CLEAN DEVELOPMENT MECHANISM
PROPOSED NEW METHODOLOGY: MONITORING (CDM-NMM)
Version 01 - in effect as of: 1 July 2004

CONTENTS

SECTION A. Identification of methodology

A.1. Title of the proposed methodology:

This methodology will build upon ACM002 "Consolidated methodology for grid-connected electricity generation from renewable sources" but will add a component for calculating GHG emissions from a newly-created reservoir, as well as a component for cases in which the grid is too small or undeveloped to provide a clear combined-margin analysis. The title of the new methodology is Hydropower Projects that Create New Reservoirs or Expand Existing Ones.

A.2. List of category(ies) of project activity to which the methodology may apply:

Category 1: Renewable Energy

A.3. Conditions under which the methodology is applicable to CDM project activities:

This methodology is applicable to renewable power generation project activities displacing grid electricity with the conditions as follows:

- There is sufficient publicly available information to document in a transparent and conservative manner the nature of the prohibitive barriers to which the proposed project activity is subject, and the nature of the means by which its registration as a CDM activity would enable the project to overcome those barriers (and thus be successfully undertaken);
- There is sufficient publicly available information to document in a transparent and conservative manner that the proposed project is occurring in a sector and investment context that does not feature the type of proposed activity as a common practice;
- The project will provide electricity to the electric grid, displacing power that would otherwise be provided by other generating sources through the operation and expansion of the electric sector. The geographic and system boundaries for the relevant electricity grid can be clearly identified and information on the characteristics of the grid is available;
- The project is in an electric sector that is not dominated by generating sources with zero- or low-operating costs such as hydro, geothermal, wind, solar, nuclear, and low-cost biomass, and this fuel mix is expected to persist for the duration of the crediting period;
- Electricity exports are included in electricity generation data used for calculating and monitoring the baseline emission rate to avoid potential leakage.

Also, this methodology will apply in cases where reservoirs are created or expanded as a result of a hydroelectric project.

A.4. What are the potential strengths and weaknesses of this proposed new methodology?

This methodology uses all the elements of ACM002. Thus, one the strengths is that it relies very much on preceding methodologies already approved by the CDM Executive Board. The methodology also requires the monitoring of emissions from reservoirs that are created or expanded by hydroelectric projects, using straightforward gas measuring and sampling techniques.

The main weakness of this methodology is that the field of monitoring methane and CO_2 emissions from reservoirs is a relatively new field, requiring new and sometimes expensive technology, as well as trained technicians and possibly laboratory facilities. Monitoring of reservoir emissions also requires sampling. On the positive side, these sampling techniques have been tested many times in both tropical and boreal regions, through extensive research and field measurements – and these techniques have therefore been assessed and refined, improving overall accuracy.

SECTION B. Proposed new monitoring methodology

B.1. Brief description of the new methodology:

This methodology will use the elements of ACM002 as this is a renewable energy project. In addition, this methodology will make an allowance for cases when a national grid is too small for a combined-margin approach and/or does not service a significant portion of electricity consumers. This is the situation in many of the poorest parts of the world, particularly countries with a very small percentage of the population served by the grid. In some cases, much of the electricity from a renewable energy project will displace both off-grid diesel and grid-connected electricity. In this situation, a combined margin approach may not be completely accurate. In cases when the hydroelectric facility is displacing a significant portion of off-grid diesel generation, the project developer – upon providing clear evidence that this is the case – can assume an emission coefficient for a modern high efficiency diesel generating unit, as is allowed for in the small-scale methodology for renewable energy. This methodology allows for both a combined margin and off-grid diesel emissions factor to be utilized when it can be determined the percentage of renewable energy that displaces each. The project developer needs to analyze if the displaced generation is off-grid and if so, what percentage. If there is any uncertainty, the project developer should use the lower and thus more conservative of the two emission factors (combined margin or off-grid, default). In some cases – in the poorest countries and in the poorest areas of countries – there may be no substantial grid at all, in which case all the electricity displaced is off-grid generation and the default is the best and only option.

Reservoirs: This methodology also proposes to be applied in cases where reservoirs are created or expanded. Studies indicate that hydroelectric power reservoirs can emit substantial amounts of methane, as well as CO_2. Methane is emitted from reservoirs that are stratified and where the bottom layers are

anoxic (lacking oxygen), leading to degradation of biomass through anaerobic processes. Where the water is well oxygenated, degradation of biomass generates carbon dioxide, not methane. Based on extensive research and field measurements, it is impossible to tell beforehand how much reservoir emissions there will be. Emissions will vary depending on a number of factors, and thus the most practical way to determine emissions is to simply monitor them after the dam impoundment takes place. This methodology will therefore monitor emissions of methane and CO2 that are emitted from reservoirs. The preferred method will be the use of air sampling at representative points in the reservoir to measure the increase in concentrations of GHGs that are emitted into chambers. Samples of the gases within the chamber will be taken over a short period of time to calculate emissions at that point, as measured in milligrams of gas (CH4 or CO2) emitted per square meter per day. These samples will be taken over different sections as the reservoir (since reservoir emissions or "flux" can vary at different points of the reservoir – often depending on depth or type of vegetation flooded). Samples will also be taken at many times during the year since flux also varies according to season and weather. All together, this testing and sampling process should obtain an accurate estimate of GHG emissions from a reservoir created by a dam. The actual process is explained in Section B.4.

B.2. Option 1: Monitoring of the emissions in the project scenario and the baseline scenario:

B.2.1. Data to be collected or used in order to monitor emissions from the project activity, and how this data will be archived:

ID number *(Please use numbers to ease cross-referencing to table B.7)*	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment
2-1	Different categories to measure in flux testing	Dam operator	Number	Estimated	Once	100%	Electronic	See "Number and Frequency of Tests" section
2-2	Emissions of CH4 at each testing site in each category to be tested	Dam operator	Milligrams of gas emitted per sq. meter	Measured	Every Other Month	Sampled	Electronic	
2-3	Emissions of CO2 at each testing	Dam operator	Milligrams of gas emitted per	Measured	Every Other Month	Sampled	Electronic	

	site in each category to be tested		sq. meter					
2-4	Sq. meters of reservoir surf area fitting ea category	Dam operator	Square meters	Estimated	Every other month	100%	Electronic	*Surface area of reservoirs can change from season to season (eg: wet season, dry season, etc.)*
2-5	For degassing, concentration of CH4 in water at point of intake	Dam operator	Milligrams of gas in concentration per liter or cubic meter	Measured	Every Other Month	Sampled	Electronic	
2-6	For degassing, concentration of CH4 in water downstream of dam	Dam operator	Milligrams of gas in concentration per liter or cubic meter	Measured	Every Other Month	Sampled	Electronic	*Note: total degassing is determined by subtracting CH4 concentration per unit of volume downstream of dam (between .05 and 1.0 km) from CH4 concentration at point of intake. That number is multiplied by total volume of water moving through dam during the testing period (item 2-7)*
2-7	Total volume of water moving through dam during testing period	Dam operator	Liters or cubic meters	Measured	Daily	100%	Electronic	

This methodology proposes to be applied in cases where reservoirs are created or expanded. Studies indicate that hydroelectric power reservoirs can emit substantial amounts of methane, as well as CO_2. Methane is emitted from reservoirs that are stratified and where the bottom layers are anoxic (lacking oxygen), leading to degradation of biomass through anaerobic processes. Where the water is well oxygenated, degradation of biomass generates carbon dioxide, not methane. Based on extensive research and field measurements, it is impossible to tell beforehand how much reservoir emissions there will be. Emissions

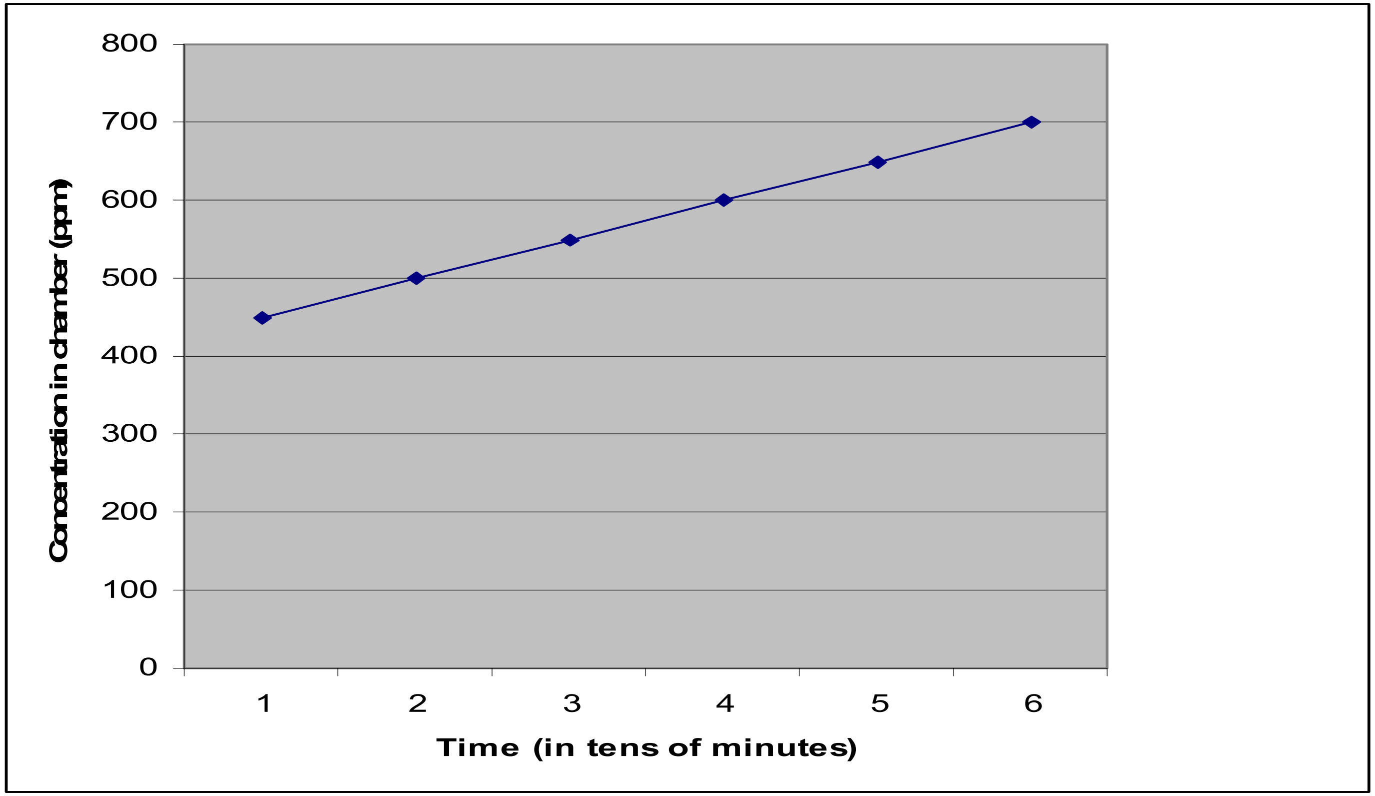
will vary depending on a number of factors, and thus the most practical way to determine emissions is to simply monitor them after the dam impoundment takes place. This methodology will therefore monitor emissions of methane and CO2 that are emitted from reservoirs. The preferred method will be the use of air sampling at representative points in the reservoir to measure the increase in concentrations of GHGs that are emitted into chambers. Samples of the gases within the chamber will be taken over a short period of time to calculate emissions at that point, as measured in milligrams of gas (CH4 or CO2) emitted per square meter per day. These samples will be taken over different sections as the reservoir (since reservoir emissions or "flux" can vary at different points of the reservoir – often depending on depth or type of vegetation flooded). Samples will also be taken at many times during the year since flux also varies according to season and weather. All together, this testing and sampling process should obtain an accurate estimate of GHG emissions from a reservoir created by a dam. The exact procedures are described in the project emissions section of the monitoring methodology.

The book *Greenhouse Gas Emissions – Fluxes and Processes*, Springer Press, 2005, lists several methods by which gross GHG emissions can be measured after a reservoir is created. Because this is a relatively new area of study, this methodology will rely on one of the most-established methods, which requires sampling of air and gas concentrations at representative points across a reservoir. There are a couple of methods available, and one is described below. However, the project developers can consider using a collection device resembling a funnel that collects gas for a 24-hour period. This funnel is then sealed and sent to laboratory for analysis. If the total area of the funnel is one square meter, then the total volume of gas collected over a 24-hour period can be used to determine GHG emissions per square meter per day in that area of the reservoir.[1]

The method described below is the use of floating chambers to capture gas samples, which are then either (a) analyzed in a laboratory or (b) analyzed on site with the use of an automated instrument – either a Non-Dispersive Infrared (NDIR) or a Fourier Transform Infrared (FTIR) instrument. Tremblay, et al, provide suggestions for the size and composition of the floating chamber, as well as how to prepare the chambers for testing, such as allowing time for equilibrium with local air. The proposed procedure for testing is as follows:

In the laboratory analysis or the automated instrument, the chamber is inserted into the water with the top sticking out of the water. Air is circulated through the devise, with samples being collected at specific time intervals (for the laboratory analysis, every 15 minutes for at least an hour and for the instrument analysis, every 20-30 seconds for up to 10 minutes). Each reading shows in an increase in CO2 and CH4 concentration in parts per million (ppm), as each test measures the rising concentration in the chamber. The results are plotted on a curve as demonstrated below:

[1] In a 2000 study prepared for the World Commission on Dams, two experts, Luiz Pinguelli Rosa and Marco Aurélio dos Santos, of the Alberto Luiz Coimbra Institute (an engineering school in Brazil) conducted a number of tests of GHG emissions at Brazilian reservoirs. The general methodology was the same, however, they used a set of funnel bubble collectors (cones of synthetic fabric on an aluminum framework and coupled with gas collecting bottles). The funnels were submersed and all air removed to avoid contamination by the atmospheric air present. After this process, the collecting bottles, full of water, were coupled to the funnel. The choice of the sampling site and the arrangement of funnels were determined by parameters such as the density of the flooded vegetation, the year the reservoir was filled, depth, presence of semi submersed vegetation, and geographic region of the reservoir. The funnels were left in place for 24 hours at the site, where, during this period, the bubbles emanating from the bottom were captured. The collection bottles were then hermetically sealed while still underwater and collected for later laboratory analysis.



The calculation of the emissions of the specific gas (flux) would use the slope of the curve (or approximate curve) and would be calculated as follows:

$$\text{Flux} = \frac{\text{slope} * F1 * F2 * \text{volume}}{\text{surface} * F3}$$

where,

slope = slope from graph of concentration versus time in ppm/minute or ppm/second
F1 = conversion factor from ppm to $\mu g \cdot m^{-3}$ (1798.45 for CO_2 and 655.47 for CH_4)
F2 = conversion factor to day from either minutes (for laboratory analysis, 1440) or seconds (for instrument analysis 86,400)

Volume = volume of air trapped in the chamber (m^3)
Surface = surface of the floating chamber over the water (m^2)
F3 = conversion factor from µg to mg (1000)

Flux is then measured in $mg/m^2/d$ for that location (milligrams of gas emitted per square meter of reservoir surface area per day)

Number and Frequency of Tests: In each location in the reservoir, the monitor should conduct at least three tests in order to ensure the reliability of the results. If the results are significantly different, then the monitor should conduct enough tests to obtain a certain result (at least three tests within 5% of each other). Separate tests would be done for both CH4 and for CO2.

The tests should be conducted in the same or similar points within the reservoir every other month in order to take into account seasonal differences within the reservoir. Fluxes may change from rainy to dry season, for example.

Finally, the tests should be done in different sections of the reservoir in order to get a representative sample of flux over different parts of the reservoir. The project developer should present to the DOE upon project validation what those categories of reservoir sections should be. For example, flux will vary from shallow portions of the reservoir to deeper points, as well as above different types of land that were originally flooded (forest, grassland, wetland, etc.). At project validation, the project developer should provide a map of the anticipated reservoir with all categories of sections to be tested (eg: different land areas and/or different potential depths), along with a justification of why those categories were established. At a minimum, categories of different depths of the reservoir and different types of land flooded should be provided. Each area or depth would be in one category and the project developer would have an estimate of the total number of square meters of reservoir cover that would be in each category. For example, wetlands cover will equal an estimated 2 million square meters; grassland, an estimated 3 million square meters – or 1-10 meters depth = X sq. meters, 11-20 meters depth = Y sq. meters, etc. These estimates will be provided to the DOE upon project validation.

Testing will therefore take place within each category across the reservoir, and the total flux determined by the testing will be multiplied by the total square meters within that category. For example, if the flux in the 1-10 meters depth range were 230 $mg/m^2/d$ that would be multiplied by the area of reservoir that were 1-10 meters deep. Each flux would be multiplied by the surface area to determine total flux for the reservoir.

Total Flux Per Testing Period (6 all together in one year): Flux at each point * number of square meters in that particular category of depth or vegetation cover * number of days between that testing period and the next period (no more than 60 days).

Degassing: in many reservoirs, degassing immediately downstream of a dam can be another important source of methane emissions. This is due to the fact that the solubility of gas is greater when pressure increases, as is often the case as water moved through a dam. There is some uncertainty, however, about how quickly the methane is emitted (within seconds is possible, thus conducting the analysis described above may not be accurate). To correct for this uncertainty, the project developer should measure the concentration of methane gas dissolved in the water the level of the intake for the spillway/turbines – again, taking

enough samples to get a single, reliable result. The developer can then take similar samples at a distance of about 0.5-1.0km downstream of the dam. Subtracting the two measurements will yield an estimate of the amount of methane no longer dissolved in the water downstream. That number would be multiplied by the total amount of water moving through the dam, which is then converted to a unit of mass emitted per day. This will give a good estimate of the methane lost due to degassing. For example, if samples show that at the intake, an average of 4.5 milligrams of CH_4 is dissolved in a liter of water – and samples downstream show an average of 3 mg/l – then what is emitted to atmosphere is 1.5 mg/liter. That number is multiplied by the number of liters moving through the dam (which should be metered and clearly known) during the testing period (no more than 60 days). Then the test is conducted again for the next testing period.

In summary, the methodology should be as follows:

Step 1: The project developer should provide – either before the reservoir is created, or after (depending on when project validation takes place) – a complete profile of the reservoir, including the different types of vegetation and other land characteristics that were flooded, along with an estimated measure of area for each different type. The profile should also include square areas of the reservoir at different depths. This profile or map of the reservoir should be provided to the DOE. Normally, this type of information would be available in most environmental impact statements.

Step 2: The reservoir profile will be used to delineate the different zones that will require testing. The project developer will provide to the DOE a sample testing protocol (number of tests that will be done in the different zones of the reservoir) along with a schedule. Other meteorological data could also be provided to determine the rainfall patterns, seasonal variations, etc. to help the DOE evaluate – at the project validation stage – that the testing protocol provides a reasonable and statistically-accurate measurement of reservoir emissions. Finally, the testing protocol should include a description of the staffing, equipment and other needs (such as a boat) that will be required, as well as the management structure for carrying out the monitoring (who will be responsible, how data will be collected and archived, etc.).

Step 3: After project validation and after the reservoir creation begins, the sampling according to the testing protocol will begin. All data will then be provided to the verifier upon project verification.

Total project emissions (PEy) =

$$\left[\sum_{N=1}^{N_{CH4}} \left(Flux_n * m^2{}_n * days_n\right) + DG_n\right] * GWP_{CH4} + \left[\sum_{N=1}^{N_{C02}} \left(Flux_n * m^2{}_n * days_n\right)\right]$$

- N_{CH4}=Number of tests, which correspond to the number of categories to measure CH4
- N_{C02}=Number of tests, which correspond to the number of categories to measure C02
- GWP_{CH4} = Global Warming Potential of methane (21)
- Flux = flux measured at each location within that category, measured in milligrams/square meter/day
- m^2 = square meters of reservoir surface area that correspond to that category
- Days = number of days within the testing period (between the first test and the next test)
- DG=Degassing, the flux of degassing emissions on other side of the dam, measured in the same units, which is converted from the difference in concentration of methane in the water at the point of intake and 0.5-1.0 km downstream of the dam and multiplied by the total amount of water moving through the dam. DG = (Total liters of Water Through Dam) * (Concentration of CH4/Liter at Intake Point – Concentration of CH4/Liter Downstream)

This figure will give total emissions in a given year but measured in milligrams. That number would then be multiplied by a conversion factor of 10^9 to get the figure in metric tonnes (1 metric tonne = 1,000,000,000 mg).

Estimates of emissions of carbon dioxide and methane from lakes have been made by a number of workers over the last decade and their findings have been summarized by Rosa et al (2002) and Tremblay *et al* (2005). Data from the more recent study, which includes observations from tropical reservoirs, suggest average emission rates of around 190 mg/m2/day for CO2 and 200 mg/m2/day for CH4.

B.2.2. Description of formulae used to estimate project emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.):

B.2.3. Relevant data necessary for determining the baseline of anthropogenic emissions by sources of greenhouse gases (GHG) within the project boundary and how such data will be collected and archived: When the combined margin approach is appropriate, the project developer will apply the following variables:

ID number *(Please use numbers to ease cross-referencing to table B.7)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper) and for how long	Comment

3-1	*Electricity produced hydroplant* (EG_y)	*Metered at Site*	*MWH*	*M*	*Hourly measurement, monthly recording*	*100%*	*Electronic/for the duration of the crediting period*	
3-2	*Carbon Emissions Factor for the entire grid* (EF_y)	*Public Data Sources*	*tCO2eq/MWH*	*C*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-3	*Carbon Emissions from Operating Margin* (EF_OM_y)	*Public Data Sources*	*tCO2eq/MWH*	*C*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-4	*Carbon Emissions Factor from build margin* (EF_BM_y)	*Public Data Sources*	*tCO2eq/MWH*	*C*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-5	*Total GHG emissions from grid* (TEM_y)	*Public Data Sources*	*tCO2eq/year*	*C*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-6	*Total electricity to grid, excluding low-cost, zero emission sources* ($TGEN_y$)	*Public Data Sources*	*MWH/year*	*M*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-7	*Amount of fossil fuel consumed in the grid* (i. $F_{i,y}$)	*Public Data Sources*	*Physical unit*	*M*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-8	*GHG co-efficient of each fuel* ($COEF_i$)	*IPCC*	*CO2/unit of fuel*	*M*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	

3-9	*Electricity generation of the plant ($jGEN_{j,y}$)*	*Public Data Sources*	*MWH*	*M*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-10	*Plant identification for OM*	*Public Data Sources*	*Name*	*M*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-11	*Plant identification for BM*	*Public Data Sources*	*Name*	*M*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-12	*Total electricity generation of imported power*	*Public Data Sources*	*MWH*	*M*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-13	*Carbon co-efficient of imported electricity*	*Public Data Sources*	*TCO2/MWH*	*C*	*Yearly*	*100%*	*Electronic/for the duration of the crediting period*	
3-14	*Non Dimensional number*	*Weight factor of OM (BM)*	-	*M*	*Yearly or fixed*	*100%*	*Electronic/for the duration of the crediting period*	*Default weight factor is 0.5 each. If the project developer wants to use another set of values, they should be monitored with reasonable reasons to be demonstrated (Wom + Wbm=1)*
3-15	-	*Documented evidences*		*M*	*Once at renewal time of crediting period*	*100%*	*Electronic/for the duration of the crediting period*	*Documented evidence of the prohibitive barriers of the proposed project activity*
3-16		*Documented evidences*		*M*	*Once at renewal time of crediting period*	*100%*	*Electronic/for the duration of the crediting period*	*Documented information related to the alternatives to the project*

B.2.4. Description of formulae used to estimate baseline emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.):

When the combined-margin approach is usable, the project developer will follow the steps as instructed in ACM002.

In cases in which the grid is too small or underdeveloped to undertake a proper combined margin analysis – and where the electricity displaced is from off-grid, diesel generation – the project developers can assume an emission coefficient for a modern diesel generating unit, as is allowed for in the small-scale methodology for renewable energy. In cases for larger-size projects, the conservative default of 0.8 TCO2/MWH will be used. The project developer must document – using the best available and transparent data sources – what amount of the renewable power that is being used to offset grid electricity (emission reductions measured using the combined margin) and off-grid (emission reductions measured using the default mentioned above).

There may be cases in which the grid is too small or underdeveloped for the combined-margin analysis alone to accurately and conservatively be used to demonstrate baseline emissions. For example, if a combined margin analysis showed that the emissions factor was 0.95 tonnes of CO2/MWH but the project were in a location where current demand is met in large part by off-grid diesel sources, the combined margin could be over-counting the emissions impact of a renewable energy project – if that project replaced less carbon-intensive diesel units.

In cases where the project will impact both grid and off-grid production, rather than trying to isolate the exact amount of electricity generated that should use the combined margin and the exact amount using the default factor, project developer will use the following conservative rule of thumb.

For any electricity supplied over the maximum production potential in the baseline year for the grid, the project developer will use the default factor of 0.8 TCO2/MWH. As mentioned before, the project developer will have documented in the additionality test that growing demand is very likely to be met by diesel generation. The remainder of the electricity generation added to the grid from the renewable project will use the more conservative number of the combined margin calculation and the default 0.8 TCO2/MWH.

For example, let's say an electricity grid in the baseline year can supply a maximum of 1200MWH a day, but after the project, at least 2000MWH is generated per day. The project developer can safely assume that at least 800MWH a day from the new renewable source are displacing off-grid, diesel generation. For any additional electricity generated by the renewable source beyond the 800MWH, the project developer will utilize the lower and more conservative of the two following numbers: the default factor and the calculated combined margin. So for renewable generation over 800 MWH, if the combined margin figure is less than 0.8 it will be used; if it greater than 0.8 than the default factor will be employed. If there are no grid-connected power plants from which to determine a build and operating margin (eg: in the poorest countries or the poorest areas within countries), the default 0.8 figure can be used.

B.3. Option 2: Direct monitoring of emission reductions from the project activity:

Option Not Selected

B.3.1. Data to be collected or used in order to monitor emissions from the project activity, and how this data will be archived:

ID number *(Please use numbers to ease cross-referencing to table B.7)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment

Option Not Selected

B.3.2. Description of formulae used to calculate project emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.):

Option Not Selected

B.4. Treatment of leakage in the monitoring plan:

Studies indicate that hydroelectric power reservoirs can emit substantial amounts of methane and carbon dioxide. Methane is emitted from reservoirs that are stratified and where the bottom layers are anoxic, leading to degradation of biomass through anaerobic processes. Where the water is well oxygenated, degradation of biomass generates carbon dioxide, not methane. In either case, it will be important to monitor GHG emissions. Reservoirs that risk being potent emitters of methane are those in warm latitudes, and which are extensive and stratified with anoxic layers.[2]

The current scientific thinking around this issue is that it is impossible to tell beforehand how much reservoir emissions there will be. Emissions will vary depending on a number of factors, and thus the most practical way to determine emissions is to simply monitor them after the dam impoundment takes place. There are methods available to monitor these emissions, and two options are presented in this methodology.

[2] To prevent stratification, water can be mixed. For example, using a free air mixing system can help reduce CH4 emissions by anchoring a horizontal perforated pipe to the bed of the reservoir, connected to a supply of air from a compressor at the surface. As the air bubbles rise they draw in water from the surrounding area, which sets up large counter-rotating cells in the adjacent water column. If the pipework was set up in the dry before impoundment begins this would provide a means of preventing stratification, which has been widely used in reservoirs elsewhere.

B.4.1. If applicable, please describe the data and information that will be collected in order to monitor leakage effects of the project activity:

ID number *(Please use numbers to ease cross-referencing to table B.7)*	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment

NA

B.4.2. Description of formulae used to estimate leakage (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.):

The main emissions potentially giving rise to leakage in the context of electric sector projects are emissions arising due to activities such as power plant construction, fuel handling (extraction, processing, and transport), and land inundation (for hydroelectric projects, see applicability conditions above). Project participants do not need to consider these emission sources as leakage in applying this methodology. Project activities using this baseline methodology shall not claim any credit for the project on account of reducing these emissions below the level of the baseline scenario.

B.5. Description of formulae used to estimate emission reductions for the project activity (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.):

The emission reduction *ERy* by the project activity during a given year *y* is the difference between baseline emissions (*BEy*) and project emissions (*PEy*), as follows:

$$ERy = BEy - PEy$$

(Note: BEy may use the combined-margin approach or the default of 0.8 TCO2/MWH, depending on whether grid or off-grid generation is displaced. If some of the renewable energy is displacing both grid and off-grid generation, the project developer will determine the percentage of off-grid generation that is displaced and apply the appropriate emissions factor – or apply the lower of the two coefficients in order to be as conservative as possible.)

B.6. Assumptions used in elaborating the new methodology:

The key assumption in this methodology is that it can basically use the entire methodology of ACM002, except for the project emissions component. For that issue, this methodology assumes, based on the latest science, that repetitive and frequent sampling, over different parts of a reservoir, can provide a realistic and accurate measurement of GHGs from reservoirs. This assumption is based on the expanding level of research that is going on in this field, which includes extensive field testing and duplication of testing using a variety of different methods (most coming up with the same general conclusions). All of these methods and a summary of the progress in researching the quantification of reservoir emissions is described in *Greenhouse Gas Emissions – Fluxes and Processes: Hydroelectric Reservoirs and Natural Environments* (Alain Tremblay, et. al, Springer Press, 2005). Another source used was a report for the World Commission on Dams, written by Luiz Pinguelli Rosa and Marco Aurélio dos Santos, of the Alberto Luiz Coimbra Institute (an engineering school in Brazil), which utilizing a similar sampling method. That paper is entitled "Certainty and Uncertainty in the Science of Greenhouse Gas Emissions from Hydroelectric Reservoirs," November, 2000.

B.7. Please indicate whether quality control (QC) and quality assurance (QA) procedures are being undertaken for the items monitored:

Data *(Indicate table and ID number e.g. 3.-1.; 3.2.)*	Uncertainty level of data (High/Medium/Low)	Explain QA/QC procedures planned for these data, or why such procedures are not necessary.
For 2-1-7	*Medium*	The reliability of testing will be ensured simply by frequent and repetitive tests. Tests must be performed until at least three results are within 5% of each other – for each point in the reservoir and for each time period within the project year. Proper training of personnel doing the testing must also be provided.
For 3-1-16 the same QC/QA procedures will be undertaken as in ACM002.	*NA*	See ACM002

B.8. Has the methodology been applied successfully elsewhere and, if so, in which circumstances?

The elements of the methodology that include the monitoring from renewable energy projects are well-established in ACM002. The new component is the measuring of reservoir emissions. There has been a good deal of work in this field, as numerous measurement initiatives have been taken in reservoirs in Canada, Brazil and other countries. These experiences, as well as the methodologies for field techniques are described in *Greenhouse Gas Emissions – Fluxes and Processes: Hydroelectric Reservoirs and Natural Environments* (Alain Tremblay, et. al, Springer Press, 2005). This method has also been used in several reservoirs, including in Brazil (see "Certainty and Uncertainty in the Science of Greenhouse Gas Emissions from Hydroelectric Reservoirs," Luiz Pinguelli Rosa and Marco Aurélio dos Santos for the World Commission on Dams, November, 2000.).

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