Validation against IPCC default values and emission factors
Comments:	NA

Data/Parameter:	V

[23] Andreae, M. O., and Merlet, P. (2001). *Emission of trace gases and aerosols from biomass burning*. *Global Biogeochemical Cycles*, 15(4), 955–966. Emission factor for black carbon from open agricultural waste burning reported as **0.10 g/kg DM** (equivalent to 0.0001 kg/kg DM). https://doi.org/10.1029/2000GB001382

Data Unit:	m^3
Description:	Surface area of chamber
Source(s) of data:	Manufacturer specification
QA/QC procedures to be applied:	NA
Comments:	NA

Data/Parameter:	A
Data Unit:	m^2
Description:	Surface area of chamber
Source(s) of data:	Manufacturer specification
QA/QC procedures to be applied:	NA
Comments:	NA

Data/Parameter:	ρ
Data Unit:	kg/m^3
Description:	Gas density
Source(s) of data:	Standard scientific values
QA/QC procedures to be applied:	NA
Comments:	Methane gas density (ρ) is assumed to be 0.717 kg/m^3 at 0 °C by default. For field conditions, it may be adjusted using the ideal gas law: $\rho = P \cdot M / R \cdot T$ where *P* is pressure (Pa), *M* is molar mass of CH_4 (0.01604 kg/mol), *R* is 8.314 J/mol·K, and *T* is temperature in Kelvin. Alternatively, a value of 0.656 kg/m^3 may be used for typical room temperature (25 °C), consistent with ideal gas behavior under standard pressure. Nitrous oxide gas density (ρ) is assumed to be 1.978 kg/m^3 at 0 °C under standard pressure. For field conditions, it may be dynamically adjusted using the ideal gas law: $\rho = P \cdot M / R \cdot T$

	where *P* is pressure in pascals (Pa), *M* is the molar mass of N_2O (0.04401 kg/mol), *R* is the universal gas constant (8.314 J/mol·K), and *T* is absolute temperature in Kelvin. For practical applications, a value of 1.805 kg/m³ may be used for room temperature (25 °C) under standard atmospheric pressure.

Appendix B: Project Risks for Consideration When Establishing Buffer Pool

The following is a list of potential events that could affect the validity of credits issued for projects in any given specific project category.

Reversal Risks

Environmental Events that result in the release of sequestered carbon, including:

- Fire
- Drought
- Disease/Pests
- Flood
- Earthquake
- Storms
- Heatwaves
- Avalanche

Human activity that unintentionally or deliberately result in the release of sequestered carbon, including:

- Land-use changes (e.g., deforestation, urban development)
- Project site abandonment (due to inadequate management, financial failure, socio-political instability, economic crises, community opposition, etc.)
- Failure of maintenance or oversight

Regulatory, Legal, and Compliance Risks

Regulatory Changes

- Alterations in national or regional regulations that invalidate or require re-evaluation of credit validity
- Introduction of new performance or safety standards that retroactively affect previously verified projects

Legal Disputes

- Litigation challenging the validity of credits
- Ownership disputes over land or resources related to the project

Compliance Failures

- Failure to adhere to regulatory requirements after credit issuance
- Non-compliance with ongoing monitoring and reporting obligations

Project Implementation and Verification Risks

Inadequate technical capacity of the VVB, VVB contractor, or project proponent, including:

- Unintentional or deliberate misrepresentation of project outcomes by the VVB, VVB contractor, or project proponents
- Inaccurate or incomplete Measurement, Reporting, and Verification processes leading to issuance of credits that do not reflect actual carbon reductions or removals
- Inaccurate data collection methods or issues related to the security, accuracy, and storage of data over time

Appendix C: Guidelines for the Measurement of Methane Emissions from Rice Fields

C.1 Objective

This appendix outlines the protocol for direct measurement of methane (CH_4) emissions from rice fields using the closed chamber method, consistent with Tier 3 (IPCC)[24], GS437[25] and Verra-VCS0051[26] rice cultivation methodologies. This approach is intended for project proponents capable of field-level sampling and laboratory analysis and aims to yield high-accuracy emissions data to support robust crediting and uncertainty management under the GHR Registry.

All sampling locations must be GPS-tagged and documented to ensure repeatability across seasons and enable verification. These coordinates must be included in the Project Monitoring Report

C.2 Applicability

Direct measurement is recommended where:

- Local emission factors are unavailable or unreliable;
- The project seeks to establish a high level of accuracy for methane fluxes;
- The project operates demonstration fields or reference/control fields.

C.3 Measurement Protocol

C.3.1 Closed Chamber measurement protocol

Measurement Method:

The closed chamber method shall be used for sampling CH_4 emissions. Chambers must meet the following criteria:

- Constructed from non-reactive, gas-tight materials (e.g., PVC or acrylic);
- Equipped with airtight sealing gaskets and vent tubes to prevent pressure buildup;
- Chambers must be installed on anchor frames (collars) embedded 5–10 cm into the soil, leaving 3–5 cm above the surface.

C.3.1.2 Sampling Frequency:

[24] **IPCC Guidelines** 2019: Refinement to 2006 Guidelines, Volume 4, Chapter 5.5 on Methane Emissions from Rice Cultivation

[25] **Gold Standard GS437**: Appendix A – Guidelines for measuring methane emissions from rice fields

[26] **Verra VM0051**: Appendix 2 – Guidelines for Field Measurements under Quantification Approach 2

- Minimum bi-weekly measurements during the cultivation period;
- Increased frequency (e.g., weekly) during critical emission windows such as 2–3 weeks post-transplantation and following fertilization or drainage events;
- Measurements must occur over 24-hour diurnal cycles or standardized time slots accounting for emission variability.

C.3.1.3 Sampling Procedure:

1. **Pre-sampling setup**: Install collars in selected sample fields at least 24 hours before first sampling.
2. **Gas collection**:
    - Place chamber over collar and seal.
    - Take gas samples at intervals (e.g., 0, 10, 20, and 30 minutes) using syringes or sampling vials.
        - Label and store samples in cool, dark containers for transport.
3. **Environmental data collection** at each event:
    - Soil temperature at 5 cm depth;
    - Water depth above soil surface;
    - Soil redox potential (if feasible);
    - Ambient air temperature and chamber headspace temperature.

C.3.2 Open Field measurement protocol

Measurement Method:

This section provides project proponents with structured guidance to perform open-field methane sampling in rice paddies using the closed chamber technique across representative project and baseline fields. This approach aligns with the Tier 3 guidelines of the IPCC 2019 Refinement, enabling field-calibrated emission estimations across spatially distinct cultivation practices.

C.3.2.1 Field Selection and Representativeness

1. **Minimum Sampling Sites:** Three samples per point taken at a minimum of three replicate sampling points is required. Where feasible, additional replicates are encouraged.
2. **Criteria for Representativeness:**

- Fields must reflect the typical management practices (irrigation, fertilization, residue handling) of the designated stratum.
- Soil texture and classification must be comparable to the overall project region to ensure consistency in flux behaviour.

3. **Spatial Diversity:** Field sampling measurements must be spaced adequately[27,28] apart (≥100 m apart where feasible) to capture local variability in environmental conditions and farm-level practices. Measurements must be accompanied by GPS recorded locations over time for permanent accuracy.

C.3.2.2 Chamber Setup and Pre-Sampling Preparations

1. **Chamber Collars:**
   - Stainless steel or PVC collars should be inserted 5–10 cm into the soil 24–48 hours before sampling.
   - The collars should accommodate flooding, maintaining stability during standing water periods.
2. **Vegetation Consideration:**
   - Rice plants inside the collar must not be disturbed. Chambers shall include a small vent to prevent pressure variation.
3. **Environmental Metadata Collection:**
   - Record water depth, soil temperature (5 cm depth), ambient temperature, air pressure, and time of sampling at each event.

C.3.2.3 Sampling Frequency and Timing

1. **Sampling Events:** Measurements should be taken at least bi-weekly, increasing to weekly during high-emission periods:
   - 1–2 weeks post-transplantation
   - After fertilizer application
   - Following irrigation or drainage events

[27] Snyder, C. S., Bruulsema, T. W., Jensen, T. L., & Fixen, P. E. (2009). *Review of greenhouse gas emissions from crop production systems and fertilizer management effects*. **Agriculture, Ecosystems & Environment**, 133(3–4), 247–266.

[28] Nitrous oxide emissions from soils: how well do we understand the processes and their controls? - University of Edinburgh Research Explorer

2. **Sampling Duration:**

   - Each sampling event shall involve at least three gas sample collections (e.g., at 0, 15, 30 minutes) from the same chamber setup.

3. **Time-of-Day Consideration:**

   - Sample during early morning (6–9 AM) and/or early afternoon (12–3 PM) to account for daily emission variations.

   - Diurnal correction factors can be derived by conducting 24-hour cycle tests on a subset of fields once per season.

C.4 Laboratory Analysis

- Gas samples must be analysed using Gas Chromatography (GC) with Flame Ionization Detector (FID);

- Calibration must be performed using standard CH_4 gas mixtures traceable to international standards;

- Detection limits and analytical uncertainty must be reported.

C.5 Emissions Calculation

Methane flux (F) per chamber event is calculated using:

$$F = \frac{\Delta C}{\Delta t} \times \frac{V}{A} \times \rho \times \frac{273}{273 + T} \times 0.24$$ **Eq. C-1**

Where:

F	Methane flux per chamber [kg CH_4/ha/day]
$\frac{\Delta C}{\Delta t}$	Rate of change in CH_4 concentration [ppm/hr]
V	Chamber volume [m^3]
A	Surface area of chamber [m^2]

ρ	Gas density [kg/m^3][29]
T	Air temperature in chamber [°C]
0.24	Unit conversion factor from mg/m²/hr to kg/ha/day

The Unit conversion factor from mg/m²/hr to kg/ha/day is derived as follows:

$$\frac{24hr}{day} \times \frac{10^4 m^2}{ha} \times \frac{1kg}{10^6 mg} = 0.24 \quad \text{Eq. C-2}$$

Seasonal methane emissions (kg CH_4/ha/cropping season) for each monitored field shall be aggregated over the cultivation period and averaged across replicate chambers. For extrapolation across the entire project area, project proponents shall apply an area-weighted average of emissions from each defined stratum (e.g., AWD vs continuously flooded fields), using their respective land coverage proportions and representative chamber data. Sampling field allocations shall follow the stratification design outlined in Section C.6.

Aggregate Over Time

Integrate or sum up the flux values from all sampling dates:

$$E_j = \sum_{i=1}^{n} F_i \times \Delta t_i \quad \text{Eq. C-3}$$

Where:

E_j	Seasonal Emissions per chamber *j* [kg CH_4/ha]
F_i	Flux on day *i* [kg CH_4/ha/day]
Δt_i	Time interval between successive sampling days [days]

[29] Methane gas density (ρ) is assumed to be 0.717 kg/m³ at 0 °C by default. For field conditions, it may be adjusted using the ideal gas law: ρ=P·M/R·T
where *P* is pressure (Pa), *M* is molar mass of CH_4 (0.01604 kg/mol), *R* is 8.314 J/mol·K, and *T* is temperature in Kelvin. Alternatively, a value of 0.656 kg/m³ may be used for typical room temperature (25 °C), consistent with ideal gas behavior under standard pressure.
Reference: **GRA-PRRG (2015).** *Guidelines for Measuring CH_4 and N_2O Emissions from Rice Paddies by Manually Operated Closed Chamber Method*. Global Research Alliance on Agricultural Greenhouse Gases.

Average Replicates Within Strata:

$$E_{stratum} = \frac{1}{r}\sum_{j=1}^{r} E_j \quad \text{Eq. C-4}$$

Where:

$E_{stratum}$	Average replicates within strata [kg CH_4/ha]
E_j	Seasonal flux from chamber *j [*kg CH_4/ha]
r	The number of replicates

C.6 Sampling Design and Stratification

- At minimum, three replicates per cultivation pattern or stratum must be measured.
- Stratification must follow parameters defined in Section 4 (e.g., water regime, organic amendments, soil type).
- Sampling fields shall be randomly selected but must also be representative of operational diversity.

Sampling Frame Setup:

- Divide the entire project area into distinct strata based on uniform practices (e.g., AWD vs flooded, different soils or inputs).
- For each stratum, identify representative sampling fields (already done during chamber setup)

Area-Weighted Averaging:

Each stratum has a measured emission rate $E_{stratum}$ and a corresponding area $A_{stratum}$

$$E_{stratum} = \frac{\sum_{s=1}^{S} E_s \times A_s}{\sum_{s=1}^{S} A_s} \quad \text{Eq. C-5}$$

Where:

$E_{stratum}$	Measured emission rate [kg CH_4/ha]
E_s	Seasonal emission rate for stratum *s* [kg CH_4/ha]
A_s	Area covered by stratum *s* [ha]
S	Total number of strata [ha]

C.7 Quality Control and Data Management

- Document calibration logs, sampling protocols, raw data sheets, and analytical reports;
- Apply outlier checks and ensure sample integrity (e.g., no overpressure leaks, stable storage temperatures);
- Employ QA/QC checks at all stages—field, transport, and lab;
- Maintain data archives for a minimum of 7 years from the end of the crediting period

C.8 Reporting Requirements

Measurement results must be reported in the Monitoring Report and include:

1. Chamber design and specifications;
2. Sampling calendar and field layout;
3. Flux calculations and seasonal aggregation;
4. Description of uncertainty and any anomalies;
5. Emission maps or summary tables by stratum.

C.9 Use in Baseline or Project Scenario

Direct measurement is encouraged for both:

- Establishing baseline emissions using control fields, or
- Monitoring project scenario emissions directly from treatment fields.

Appendix D: Guidelines for the Measurement of Nitrous Oxide Emissions from Rice Fields (Direct measurement approach

D.1 Objective

This appendix outlines the direct field-level protocol for measuring nitrous oxide (N_2O) emissions from rice cultivation using static chamber techniques, in alignment with Tier 3 guidance from Tier 3 (IPCC)[30], GS437[31] and Verra-VCS0051[32] rice cultivation methodologies. The objective is to support high-precision emissions accounting for crediting under the GHR Registry, particularly in practices involving a significant change in farming practices such as the switching to AWD, or the application of synthetic nitrogen fertilizer or organic amendments.

All sampling locations must be GPS-tagged and documented to ensure repeatability across seasons and enable verification. These coordinates must be included in the Project Monitoring Report.

D.2 Applicability

Direct N_2O measurement is recommended when:

- Projects apply site-specific nitrogen inputs (synthetic/organic);
- The goal is to validate emission reductions from altered N management (e.g., split application, reduced rate, enhanced efficiency fertilizers);
- Local emission factors are insufficient or lack temporal resolution.

D.3 Measurement Protocol

D.3.1 Chamber-Based Measurement Protocol

Measurement Method:

- A non-steady-state (static) chamber shall be used to capture soil surface N_2O fluxes.
- Chambers must be gas-tight, with reflective outer surfaces to minimize internal heating.
- Each chamber shall be equipped with septa for sample extraction and a vent tube to equilibrate pressure.

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[30] **IPCC Guidelines** 2019: Refinement to 2006 Guidelines, Volume 4, Chapter 5.5 on Emissions from Rice Cultivation

[31] **Gold Standard GS437**: Methane Emission Reduction by adjusted Water management practice in rice cultivation – Gold Standard for the Global Goals

[32] **Verra VM0051**: VM0051 Improved Management in Rice Production Systems, v1.0 - Verra

Collar Setup:

- PVC or stainless-steel collars are to be inserted 5–8 cm into the soil at least 24 hours before sampling.
- Vegetation within the collar must remain undisturbed.
- Collar tops must be leveled and aligned to ensure airtight sealing with the chamber lid.

Sampling Frequency:

- Minimum: weekly sampling throughout the cropping period.
- Increased frequency (2–3 times per week) is recommended during fertilization windows and immediately after major rainfall or irrigation events.

Sampling Duration and Timing:

- Samples should be collected at 0, 20, and 40 minutes post-closure.
- Sampling must be scheduled between 8:00–11:00 AM to capture peak emission periods while avoiding diurnal bias.
- Repeat measurements of three samples per sampling point over a minimum of three replicate sampling points is required for a total of nine samples. Where feasible, additional replicates are encouraged.
- To ensure spatial independence and avoid clustering, all sampling points within a field shall be located at a minimum distance of 100 meters from one another, unless physical field constraints prevent such spacing.

D.3.2 Environmental Data Collection

At each event, record the following:

- Soil temperature (at 5 cm depth)
- Soil moisture content
- Water level above or below surface (for intermittently flooded paddies)

- Chamber air temperature
- Recent rainfall or irrigation events

D.4 Laboratory Analysis

Gas samples must be analyzed via Gas Chromatography (GC) with an Electron Capture Detector (ECD) specifically calibrated for N_2O detection.

- Laboratory calibration must use traceable standard N_2O gas mixtures.
- Detection limits and repeatability must be documented.

D.5 Emissions Calculation

Nitrous oxide flux (F) is calculated as:

$$F = \frac{\Delta C}{\Delta t} \times \frac{V}{A} \times \rho \times \frac{273}{273 + T} \times 0.024 \quad \text{Eq. D-1}$$

Where:

F	Flux of Nitrous Oxide [kg N_2O-N/ha/day/°C]
$\frac{\Delta C}{\Delta t}$	Rate of change in N2O-N concentration [ppm/hr]
V	Chamber volume [m^3]
ρ	Gas density [kg/m^3][33]
A	Surface area of chamber [m^2]
T	Air temperature in chamber [°C]
0.024	Unit conversion factor from mg N_2O-N /m^2/hr to kg N_2O-N/ha/day

The unit conversion factor from mg/m²/hr to kg/ha/day is derived as follows:

$$1 mg/m^2/hr = 1 \times 10^{-6} \times 10^4 \times 24 = 0.024 kg/ha/day \quad \text{Eq. D-2}$$

[33] Nitrous oxide gas density (ρ) is assumed to be 1.978 kg/m³ at 0 °C under standard pressure. For field conditions, it may be dynamically adjusted using the ideal gas law: $\rho = P \cdot M / R \cdot T$
where *P* is pressure in pascals (Pa), *M* is the molar mass of N_2O (0.04401 kg/mol), *R* is the universal gas constant (8.314 J/mol·K), and *T* is absolute temperature in Kelvin. For practical applications, a value of 1.805 kg/m³ may be used for room temperature (25 °C) under standard atmospheric pressure.
Reference: **GRA-PRRG (2015).** *Guidelines for Measuring CH_4 and N_2O Emissions from Rice Paddies by Manually Operated Closed Chamber Method*. Global Research Alliance on Agricultural Greenhouse Gases

D.6 Aggregation Over Time and Space

Integrate or sum up the flux values from all sampling dates:

$$E_j = \sum_{i=1}^{n} F_i \times \Delta t_i$$	Eq. D-3

Where:

E_j	Seasonal Emissions per chamber *j* [kg N_2O/ha]
F_i	Flux on day *i* [kg N_2O/ha/day]
Δt_i	Time interval between successive sampling days [days]

Integrate flux data over time to derive seasonal emissions per hectare. Aggregate replicate measurements within each stratum and apply area-weighted averaging across the project boundary.

$$E_{stratum} = \frac{1}{r} \sum_{j=1}^{r} E_j$$	Eq. D-4

Where:

$E_{stratum}$	Average replicates within strata [kg N_2O-N/ha/season]
E_j	Seasonal flux from replicate *j* [kg N_2O-N/ha/season]
r	The number of replicates [dimensionless]

$$E_{project} = \frac{\sum_{s=1}^{S} E_s \times A_s}{\sum_{s=1}^{S} A_s}$$	Eq. D-5

Where:

$E_{project}$	Emission rate from project [kg N_2O-N/season]
E_s	Emission rate from stratum *s* [kg N_2O-N/ha/season]
A_s	Area of stratum *s* [ha]
S	Total number of strata

D.7 Sampling Design and Stratification

Minimum three replicates per distinct fertilization or water regime stratum and three samples per point. Stratification based on: fertilizer type and rate, soil texture, water management.

D.8 Quality Control and Data Management

Store and label samples with timestamps and GPS coordinates.

- Conduct chamber leak checks periodically.
- Maintain calibration logs and retain sample data for 7 years.
- Use field blanks and duplicates for QA/QC.

D.9 Reporting Requirements

The Monitoring Report must include:

- Chamber and collar design
- Sampling schedule and map of field locations
- N_2O flux calculation sheets
- Environmental metadata records
- QA/QC procedures and anomalies observed

D.10 Use in Baseline or Project Scenario

Direct N_2O measurement may be used in both baseline and project conditions to demonstrate the impact of nitrogen optimization or alternate fertilization schedules.

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