Approved baseline methodology AM0022

"Avoided Wastewater and On-site Energy Use Emissions in the Industrial Sector"

Source

This methodology is based on the Korat Waste To Energy Project, Thailand, whose Project Design Document, New Baseline and Monitoring Methodology were prepared by EcoSecurities Ltd on behalf of Korat Waste To Energy Company, Sanguan Wongse Industries Co Ltd, Clean Technologies Thailand, Waste Solutions Ltd and EcoSecurities Ltd. For more information regarding the proposal and its consideration by the Executive Board please refer to case NM0041-rev2: "Korat Waste To Energy Project, Thailand" on http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html.

Selected approach from paragraph 48 of the CDM modalities and procedures

"Existing actual or historical emissions, as applicable"

Applicability

This methodology is applicable to projects that introduce anaerobic treatment systems in existing industrial lagoon-based water treatment facilities under the following conditions:

- Project is implemented in existing lagoon-based industrial waste water treatment facilities for wastewater with high organic loading;
- The organic wastewater contains simple organic compounds (mono-saccharides). If the methodology is used for waste water containing materials not akin to simple sugars a CH_4 emissions factor different from 0.21 kgCH4/kgCOD has to be estimated and applied;
- The methodology is applicable only to the improvement of existing wastewater treatment facilities. It is not applicable for new facilities to be built or new build to extend current site capacity;
- It can be shown that the baseline is the continuation of a current lagoon system for managing waste water. In particular, the current lagoon based system is in full compliance with existing rules and regulations;
- The depth of the anaerobic lagoons should be at least 1m[1];
- The temperature of the wastewater in the anaerobic lagoons is always at least 15 °C;
- In the project, the biogas recovered from the anaerobic treatment system is used on-site for heat and/or power generation, surplus biogas is flared;
- Heat and electricity needs per unit input of the water treatment facility remain largely unchanged before and after the project;
- Data requirements as laid out in the related Monitoring Methodology are fulfilled. In particular, organic materials flow into and out of the considered lagoon based treatment system and the contribution of different removal processes can be quantified (measured or estimated).

This baseline methodology shall be used in conjunction with the approved monitoring methodology AM0022 ("Avoided Wastewater and On-site Energy Use Emissions in the Industrial Sector").

[1] In particular, loading in the waste water streams has to be high enough to assure that the lagoon develops an anaerobic bottom layer and that algal oxygen production can be ruled out.

Project activity

The project activity foresees the introduction of a new anaerobic treatment facility into an existing lagoon-based treatment system for industrial organic waste water treatment. The output of partially treated water of the new anaerobic treatment facility will be fed into the existing lagoon system. With this, the methane emissions from the overall treatment system are reduced. The biogas collected in the anaerobic treatment facility is used for the generation of heat and/or electrical power, thus substituting the use of fossil fuels for heating and/or power generation or reducing the demand of power from the electricity grid, reducing CO_2 emissions. Surplus biogas from anaerobic treatment is flared.

Project Boundaries

Project boundaries should be drawn encompassing (as appropriate):

- Methane emissions from the existing lagoon-based waste water treatment system up to, and including, the point at which organic material flows can be quantified or estimated into and out of the wastewater treatment facility;
- Potential methane emissions from the newly introduced anaerobic waste water treatment facility (or demonstration that they are negligible);
- CO_2 emissions from displaced fossil fuel use for on site heat and/or power generation;
- CO_2 emissions from displaced fossil fuel use for offsite/grid generation of electricity that would otherwise have been produced;
- Methane emissions from incomplete combustion of biogas in heat and/or power generation or in flare systems, or from leakage in piping.

Ignored emissions include: nitrous oxide from the waste treatment system, and nitrous oxide from biogas combustion and/or destruction.

Decision trees supporting the boundary setting are provided in the section on *Baseline Boundaries* (please refer to page 9 below).

Project Emissions

Total estimated project emissions are the sum of fugitive methane emissions from the existing lagoon-based water treatment system, from possible methane emissions from the new anaerobic waste water treatment facility, from incomplete biogas combustion, biogas leaks.

Total Project emissions:

$$E_{project} = E_{CH4\_lagoons} + E_{CH4\_NAWTF} + E_{CH4\_IC+Leaks} \quad \textbf{(1)}$$

where:

$E_{project}$ are the Total Project Emissions (tCO_2e)
$E_{CH4\_lagoons}$ are the fugitive methane emissions from lagoons from equations 2 (tCO_2e)
E_{CH4_NAWTF} are the fugitive methane emissions from the new anaerobic waste water treatment facility (tCO_2e)
$E_{CH4\_IC+leakss}$ are the methane emissions from inefficient combustion and leaks (tCO_2e)

Fugitive Methane Emissions From Lagoons
Fugitive Methane Emissions From Lagoons are:

$$E_{CH4\_lagoons} = M_{lagoon\_anaerobic} \cdot EF_{CH4} \cdot GWP_{CH4} \qquad \textbf{(2)}$$

where:

$M_{lagoon\_anaerobic}$ is the amount of organic material removed by anaerobic processes in the lagoon system (kg COD[2])
EF_{CH4} is the methane emission factor (kg CH_4 / kg COD). A default COD to Methane conversion factor of 0.21kg CH4/kgCOD is used[3]. If the methodology is used for waste water containing materials not akin to simple sugars a CH_4, a different emissions factor different has to be estimated and applied. Where a metric for organic wastewater flows other than COD is to be applied, the developer should set out the case for a relevant carbon emission factor.
GWP_{CH4} is the Global Warming Potential of methane (GWP_{CH4} = 21)

The total removal of COD from individual lagoons is a function of:

- Aerobic surface oxidation of COD;
- Chemical oxidation in lagoons (where oxidative species such as sulphate are present);
- Sedimentation of material that microbes are unable to degrade before they form a bottom sediment; and,
- COD degradation as a result of anaerobic micro bacterial activity.

Because individual ponds act in unique manner the total removal and its components must be characterized on a project specific basis.

The mass balance in the considered lagoon system provides the amount of organic material removed by anaerobic processes:

$$M_{lagoon\_anaerobic} = M_{lagoon\_total} - M_{lagoon\_aerobic} - M_{lagoon\_chemical\_ox} - M_{lagoon\_deposition} \qquad \textbf{(3)}$$

where:

M_{lagoon_total} is the total amount of organic material removed in the lagoon system from equation 5 (kg COD)
$M_{lagoon\_aerobic}$ is the amount of organic material degraded aerobically in the lagoon system (kg COD). Surface aerobic losses of organic material in pond based systems equal to 254 kg COD per hectare of pond surface area and per day is assumed to be lost through aerobic processes. Where other more project specific losses can be determined, these should be applied.
$M_{lagoon\_chemical\_ox}$ is the amount of organic material lost through chemical oxidation in the lagoon system (kg COD)
$M_{lagoon\_deposition}$ is the amount of organic material lost through deposition in the lagoon system from equation 6 (kg COD)

A sensitivity analysis should be carried out for the surface aerobic losses of organic material to assess its applicability under individual project situations.

---

[2] The manner in which organic material load is quantified is not specified here. It is left to the project developer to justify an appropriate choice of wastewater concentration metric depending upon local circumstances. However, in line with IPCC quantification of industrial wastewater treatment a recommendation is made to apply COD (Chemical Oxygen Demand) as the measure of wastewater organic material load.
[3] Source: IPCC, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, page 5.16.

Deposition, total removal as well as chemical oxidation are project specific factors that must be quantified on a project by project basis.

In order to assess the amount of COD actually entering the anaerobic system (the lagoons) the amount of COD removed as a result of the new waste water treatment facility must be determined. This is set out in Equation 4.

Project Organic Material Entering Lagoon System from New Anaerobic Water Treatment System is:

$$M_{lagoon\_input} = M_{input\_total} \cdot (1 - R_{NAWTF}) \qquad \textbf{(4)}$$

where:

M_{lagoon_input} is the input of organic material from the new project anaerobic waste water treatment facility into the lagoon system (kg COD)

M_{input_total} is the total amount of organic material fed into the new project water treatment facility (kg COD)

R_{NAWTF} is the total organic material removal efficiency of the new project water treatment facility (-). It is a project specific factor used to estimate how much COD will be removed from the system. The most appropriate manner to estimate this factor is to undertake pilot plant trials with a pilot scale digester system prior to project implementation. Where this is not possible, manufacturers estimates as to equipment removal efficiencies may be applied. This factor will be used to determine estimates of COD flows to the project lagoon system, and the related monitoring methodology (AM0022 "Avoided Wastewater and On-site Energy Use Emissions in the Industrial Sector") sets out how the actual amount of COD can be monitored to allow calculation of actual project emissions.

Total Material Removed In Lagoon System is:

$$M_{lagoon\_total} = M_{lagoon\_input} \cdot R_{lagoon} \qquad \textbf{(5)}$$

where:

M_{lagoon_total} is the total amount of organic material removed in the lagoon system through various routes (kg COD)

R_{lagoon} is the total organic material removal ratio of the lagoon (-). It is a project specific factor, and is equal to the proportion of organic material removed (through all routes) within the boundaries of the lagoon system under consideration. This factor should be determined by carrying out a series of biochemical tests prior to project implementation. These tests will determine the COD flows into the system, and the COD flows out of the system at the system boundary. The relative difference of COD flowing in and out of the system over a period of time will allow determination of the Total Organic Material Removal Ratio.

Material Deposition In Lagoon System is:

$$M_{lagoon\_deposition} = M_{lagoon\_input} \cdot R_{deposition} \qquad \textbf{(6)}$$

where:

R_{lagoon} is the organic material deposition ratio of the lagoon. It is equal to the proportion of organic material physically sedimented in lagoons within the project boundaries. It is a project specific factor derived by assessing the relative ability of COD in the waste water stream to sediment in the project boundaries, through pre project analysis.

Details on the determination of Organic Removal Ratio, Aerobic Decomposition of COD at Lagoon Surfaces, Determining Rates of Sedimentation and Chemical Oxidation are given in Appendices 1, 2 and 3.

Methane emissions from new anaerobic waste water treatment facility
Methane emissions from the specific anaerobic waste water treatment facility that is implemented with the project, should be assessed and estimated based on measurements, technology supplier data and expert estimates. They may be neglected if documented evidence for their insignificance is given.

Methane emissions from Inefficient Combustion Emissions
The combustion of biogas methane may give rise to significant methane emissions as a result of incomplete, or inefficient combustion. The three predominant potential routes for the destruction of methane are:

- Biogas flaring;
- Biogas use in heating systems;
- Biogas use for on site electricity generation.

This methane should be quantified through equation 7.

$$E_{CH4\_IC+Leaks} = \sum_r V_r \cdot C_{CH4\_r} \cdot (1 - f_r) \cdot GWP_{CH4} \quad \textbf{(7)}$$

where:

the sum is made over the three predominant routes r for methane destruction (flaring, heating, power generation);
V_r is the biogas combustion process volume in route r (Nm^3)
C_{CH4} is the methane concentration in biogas (tCH_4/Nm^3)
f_r is the proportion of biogas destroyed by combustion (-)

Methane Emissions From Leaks in Biogas System
Leaks in the biogas system include leaks from any anaerobic digester and leaks from the biogas pipeline delivery system.
Although no proposal is set out here as to how biogas leaks from any anaerobic digester system is to be quantified, as this is a purely project specific factor, the project developer must provide, justify and take into account specific data required to calculate related emissions when applying this methodology. In addition, the amount of biogas leaking from the biogas delivery system (pipeline) shall be calculated. Where these pipelines are short (ie, less than 2km, and for on site delivery only) there may be limited leakage where high quality materials are utilised in construction. To test this assertion, tests should be carried out annually to determine how much biogas (and finally methane) leaks.

Baseline

Baseline Determination

The baseline determination methodology consists of a six-step process in order to define the baseline and to demonstrate that the continuation of current practices (existing lagoon based waste water treatment system without biogas use) is the baseline:

1. **Listing** a range of potential baseline options; i.e. option(s) available to the project participants or similar project developers that provide waste water disposal services comparable with the proposed CDM project activity. Options that might be considered include: Direct release of wastewaters to a nearby water body; new anaerobic digestion or aerobic treatment facilities (activated sludge or filter bed type treatment), continuation of the current situation and the proposed anaerobic treatment facility not undertaken as a CDM project activity;

2. **Select** the barriers from the range of potential barriers that can be demonstrated to be significant in the context of the particular project under consideration i.e. that may prevent the implementation of any of the considered options. Identify barriers expected to be the most significant, where any difference in their relative impacts occurs. The most significant barriers should be documented and their impact on the particular options under consideration explained. Barriers that are considered absolute must be drawn out and identified. Where an absolute barrier is identified the option can not be considered the baseline. An example of this would be a legal barrier to the continuation of the baseline scenario- no further assessment of this option will be carried out;

3. **Score** the barrier. This can be done by addressing a range of potential questions, as set out in Table 1 below. Where a barrier exists Select **Y**, Where a barrier does not exist select **N**, where the question is not relevant select **NA.** Where a barrier is identified, the project proponent shall provide transparent and documented evidence, and offer conservative interpretations of this documented evidence, as to how it demonstrates the existence and significance of the identified barriers. Anecdotal evidence can be included, but alone is not sufficient proof of barriers. In scoring the barriers, factors mitigating barriers such as the existence of programmes for technology support in the host country or subsidies available should be taken into consideration;

4. **Compare,** through assessment of the barriers results, which is the most plausible baseline option and determine whether, on balance, it can be shown that particular barriers drive a particular baseline option;

5. **Investment Analysis:** In situations where more than one baseline option results from the barrier analysis in steps 2 to 4, the financial viability of each these options should be assessed as described in Step 2 (Investment Analysis) of the *Tool for the Demonstration and Assessment of Additionality* (EB16 Annex 1) to differentiate between options and determine the most likely baseline scenario;

6. **Conclusion:** The baseline determination should demonstrates that the current and historic practices (and emissions) on the site would continue in the absence of the CDM project activity (i.e. are the baseline). If any of the other alternative baseline options is more likely, this conclusion cannot be drawn and the present methodology is not applicable for the specific project activity.

Table 1: Barrier Test Framework[4]

Barrier Tested / **Plausible Baseline Alternative**	**Alternative 1**	**Alternative 2**	**Alternative 3**
Legal			
• Does the practice violate any host country laws or regulations or is it not in compliance with them?			
Technical			
• Is this technology option currently difficult to purchase through local equipment suppliers?			
• Are skills and labour to operationalize and maintain this technology in country insufficient?			
• Is this technology outside common practice in similar industries in the country?			
• Is performance certainty not guaranteed within tolerance limits?			
• Is there real, or perceived, technology risk associated with the technology?			
Financial			
• Is the technology intervention financially less attractive in comparison to other technologies (taking into account potential subsidies, soft loans or tax windows available)?			
• Is equity participation difficult to find locally?			
• Is equity participation difficult to find internationally?			
• Are site owners/ project beneficiaries carrying any risk?			
• Is technology currency (country) denomination a risk?			
• Is the proposed project exposed to commercial risk?			
Social			
• Is the understanding of the technology low in the host country/industry considered?			
Business Culture			
• Is there a reluctance to change to alternative management practices in the absence of regulation?			
Other			
• …			

Key – Y: barrier exists; N: barrier does not exist; NA: question is not relevant

[4] Note: The list of potential questions and related barriers in Table 1 is not exhaustive, and project developers are encouraged to identify and justify other potential barriers preventing any of the project options identified.

Baseline Boundaries

Baseline boundaries are almost identical to the project boundaries mentioned above, but do not include potential methane emissions from the project anaerobic waste water treatment facility, or from biogas (incomplete combustion, leaks).

Baseline boundaries should be drawn encompassing (as appropriate):

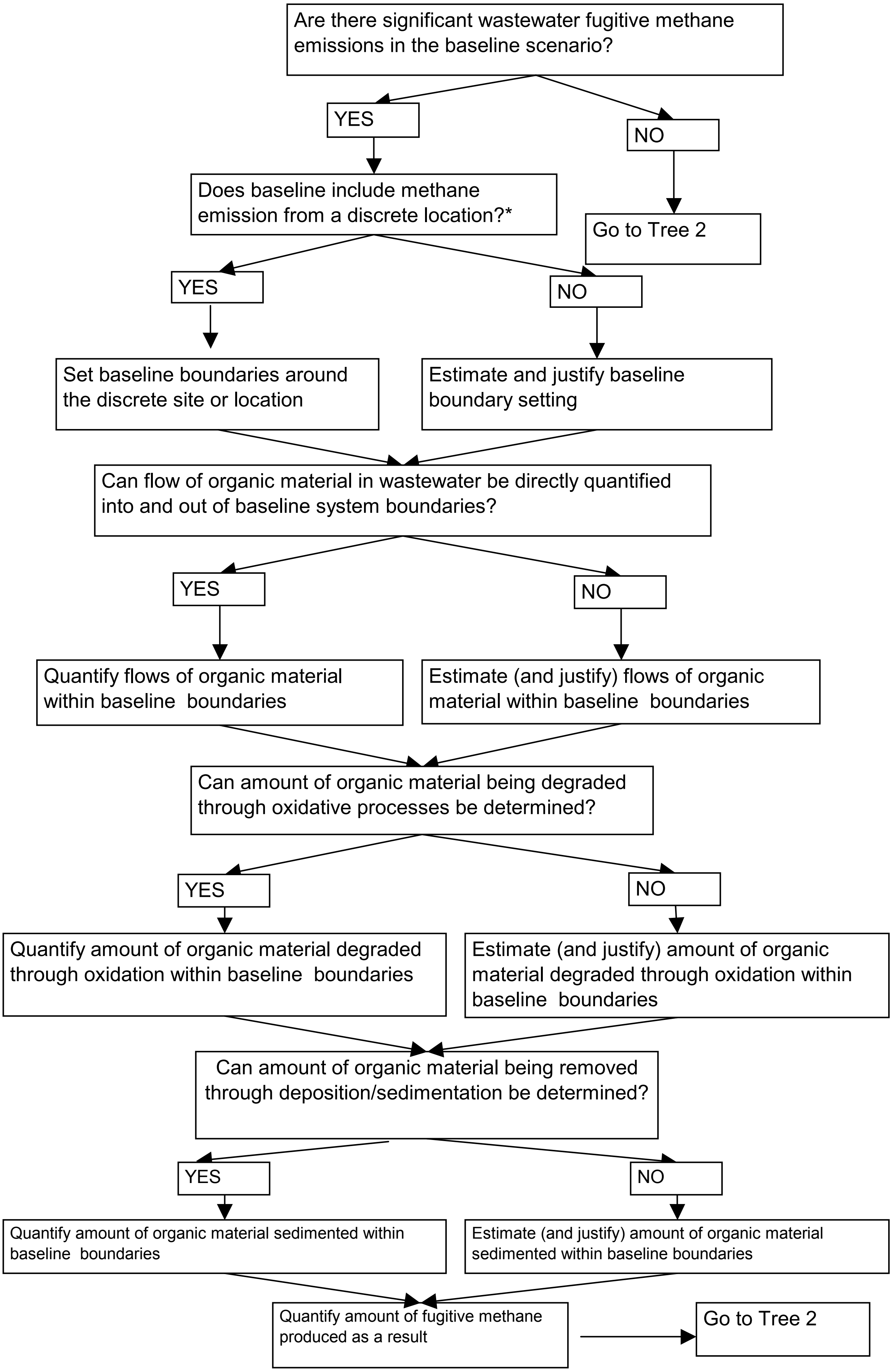
- Methane emissions from the existing lagoon-based waste water treatment system up to, and including, the point at which organic material flows can be quantified or estimated into and out of the wastewater treatment facility;
- CO_2 emissions from fossil fuel use for on site heat and/or power generation;
- CO_2 emissions from fossil fuel use for offsite/grid generation of electricity that would otherwise have been produced.

Ignored emissions are: nitrous oxide from the waste treatment system, nitrous oxide and methane from fossil energy use in heat and/or electricity generation.

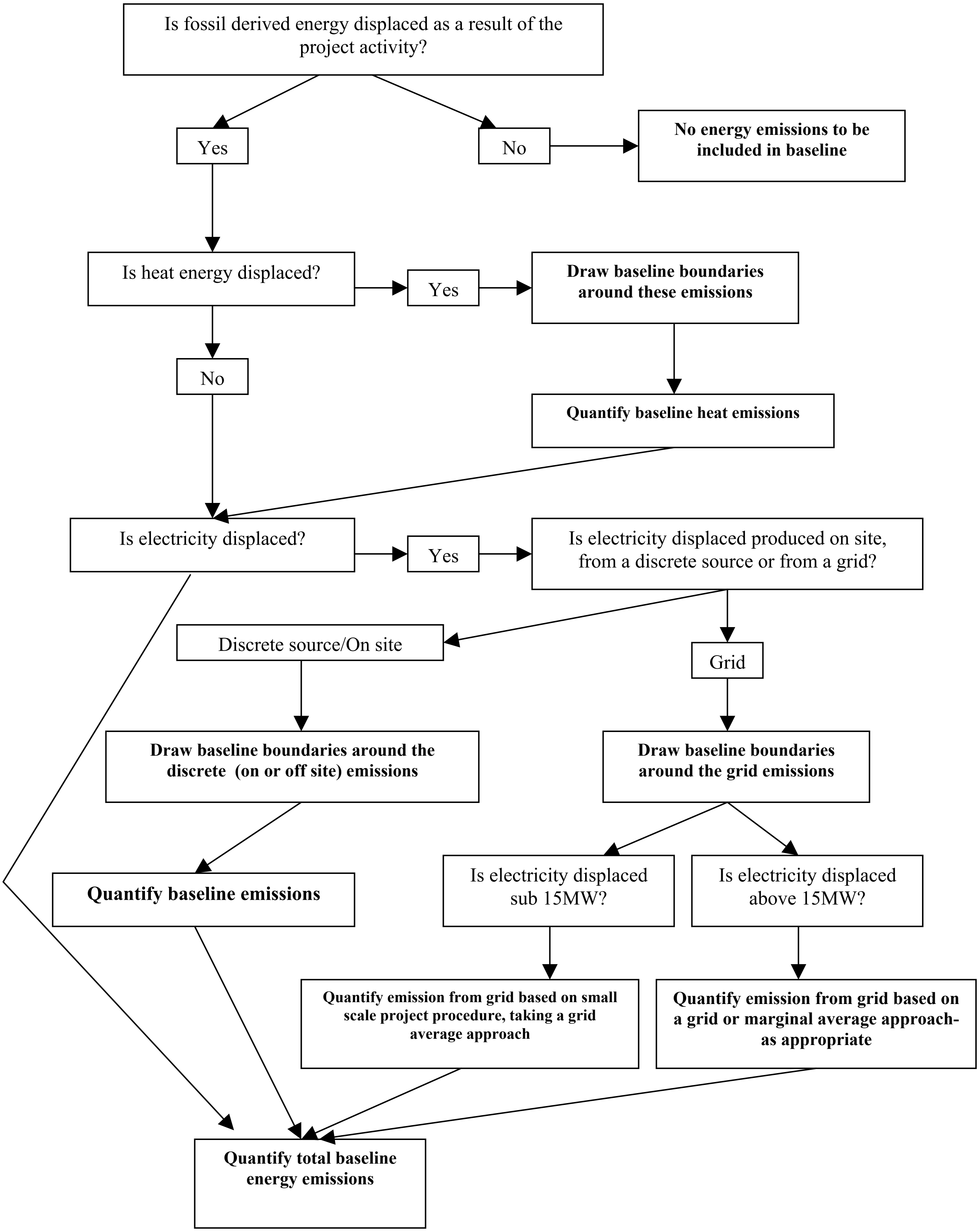
The following decision trees aim to both guide boundary setting and also determine what elements must be considered to quantify baseline emissions:

- Decision Tree 1 supports the developer identifying the elements relevant to fugitive methane emissions quantification. It aims to guide the developer through understanding some of the primary elements to consider when setting baseline boundaries and emissions;
- Decision Tree 2 supports the developer identifying whether the baseline includes on or offsite energy related emissions, and where to draw boundaries. Where biogas energy is to be produced and used in the project scenario the emissions in the baseline that are to be materially affected must be identified.

Decision Tree 1, Baseline Boundaries & Fugitive Methane Quantification



Decision Tree 2- Determine Baseline Boundaries and Energy Emissions[5]



[5] For electricity installations greater than 15MW, ACM 0002 must be applied.

Baseline Emissions

Total estimated baseline emissions are the sum of fugitive methane emissions from the existing lagoon-based water treatment system and CO_2 emissions from the generation of heat on site and/or the generation of power on site or off site.

Total Baseline Emissions:

$$E_{BL} = E_{CH4\_lagoons\_BL} + E_{C02\_heat+power\_BL} + E_{CO2\_grid\_BL} \tag{8}$$

where:

E_{BL} are the Total Baseline Emissions (tCO_2e)
$E_{CH4\_lagoons\_BL}$ are the fugitive methane emissions from lagoons in the baseline case (tCO_2e). They are calculated with baseline data based on equation 2 in the section on project emissions.
$E_{CO2\_heat+powers\_BL}$ are the CO_2 emissions from on site fossil heat and/or power generation in the baseline case (tCO_2) that are displaced by generation based on biogas collected in the anaerobic treatment facility.
$E_{CO2\_grid\_BL}$ are the CO_2 emissions related to electricity supplied by the grid in the baseline case (tCO_2) that are displaced by generation based on biogas collected in the anaerobic treatment facility.

On Site Heat and On-site Power Generation Emissions displaced by generation based on biogas collected in the anaerobic treatment facility

In calculating CO_2 emissions from on site heat displaced by biogas collected in the anaerobic treatment, the use of fossil fuels is considered:

$$E_{C02\_heat+power} = F \cdot NCV \cdot EF \tag{9}$$

where:

F is the corresponding amount of fossil fuel used for on site heat and/or power generation (unit)
NCV is the net calorific value of the fossil fuel considered (TJ/unit). Site specific local NCV values should be applied where available; however, should this information not be available, IPCC data may suffice for that specific country[6].
EF is the carbon emission factor of the fossil fuel considered (tCO_2/TJ).

[6] IPCC (1996) Revised Guidelines for National GHG Inventories. Table 1.3, IPCC Reference Approach, steps 3-6.

On site and off site Grid Power Generation Emissions displaced by generation based on biogas collected in the anaerobic treatment facility

For displaced electricity generated off site different quantification processes for carbon emission factors (CEF) may be applied[7]:

- Sub 15MW Generation: Where the project will have sub 15MW of installed capacity the small scale procedures for sub 15MW electricity generation for export to a grid, as set out by the CDM Executive Board, may be applied (under 1D, Renewable Energy Projects for a Grid).
- 15MW+ Generation: Where the project will have more than 15MW of installed capacity the approved consolidated methodology ACM 002 should be applied.

Displaced electricity CO_2 emissions are:

$$E_{CO2\_grid} = EL \cdot CEF \quad \textbf{(10)}$$

where:

EL is the amount of electricity displaced by the electricity generated from the biogas collected from the anaerobic treatment facility
CEF is the lowest among (i) carbon emission factor of the grid as discussed above (tCO_2e/MWh) and (ii) carbon emission factor of the on site electricity generation equipment displaced if any (tCO_2e/MWh)
In the baseline case, without the new anaerobic treatment facility, no material is degraded from the waste water before entering the lagoon system and all the organic material to be treated enters the lagoon system. Equation (4) in the project case has to be changed for the baseline into:

Baseline Organic Material Entering Lagoon System from New Anaerobic Water Treatment System is:

$$M_{lagoon\_input\_BL} = M_{input\_total} \quad \textbf{(11)}$$

where:

$M_{lagoon\_input\_BL}$ is the input of organic material from the new project anaerobic waste water treatment facility into the lagoon system (kg COD)
M_{input_total} is the total amount of organic material fed into the baseline water treatment facility (kg COD). It is the same amount as fed into the project water treatment facility.

All emission factors, surface aerobic losses of organic material, aerobic degradation, deposition or removal as well as chemical oxidation are determined in the same way as described for the project scenario in the section on project emissions above.

Leakage

Leakage is considered to be negligible.

[7] The CER methodologies currently apply only to the *generation* of electricity for export to a grid systems. However, this methodology seeks to extend available methodology to activities where electricity is also to be *used* on site, but where current (baseline) supply is drawn from a grid system. The rationale for this is that the impact of such activities (displacing capacity from a grid where electricity is to be alternatively generated on site and generation for export grid and displacement of current grid capacity) have exactly the same implications in terms of the impact on displacing other generating capacity from the grid.

Emission Reductions

Emission reductions, ER (t CO_2e) are calculated as the difference between baseline (equation 8) and project (equation 1) emissions. Leakage is considered to be negligible.

$$ER = E_{BL} - E_{project} \quad \textbf{(12)}$$

Additionality

If the baseline determination in this methodology (see section "Baseline" above) demonstrates that the baseline is different from the proposed project activity not undertaken as a CDM project activity, it may be concluded that the project is additional.

Approved monitoring methodology AM0022

"Avoided Wastewater and On-site Energy Use Emissions in the Industrial Sector"

Source

This methodology is based on the Korat Waste To Energy Project, Thailand, whose Project Design Document, New Baseline and Monitoring Methodology were prepared by EcoSecurities Ltd on behalf of Korat Waste To Energy Company, Sanguan Wongse Industries Co Ltd, Clean Technologies Thailand, Waste Solutions Ltd and EcoSecurities Ltd. For more information regarding the proposal and its consideration by the Executive Board please refer to case NM0041-rev2: "Korat Waste To Energy Project, Thailand" on http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html

Applicability

This methodology is applicable to projects that introduce anaerobic treatment systems in existing industrial lagoon-based water treatment facilities under the following conditions:

- Project is implemented in existing lagoon-based industrial waste water treatment facilities for wastewater with high organic loading;
- The organic wastewater contains simple organic compounds (mono-saccharides). If the methodology is used for waste water containing materials not akin to simple sugars a CH_4 emissions factor different from 0.21 kgCH4/kgCOD has to be estimated and applied;
- The methodology is applicable only to the improvement of existing wastewater treatment facilities. It is not applicable for new facilities to be built or for capacity additions;
- It can be shown that the baseline is the continuation of a current lagoon system for managing waste water. In particular, the current lagoon based system is in full compliance with existing rules and regulations;
- The depth of the anaerobic lagoons should be at least 1m[8];
- The temperature of the wastewater in the anaerobic lagoons is always at least 15 °C;
- In the project, the biogas recovered from the anaerobic treatment system is used on-site for heat and/or power generation, surplus biogas is flared;
- Heat and electricity needs per unit input of the water treatment facility remain largely unchanged before and after the project.;
- Data requirements as laid out in the related Monitoring Methodology are fulfilled. In particular, organic materials flow into and out of the considered lagoon based treatment system and the contribution of different removal processes can be quantified (measured or estimated).

This monitoring methodology shall be used in conjunction with the approved baseline methodology AM0022 ("Avoided Wastewater and On-site Energy Use Emissions in the Industrial Sector").

[8] In particular, loading in the waste water streams has to be high enough to assure that the lagoon develops an anaerobic bottom layer and that algal oxygen production can be ruled out.

Monitoring Methodology

The methodology allows for the monitoring of both the project and baseline scenario emissions. This occurs through use of project specific data (where appropriate in a project specific situation) as direct indicators of the actual baseline. The main elements to be monitored include:

1. Fugitive methane: through the assessment of organic material flows through the project and the baseline system;
2. Electricity generated from the biogas collected in the anaerobic treatment facility and consumed on site or sent the grid;
3. On-site heat generated from the biogas collected in the anaerobic treatment facility;
4. Inefficient biogas combustion emissions in project: emissions arising though inefficient destruction of biogas in the heating systems, electricity gen sets and emergency flares will be quantified through assessing the efficiency of biogas destruction during equipment O&M cycles;
5. Biogas leakage in project: through leaks in the pipeline during transportation of biogas, or its production in anaerobic digesters.

Parameters to be monitored

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

ID number	Data type	Data variable	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
1.	volume	Wastewater flows entering system boundary.	m^3	M	continuously	100%	electronic	
2.	volume	Wastewater flows leaving project treatment facility.	m^3	M	continuously	100%	electronic	
3.	concentration	wastewater organic material concentration entering the project boundary.	kg COD/ m^3 [9]	M	daily	100%	paper and transferred to electronic	Indicator of baseline wastewater methane emissions. Organic material concentration can be sampled on site, but off-site analysis by an accredited lab is recommended.
4.	concentration	wastewater organic material concentration leaving the treatment facility.	kg COD/ m^3 [10]	M	daily	100%	paper and transferred to electronic	Indicator of project wastewater methane emissions. Organic material concentration can be sampled on site, but off-site analysis by an accredited lab is recommended.

[9] COD is set out here as the concentration metric, however, to ensure continuity with the related baseline methodology, it is recommended that the project developer be able to choose an appropriate metric to suit project specific information availability.

[10] COD is set out here as the concentration metric, however, to ensure continuity with the related baseline methodology, it is recommended that the project developer be able to choose an appropriate metric to suit project specific information availability.

ID number	Data type	Data variable	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
5.	volume	Volume of biogas sent to facility heaters.	Nm^3	measured	continuously	100%	electronic	The biogas volume and biogas Calorific Value will indicate the amount of fuel oil displaced. Volume in Nm^3, normalised to take into account pressure and temperature.
6.	volume	Volume of heating oil/diesel sent to facility heaters.	dm^3	measured	continuously	100%	electronic	A project specific CV should be applied where possible The carbon content of the fuel is determined by using a CEF of 73.33 & 74.07 tonnes CO_2/TJ energy for fuel and diesel oil respectively.
7.	energy content	Electricity generated from the biogas collected in the anaerobic treatment facility and consumed on site or sent the grid	MWh	measured	continuously	100%	electronic	Indicates grid electricity displaced.
8.	volume	Fossil fuel volume equivalent to generate the same amount of heat generated from the biogas collected in the anaerobic treatment facility.	dm^3	calculated	continuously	100%	electronic	

ID number	Data type	Data variable	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
9.	volume	Biogas sent to flares	Nm^3	measured	continuously	100%	electronic	Volume in Nm^3, normalised to take into account pressure and temperature.
10.	volume	Biogas sent to gen sets	Nm^3	measured	continuously	100%	electronic	Volume in Nm^3, normalised to take into account pressure and temperature.
11.	concentration	Biogas methane concentration	%	measured	continuously			Measured by near infrared spectrometry (extremely accurate).
12.	percentage	Flare combustion efficiency	%	measured	bi-annually	100%	electronic	
13.	concentration	Amount of chemical oxidising agents entering system boundary.	Tonnes $/m^3$	measured	continuously	100%	electronic	
14.	percentage	Gen set combustion efficiency	%	measured	During regular O&M cycle (minimum of annually)	100%	electronic	
15.	percentage	Heating system combustion efficiency	%	measured	During regular O&M cycle (minimum of annually)	100%	electronic	

ID number	Data type	Data variable	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
16.	volume	Flow of wastewater directly to the current water treatment system, and bypassing the new wastewater treatment facility	m^3	measured	continuously	100%	electronic	Bypass flow measured by ultrasonic level sensor
17.	percentage	Loss of biogas from pipeline	%	measured	annually	100%	electronic	Integrity of biogas pipeline for losses of biogas methane will be tested annually through pressurizing the system and establishing pressure drops through leakage.
18.	mass	Organic material removed from wastewater facility	t COD	measured	annually	100%	electronic	Removals of COD after monitoring and prior to entry to the lagoon system should be recorded to ensure CH_4 emissions are not overestimated. This maybe material screened out after the wastewater concentration is recorded.
19.	energy concentration	Biogas calorific value	J/Nm^3	measured	annually	100%	electronic	

Quality Control (QC) and Quality Assurance (QA) Procedures

(ID numbers correspond to parameters in table above)

ID number	Data monitored	Uncertainty level of data (High/Medium/Low)	Are QA/QC procedures planned for these data?	Outline explanation why QA/QC procedures are or are not being planned.
1.	Wastewater flows entering system boundary	Low	Yes	Flow meters should be subject to a regular maintenance and testing regime to ensure accuracy
2.	Wastewater flows leaving project treatment facility	Low	Yes	Flow meters should be subject to a regular maintenance and testing regime to ensure accuracy
3.	Wastewater organic material concentration entering the project boundary.	Low/Medium	Yes	COD should be sampled frequently, and tests carried out by accredited laboratory each week.
4.	Wastewater organic material concentration leaving the project treatment facility.	Low/ Medium	Yes	COD should be sampled frequently, and tests carried out by accredited laboratory each week.
5.	Volume of biogas sent to facility heaters.	Low	Yes	Biogas meters should be subject to a regular maintenance and testing regime to ensure accuracy
6.	Volume of heating oil sent to facility heaters.	Low	Yes	Volume of oil used may be demonstrated via bills to facility showing oil purchases (external verification available)
7.	Electricity sent to facility &/or exported to grid	Low	Yes	Regular maintenance can ensure optimal operation of engines and generators. The heat rate used for calculation of ERs will be checked annually or more often if significant deviations from standard or previously used heat rate is observed. Electricity

ID number	Data monitored	Uncertainty level of data (High/Medium/Low)	Are QA/QC procedures planned for these data?	Outline explanation why QA/QC procedures are or are not being planned.
				exported to the grid can be demonstrated via payment receipts from third parties.
8.	Electricity consumed from grid	Low	Yes	Bills to facility from the local utility for electricity drawn from the grid can be used to verify electricity use (external verification available).
9.	Fossil fuel volume used in on site generation of electricity	Low	Yes	Bills from suppliers may provide QA (external verification available).
10.	Biogas sent to flares	Low	Yes	Biogas meters should be subject to a regular maintenance and testing regime to ensure accuracy.
11.	Biogas sent to gen sets	Low	Yes	Biogas meters should be subject to a regular maintenance and testing regime to ensure accuracy.
12.	Biogas methane concentration	Low	Yes	Biogas methane concentration should be measured by near infrared spectrometry or other quantitative process.
13.	Flare combustion efficiency	Medium	Yes	Flare combustion efficiency should be calibrated annually. Efficiency rating will be determined. Combustion efficiency should be determined during regular O&M down time and as part of the regular O&M schedule.
14.	Oxidizing chemical material entering system boundary	Low	Yes	Regular samples will test for concentration of oxidising agents where they are identified as being likely to be present in waste water when they are part of the process (ie sulphuric acid).
15.	Gen set combustion efficiency	Medium	Yes	Gen set combustion efficiency should be determined during regular O&M down time and as part of the regular O&M schedule. This should be a minimum of annually.
16.	Heating system combustion efficiency	Medium	Yes	Combustion efficiency should be determined during regular O&M down time and as part of the regular O&M schedule. This should be a minimum of annually.

ID number	Data monitored	Uncertainty level of data (High/Medium/Low)	Are QA/QC procedures planned for these data?	Outline explanation why QA/QC procedures are or are not being planned.
17.	Flow of wastewater directly to the current water treatment system, and bypassing the new wastewater treatment facility	Low/ Medium	Yes	Regular calibration of monitoring equipment.
18.	Loss of biogas from pipeline	Medium	Yes	Annual checks to be carried out to international standards
19.	Removal of organic material from waste water system	Low	No	
20.	Biogas calorific value	Low	Yes	Annual checks to be carried out to international standards

Other information:

APPENDIX 1 – AEROBIC DECOMPOSITION OF COD AT LAGOON SURFACES

Residual aerobic BOD removal in heavily loaded anaerobic lagoon systems depends on a combination of low oxygen production by algal activity and an oxygen diffusion component from the air into the surface layer of the water column. Aerobic metabolism by facultative anaerobic micro-organism in heavily loaded anaerobic lagoon systems will rapidly consume the oxygen within the first few centimeters of the water column and produce strict anaerobic conditions that result in quantitative BOD conversion to methane below the surface. Algal oxygen production is dependent on light. A high content of suspended sludge solids (light scattering) and a dark colour (pigments) in the lagoon water such as in the KWTE case and other similar lagoon systems will thus prevent extensive algal oxygen production in the lagoons. This is very similar to the situation in sugar cane wastewater lagoons (dark color). Aerobic BOD removal depends mainly on the oxygen diffusion component in both of these cases.

The aerobic BOD removal in the Colombian sugar cane industry wastewater lagoon case study is considered appropriate for the KWTE situation in particular, and other similar lagoon systems, because sugar cane wastewater is highly colored and together with high levels of phenolics this minimizes extensive algal oxygen production. Aerobic BOD removal depends thus primarily on the rate of oxygen diffusion through the pond surface in the Colombian sugar cane industry wastewater lagoon case study. This oxygen diffusion rate is small when compared to the methane production rate in the KWTE case, and in other facultative lagoons that have become anaerobic, and depends on the surface area, wind speed and temperature. Therefore any effects of a potential bias in this rate caused by the geographic/climatic idiosyncrasies or difference between the tropical Colombian climate and the tropical climate in Thailand will be negligible.

Background to Application of This Factor: Within the lagoon system oxidation will take place as a result of an interaction of the wastewater with the atmosphere. Oxygen crosses the surface layer through diffusion. Very little credible data was felt to be available to assess the loss of COD through this route in an anaerobic lagoon system. The project team felt that to ignore this loss route would actually risk overestimating the emissions of baseline fugitive methane emissions in the pond system. Thus the application of data from a Colombian study on this issue was felt to be justifiable, in the absence of UNFCCC or other internationally acceptable data.

The Basis of the Value Applied: The 254 kg COD/ha/day value is based on a Colombian case study (4) with sugar cane processing wastewater lagoons with a large proportion of recalcitrant carbon (low BOD/COD ratio). This value includes an 80% safety factor for any incomplete COD conversion in the BOD test. The value is not a measurement but an ultra-conservative estimate for the situation at KWTE, and other similar lagoon systems, which has a much larger proportion of degradable carbon and thus a BOD/COD ratio closer to unity. The actual sugar factory wastewater pond BOD removal data in the Colombian case study were about 100 kg BOD5/ha/day[11] (average over 3 years) despite BOD loading rates that were between 200 and 400 kg BOD/ha/day.

The World Bank Technical Paper Number 6 (5) defines design BOD loading rates for facultative lagoons in developing countries of about 400 kg BOD/ha/day for sewage with expected 70% removal of the readily available BOD in facultative lagoons. Sewage is highly biodegradable. The resulting calculated value for actual aerobic/anaerobic BOD removal in facultative lagoons (0.7 x 400) of 280 kg BOD/ha/day is close to our figure of 254 kg COD/ha/day used for industrial wastewater with a significant proportion of recalcitrant constituents (see below) supporting the conservative nature of our 254 kg COD/ha/day figure.

[11] BOD, BOD5 and COD are all tests of the organic loading of a waste water stream

Further, facultative lagoons are by definition those with a depth of 3 - 8 ft and are designed for combined aerobic (surface) and anaerobic (sediment) processes. Reference 2 below gives a typical acceptable BOD loading for facultative lagoons of 10- 100 lb BOD5/acre/day = 11 - 110 kg BOD5/ha/day (depending on the temperature 0 C - 40 C and based on a vast amount of empirical data in the USA). As the aerobic BOD removal rate in the facultative pond must be less than the BOD loading rate, and as all oxygen must be consumed by definition (facultative lagoons have an anaerobic bottom layer), this shows that the diffusive oxygen transfer through the surface is less than 110 kg BOD5/ha/day. This confirms the ultra- conservative nature of the estimated aerobic BOD removal parameter of 254 kg BOD/ha/day.

It is concluded that this loading rate is actually already greater than the actual surface aerobic losses if the lagoon depth is greater than 3 ft because some anaerobic BOD removal co- occurs. Reference 2 below gives for warm climates a typical acceptable BOD loading rate of 90 kg BOD/ha/day. These US guidelines for warm climates are essentially in agreement with the actual observations in reference 4.

Reference 3 below shows clearly that the BOD 5 for readily degradable components is always an underestimate of **the true ultimate carbonaceous BOD** which is basically equivalent to the COD of the degradable carbon. For sugar cane waste water, the ratio BOD5/COD for the degradable carbon is about 0.8 and the ratio of biodegradable COD/total COD about 0.54 –0.65. Thus if one corrects the maximum acceptable BOD load figure from the technical literature for these effects (110 / 0.8 / 0.54 kg BOD5/ha/day = 254 kg BOD5/ha/day) one arrives at an estimated maximum achievable COD loading rate of about 254 kg COD/ha /day including any sediment activity. That is the “worst (or maximum) case” value that we adopted for the assessment of the aerobic BOD removal activity in order to be quite conservative to allow for a wide range of possible load and operation conditions of the lagoons from KWTE and any other agro-industrial wastewater treatment facilities.

Conservatism & Risk: It should be borne in mind that in a great number of pond systems with COD loadings far in excess of this 100kg BOD/ha/day (254kg COD/ha/day) that **actual diffusion** of oxygen into the pond system across the pond surface/ atmosphere boundary to destroy aqueous COD is a prerequisite for this maximum COD destruction to be achieved. In many pond systems where COD loadings are far in excess of this value, bubbles of biogas on the pond surface may actually preclude even this COD destruction rate to be achieved. The image below from a typical pond may demonstrate how this may be so. Thus, even this value of 254kg/ha/day may be high in some situations, and thus conservative.

Image: Biogas evolution in a failing facultative lagoon system, ie where COD inputs are greater than 254 kg COD/ha/day.

Further, the contribution of this loss route in a reference pond system, here a typical project pond system (at KWTE in Thailand), may help inform the risk with under estimating this 254kg COD/ha/day value. The table below performs a sensitivity analysis that demonstrates that in this particular reference case an error of some 2,300% (ie a removal rate of some 6,000 kg/ha/day) is required before a material difference in emission reductions is observed (here application of this removal rate sees a reduction in the emission reductions estimate by some 0.84%).

It should noted that in situations where (in the project scenario) the COD leaving any anaerobic digester is still in excess of 254kgCOD/ha/day, the same maximum amount of COD can be removed through this loss route in both project and baseline scenarios, and any error in this value will be reflected in both project and baseline situations. It should also be noted that in the reference case described here, that the COD loading is indeed in excess of this 254 kg COD/ha/day value- and this is felt to be typical of all but exceptional situations as anaerobic systems are never 100% efficient in removing organic material.

Sensitivity Analysis

Surface Oxidative Removal & COD Sensitivity Analysis

Surface Oxidative Removal Rate	**Error Factor Applied**	**Baseline Lagoon Emissions**	**Sensitivity**	**Project Pond Emissions**	**Sensitivity**	**Emissions Reductions Estimated**	**Sensitivity**
kg/ha/day	%	T CO_2e	%	T CO_2e	%	T CO_2e	%
254	-	338,277	-	33,664	-	2,537,818	-
317.5	25%	337,854	0.13%	33,241	1.3%	2,537,818	0
381	50%	337,431	0.25%	32,818	0.25%	2,537,818	0
508	100%	336,584	0.50%	31,972	0.50%	2,537,818	0
5,200	2,047%	305,323	9.7%	711	97.9%	2,537,818	0
6,000	2,362%	299,993	11.3%	0	100%	2,516,428	0.84%

Source: Data generated via sensitivity around projected KWTE pond loadings.

The previous section sets out the conservative nature of this COD oxidation factor, the table above demonstrates that this factor has no material effect on emission reductions estimated or monitored until the value increases some 23 fold. For this reason, it is felt that the risk of inaccuracy in this value is extremely low, and will have little material impact on Emissions Reductions.

References:

1. P N Cheremisimoff, Handbook of Water and Wastewater Treatment Technology, Marcel Dekker, 1995 pp. 241-247

2. Cites R, Tchobanoglous G, Small and Decentralised Wastewater Management Systems, McGraw Hill 1998, pp.534- 536

3. P N Cheremisimoff, Handbook of Water and Wastewater Treatment Technology, Marcel Dekker, 1995 pp. 238-241

4. CX Calero, D D Mara, M R Pefia (2000). Anoxic ponds in the sugar cane industry: a case study from Colombia. Water Science and Technology 42(10-11): 67-74

5. J P Arthur. Notes on the Design and Operation of Waste Stabilisation Ponds in Warm Climates. Urban Development Paper No 6, The World Bank, Washington, USA

APPENDIX 2: THE ORGANIC REMOVAL RATIO

The following aims to allow the user of this methodology a better understanding of both how to measure the organic removal ratio and, more importantly, a better understanding of its function in the methodology.

Four key questions need to be discussed here:

1. What is the Organic Removal Ratio?
2. How is the Organic Removal Ratio used to quantify anaerobic decomposition and emissions of biogas methane?
3. Why is the Organic Removal Ratio calculated, and why is a default factor not appropriate?
4. How are the Organic Removal Ratio and other relevant values determined?

1. What is the Organic Removal Ratio

The Organic Removal Ratio measures the reduction of organic material[12] in a wastewater stream between its entry into, and exit from, the project's baseline system boundaries. It is a project specific, **quantified**, factor incorporating the sum total of losses of Chemical Oxygen Demand between system boundary entry and exit points.

Losses of COD in a lagoon/pond system are through three main routes:

1. Oxidative destruction, either aerobic at the pond surface, or through oxidation where there is a presence of an oxidizing species such as sulphate from sulphuric acid for example (SO_4^{2-} from H_2SO_4);
2. Sedimentation of certain suspended materials that can be lost through other routes, and settle to the lagoon bottom, remaining on a more or less permanent basis; and,
3. Anaerobic decomposition to produce biogas (and consequently fugitive methane).

The proposed methodology directly acknowledges the fact that - in some cases - not all COD removed in the existing pond system is lost through anaerobic processes.

(From Annex Equation 2a of Annex 3 to the PDD):

Equation 1: Determining the removal of chemical oxygen demand

Total Organic Material Removal Ratio	X	Project Organic Material Being Treated	=	Organic Material Degraded (removed) In Lagoon System in baseline scenario

The equation above shows how the total amount of organic material entering and being degraded or removed from the lagoon system can be quantified.

[12] The wastewater stream carries with it organic material that is quantified using the IPCC accepted parameter of COD, or Chemical Oxygen Demand.

2. How is the Organic Removal Ratio used to quantify anaerobic decomposition and emissions of biogas methane?

In a pond or lagoon system, where several complex chemical and biochemical processes are happening simultaneously, experts recognize that it is extremely difficult to directly measure biogas methane emissions from anaerobic activity alone.

The equation below, therefore, sets out the relationship between the total Chemical Oxygen Demand removed in the lagoon system and each individual loss route, as agreed upon by specialists in anaerobic digestion. (The total COD removed has been calculated through the observed organic removal ratio as shown in Equation 1.):

Equation 2: Chemical oxygen demand degradation or loss routes

Organic Material Degraded (removed) In Lagoon System* (From Equation 1)	=	Organic material degraded or removed by anaerobic processes + Amount of organic material degraded aerobically + Amount of organic material degraded through chemical oxidation + Total amount of organic material lost through deposition

* All references are to materials quantified in the baseline system boundaries

Equation 2 can be transposed to determine the amount of COD lost through anaerobic processes

Equation 3: Determining the chemical oxygen demand degraded through anaerobic processes

Organic material degraded or removed by anaerobic processes*	=	Total amount of organic material degraded (removed) in lagoon system - Amount of organic material degraded aerobically - Amount of organic material degraded through chemical oxidation - Total amount of organic material lost through deposition

* All references are to materials quantified in the baseline system boundaries

Scientific advice indicates that using this equation allows the project developer to determine the amount of chemical oxygen demand lost through anaerobic routes (and hence baseline biogas methane), where the other factors can be determined.

Fugitive methane emissions from anaerobic degradation can be calculated through Equation 4.

Equation 4: Determining fugitive methane emissions

Fugitive methane emissions (T CO_2e)	=	Organic Material Degraded or Removed by Anaerobic Processes (Equation 3)	X	Maximum methane[13] production Factor **X** GWP for Methane

Using Equation 4 (directly above), and taking the results of Equation 3 (above), Equation 5 (below) allows us to show how fugitive methane emission can be calculated where the total amount of chemical oxygen demand degraded and the amounts lost through aerobic, chemical oxidative and sedimentation routes are known.

[13] Here the methane emissions factor is the same as B_O used in the *IPPC 1996 National Inventory Guidelines*, which is 0.25kg CH_4 per kg COD lost through anaerobic decomposition.

Equation 5: Determining fugitive methane emissions (2)

$$\begin{array}{c}\text{Fugitive}\\ \text{methane}\\ \text{emissions}\\ (\text{T } CO_2e)\end{array} = \left(\begin{array}{c} \text{Total amount of organic material degraded (removed)}\\ \text{in lagoon system (Equation 1)}\\ - \\ \text{Amount of organic material degraded aerobically}\\ - \\ \text{Amount of organic material degraded through chemical}\\ \text{oxidation}\\ - \\ \text{Total amount of organic material lost through}\\ \text{deposition} \end{array} \right) \text{X} \begin{array}{c}\text{Maximum}\\ \text{methane}\\ \text{production Factor}\\ \textbf{X}\\ \text{GWP for Methane}\end{array}$$

Taking Equation 5 one step further, and applying the knowledge from Equation 1, Equation 6 draws the relevant variables together to show the relationship between fugitive methane, the amount of organic material entering baseline boundaries, the quantified organic removal ratio, and organic material removed through other loss routes.

Equation 6: Determining fugitive methane emissions (3)

$$\begin{array}{c}\text{Fugitive}\\ \text{methane}\\ \text{emissions}\\ (\text{T } CO_2e)\end{array} = \left(\begin{array}{c} \begin{array}{c}\text{Project Organic Material}\\ \text{Being Treated}\end{array} \text{ X } \begin{array}{c}\text{Total Organic Material}\\ \text{Removal Ratio}\end{array}\\ - \\ \text{Amount of organic material degraded aerobically}\\ - \\ \text{Amount of organic material lost through chemical}\\ \text{oxidation}\\ - \\ \text{Total amount of organic material lost through}\\ \text{deposition} \end{array} \right) \text{X} \begin{array}{c}\text{Maximum}\\ \text{methane}\\ \text{production Factor}\\ \textbf{X}\\ \text{GWP for Methane}\end{array}$$

3. Why is the Organic Removal Ratio calculated, and why is a default factor not appropriate?

The organic removal ratio used in this methodology describes essentially the same parameter as the MCF (Methane Conversion Factor) set out in the *IPCC 1996 Revised Guidelines for National Greenhouse Gas Inventories*, and also accepted in AM0006 and AM0013. The IPCC MCF assumes (generically across nations and regions) that all Chemical Oxygen Demand removed is lost through anaerobic biogas methane producing routes. The IPCC MCF makes **generic assumptions** as to losses of Chemical Oxygen Demand.

The main differences between the IPCC MCF and this NM0041 organic removal ratio therefore are:

- The MCF is often informed by generic assumptions, NM0041's organic removal ratio is quantified on a project specific basis;
- The MCF assumes all losses of chemical oxygen demand are through anaerobic (biogas methane producing) routes; NM0041's organic removal ratio is the sum of all loss routes, which will lead to a more accurate determination of the losses of COD through anaerobic activity.

The assumptions made in defining the IPCC MCF are validated by the technical weight behind them, and are valid for macro level nation wide assessment of GHG emissions. The proposed methodological approach of NM0041 to use an Organic Removal Ratio was taken because the scientific advisors supporting the methodology development strongly recommended that this approach would be more accurate and conservative on a site specific basis.

Use of a site specific, measured, Organic Removal Ratio allows the loss of Chemical Oxygen Demand through anaerobic (biogas methane producing) routes to be more accurately quantified through site-specific quantification of Chemical Oxygen Demand losses (as opposed to using generic default loss factors). Discounting losses of Chemical Oxygen Demand through non-anaerobic chemical & surface oxidation and sedimentation routes (routes that do not contribute to biogas methane production) are vital to such an accurate representation of anaerobic Chemical Oxygen Demand losses and biogas methane production.

Example

To offer an example of why a site specific Organic Removal Ratio may be superior to a default parameter, the following represents a real project in SE Asia. Baseline emissions are quantified utilising the site-specific organic removal ratio and the relevant default MCF value for comparative purposes.

Project Specifics

- 2MWeq project in SE Asia
- Annual Chemical Oxygen Demand loading of waste water = 15,684 tonnes COD

Generic MCF Application

- MCF = 90% (Source: Chapter 6, table 6.8, Volume 2, *IPCC 1996 Revised Guidelines for National Greenhouse Gas Inventories*)
- B_0 = 0.25 t CH_4/t Chemical Oxygen Demand

Baseline emissions = Total Chemical Oxygen Demand x B_0 x MCF x 21
= 15,684 (t COD) x 0.25 x 0.9 x 21
= 74,100 t CO_2e

Organic Removal Ratio Application

- Organic Removal Ratio = 94.21%
- Amount of COD lost in system = 94.21% * 15,684
  = 14,775 t COD pa
- COD losses to sulphate = 836 t pa (2.88 kg COD/ m^3 waste water)
- COD surface aerobic losses = 258 t pa (254 kg COD/ha/day)
- COD losses to sedimentation = 2,384 t pa (15.2% of all COD)

From Equation 3, above the organic material degraded through anaerobic process can be determined:

Organic material degraded or removed by anaerobic processes	=	Total amount of organic material degraded (removed) in lagoon system (15,684 x 94.21% = 14,776 t COD)) - Amount of organic material degraded aerobically (258 t COD) - Amount of organic material degraded through chemical oxidation (836 t COD) - Total amount of organic material lost through deposition (2,384 t COD)

Organic material degraded or removed by anaerobic processes (tonnes COD) = 11,296 t COD

From Equation 6, above the amount of fugitive biogas methane emissions in the baseline can be determined:

$$\text{Fugitive methane emissions (T } CO_2\text{e)} = \left(\begin{array}{c} \text{Project Organic Material Being Treated (15,684 t COD)} \times \text{Total Organic Material Removal Ratio (94.21\%)} \\ - \\ \text{Amount of organic material degraded aerobically (258 t COD)} \\ - \\ \text{Amount of organic material lost through chemical oxidation (836 t COD)} \\ - \\ \text{Total amount of organic material lost through deposition (2,384 t COD)} \end{array} \right) \times \begin{array}{c} \text{Maximum methane production Factor} \\ (0.25 \text{ t } CH_4\text{/t COD}) \\ \times \\ \text{GWP for Methane (21)} \end{array}$$

Fugitive methane emissions (t CO_2e) = 59,304t CO_2e

<u>Conclusions</u>

Generic MCF calculation of fugitive biogas methane emissions = **74,100 t CO_2e**

Organic Removal Ratio calculated fugitive biogas methane emissions = **59,304t CO_2e**

It is clear, that by taking into account COD removals by non-anaerobic routes, that a more accurate picture of fugitive methane GHG emissions can be developed.

4. How are the Organic Removal Ratio and other relevant values measured?

In order to utilise the Organic Removal Ratio to accurately quantify anaerobic (biogas methane producing) loss of Chemical Oxygen Demand, a number of values must be quantified, these are:

- The Organic Removal Ratio;
- Amount of organic material lost through deposition;
- Amount of organic material lost through aerobic oxidation; and
- Amount of organic material lost through chemical oxidation.

The determination of each is set out below. Each value can be determined during an on site chemical assessment through carrying out a series of

Determining the Organic Removal Ratio

The organic removal ratio is calculated by undertaking a series of chemical analyses on the lagoon site. A series of Chemical Oxygen Demand samples should be taken at the inlet point to the lagoon system, or wherever the wastewater enters the system boundaries. In parallel, a series of COD samples should be taken at the point of exit from the lagoon system or system boundaries. An analysis of these samples under recognised best practice conditions by qualified personnel will show the difference in COD entering and leaving the lagoon/system boundaries. An analysis of the proportion of COD lost will inform the Organic Removal Ratio:

Equation 7: Quantifying the organic removal ratio

$$\text{Organic Removal Ratio} = \frac{\text{COD into lagoon/system boundaries} - \text{COD out of lagoon/system boundaries}}{\text{COD into lagoon/system boundaries}}$$

Determining Losses of Chemical Oxygen Demand Through Sedimentation

Determining the amount of Chemical Oxygen Demand that is lost through sedimentation is carried out by assessing the type of organic waste material to determine the likelihood of any sedimentation actually taking place. In parallel the conditions in the pond system under investigation must also be assessed to characterise the pond dynamics in relation to mixing. Some ponds will be so anaerobically active as to keep alls material that would sediment in a state of permanent suspension, this material is then anaerobically degraded.

Where a likelihood of sedimentation is identified, the proposed route to determine the portion of Chemical Oxygen Demand lost to sedimentation is to monitor over time both the rate of COD entering the pond system and the rate at which pond depth alters over time. Utilising best practice the relationship between pond depth and sedimentation can be characterised. An appendix sets out one proposed route to achieving this by project engineers, though the methodology user will be encouraged to utilize alternative techniques where they may be appropriate and where they can be demonstrated to be effective, transparent and conservative.

Determining Losses of Chemical Oxygen Demand Through Surface Aerobic Oxidation

A separate appendix (Appendix 1) explains how a default factor can be applied. It also describes under what conditions this default factor is valid.

Determining Losses of Chemical Oxygen Demand Through Chemical Oxidation

An analysis must be carried out to determine firstly whether there are oxidative chemical species in the wastewater. The most likely chemical species that may be present is the sulphate ion (SO_4^{2-}) from use in the process of sulphuric acid. This chemical species will oxidise organic material, and reduce chemical oxygen demand. For example, where the concentration of sulphate is observed to be 1 kg/m^3 of waste water, 0.651kg/m^3 of Chemical Oxygen Demand will be removed through chemical reaction with the sulphate.

While determining the chemical oxygen demand of the wastewater, a parallel series of test must be carried out to determine the presence and concentration of any oxidative chemicals, such as sulphate using recognized best practice conditions by qualified personnel.

APPENDIX 3 : DETERMINING RATES OF SEDIMENTAION

Pond Based Sedimentation Determination

From Waste Solutions engineers.

Clearly, there are many different ways one can approach the measurement of COD sedimentation rates in a pond. Daily pond sedimentation rates vary in a seasonally operated industry. There are thus no hard average numbers for the dynamic deposition rate to be expected. The first task will be to determine whether the waste water contains material that is likely to sediment, and assess whether the pond dynamics are such that such sedimentation will occur. Where these conditions occur an analysis must be carried out as to the rate of this sedimentation.

One way of producing a robust, cost effective and practical method, would be to measure the net annual effect of the COD deposition into the sediment of individual ponds at the site in question and at long time intervals, because the pond sediment sludge amount accumulates gradually over the years. This is often shown by the historic evidence of gradually shrinking working volumes of the treatment pond(s) in question.

Proposed methodology to determine the net annual COD sedimentation in waste water treatment ponds

A GPS grid of at least 20 sampling points/pond will be put over each pond that is monitored. The distance of the GPS points from the pond bank needs to be at least 2 m. Twice a year (start of season and end of season) the following protocol will be performed:

(a) At each sampling time, determine pond water level height at all four corners of the pond by theodolite against an absolute height reference, ideally a concrete wall (accuracy > +/- 5 mm).

(b) Using an immersible turbidimeter mounted on a calibrated depth probe chain measure the sediment surface height relative to the water surface at the points indicated by the GPS grid.
Note: Gas masks/face shields need to be worn for this task due to the risk of H2S poisoning and high temperatures. There is also a high fire risk on the pond surface. Thus under no circumstances can flammable items, cellphones or other equipment that could trigger a spark be brought onto the pond surface. This instruction must be obeyed at all times.

With a rowing boat determine at each GPS point the relative pond water column depth relative to the absolute height reference determined under (a). Calculate the relative increase/decrease in the average sediment height of the pond system twice/year ,i.e. at the beginning and the end of a season determining the change in between seasons by calculation.

(c) Obtain a 10 cm diam x 40 cm core of the sediment layer at each GPS point with a core sampler (4 " plastic pipe). Combine the 0-20 cm layer cores and the 20-40 cm layer cores for all 20 points into a large drum. Mix the combined 0-20 cm (fraction A) and 20-40 cm samples (fraction B) with a metal or plastic rod. Take four random sub-samples of each of the two combined samples to determine VSS, TSS and COD. Carry out the sediment composition analysis in an experienced laboratory such as Waste Solutions Ltd, Analytical Laboratory.

(d) Calculate the mean+/- SD for COD, VSS, TSS of each group. Perform a test of statistical significance of any observed changes (t-test, paired) by comparing the paired pre-season/pre-season and paired post-season/ post-season samples for two consecutive years. Any real COD accumulation/deposition trend (if real) must be visible in the paired pre-season/pre-season and paired post-season/ post-season time points. The net COD deposition relative for the methane abatement balance in a season is determined by comparing the net sediment mass (COD, VSS, TSS) in the pond at the beginning of a new season with the previously measured pre-existing net deposition at the beginning of the previous season. It is assumed that the net sediment COD deposition by sedimentation in a steady state situation has the composition of the sediment material of the B-fraction because the B-fraction is the actual accumulating stable end product in the pond sediment.

(e) The amount of accumulated sediment COD/pond deposited every year is then determined as follows.

- Determine B-fraction COD content (g COD/g sediment; wet basis))
- Calculate the net accumulated COD in pond (Mg/pond/year)as:

Accumulated COD = [area (m2) x increase (m/year)] x sediment density x COD content B-fraction (gCOD/gwet)

- Trend the COD accumulation rate over several years