Draft revision to the approved baseline and monitoring methodology AM0023

"Leak detection and repair in gas production, processing, transmission, storage and distribution systems and in refinery facilities"

I. SOURCE, DEFINITIONS AND APPLICABILITY

Source

This baseline and monitoring methodology is based on the following proposed methodology:

- NM00091: "Leak reduction from natural gas pipeline compressor or gate stations", whose baseline study, monitoring and verification plan and project design document, were prepared by QualityTonnes on behalf of MoldovaGas.

This methodology also refers to the latest approved version of the:

- "Combined tool to identify the baseline scenario and demonstrate additionality".

For more information regarding the proposed new methodologies and these tools, as well as their consideration by the Executive Board, please refer to <http://cdm.unfccc.int/goto/MPappmeth.>.

Selected approach from paragraph 48 of the CDM modalities and procedures

"Existing actual or historical emissions".

Definitions

For the purpose of this methodology, the following definitions apply:

Component. Above-ground process equipment in natural gas production, processing, transmission, storage, distribution systems and in refinery facilities, including the following:

- Valves;
- Flanges and other connectors;
- Pump seals;
- Compressor seals;
- Pressure relief valves. Pressure relief valves are only accountable under this methodology when the gas pressure is less than the set point to open the valve (i.e. when the relief valve is closed);
- Open-ended lines, and sampling connections. Leaks from open-ended lines and sampling connections occur at the point of the line open to the atmosphere and are usually controlled by using caps, plugs, and flanges. Leaks can also be caused by the incorrect implementation of the block and bleed procedure.
- Others: Diaphragms, drains, dump arms, hatches, instruments, meters, polished rods, and vents.

Refinery gas. Also known as still gas, can be defined as: "Any form or mixture of gases produced in refineries by distillation, cracking, reforming and other processes. The principal constituents are methane, ethane, ethylene, normal butane, butylene, propane, propylene, etc. Still gas is used as a refinery fuel and a petrochemical feedstock” [1,2,3,4] and is generally produced from light ends distillation units of refinery facilities, where it has a pressure that allows its immediate use.

Physical leak. The unintentional and continuous loss of natural gas or refinery gas from a component. The leaking may occur past a seal, mechanical connection or minor flaw on the component at a rate that is in excess of normal tolerances allowed by the manufacturer. Leaks may occur due to normal wear and tear, improper or incomplete assembly of components, inadequate material specification, manufacturing defects, damage during installation or use, corrosion, fouling and demanding service conditions (e.g. vibrations and thermal cycling).

Leak detection and repair (LDAR) program. A structured program to detect and repair physical leaks from components. If a component is determined to have a physical leak, then the component is tagged and the physical leak repaired within a specified time. In the context of this methodology the following types of LDAR programs are defined:

- **Conventional LDAR program.** This comprises (where applicable) physical leaks detected by worker audio, visual and olfactory responses, area and building monitoring for flammable or toxic gases, worker personal monitors and leak checks performed as part of normal inspection and maintenance activities. The conventional LDAR program shall also comprise any additional leak detection and repair measures required and enforced by local regulations. The physical leaks that are detected and repaired within the framework of conventional LDAR cannot be included in the project activity;
- **Advanced LDAR program.** A program that is in addition to the conventional LDAR program.

Repair of physical leaks. A repair of a physical leak occurs when the natural gas or refinery gas losses from a physical leak at a component are reduced to within normal manufacturer’s tolerances for periods during which the component is in pressurized natural gas or refinery gas service. The repair may be achieved by tightening or adjusting the component, applying sealants, replacing packing materials or seals, repairing or replacing the component. Conversion to better performing components, packing materials, and seals, conversion to sealless technologies can help to reduce the project emissions.

Process venting. Engineered or intentional releases of natural gas or refinery gas to the atmosphere, such as the venting of natural gas or refinery gas by pneumatic devices, equipment and pipeline depressurization events, disposal of processing waste or by-product streams (e.g. dehydrator and storage tank vents), and discharges from emergency pressure relief events.

Maintenance. It is a set of activities that are performed on components in accordance to international standards[5] in order to correct or to prevent any degradation in their operating conditions. The maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning and the effects limited.

1 <http://www.energy.ca.gov/oil/refinery_output/definitions.html>. updated 2002.

2 <http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/glosri.pdf> IPCC.

3 <http://unfccc.int/resource/cd_roms/na1/ghg_inventories/english/8_glossary/Glossary.htm>.

4 <http://stats.oecd.org/glossary/detail.asp?ID=4621> based on Energy Statistics of OECD Countries: 1999-2000, 2002 Edition, International Energy Agency, Paris, Part 2 – Notes on Energy Sources. Created 2002.

5 See, for example: <http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=29242> and <http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=31170>.

Applicability

This methodology is applicable to project activities that reduce physical leaks in components through the introduction of an advanced LDAR program.

The methodology is applicable under the following conditions:

- During the last three years prior to the implementation of the project activity, no advanced LDAR program was in place to address physical leakage from components that are included in the project boundary;
- New physical leaks that are detected at components during the crediting period (e.g. not at the time the project starts) are accountable only if the components were included in the project boundary at the validation of the project activity;
- Physical leaks that need to be repaired due to current regulations and legislation are accountable only if it can be demonstrated that relevant regulations and legislation are not enforced in the country.

Note that this methodology is not applicable to:

- Physical leaks that are detected and repaired under a conventional LDAR program;
- Physical leaks that can be repaired by tightening/re-greasing or by similar measures;
- Physical leaks that are identified on components where the latest scheduled maintenance or replacement was not done before the starting date of a project activity as documented through maintenance logs, maintenance schedules, maintenance guidelines, worker logbooks, or other similar sources;
- Reductions in process venting;
- Reductions in natural gas or refinery gas combustion by process heaters or boilers, engines and thermal oxidizers.

In addition, the applicability conditions of the tools referred to above apply.

Finally, the methodology is only applicable if the most likely baseline scenario is the continuation of the current practice.

II. BASELINE METHODOLOGY PROCEDURE

Project boundary

The spatial extent of the project boundary includes the components where the project activity is being implemented. The spatial extent of the project boundary should be clearly illustrated in the CDM-PDD. Moreover, only methane (CH_4) emissions from physical leaks that were detected through the introduction of the advanced LDAR program should be included in the project boundary. The project boundary should be defined by clear definition of all components that are, or could be, sources of physical leakage.

For the purpose of defining the project boundary a database should be used, which is further described in Step 2 of the Baseline emissions section of this methodology.

The emission sources included in or excluded from the project boundary are shown in Table 1.

Table 1: Emissions sources included in or excluded from the project boundary

	Source	Gas	Included?	Justification / Explanation
Baseline	Physical leaks from the components included in the project boundary	CO_2	No	The CO_2 content in natural gas/refinery gas is very low. Exclusion is conservative
		CH_4	Yes	Main source of emissions
		N_2O	No	The N_2O content in natural gas/refinery gas is negligible
Project Activity	Physical leaks from the components included in the project boundary	CO_2	No	The CO_2 content in natural gas/refinery gas is very low. Exclusion is conservative
		CH_4	Yes	Main source of emissions
		N_2O	No	The N_2O content in natural gas/refinery gas is negligible

Procedure for the selection of the baseline scenario and the demonstration of additionality

The selection of the baseline scenario and the demonstration of additionality should be conducted using the "Combined tool to identify the baseline scenario and demonstrate additionality".

Emission reductions

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y \quad (1)$$

Where:

ER_y = Emission reductions for crediting year *y* (tCO_2e)
BE_y = Baseline emissions for crediting year *y* (tCO_2e)
PE_y = Project emissions for crediting year *y* (tCO_2e)

Baseline emissions

Baseline emissions are determined based on the quantity of CH_4 emitted through physical leaks that are detected and repaired as part of the project activity (i.e., by the advanced LDAR program).

Baseline emissions are calculated in these four steps:

Step 1: Establishment of criteria to identify which types of physical leaks are eligible for crediting.

Step 2: Establishment of a database to manage all information related to the project activity.

Step 3: Documentation of the schedules for the maintenance and replacement of components.

Step 4: Calculation of baseline emissions.

Step 1: Establishment of criteria to identify which types of physical leaks are eligible for crediting

For this purpose, project participants should first describe and assess in the CDM-PDD the current leak detection and repair practices applied by the operating company as well as the relevant local industry and regulatory standards. Based on this information, the project participants should classify different types of physical leaks. The following criteria may, *inter alia*, be taken into account in the classification of physical leaks:

- **Safety aspects.** Some physical leaks need to be repaired for safety reasons. An assessment of the safety regulations, local industry safety standards and their implementation may help in identifying what types of physical leaks are detected and repaired under the current safety regulations or other legislation of the country and local industry safety practices. In some case there may be a separate emergency repair apparatus specially dedicated to repair leaks that are considered safety risks;
- **Accessibility.** Some physical leaks may not get detected by a conventional LDAR program because they are inaccessible (e.g. they occur in crowded areas, are unsafe to access due to hot surfaces, or they are elevated and require ladders with fall-protection or lifts to access);
- **Visibility, audibility and/or smell.** Some companies may detect and repair physical leaks only if staff see, smell or hear the physical leak;
- **Practicability of repairs.** Some physical leaks may only get repaired where they are deemed economical to fix or if spare parts or industry standard repair materials are available;
- **Leak detection technologies.** The types of physical leaks that are identified may depend on the technology used to detect physical leaks. The introduction of new advanced technologies as part of the project activity may help to identify physical leaks that would otherwise not be detected. It has to be defined which types of physical leaks are usually detected using the current technological means and measurement instruments.

In undertaking the assessment, the following type of information shall be used:

- Written protocols and all physical leak repair records available from the previous years;
- Equipment component specifications and design standards;
- Written internal procedures which instruct staff how to identify and repair physical leaks;
- Interviews with key staff of the company, in particular managers responsible for physical leak detection and repair, e.g. on practices undertaken that are not part of documented protocols;
- Documentation on the technologies and measurement instruments used to detect physical leaks and repair materials available to undertake repairs.

Using this type of information, clear criteria should be established to identify whether the detection and repair of a physical leak during project implementation would also have occurred under conventional LDAR. These criteria should be documented in the CDM-PDD and be validated by the DOE.

To facilitate the decision making process when classifying detected physical leaks as part of either a conventional or advanced LDAR program during the project, a flowchart could be used like the example shown in Figure 1 below.

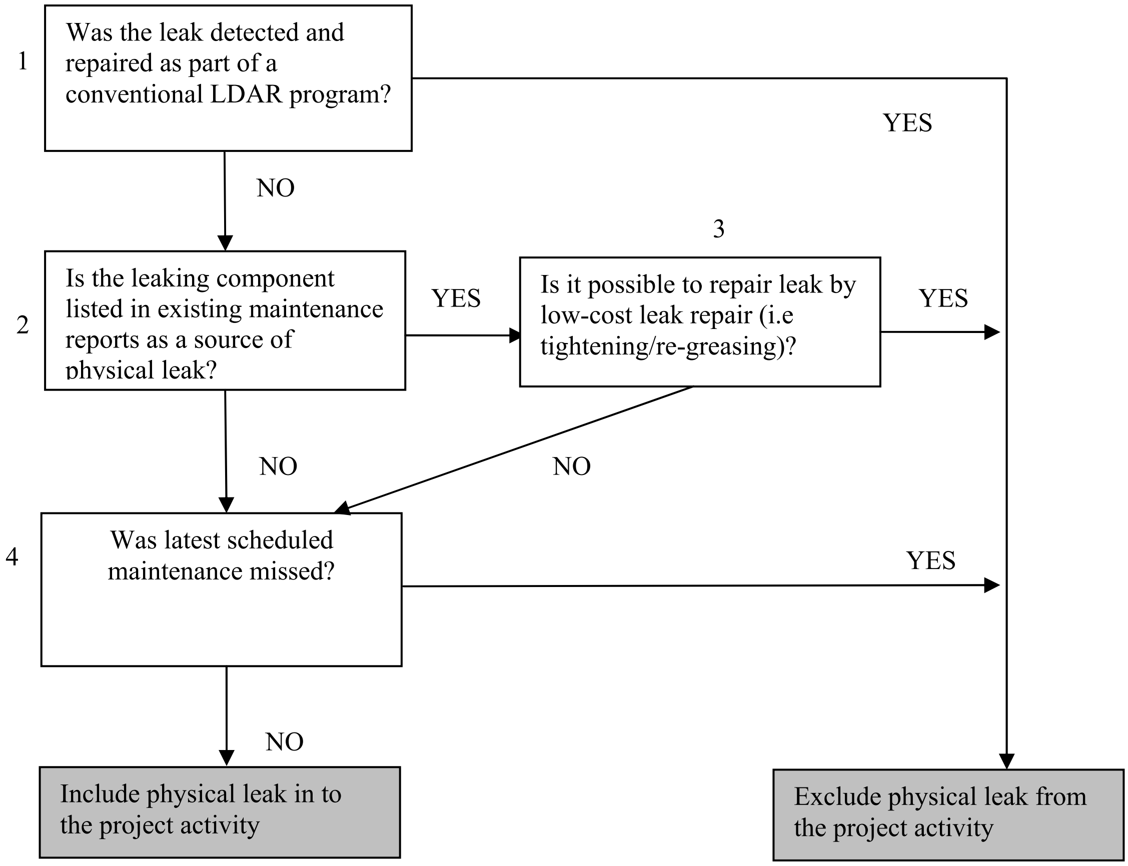

Figure 1: Criteria for inclusion/exclusion leak in/from project activities

Step 2: Establishment of a database to manage all information related to the project activity

As part of an advanced LDAR program, a database shall be established to manage all relevant information related to the detection and repair of physical leaks. All data collected during project implementation should be entered into this database. The database should, inter alia, include the following information on each physical leak:

(1) Data to clearly identify the component: ID number, type of component, size of component, service, process unit or area, location of the component, type of the facility, digital photo number, etc;

(2) Relevant information on the detection of the physical leak: date of detection, detection method applied, who detected the leak, detection reading if applicable e.g. screening value or leak image, etc;

(3) In case measurements of the flow from the physical leak are undertaken, relevant information on the measurement: date of measurement, the measurement method applied, the measured leak rate $F_{CH4,}$ and the uncertainty of the measurement;

(4) Hours during which the component is in pressurized natural gas or refinery gas service since the last leak survey or facility turnaround;

(5) Information regarding the eligibility of the physical leak to be included in the project activity (information that is required to distinguish between leaks detected by the conventional LDAR program and the advanced LDAR program);

(6) Information regarding the time in which the physical leak is eligible for crediting year *y*

(7) Relevant information on the repair of the detected physical leak: date of physical leak repair attempts and final successful physical leak repair.

In addition to the information that is required to be entered in the database, all of the following three ways of tagging leak locations and tracking leak measurements must be applied to clearly identify a leak location:

(1) A digital photo of the leak itself is taken and this photograph is then documented together with the actual leakage rate and measurement date;

(2) The leak itself is physically tagged on-site and the leak rate and measurement date are written on the tag; and

(3) The location of the leak is documented on a drawing of the facility itself, when the leak measurement and date are entered into the database.

The database should be continuously updated during the crediting period with information on the physical leaks repaired during the crediting period. The data in the database should also be included in each monitoring report.

Step 3: Documentation of the schedules for replacement of components

In the absence of an advanced LDAR, the physical leak would often cease to leak when the equipment would be replaced.

In calculating baseline emissions, it is assumed that a physical leak would have continued to emit gas until the component concerned would have been either maintained or replaced. In all cases the maximum period for which baseline emissions from a leak are accountable is:

(a) Seven years in the case that a renewable crediting period is chosen;

(b) The end of the crediting period in the case that a non-renewable crediting period is chosen.

The expected time schedules for the replacement of components that may be subject to leaks shall be identified in cases where such time schedules exist. For this purpose, it should be identified when a single component or the entire facility would be subject to replacement in the baseline scenario.

In order to identify the schedules of replacements that would take place in the baseline scenario, project participants should use written documentation by the company and interviews with managers on performed and planned replacements. The expected schedule of replacements should be documented in the CDM-PDD and be validated by the DOE.

Step 4: Calculation of baseline emissions

There are two options for the calculation of baseline emissions. The choice taken by project participants should be documented in the CDM-PDD and cannot be changed during the crediting period. In addition baseline emissions are capped to the baseline emission level of the first crediting year.

Option 1. Use any tool listed in the monitoring equipment section to detect (but not to quantify) the physical leaks and apply default emission factors developed by the American Petroleum Institute (API). Emissions should be calculated by multiplying the CH_4 fraction in the natural gas or refinery gas with the appropriate emission factors and then summing up all components that are accountable for the baseline emissions in a crediting year *y*, as follows:

$$BE_y = \min\left\{BE_{CAP}; \frac{1}{1000} \times GWP_{CH_4} \times w_{CH_4,y} \times \sum_i \sum_r \left[EF_i \times T_{i,r}\right]\right\} \quad \textbf{(2)}$$

Where:

BE_y	=	Baseline emissions for crediting year *y* (t CO_2e)
BE_{CAP}	=	Capped quantity of the baseline emissions, defined as the baseline emissions for the first year of the crediting period (t CO_2e)
GWP_{CH4}	=	Global warming potential of methane valid for the commitment period (t CO_2e / t CH_4)
$w_{CH4,y}$	=	Average mass fraction of methane in the natural gas/refinery gas for crediting year *y* (kg CH_4 / kg gas)
EF_i	=	Emission factor for the component type *i* (kg/hour/component type)
$T_{i,r}$	=	The time the component *r* of component type *i* would leak in the baseline scenario and would be eligible for crediting during the crediting year *y* (hours)
i	=	Component types as classified by the API Compendium (“API Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry” 2009, tables 6-17, 18, 19, 21)
r	=	Components of component type *i* for which physical leaks were detected during initial survey and repaired and which would leak in the baseline scenario during the crediting year *y*

Option 2: Measure the flow rates of the physical leaks through the use of a Hi-Flow Samplers^{TM}, calibrated bag or other suitable flow measurements technology as described in the monitoring equipment section below.

Baseline emissions are calculated as follows:

$$BE_y = \min\left\{BE_{CAP},\ ConvFactor \times \sum_j \left[F_{CH4,j} \times T_{j,y} \times (1 - UR_j)\right] \times GWP_{CH4}\right\} \quad \textbf{(3)}$$

Where:

BE_y	=	Baseline emissions for crediting year *y* (t CO_2e)
BE_{CAP}	=	Capped quantity of the baseline emissions, defined as the baseline emissions for the first year of the crediting period (t CO_2e)
ConvFactor	=	Conversion factor to convert Nm^3 CH_4 into t CH_4
j	=	All physical leaks that are included in the project activity for which physical leaks were detected and repaired and which would leak in the baseline scenario during the crediting year *y*
$F_{CH4,j}$	=	Measured flow rate of methane for the physical leak *j* from the leaking component (m^3 CH_4 / h)
UR_j	=	Uncertainty range for the flow rate measurement method applied to physical leak *j*
$T_{j,y}$	=	The time the relevant component, in which physical leak *j* occurred, would leak in the baseline scenario and would be eligible for crediting during the crediting year *y* (hours)
GWP_{CH4}	=	The global warming potential of methane valid for the commitment period (t CO_2e / t CH_4)

The uncertainty of the measurement is taken into account conservatively by using the flow rate at the lower end of the uncertainty range of the measurement at a 95% confidence interval for baseline emissions from leaks. For example, if the measured flow rate is 1 m^3/h and the uncertainty range of the measurement method is ±10%, emissions reductions shall be calculated based on a flow rate of 0.9 m^3/h. Given the large quantity of measurements potentially involved in the baseline study, calculation methods provided in the 2006 IPCC Guidelines to calculate UR using the combined uncertainties of all measurements can be used.

The following assumption should be made in the calculation of baseline emissions:

- For components where no physical leak were detected at the initial survey and where physical leak(s) were detected during a subsequent survey, baseline emissions shall be accounted from the moment when the leak was detected;
- Baseline emissions from a specific leak *j* or a specific component *r* are included in the calculations until whichever of the following occurs first:
  - (a) The equipment concerned is replaced for a non-leak related reason (i.e. it breaks down); or
  - (b) The end of the last crediting period of the overall project activity; or
  - (c) The maximum period for which a specific leak is can be accounted towards emission reductions is over. This maximum period is seven years (in the case that a renewable crediting period is chosen) or the end of the crediting period (in the case that a non-renewable crediting period is chosen).

Project emissions

Project emissions include emissions from physical leaks that take place on components included in the project boundaries in the following cases:

- If a repair of a physical leak ceases to function, for as long as it is not repaired again; or
- If a new physical leak is detected in a component which was part of the initial survey and for which no physical leak was detected during that survey, as long as that physical leak is not repaired.

Project emissions are calculated as follows:

In case of **Option 1:**

$$PE_y = \frac{1}{1000} \times GWP_{CH4} \times w_{CH4,y} \times \sum_i \sum_x \left[EF_i \times T_{i,x} \right] \quad \textbf{(4)}$$

Where:

PE_y	=	Project emissions for crediting year *y* ($t\ CO_2e$)
GWP_{CH4}	=	Global warming potential of methane valid for the commitment period ($t\ CO_2e / t\ CH_4$)
i	=	Component types as classified by the API Compendium (“API Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry” 2009, tables 6-17, 18, 19, 21)
$w_{CH4,y}$	=	Average mass fraction of methane in the natural gas/refinery gas for crediting year *y* ($kg\ CH_4 / kg$ gas)

EF_i	=	Emission factor for the component type *i* (kg/hour/component type)
$T_{i,x}$	=	The time the component x of component type *i* was leaking during the crediting year *y* (hours)
x	=	All components of component type *i* that are accounted for as project emissions during the crediting year *y*

In case of **Option 2:**

$$PE_y = ConvFactor \times \sum_z \left[F_{CH4,z} \times T_z \times (1 + UR_z)\right] \times GWP_{CH4} \qquad \textbf{(5)}$$

Where:

PE_y	=	Project emissions in crediting year *y* (tCO_2e)
ConvFactor	=	Conversion factor to convert Nm^3 CH_4 into t CH_4
z	=	All leaks that are accounted for as project emissions during the crediting year *y*
$F_{CH4,z}$	=	The leak flow rate of methane for the physical leak *z* from the leaking component (Nm^3CH_4/h)
UR_z	=	The uncertainty range for the measurement method applied to leak *z*
T_z	=	The time the relevant component has been leaking during the crediting year *y* (hours)
GWP_{CH4}	=	Global warming potential of methane valid for the commitment period (t CO_2e / t CH_4)

The uncertainty of the measurement is taken into account conservatively by using the flow rate at the upper end of the uncertainty range of the measurement at a 95% confidence interval for project emissions from leaks. For example, if the measured flow rate is 1 m^3/h and the uncertainty range of a measurement is ±10% , emissions reductions will be calculated at an effective flow rate of 1.1 m^3/h. Given the large quantity of measurements potentially involved, calculation methods provided in the 2006 IPCC Guidelines to calculate UR using the combined uncertainties of all measurements can be used.

The following assumptions should be made in the calculation of project emissions:

- If a repair of a physical leak ceases to function, it is conservatively assumed that the leak resumed either:
  - (a) At the same flow rate that was measured prior to its repair when using only leak detection equipment;
  - (b) At the newly measured leak rate if the leak is re-measured using leak measurement equipment at the time of monitoring (in case of Option 2);
  - (c) At the flow rate specified by the API Compendium (in case of Option 1).

  It is further assumed that the leak resumed at the day when the leak was last checked and confirmed not to leak and that it continued to leak for the entire time since that date. Thus, leaks where the repair failed should be included in the project emissions;
- For components where no physical leak was detected at the initial survey and where physical leak(s) were detected during subsequent survey, project emissions from these components shall be accounted since the moment when the leak was detected;

- Project emissions from a specific physical leak are included in the calculations until whichever of the following are earlier:
  (a) The date of any repair of the physical leak, as long as the repair does not cease to function; or
  (b) The equipment concerned is replaced (i.e. it breaks down).

Crediting period

The crediting period of the project activity should start at the date of first successful repair of a physical leak as part of the project activity.

Leakage

No significant leakage is expected to occur in these types of projects.

Data and parameters not monitored

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

Data / Parameter:	GWP_{CH4}
Data unit:	t CO_2 / t CH_4
Description:	Global warming potential of CH_4 valid for the commitment period
Source of data:	IPCC
Value to be applied:	Project participants shall update GWPs according to any decisions by the CMP. GWP_{CH4}=21 for the first commitment period
Any comment:	This value applies for the calculation of the baseline and project emissions

Data / Parameter:	ConvFactor
Data unit:	t CH_4 / Nm^3 CH_4
Description:	The factor to convert Nm^3 CH_4 into t CH_4
Source of data:	-
Value to be applied:	-
Any comment:	The leak flow rate ($F_{CH4,i}$) and conversion factor (*ConvFactor*) should be reduced to the same reference conditions. For example, if local industry's "normal conditions" defined as 20 degree Celsius and 101.3 kPa, a value of 0.00067 (IPCC 2006 Vol.2, p. 4.12) is used to convert from Nm^3 CH_4 into t CH_4, and the flow rate should be determined for reference conditions of 20 degree Celsius and 101.3 kPa

Data / Parameter:	EF_i
Data unit:	kg/hour/component type
Description:	The emission factor for the relevant component type
Source of data:	API Compendium 2009. Tables 6-17, 18, 19, 21
Value to be applied:	**Natural Gas Transmission Compressor Station Component Emission Factors**

Component	**ON COMPRESSOR**	**OFF COMPRESSOR**
	Emission Factor, kg/hr/component	
MAIN LINE PRESSURE (3447.4 to 6894.8 kPa)		

Ball/Plug Valves	1.31E-03	1.09E-02
Blowdown Valves	--	4.24E-01
Compressor Cylinder Joints	2.02E-02	--
Packing Seals - Running	1.77	--
Packing Seals -Idle	2.59	--
Compressor Valves	8.39E-03	--
Control Valves	--	8.71E-03
Flanges	1.66E-03	6.54E-04
Gate Valves	--	1.25E-03
Loader Valves	3.52E-02	--
Open-Ended Lines (OEL)	--	1.67E-01
Pressure Relief Valves (PRV)	--	1.18E-01
Regulators	--	4.09E-04
Starter Gas Vents	--	8.34E-02
Threaded Connectors	1.51E-03	1.23E-03
Centrifugal Seals - Dry	--	1.28E-01
Centrifugal Seals - Wet	--	5.69E-01
Unit Valves	--	7.29E-03
FUEL GAS PRESSURE (482.6 to 689.5 kPa)		
Ball/Plug Valves	2.05E-04	1.04E-03
Control Valves	--	5.03E-03
Flanges	--	4.09E-04
Fuel Valves	5.64E-02	--
Gate Valves	--	8.79E-04
Open-Ended Lines (OEL)	--	5.17E-03
Pneumatic Vents	--	1.57E-01
Regulators	--	8.24E-03
Threaded Connectors	2.47E-03	6.54E-04

Natural Gas Transmission and Storage Average Emission Factors

Component	Emission Factor, kg/hr/component
Block valves	0.002140
Control valves	0.01969
Connectors	0.0002732
Compressor seals – reciprocating	0.6616
Compressor seals – centrifugal	0.8139
Pressure relief valves	0.2795
Open-ended lines (OEL)	0.08355
OEL - station or pressurized compressor blowdown system	0.9369
OEL – depressurized reciprocating (comp. blowdown system)	2.347
OEL – depressurized centrifugal (comp. blowdown system)	0.7334
OEL – overall pressurized/ depressurized reciprocating (comp. blowdown system)	1.232

OEL – overall pressurized/ depressurized centrifugal (comp. blowdown system)	0.7945
Orifice meter	0.003333
Other gas meter	0.000009060

Natural Gas Distribution Meter/Regulator Stations Average Emission Factors

Component	Emission Factor, kg/hr/component
Valves	0.00111
Control valves	0.01969
Connectors	0.00011
Pressure relief valves	0.01665
Open-ended lines (OEL)	0.08355
OEL – station blowdown	0.9369
Orifice meter	0.00333
Other gas meter	0.00001

Other systems (refinery, etc.)

Component – Service	Emission Factor, kg/hr/component
Valves	2.81E-03
Connectors	8.18E-04
Control valves	1.62E-02
Pressure relief valves	1.70E-02
Pressure regulators	8.11E-03
Open ended lines	4.67E-01
Chemical injection pumps	1.62E-01
Compressor seals	7.13E-01
Compressor starts	6.34E-03
Controllers	2.38E-01

Any comment:	-

III. MONITORING METHODOLOGY

Monitoring procedures

1. Establishment of a database

Please refer to Step 2 of the Baseline emissions section.

2. Data collection during project implementation

The implementation of the project involves an initial survey and regular subsequent surveys of each component within the project boundary. Increasing the frequency at which physical leak surveys are conducted will tend to increase the level of physical leak control achieved.

Monitoring equipment

Project participants may use the following tools to detect, but not to quantify, physical leaks in components:

- **Electronic gas detectors** using small hand-held gas detectors or "sniffing" devices to detect accessible physical leaks. Electronic gas detectors are equipped with catalytic oxidation and thermal conductivity sensors designed to detect the presence of specific gases. Electronic gas detectors can be used on larger openings that cannot be screened by soaping;
- **Organic Vapor Analyzers (OVAs)** and **Toxic Vapor Analyzers (TVAs)** are portable hydrocarbon detectors that can also be used to identify physical leaks. An OVA is a flame ionization detector (FID), which measures the concentration of organic vapors over a range of 0.5 to 50,000 parts per million (ppm). TVAs and OVAs measure the concentration of methane in the area around a physical leak;
- **Acoustic leak detection** using portable acoustic screening devices designed to detect the acoustic signal that results when pressurized gas escapes through an orifice. As gas moves from a high-pressure to a low-pressure environment across a physical leak opening, the turbulent flow produces an acoustic signal, which is detected by a hand-held sensor or probe, and read as intensity increments on a meter. Although acoustic detectors do not measure physical leak rates, they provide a relative indication of leak size – a high intensity or "loud" signal corresponds to a greater leak rate.
- **Optical Gas Imaging Instruments.** There are two general classes of such instruments, active and passive instruments. The active type uses a laser beam that is reflected by the background. The attenuation of the beam passing through a hydrocarbon cloud provides the optical image. The passive type uses ambient illumination to detect the difference in heat radiance of the hydrocarbon cloud. Optical gas imaging instruments do not measure leak rates, but allows faster screening of components than FID detectors.

One of the following technologies shall be used to measure leak flow rates:

- **Bagging techniques** are commonly used to measure flow rates of physical leaks. The leaking component or leak opening is enclosed in a "bag" or tent. An inert carrier gas such as nitrogen is conveyed through the bag at a known flow rate. Once the carrier gas attains equilibrium, a gas sample is collected from the bag and the methane concentration of the sample is measured. The flow rate of the physical leak from the component is calculated from the purge flow rate through the enclosure and the concentration of methane in the outlet stream as follows:

$$F_{CH4,i} = F_{purge,i} \times w_{CH4,i} \quad (6)$$

Where:

$F_{CH4,i}$	=	The leak flow rate of methane for leak *i* from the leaking component (m^3CH_4/h)
$F_{purge,i}$	=	The purge flow rate of the clean air or nitrogen at leak *i* (m^3/h)
$w_{CH4,i}$	=	The measured mass fraction of methane in the natural or refinery gas during the crediting year *y* (kg CH_4 / kg gas)

- **High volume or Hi-Flow Samplers™** capture all emissions from a leaking component to quantify leak flow rates. Leak emissions, plus a large volume sample of the air around the leaking component, are pulled into the instrument through a vacuum sampling hose. High volume samplers are equipped with dual hydrocarbon detectors that measure the concentration of hydrocarbon gas in the captured sample, as well as the ambient hydrocarbon gas concentration. Sample measurements are corrected for the ambient hydrocarbon concentration, and the leak rate is calculated by multiplying the flow rate of the measured sample by the difference between the ambient gas concentration and the gas concentration in the measured sample. Methane emissions are obtained by calibrating the hydrocarbon detectors to a range of concentrations of methane-in-air. High volume samplers are equipped with special attachments designed to promote complete emissions capture and to prevent interference from other nearby emissions sources.[6] The hydrocarbon sensors are used to measure the exit concentration in the air stream of the system. The sampler essentially makes rapid vacuum enclosure measurements;

- **Calibrated bag** measurements use anti-static bags of known volume (e.g. 0.085 m^3 or 0.227 m^3) with a neck shaped for easy sealing around the vent. Measurement is made by timing the bag expansion to full capacity while also employing a technique to completely capture the leak while the inflation is being timed. The measurement is repeated on the same leak source numerous times (at least 7, typically 7 to 10 times) to ensure a representative average for the fill times (outliers or problem times should be omitted and the tests rerun until a representative average rate is established). The temperature of the gas is measured to allow correction of volume to standard conditions. Additionally, the gas composition is measured to verify the proportion of methane in the vented gas, since in some cases air may also be vented, resulting in a mixture of natural gas and air. Calibrated bags allow for reliable measurement of leak flow rates of more than 250m^3/h. The leak flow rate of methane is calculated as follows:

$$F_{CH4,i} = V_{bag} \times w_{sampleCH4,i} \times 3600 / t_{aver,i} \quad (7)$$

Where:

$F_{CH4,i}$	=	The leak flow rate of methane for leak *i* from the leaking component (m^3/h)
V_{bag}	=	Volume of calibrated bag used for measurement (m^3)
$w_{sampleCH4,i}$	=	The concentration of methane in the sample flow from leak *i* (volume percent)
$t_{aver,i}$	=	Average bag fill time for leak *i* (seconds)

5. Monitoring requirements

For each component where a physical leak has occurred, the following information should be collected during regular monitoring checks:

- Date of monitoring;
- An assessment whether the relevant component has been replaced after the repair of the leak;
- The number of hours during which the component is in pressurized natural gas or refinery gas service;
- An assessment whether the repair of the leak functions appropriately.

All information should be added to the database and be included in monitoring reports.

[6] The background concentration must be subtracted from the main sample concentration because it may be elevated due to other leaks in the vicinity of the leak being measured. Variables such as wind speed and wind direction may cause the background concentration to fluctuate, so the background is measured simultaneously with the sample concentration.

Data and parameters monitored

In some cases particular measuring tools may also automatically account for certain parameters that do not need to be separately measured.

Data / Parameter:	$T_{i,x}$
Data unit:	Hours
Description	The time the component x of component type *i* was leaking during the crediting year *y* (hours)
Source of data used:	Plant records
Measurement procedures (if any)	Any outages will be recorded
Recording frequency	Constant
Proportion of data to be monitored	100%
QA/QC procedures to be applied	Any outages resulting from system repairs will be documented and logged in the project database in the form of a reduction in the time of operation. To be clear, if an unrelated activity requires the shut-down of an already repaired piece of equipment, the hours of operation for every piece of affected equipment with be reduced in the database for the entire duration of the shut-down. Any other unscheduled shutdown will also be timed and accounted for through a reduction of operating hours
Any comment:	-

Data / Parameter:	T_z
Data unit:	Hours
Description	The time (in hours) the relevant component has been leaking during the crediting year *y*
Source of data used:	Plant records
Measurement procedures (if any)	Any outages will be recorded
Recording frequency	Constant
Proportion of data to be monitored	100%
QA/QC procedures to be applied	Any outages resulting from system repairs will be documented and logged in the project database in the form of a reduction in the time of operation. To be clear, if an unrelated activity requires the shut-down of an already repaired piece of equipment, the hours of operation for every piece of affected equipment with be reduced in the database for the entire duration of the shut-down. Any other unscheduled shutdown will also be timed and accounted for through a reduction of operating hours
Any comment:	-

Data / Parameter:	Temperature and pressure of natural gas
Data Unit	ºC and bar
Source of data used:	Conditions observed at the point and time of the leak rate measurement
Measurement procedures (if any)	-
Recording frequency	At the time of each leak measurement
Proportion of data to be monitored	100%

QA/QC procedures to be applied	Data measurement equipment will be calibrated and double checked on a regular basis. The manufacturer's recommended calibration procedures shall be applied
Any comment:	Applicable only in the case that option 2 for the calculation of baseline and project emissions is selected

Data / Parameter:	$T_{i,r}$
Data unit:	Hours
Description	The time the component *r* of component type *i* would leak in the baseline scenario and would be eligible for crediting during the crediting year *y* (hours)
Source of data used:	Plant records
Measurement procedures (if any)	Any outages will be recorded
Recording frequency	Constant
Proportion of data to be monitored	100%
QA/QC procedures to be applied	Any outages resulting from system repairs will be documented and logged in the project database in the form of a reduction in the time of operation. To be clear, if an unrelated activity requires the shut-down of an already repaired piece of equipment, the hours of operation for every piece of affected equipment with be reduced in the database for the entire duration of the shut-down. Any other unscheduled shutdown will also be timed and accounted for through a reduction of operating hours
Any comment:	-

Data / Parameter:	$T_{j,y}$
Data unit:	Hours
Description	The time the relevant component, in which physical leak *j,* occurred, would leak in the baseline scenario and would be eligible for crediting during the crediting year *y* (hours)
Source of data used:	Plant records
Measurement procedures (if any)	Any outages will be recorded
Recording frequency	Constant
Proportion of data to be monitored	100%
QA/QC procedures to be applied	Any outages resulting from system repairs will be documented and logged in the project database in the form of a reduction in the time of operation. To be clear, if an unrelated activity requires the shut-down of an already repaired piece of equipment, the hours of operation for every piece of affected equipment with be reduced in the database for the entire duration of the shut-down. Any other unscheduled shutdown will also be timed and accounted for through a reduction of operating hours
Any comment:	-

Data / Parameter:	UR_j
Data Unit	Fraction
Description:	The uncertainty range for the measurement method applied to leak *j*
Source of data used:	Manufacturer data and/or IPCC GPG
Measurement procedures (if any)	Estimated, where possible, at a 95% confidence interval, consulting the guidance provided in Chapter 6 of the 2000 IPCC Good Practice Guidance. If leak measurement equipment manufacturers report an uncertainty range without specifying a confidence interval, a confidence interval of 95% may be assumed
Recording frequency	Periodically
Proportion of data to be monitored	100%
QA/QC procedures to be applied	-
Any comment:	Applicable only in the case that option 2 for the calculation of baseline and project emissions is selected

Data / Parameter:	UR_z
Data Unit	Fraction
Description:	The uncertainty range for the measurement method applied to leak *z*
Source of data used:	Manufacturer data and/or IPCC GPG
Measurement procedures (if any)	Estimated, where possible, at a 95% confidence interval, consulting the guidance provided in Chapter 6 of the 2000 IPCC Good Practice Guidance. If leak measurement equipment manufacturers report an uncertainty range without specifying a confidence interval, a confidence interval of 95% may be assumed
Recording frequency	Periodically
Proportion of data to be monitored	100%
QA/QC procedures to be applied	-
Any comment:	Applicable only in the case that option 2 for the calculation of baseline and project emissions is selected

Data / Parameter:	$w_{CH_4,y}$, $w_{CH4,i,}$
Data Unit	kg CH_4/kg gas
Description:	Average mass fraction of methane in the natural gas/refinery gas for crediting year *y*
Source of data used:	Direct measurement
Measurement procedures (if any)	
Recording frequency	Periodically
Proportion of data to be monitored	100%
QA/QC procedures to be applied	For the purpose of determining average mass fraction of methane, a natural gas or refinery gas sample should be collected and chemical analysis should be made in the laboratory
Any comment:	-

Data / Parameter:	$w_{sampleCH4,i}$
Data Unit	volume percent
Description:	The concentration of methane in the sample flow from leak *i*
Source of data used:	Direct measurement
Measurement procedures (if any)	
Recording frequency	Periodically
Proportion of data to be monitored	100%
QA/QC procedures to be applied	-
Any comment:	Applicable only in the case that option 2 for the calculation of baseline and project emissions is selected

Data / Parameter:	$F_{CH4,\ i}$/$F_{CH4,\ z}$/
Data unit:	m^3CH_4/h
Description	The leak flow rate of methane for leak (*i*, *z)* from the leaking component
Source of data used:	On-site measurements
Measurement procedures (if any)	Procedures requires by manufactures of the equipment used to measure leak flow rates should be followed
Recording frequency	Annual
Proportion of data to be monitored	100%
QA/QC procedures to be applied	-
Any comment:	Applicable only in the case that option 2 for the calculation of baseline and project emissions is selected. The leak flow rate ($F_{CH4,j}$) and conversion factor (*ConvFactor*) should be corrected to the same reference temperature and pressure conditions. For example if value of 0.00067 (IPCC 2006 Vol.2, p. 4.12) is used to convert from m^3 CH_4 into t CH_4, then the flow rate should corrected to reference conditions of 20 degree Celsius and 101.3 kPa.

Data / Parameter:	$F_{purge,i}$
Data unit:	m^3/h
Description	The purge flow rate of the clean air or nitrogen at leak *i*
Source of data used:	On-site measurements
Measurement procedures (if any)	Procedures requires by manufactures of the equipment used to measure leak flow rates should be followed
Recording frequency	Annual
Proportion of data to be monitored	100%
QA/QC procedures to be applied	-
Any comment:	Applicable only in the case that option 2 for the calculation of baseline and project emissions is selected. The purge flow rate and leak flow rate should be corrected to the same reference temperature and pressure conditions

Data / Parameter:	$t_{aver,i}$
Data unit:	sec
Description	Average bag fill time for leak *i*
Source of data used:	On-site measurements
Measurement procedures (if any)	Procedures requires by manufactures of the equipment used to measure leak flow rates should be followed
Recording frequency	Annual
Proportion of data to be monitored	100%
QA/QC procedures to be applied	-
Any comment:	Applicable only in the case that option 2 for the calculation of baseline and project emissions is selected

Data / Parameter:	BE_{CAP}
Data unit:	t CO_2e
Description:	Capped quantity of the baseline emissions, defined as the baseline emissions for the first year of the crediting period
Source of data:	Monitored baselines emissions during the first year of the first crediting period
Value to be applied:	-
Any comment:	-

History of the document

Version	**Date**	**Nature of revision(s)**
04.0.0	EB 63, Annex # 29 September 2011	Revision to: • Expand the applicability of the methodology to more installations; • Introduce an option to use default values; • Improve the monitoring section; • Improve the clarity of the language; • Assess the internal consistency of the methodology; Due to the overall modification of the document, no highlights of the changes are provided.
03	EB 50, Annex 4 16 October 2009	The methodology was revised in response to AM_REV_0161, to expand scope of the applicable leak flow rate measurement techniques to include calibrated bags and ultrasonic meters.
02.1	EB 45, Annex 7 13 February 2009	Editorial revision to adjust the text in the Project Boundary section to be consistent with the Applicability Conditions section as modified from version 01 to version 02 of this methodology.
02	EB 31, Annex 10 4 May 2007	Revision to expand the applicability of the approved methodology to project activities that reduce leakage in distribution systems above ground.
01	EB 20, Annex 13 8 July 2005	Initial adoption.
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