CDM-MP58-A03

Draft Large-scale Methodology

AM0028: ~~N2O destruction in the tail gas of Nitric Acid or Caprolactam production plants~~ N_2O destruction in the tail gas of Caprolactam production plants

Version 06.0.0

Sectoral scope(s): 05

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United Nations
Framework Convention on
Climate Change

COVER NOTE

1. Procedural background

1. The methodology "AM0028: N_2O destruction in the tail gas of Nitric Acid or Caprolactam Production Plants" is applicable to project activities that destroy N_2O emissions either by catalytic or thermal decomposition or catalytic reduction of N_2O in the tail gas of nitric acid or caprolactam production plants (i.e. tertiary destruction).

2. The Executive Board (hereinafter referred to as the Board) of the clean development mechanism (CDM), at its sixty-sixth meeting (EB 66 report, para 92) requested the Methodologies Panel to assess these methodologies for N_2O abatement from nitric acid production, taking into account the potential issue brought to the attention of the Board by the secretariat, including:

    (a) Clear identification of perverse incentives;

    (b) Provide an analysis of the impact of the incentives in terms of emission reductions;

    (c) Provide recommendation to the Board on how to address the issues.

3. A consultant was contracted and provided input and a recommendation for approval of the draft revised AM0028 and ACM0019 and withdrawal of AM0034 and AM0051 was made at MP 57 for consideration at EB 69.

4. The recommendation was rejected at EB 69 (paragraph 82), and a request made to the Methodologies Panel to work further on the issues which have been identified in the period after publication of the recommendation in the MP 57 report and the EB 69.

2. Purpose

5. The purpose of the proposed revision is to limit the use of the methodology to Caprolactam production plants.

3. Key issues and proposed solutions

6. The draft revision

    (a) Removes all references to nitric acid plants;

    (b) Changes the title from "N_2O destruction in the tail gas of Nitric Acid or Caprolactam Production Plants" to "N_2O destruction in the tail gas of Caprolactam production plants".

4. Impacts

7. The methodology was approved at EB 23 in February 2006 and the last amendment to version 05.1.0 was approved at EB 60 in April 2011. So far twenty projects have been

registered applying this methodology. Twenty-seven projects are currently listed as under validation applying this methodology.

5.   Proposed work and timelines

8.   The proposed draft revision of the methodology is recommended by the Methodologies Panel to be considered by the Board at its seventieth meeting. No further work is envisaged.

6.   Recommendations to the Board

9.   The Methodologies Panel recommends that the Board adopts the draft revised methodology.

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1. Introduction

1. The following table describes the key elements of the methodology:

Table 1. Methodology key elements

Typical projects	Replacement or modification of existing anaerobic manure management systems in livestock farms, or treatment of manure collected from several farms in a centralized plant to achieve methane recovery and destruction by flaring/combustion or energetic use of the recovered methane
Type of GHG emissions mitigation action	(a) GHG destruction. GHG destruction and displacement of more- GHG -intensive service

2. Scope, applicability, and entry into force

2.1. Scope

2. The proposed methodology is applicable to project activities that destroy N$_2$O emissions either by catalytic or thermal decomposition or catalytic reduction of N$_2$O in the tail gas of nitric acid or caprolactam production[1] plants (i.e. tertiary destruction).

2.2. Applicability

3. The following conditions apply:

(a) The applicability is limited to the existing production capacity measured in tonnes of nitric acid or caprolactam, where the commercial production had begun no later than 31 December 2005. The definition of "existing" production capacity is applied for the process with the existing ammonia oxidization reactor where N$_2$O is generated and not for the process with new ammonia oxidizer. Existing production "capacity" is defined as the designed capacity, measured in tonnes of nitric acid or caprolactam per year;

(b) Existing caprolactam plants are limited to those employing the Raschig process not using any external sources of nitrogen compounds other than feed ammonia, or those employing the HPO® process that may use nitric acid as an external nitrogen source for caprolactam production in addition to feed ammonia;

(c) The project activity will not result in shut down of an existing N$_2$O destruction or abatement facility at the nitric acid or caprolactam production plant;

(d) The project activity shall not affect the nitric acid or caprolactam production level;

(e) The project activity will not cause an increase in NOX emissions;

(f) In case a DeNOX unit is already installed prior to the start of the project activity, the installed De-NOX is a Selective Catalytic Reduction (SCR) De-NOX unit;

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[1] Caprolactam production plants including the ammonia oxidation reactor (AOR) where N$_2$O is generated.

(g)   The N_2O concentration in the flow at the inlet and the outlet of the catalytic N_2O destruction facility is measurable. Furthermore, for a caprolactam plant using the HPO® process, the N_2O concentration in the gas flow between the ammonia oxidation reactor and the absorption column is also measurable, and the N_2O in the product flow from the absorption column to the HPO® process area is quantifiable.

2.3. Entry into force

4.   The date of entry into force of the revision is the date of the publication of the EB 70 meeting report on 23 November 2012

3.   Normative references

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

(a)   "NM0111 Baseline Methodology for catalytic N2O destruction in the tail gas of Nitric Acid Plants" submitted by Carbon Projektentwicklung GmbH."

6.   This methodology also refers to the latest approved versions of the following tools:

(a)   "Tool for the demonstration and assessment of additionality;"

(b)   "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion."

7.   For more information regarding the proposed new methodology and the tools, as well as their consideration by the Executive Board (hereinafter referred to as the Board) of the clean development mechanism (CDM)~~Executive Board~~ please refer to <http://cdm.unfccc.int/goto/MPappmeth>.

4.   Definitions

8.   The definitions contained in the Glossary of CDM terms shall apply.

5.   Baseline methodology

5.1. Project boundary

9.   For the purpose of determining project activity emissions, project participants shall include the followings in the project boundary:

(a) N_2O concentration in the flow stream of the tail gas;

(b)   In case no SCR DeNOX unit has been installed prior to the start of the project activity, GHG emissions related to the production of ammonia used for the NOX reduction will be considered as project emissions. In case a SCR DeNOX unit has been installed prior to the start of the project activity, GHG emissions related to the production of ammonia used for NO_X reduction will not be considered as project emissions;

(c)   Hydrocarbons as a reducing agent to enhance the efficiency of a N_2O catalytic reduction facility.

10. For the purpose of determining baseline emissions, project participants shall include the following emission sources:

    (a) N_2O concentration in the flow stream of the tail gas insofar as the N_2O is formed in the ammonia oxidation reactor;

    (b) In case no SCR DeNOX unit has been installed prior to the start of the project activity, GHG emissions related to the production of ammonia used for NOX reduction will be considered zero in the baseline. In case SCR $DeNO_X$ unit has been installed prior to the start of the project activity, GHG emissions related to the production of ammonia used for NO_X reduction will not be considered.

11. Table 2 illustrates which emissions sources are included and which are excluded from the project boundary for determination of both baseline and project emissions.

Table 2. **Overview on emission sources included or excluded from the project boundary**

Baseline emissions

Source	Gas		Justification/Explanation
Emissions of N_2O as a result of side reaction to the ammonia oxidation in the ~~nitric acid or~~ caprolactam production process	N_2O	Included	Main emission source, taking national N_2O emission regulations into account
In an HPO® caprolactam production process, emissions of N_2O as a result of the decomposition of hydroxylamine (hyam) in the absorption column	N_2O	Excluded	The amount of hyam entering the absorption column from the HPO® process depends on circumstances in the rest of the HPO® process. Exclusion from the baseline emissions removes any incentive to manipulate this N_2O formation
Emissions related to the production of ammonia used for NO_X reduction (Attention: Ammonia used for NO_X-reduction does not cause GHG emissions, only the production of ammonia causes GHG emissions)	CO_2 CH_4 N_2O	Included	In case SCR $DeNO_X$ unit is already installed prior to the project start: ammonia input for SCR is considered to be of the same magnitude to project related ammonia input for NO_X reduction. Baseline emissions and project emissions are similar and therefore not considered for calculation. In case no SCR $DeNO_X$-unit is already installed prior to the project start: ammonia input for NO_X reduction is considered 0 for baseline emissions

Source	Gas		Justification/Explanation
N$_2$O emissions from SCR DeNO$_X$-unit	N$_2$O	Excluded	The presence of a SCR DeNOX unit tends to increase the N$_2$O emissions. Therefore the ex post measurement of the baseline emissions at the inlet of the N$_2$O destruction facility represents a conservative determination of the baseline N$_2$O emissions

Project emissions

Source	Gas		Justification/Explanation
Emissions of N$_2$O as a result of side reaction to the ~~nitric acid or~~ caprolactam production process	N$_2$O	Included	Main emission source, taking national N$_2$O emission regulations into account
Emissions related to the production of ammonia used for NO$_X$ reduction (Attention: Ammonia used for NO$_X$ reduction does not cause GHG emissions, only the production of ammonia causes GHG emissions)	CO$_2$ CH$_4$ N$_2$O	Included	In case SCR DeNO$_X$ unit is already installed prior to the project start: ammonia input for SCR is considered to be of the same magnitude to project related ammonia input for NO$_X$ reduction. Baseline emissions and project emissions are similar and therefore not considered for calculation. In case no SCR DeNO$_X$-unit is already installed prior to the project start: ammonia input for NO$_X$ reduction is considered zero for baseline emissions
In case of thermal N$_2$O decomposition process installed: Emissions at the project site resulting from fuel combustion to maintain the required temperature in the reaction chamber	CO$_2$	Included	Thermal destruction of N$_2$O requires high temperatures in order to maintain the reaction. The heat is provided by a burner that uses fossil fuels. Emissions related to the combustion are considered in the project boundaries

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Source	Gas		Justification/Explanation
In case of N_2O reduction process installed: Emissions at the project site resulting from hydrocarbons used as reducing agent and/or re-heating the tail gas	CH_4 and/or CO_2	Included	Hydrocarbons are used as reducing agent and/or re-heating the tail gas to enhance the efficiency of a N_2O catalytic reduction facility. In this case hydrocarbons are mainly converted to CO_2, while some hydrocarbons may remain intact. Fractions of unconverted methane are either measured (monitored online) or all methane used as reducing agent is assumed as completely unconverted. All other hydrocarbons, with more than two molecules of carbon, are assumed to be completely converted to CO_2
Emissions from electricity demand	CO_2 CH_4 N_2O	Excluded	GHG emissions related to the electricity consumption are insignificant (< 0.005%) and are excluded as monitoring would lead to unreasonable costs
Emissions related to the production of the hydrocarbons	CO_2 CH_4 N_2O	Excluded	GHG emissions related to the production of hydrocarbons used as reducing agent represent less than 0.001% of expected emission reductions and will not be taken into account due to unreasonable costs for monitoring

12. As shown in Figure 1 (Destruction facility inside of the pressure zone, tail gas turbine downstream of project) and Figure 2 (Destruction facility not in pressure zone, tail gas turbine located upstream), the spatial extent of the project boundary comprises:

(a) The catalytic N_2O destruction facility including auxiliary ammonia and/or hydrocarbon input;

(b) For caprolactam plants using the HPO® process, the flow of product gas of the ammonia oxidation reactor to the absorption column, and the flow of product liquid from the absorption column to the HPO® process area; and

(c) For monitoring purposes only, the <mark>nitric acid or</mark> caprolactam production plant, to measure the <mark>nitric acid or</mark> caprolactam output and operating parameters of the ammonia oxidation reactor.

Figure 1: Project boundary (destruction facility in pressure zone, tail gas turbine upstream)
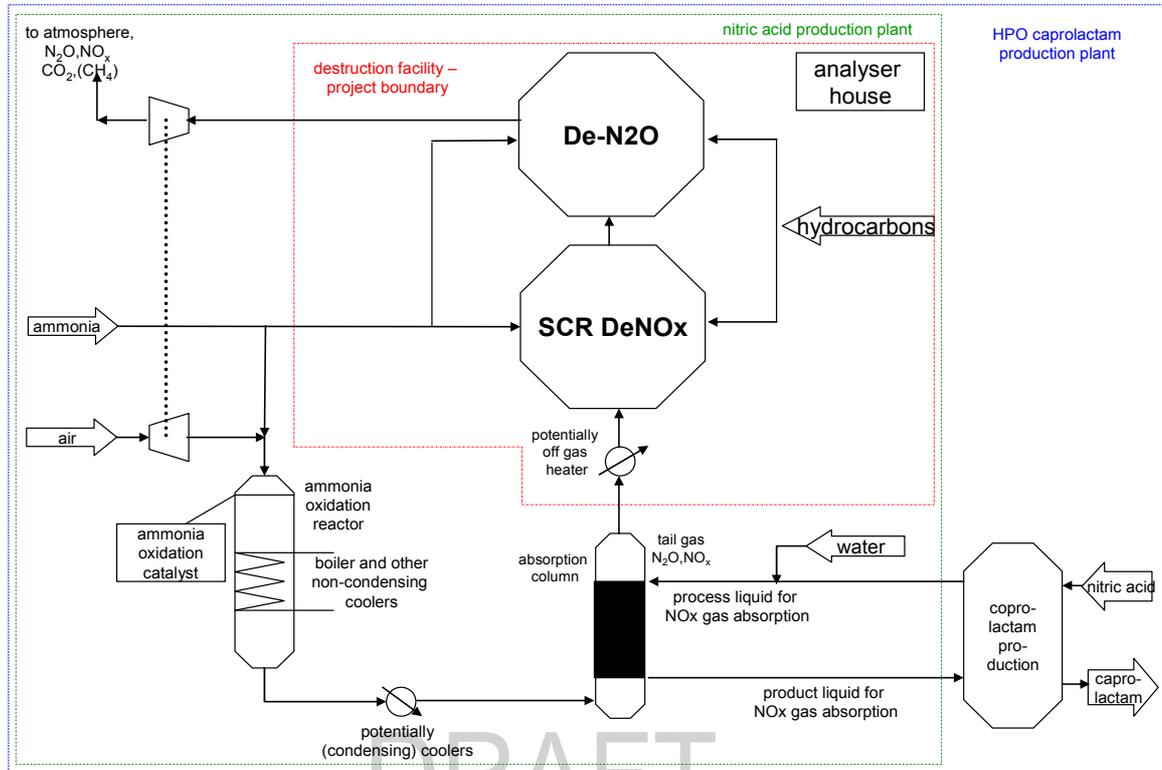
Figure 2: Project boundary (destruction facility outside pressure zone, tail gas turbine downstream)
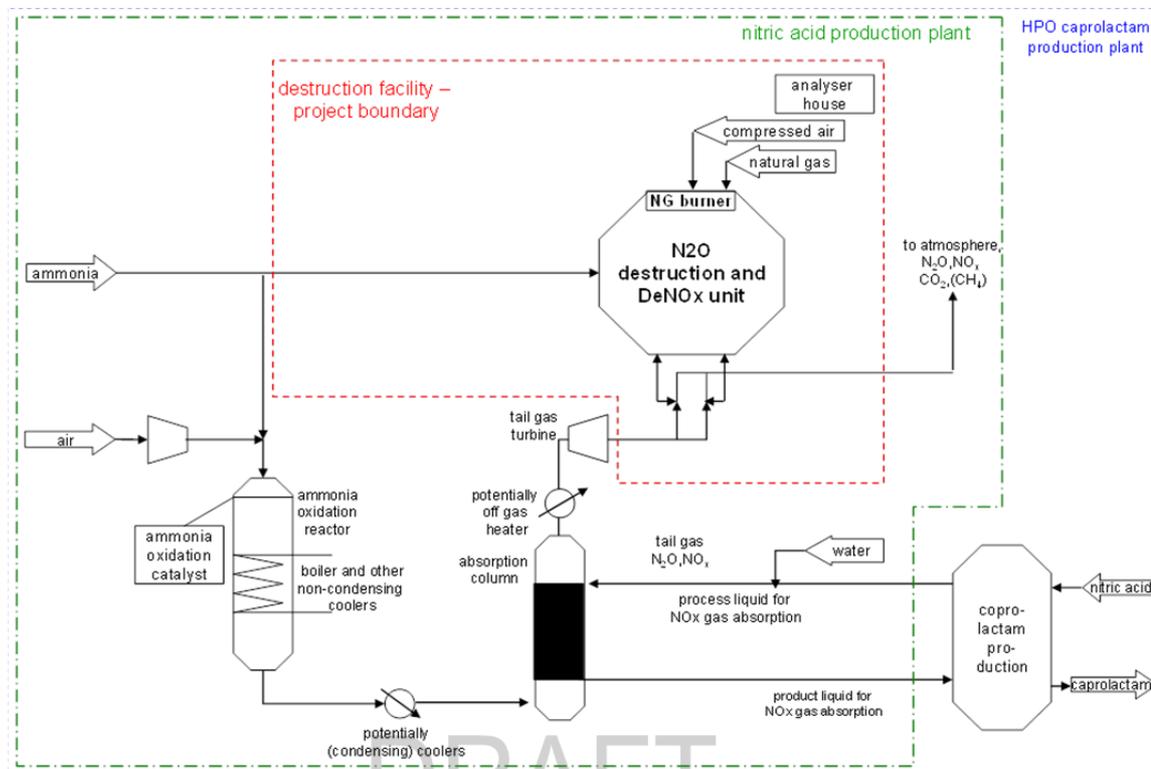
5.1.1. Step 1: Identify technically feasible baseline scenario alternatives to the project activity

13. The baseline scenario alternatives should include all technically feasible options which are realistic and credible.

5.1.1.1. Sub-step 1a: The baseline scenario alternatives should include all possible options that are technically feasible to handle N_2O emissions. These options are, inter alia:

(a) Status quo: The continuation of the current situation, where there will be no installation of technology for the destruction or abatement of N_2O;

(b) Switch to alternative production method not involving ammonia oxidation process;

(c) Alternative use of N_2O such as:

    (i) Recycling of N_2O as a feedstock for the plant;

    (ii) The use of N_2O for external purposes;

(d) Installation of a Non-Selective Catalytic Reduction (NSCR) DeNO$_X$ unit;[2]

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[2] NSCR: As NSCR DeNO$_X$-unit will reduce N_2O emissions as a side reaction to the NO$_X$-reduction. Consequently, new NSCR installation can be seen as alternative N_2O reduction technology.

(e) The installation of an N_2O destruction or abatement technology:

    (i) Tertiary measure for N_2O destruction;

    (ii) Primary or secondary measures for N_2O destruction or abatement.

14. These options should include the CDM project activity not implemented as a CDM project.

5.1.1.2. **Sub-step 1b: In addition to the baseline scenario alternatives of Step 1a, all possible options that are technically feasible to handle NO_X emissions should be considered. The installation of a NSCR DeNOX unit could also cause N_2O emission reduction. Therefore NO_X emission regulations have to be taken into account in determining the baseline scenario. The respective options are, inter alia:**

(a) The continuation of the current situation, where either a $DeNO_X$-unit is installed or not;

(b) Installation of a new Selective Catalytic Reduction (SCR) $DeNO_X$ unit;

(c) Installation of a new Non-Selective Catalytic Reduction (NSCR) $DeNO_X$ unit;

(d) Installation of a new tertiary measure that combines NOX and N_2O emission reduction.

5.1.2. **Step 2: Eliminate baseline alternatives that do not comply with legal or regulatory requirements**

(a) The baseline alternatives shall be in compliance with all applicable legal and regulatory requirements, even if these laws and regulations have objectives other than GHG reductions (N_2O), e.g. national or local NO_X regulations or by-product waste. This step does not consider national and local policies that do not have legally-binding status. Eliminate all baseline alternatives that do not comply with the legal and regulatory requirements on N_2O and NO_X emissions;

(b) If an alternative does not comply with all applicable legislation and regulations, then show that, based on an examination of current practice in the country or region in which the law or regulation applies, those applicable legal or regulatory requirements are systematically not enforced and that non-compliance with those requirements is widespread in the country. If this cannot be shown, then eliminate the alternative from further consideration;

(c) If the proposed project activity is the only alternative amongst the ones considered by the project participants that is in compliance with all regulations with which there is general compliance, then the proposed project activity is the baseline scenario.

15. The following table shows potential baseline scenarios taking legal or regulatory requirements into account:

Table 3.   Potential baseline scenarios taking legal or regulatory requirements

~~Nitric Acid or~~ Caprolactam production plant in compliance with N$_2$O and NO$_X$ regulation	~~Nitric Acid or~~ Caprolactam production plant not in compliance with NO$_X$ regulation	~~Nitric Acid or~~ Caprolactam production plant not in compliance with N$_2$O regulation
Continuation Status quo	SCR DeNO$_X$ installation N	SCR De-NO$_X$ installation that combines N$_2$O and NO$_X$ emission reduction
Installation of N$_2$O destruction or abatement technology	NSCR De-NO$_X$ installation	Installation of N$_2$O destruction or abatement technology
Alternative use of N$_2$O	Tertiary measure that combines NO$_X$ and N$_2$O emission reduction	Alternative use of N$_2$O

5.1.3. Step 3: Eliminate baseline alternatives that face prohibitive barriers (barrier analysis)

5.1.3.1.   Sub-step 3a: On the basis of the alternatives that are technically feasible and in compliance with all legal and regulatory requirements, the project participant should establish a complete list of barriers that would prevent alternatives to occur in the absence of CDM. Barriers should include, among others:

(a)   Investment barriers, inter alia:

   (i)   Debt funding is not available for this type of innovative project activity;

   (ii)   No access to international capital markets due to real or perceived risks associated with domestic or foreign direct investment in the country where the project activity is to be implemented;

(b)   Technological barriers, inter alia:

   (i)   Technical and operational risks of alternatives;

   (ii)   Technical efficiency of alternatives (e.g. N$_2$O destruction, abatement rate);

   (iii) Skilled and/or properly trained labour to operate and maintain the technology is not available and no education/training institution in the host country provides the needed skill, leading to equipment disrepair and malfunctioning;

   (iv)   Lack of infrastructure for implementation of the technology.

(c)   Barriers due to prevailing practice, inter alia:

   (i)   The project activity is the "first of its kind": No project activity of this type is currently operational in the host country or region.

16.   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. The type of evidence to be provided may include:

(a)   Relevant legislation, regulatory information or industry norms;

(b)   Relevant (sectoral) studies or surveys (e.g. market surveys, technology studies, etc.) undertaken by universities, research institutions, industry associations, companies, bilateral/multilateral institutions etc.;

(c)   Relevant statistical data from national or international statistics;

(d)   Documentation of relevant market data (e.g. market prices, tariffs, rules);

(e)   Written documentation from the company or institution developing or implementing the CDM project activity or the CDM project developer, such as minutes from Board meetings, correspondence, feasibility studies, financial or budgetary information, etc.;

(f)   Documents prepared by the project developer, contractors or project partners in the context of the proposed project activity or similar previous project implementations;

(g)   Written documentation of an independent expert judgement from industry, educational institutions (e.g. universities, technical schools, training centers), industry associations and others.

5.1.3.2.   Sub-step 3b: Show that the identified barriers would not prevent the implementation of at least one of the alternatives (except the proposed CDM project activity)

17.   If any of the baseline scenario alternatives face barriers that would prohibit them from being implemented, then these should be eliminated.

18.   If all project alternatives are prevented by at least one barrier, either the proposed CDM project is itself the baseline or the set of project alternatives has to be completed to include the potential baseline.

19.   If there are several potential baseline scenario candidates, either choose the most conservative alternative as a baseline scenario and go to Step 5, otherwise go to Step 4.

5.1.4. Step 4: Identify the most economically attractive baseline scenario alternative

20.   Determine which of the remaining project alternatives that are not prevented by any barrier is the most economically or financially attractive.

21.   To conduct the investment analysis, use the following sub-steps:

5.1.4.1.   Sub-step 4a: Determine appropriate analysis method

22.   Determine whether to apply a simple cost analysis or an investment comparison analysis. If all remaining project alternatives generate no financial or economic benefits other than CDM related income, then apply the simple cost analysis (Option I). Otherwise, use the investment comparison analysis (Option II).

5.1.4.2. Sub-step 4b: Option I: Apply simple cost analysis

23. Document the costs associated with alternatives to the CDM project activity and demonstrate that the corresponding activities produce no financial or economic benefits.

    (a) If all alternatives do not generate any financial or economic benefits, then the least costly alternative among these alternative is pre-selected as the most plausible baseline scenario candidate;

    (b) If one or more alternatives generate financial or economic benefits, then the simple cost analysis cannot be used to select the baseline scenario.

5.1.4.3. Sub-step 4c: Option II: Apply investment comparison analysis

24. Identify the financial indicator, such as IRR,[3] NPV, cost benefit ratio, or unit cost of service most suitable for the project type and decision-making context.

25. Calculate the suitable financial indicator for each of the project alternatives that have not been eliminated in Step 3 and include all relevant costs (including, for example, the investment cost, the operations and maintenance costs, financial costs, etc.) and revenues (including subsidies/fiscal incentives[3], etc. where applicable), and, as appropriate, non-market costs and benefits in the case of public investors.

26. Present the investment analysis in a transparent manner and provide all the relevant assumptions in the CDM-PDD, so that a reader can reproduce the analysis and obtain the same results. Clearly present critical techno-economic parameters and assumptions (such as capital costs, fuel prices, lifetimes, and discount rate or cost of capital). Justify and/or cite assumptions in a manner that can be validated by the DOE. In calculating the financial indicator, the project's risks can be included through the cash flow pattern, subject to project-specific expectations and assumptions (e.g. insurance premiums can be used in the calculation to reflect specific risk equivalents).

27. Assumptions and input data for the investment analysis shall not differ across the project activity and its alternatives, unless differences can be well substantiated.

28. Present in the CDM-PDD submitted for validation a clear comparison of the financial indicator for the proposed project alternative.

29. The alternative that has the best indicator (e.g. highest IRR) can be pre-selected as the most plausible baseline scenario candidate.

5.1.4.4. Sub-step 4d: Sensitivity analysis (only applicable to Option II)

30. Include a sensitivity analysis that shows whether the conclusion regarding the financial attractiveness is robust to reasonable variations in the critical assumptions. The investment analysis provides a valid argument in selecting the baseline only if it

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[3] For the investment comparison analyses, IRRs can be calculated either as project IRRs or as equity IRRs. Project IRRs calculate a return based on project cash outflows and cash inflows only, irrespective of the source of financing. Equity IRRs calculate a return to equity investors and therefore also consider amount and costs of available debt financing. The decision to proceed with an investment is based on returns to the investors, so equity IRR will be more appropriate in many cases. However, there will also be cases where a project IRR may be appropriate.

consistently supports (for a realistic range of assumptions) the conclusion that the pre-selected baseline scenario candidate is likely to remain the most financially and/or economically attractive.

31. In case the sensitivity analysis is not fully conclusive, select the most conservative among the project alternatives that are the most financially and/or economically attractive according to both Steps 4.c and the sensitivity analysis in the Step 4.d, e.g. if the sensitivity analysis shows that one or more project alternatives compete with the one identified in Step 4.c., select the alternative with the lowest GHG emissions.

5.1.5. Step 5: Re-assessment of baseline scenario in course of proposed project activity's lifetime

32. At the start of a crediting period, a re-assessment of the baseline scenario due to new or modified NO$_X$ or N$_2$O emission regulations should be executed as follows:

5.1.5.1. Sub-step 5a: New or modified NO$_X$-emission regulations

33. If new or modified NO$_X$ emission regulations are introduced after the project start, determination of the baseline scenario will be re-assessed at the start of a crediting period. Baseline scenario alternatives to be analysed should include, inter alia:

    (a) Selective Catalytic Reduction (SCR);

    (b) Non-Selective Catalytic Reduction (NSCR);

    (c) Tertiary measures incorporating a selective catalyst for destroying N$_2$O and NO$_X$ emissions;

    (d) Continuation of baseline scenario.

34. For the determination of the adjusted baseline scenario the project participant should re-assess the baseline scenario and shall apply baseline determination process as stipulated above (Steps 1 – 5).

Table 4. Potential outcomes of the re-assessment of the baseline scenario (to be in line with NO$_X$ regulation)

	Consequence (adjusted baseline scenario)
SCR De-NO$_X$ installation	Continuation of original (N$_2$O) baseline scenario
NSCR De-NO$_X$ installation	The N$_2$O emissions outlet of NSCR become adjusted baseline N$_2$O emissions, as NSCR may reduce N$_2$O emissions as well as NO$_X$
Tertiary measure that combines NO$_X$ and N$_2$O emission reduction	Adjusted baseline scenario results in zero N$_2$O emissions reduction
Continuation of original baseline scenario	Continuation of original baseline scenario

5.1.5.2. Sub-step 5b: New or modified N₂O - regulation

35. If legal regulations on N₂O emissions are introduced or changed during the crediting period, the baseline emissions shall be adjusted at the time the legislation has to be legally implemented.

36. The methodology is applicable if the procedure to identify the baseline scenario results in that the most likely baseline scenario is the continuation of emitting N₂O to the atmosphere, without the installation of N₂O destruction or abatement technologies, including technologies that indirectly reduce N₂O emissions (e.g. NSCR DeNO$_X$ units).

5.2. Additionality

37. The additionality of the project activity shall be demonstrated and assessed using the latest version of the "Tool for demonstration and assessment of additionality" agreed by the Board.

38. Because of the similarity of both approaches used to determine the baseline scenario and the additionality tool, Step 1 of the "Tool for demonstration and assessment of additionality" can be ignored.

39. Consistency shall be ensured between the baseline scenario determination and additionality demonstration. The baseline scenario alternative selected in the previous section shall be used when applying Steps 2 to 5 of the "Tool for demonstration and assessment of additionality" In case of re-assessment of baseline scenario (as a consequence of new NO$_X$ regulations) in course of proposed project activity's lifetime, the re-assessment has to be undertaken according to section 4. Furthermore, the additionality test shall be undertaken again.

5.3. Project emissions

40. The emissions due to the project activity are composed of: (a) the emissions of not destroyed N₂O; and (b) emissions from auxiliary ammonia and hydrocarbons input resulting from the operation of the N₂O destruction facility including the emissions from auxiliary fossil fuel combustion, if any in case of thermal decomposition of N₂O. The procedure of determining the project N₂O emissions is similar to that used for determining baseline emissions.

41. Project emissions are defined by the following equation:

$$PE_y = PE_{ND,y} + PE_{DF,y}$$ Equation (1)

Where:

PE_y = Project emissions in year y (t CO₂e)

$PE_{ND,y}$ = Project emissions from N₂O not destroyed in year y (tCO₂e)

$PE_{DF,y}$ = Project emissions related to the operation of the destruction facility in year y (tCO₂e)

5.3.1. N_2O emissions not destroyed by the project activity

42. N_2O emissions not destroyed by the project activity are calculated based on the continuous measurement of the N_2O concentration in the tail gas of the N_2O destruction facility and the volume flow rate of the tail gas stream.

43. The emissions of non destroyed N_2O are given by:

$$PE_{ND,y} = PE_{N2O,y} \times GWP_{N2O}$$
<div align="right">Equation (2)</div>

Where:

$PE_{ND,y}$ = Project emissions from N_2O not destroyed in year y (t CO_2e)

$PE_{N2O,y}$ = Project emissions of N_2O in year y (tN_2O)

GWP_{N2O} = Global warming potential of N_2O = 310

$$PE_{N2O,y} = \sum_{i}^{n} F_{TE,i} \times CO_{N2O,i} \times M_i$$
<div align="right">Equation (3)</div>

Where:

$PE_{N2O,y}$ = Project emissions of N_2O in year y (tN_2O)

$F_{TE,i}$ = Volume flow rate at the exit of the destruction facility during interval i (m^3/h)[4]

$CO_{N2O,i}$ = N_2O concentration in the tail gas of the N_2O destruction facility during interval i (tN_2O/m3)

M_i = Length of measuring interval i (h)

i = Interval

n = Number of intervals during the year

5.3.2. Project emissions from the operation of the destruction facility

44. The operation of the N_2O destruction facility may require the use of ammonia (NH3)and hydrocarbons (HC) (e.g. natural gas, LPG, butane) as input streams and auxiliary fossil fuel to supplement heat input required for maintaining the desired temperature in case of thermal decomposition of N_2O.

45. The emissions related to the operation of the N_2O destruction facility are given by (1) upstream emissions related to the production of ammonia used as input; (2) on-site

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[4] $F_{TE,i}$ and $CO_{N2O,i}$ should be measured simultaneously and at same basis (wet or dry) and values should be expressed on the same basis (wet or dry) and should be corrected to normal conditions (101.325 kPa, 0 deg C). If the instrument (or measurement system) uses an algorithm to convert actual conditions to normal conditions, the proper source of such an algorithm should be used (e.g. based on procedures of EN14181). For all the cases, either manual or algorithm-based conversion of actual conditions to normal conditions, the temperature and pressure of actual conditions of gas should be recorded.

emissions due to the hydrocarbons use as input to the N_2O destruction facility; and (3) on-site emissions due to the fossil fuel (FF) use (e.g. natural gas, LPG, butane) as input to the N_2O destruction facility (thermal decomposition):

$$PE_{DF,y} = PE_{NH3,y} + PE_{HC,y} + PE_{FF,y}$$
<div align="right">Equation (4)</div>

Where:

$PE_{DF,y}$	=	Project emissions related to the operation of the destruction facility in year y (t CO_2e)
$PE_{NH3,y}$	=	Project emissions related to ammonia input to destruction facility in year y (t CO_2e)
$PE_{HC,y}$	=	Project emissions related to hydrocarbon input to destruction facility and/or re-heater in year y (t CO_2e)
$PE_{FF,y}$	=	Project emissions related to the combustion of fossil fuels in year y (tCO_2)

5.3.2.1. Ammonia input to the destruction facility

(a) In case an existing SCR DeNO$_X$ unit is already installed prior to the starting date of the project activity or has to be installed according to legal requirements, the project ammonia input will be considered equal to the ammonia input of the baseline scenario;

(b) Should no SCR DeNO$_X$ unit be installed prior to the starting date of the project activity, project emissions related to the production of ammonia are considered as follows:

$$PE_{NH3,y} = Q_{NH3,y} \times EF_{NH3}$$
<div align="right">Equation (5)</div>

Where:

$PE_{NH3,y}$	=	Project emissions related to ammonia input to destruction facility in year y (tCO_2e)
$Q_{NH3,y}$	=	Ammonia input to the destruction facility in year y (tNH_3)
EF_{NH3}	=	GHG emissions factor for ammonia production (CO_2e/tNH_3)

46. Please note: Ammonia input for NO$_X$ emission reduction will not cause GHG emissions other than related to the production of ammonia.

47. A default factor of 2.14 t CO_2e/tNH_3 is suggested (GEMIS 4.2).

5.3.2.2. Hydrocarbon input

48. Hydrocarbons can be used as reducing agent and/or re-heating the tail gas to enhance the catalytic N_2O reduction efficiency. In this case hydrocarbons are mainly converted to CO_2 ($HCE_{C,y}$), while some methane remain unconverted to CO_2 ($HCE_{NC,y}$).

49. The emissions from hydrocarbon input are:

$$PE_{HC,y} = HCE_{C,y} + HCE_{NC,y} \qquad \text{Equation (6)}$$

Where:

$PE_{HC,y}$	=	Project emissions related to hydrocarbon input to destruction facility and/or re-heater in year y (t CO$_2$e)
$HCE_{C,y}$	=	Converted hydrocarbon emissions in year y (t CO$_2$)
$HCE_{NC,y}$	=	Methane emissions in year y (t CO$_2$e)

50.   For calculation of the GHG emissions related to the hydrocarbons converted and not converted, the following formulae are used:

$$HCE_{NC,y} = \rho_{CH4} \times Q_{CH4,y} \times GWP_{CH4} \times (1 - OXID_{CH4}/100) \qquad \text{Equation (7)}$$

Where:

$HCE_{NC,y}$	=	Methane emissions in year y (t CO$_2$e)
ρ_{CH4}	=	Methane density (t/m^3)
$Q_{CH4,y}$	=	Methane used in year y (m^3)
GWP_{CH4}	=	Global warming potential of methane
$OXID_{CH4}$	=	Oxidation factor of methane (%)

$$HCE_{C,y} = \rho_{HC} \times Q_{HC,y} \times EF_{HC} \times \frac{OXID_{HC}}{100} + \rho_{CH4} \times Q_{CH4,y} \times \frac{OXID_{CH4}}{100} \qquad \text{Equation (8)}$$

Where:

$HCE_{C,y}$	=	Converted hydrocarbon emissions in year y (t CO$_2$e)
ρ_{HC}	=	Hydrocarbon density (t/m^3)
$Q_{HC,y}$	=	Hydrocarbon, with two or more molecules of carbon, input in year y (m^3)
$OXID_{HC}$	=	Oxidation factor of hydrocarbon (%), with two or more molecules of carbon
EF_{HC}	=	Carbon emissions factor of hydrocarbon (tCO$_2$/t HC), with two or more molecules of carbon

51.   The hydrocarbon CO$_2$ emission factor is given by the molecular weights and the chemical reaction when hydrocarbons are converted (e.g. where CH$_4$ is used as hydrocarbon, each converted tonne of CH$_4$ results in 44/16 tonnes of CO$_2$, thus the hydrocarbon emission factor is 2.75).

52.   Project emissions are limited to the design capacity of the existing ~~nitric acid or~~ caprolactam production plant. If the actual production of ~~nitric acid or~~ caprolactam ($P_{product,y}$) exceeds the design capacity ($P_{product,max}$) then emissions related to the

production above $P_{product,max}$ will neither be claimed for the baseline nor for the project scenario.

5.3.2.3. Combustion of fossil fuels

53. In the thermal N$_2$O destruction process fossil fuels (e.g. natural gas) is combusted in a burner to supply the heat required to maintain the reaction. The calculation of project emissions from combustion of fossil fuels ($PE_{FF,y}$) and the respective monitoring shall be done in accordance with the latest "Tool to calculate project or leakage CO$_2$ emissions from fossil fuel combustion".

54. If no fuel combustion is involved, e.g. in the case of catalytic N$_2$O destruction, the respective part in equation 4 is set to zero.

5.4. Baseline emissions

55. Baseline emissions are given by the following equation:

$$BE_y = BE_{N2O,y} \times GWP_{N2O}$$ Equation (9)

Where:

BE_y = Baseline emissions in year y (t CO$_2$e)

$BE_{N2O,y}$ = Baseline emissions of N$_2$O in year y (tN$_2$O)

GWP_{N2O} = Global warming potential of N$_2$O = 310

56. Depending on the implementation of regulations on N$_2$O emissions and the character of the regulation, baseline N$_2$O emissions ($BE_{N2O,y}$) are calculated as shown below:

5.4.1. Case 1: The most plausible baseline scenario is that no N$_2$O would be abated in the absence of the project activity (i.e. no secondary or tertiary reductions measures and no NSCR De-NO$_X$ unit would be installed)

5.4.1.1. Case 1.1: ~~Nitric acid and~~ caprolactam plants using the Raschig production process

57. In the case of a ~~nitric acid plant or~~ a caprolactam plant using the Raschig process, baseline emissions are limited to the design capacity of the existing ~~nitric acid or~~ caprolactam production plant. If the actual production of ~~nitric acid or~~ caprolactam ($P_{product,y}$) exceeds the design capacity ($P_{product,max}$) then emissions related to the production above $P_{product,max}$ will not be claimed for the baseline scenario.

58. $P_{product,y}$ = Production of ~~nitric acid or~~ caprolactam in year y (t Product)

59. $P_{product,max}$ = Design capacity ~~of nitric acid or~~ caprolactam production (t Product)

If,

$$P_{product,y} < P_{product,max}$$ Equation (10)

Then,

$$BE_{N2O,y} = QB_{N2O,y}$$
Equation (11)

Where:

$BE_{N2O,y}$ = Baseline emissions of N$_2$O in year *y* (tN$_2$O)

$QB_{N2O,y}$ = Quantity of N$_2$O supplied to the destruction facility from ammonia oxidation in year *y* (tN$_2$O)

$$QB_{N2O,y} = QI_{N2O,y}$$
Equation (12)

Where:

$QB_{N2O,y}$ = Quantity of N$_2$O supplied to the destruction facility from ammonia oxidation in year *y* (tN$_2$O)

$QI_{N2O,y}$ = Quantity of N$_2$O emissions at the inlet of the destruction facility in year *y* (tN$_2$O)

60. The total quantity of N$_2$O supplied to the N$_2$O destruction facility (DF) is calculated based on continuous measurement of the tail gas volume flow rate and the N$_2$O concentration at the inlet of the N$_2$O destruction facility. Therefore the quantity of the N$_2$O at the inlet is given by:

$$QI_{N2O,y} = \sum_{i}^{n} F_{TI,i} \times CI_{N2O,i} \times M_i$$
Equation (13)

Where:

$QI_{N2O,y}$ = Quantity of N$_2$O emissions at the inlet of the destruction facility in year *y* (tN$_2$O)

$F_{TI,i}$ = Volume flow rate at the inlet of the destruction facility during interval *i* (m^3/h)[5]

$CI_{N2O,i}$ = N$_2$O concentration a destruction facility inlet during interval *i* (tN$_2$O/m^3)

M_i = Length of measuring interval *i* (h)

i = Interval

n = Number of intervals during the year

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[5] $F_{TI,i}$ and $CI_{N2O,i}$ should be measured simultaneously and at same basis (wet or dry) and values should be expressed on the same basis (wet or dry) and should be corrected to normal conditions (101.325 kPa, 0 deg C) . If the instrument (or measurement system) uses the algorithm to convert actual conditions to normal conditions, the proper source of such algorithm should be used (e.g. based on procedures of EN14181). For all the cases, either manual or algorithm-based conversion of actual conditions to normal conditions, the temperature and pressure of actual conditions of gas should be recorded.

If,

$$P_{product,y} \geq P_{product,max} \qquad\qquad \text{Equation (14)}$$

Then,

~~$BE_{N2O,y} = SE_{N2O,y} \times P_{product,max}$ for Nitric acid plants,or~~ (15)

$$BE_{N2O,y} = min\left(SE_{N2O,y}; EF_{N2O,IPCC}\right) \times P_{product,max} \text{ for Raschig process} \qquad \text{Equation (15)}$$

Where:

$BE_{N2O,y}$	=	Baseline emissions of N_2O in year y (tN_2O)
$SE_{N2O,y}$	=	Specific N_2O emissions per unit of output product of ~~nitric acid or~~ caprolactam in year y (tN_2O/t Product)
$P_{product,max}$	=	Design capacity (t Product)
$EF_{N2O,IPCC}$	=	Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N_2O emission process (in this case a high-pressure nitric acid plant); 5.4 kgN_2O/t Product

61. The specific N_2O emissions per unit of output of ~~nitric acid or~~ caprolactam are defined as:

$$SE_{N2O,y} = QI_{N2O,y}/P_{product,y} \qquad\qquad \text{Equation (16)}$$

Where:

$SE_{N2O,y}$	=	Specific N_2O emissions per unit of output of ~~nitric acid or~~ caprolactam in year y (tN_2O/t Product)
$QI_{N2O,y}$	=	Quantity of N_2O emissions at the inlet of the destruction facility in year y (tN_2O)

5.4.1.2. Case 1.2: Caprolactam plants using the HPO® production process

62. In the case of a caprolactam plant using the HPO® process, baseline emissions are limited to the existing design capacity of on-site calculated nitric acid production, which depends upon the design capacity of the existing ammonia oxidation reactor. If the actual calculated nitric acid production ($P_{product,calc,y}$) exceeds the design capacity ($P_{product,calc,max}$), then emissions related to the production above $P_{product,calc,max}$ will not be claimed for the baseline scenario.

63. $P_{product,calc, y}$ = On-site calculated nitric acid production in year y (t HNO_3)

64. $P_{product,calc,max}$ = On-site design capacity of calculated nitric acid production (t HNO_3)

$$P_{productcalc,y} = A_{OR,y} \times M(NH_3)^{-1} \times \eta_{NO} \times \eta_{abs} \times M(HNO_3) \qquad \text{Equation (17)}$$

$$P_{productcals,max} = A_{OR,max} \times M(NH_3)^{-1} \times \eta_{NO} \times \eta_{abs} \times M(HNO_3)$$ Equation (18)

Where:

$A_{OR,y}$	=	Actual ammonia input to oxidation reactor in year y (tNH3/yr)
$A_{OR,max}$	=	Maximum historical ammonia input to oxidation reactor (tNH3/yr)
$M(NH_3)$	=	Molar mass of ammonia = 17 tonnes/Mmol
$M(HNO_3)$	=	Molar mass of nitric acid = 63 tonnes/Mmol
η_{NO}	=	Ammonia oxidation reactor oxidation efficiency = 93%[6]
η_{abs}	=	Efficiency of the absorption column = 99%[7]

If,

$$P_{productcalc,y} < P_{productcalc,max}$$ Equation (19)

then

$$BE_{N2O,y} = QB_{N2O,y}$$ Equation (20)

and

$$QB_{N2O,y} = min\{QI_{N2O,y}; (QA_{N2O,y} - QP_{N2O,y})\}$$ Equation (21)

Where:

$QB_{N2O,y}$	=	Quantity of N_2O supplied to the destruction facility from ammonia oxidation in year y (tN$_2$O)
$QI_{N2O,y}$	=	Quantity of N_2O emissions at the inlet of the destruction facility in year y (tN$_2$O)
$QA_{N2O,y}$	=	Quantity of N_2O in the gas flow between the ammonia oxidation reactor and the absorption column in year y (tN2O)
$QP_{N2O,y}$	=	Quantity of N_2O in the product flow from the absorption column to the HPO® process area in year y (tN$_2$O)

65.   The total quantity of N_2O supplied to the N_2O destruction facility (DF) is calculated based on continuous measurement of the tail gas volume flow rate and the N_2O concentration at the inlet of the N_2O destruction facility. Therefore the quantity of the N_2O at the inlet is given by:

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[6] C. Keleti (ed), Nitric Acid and fertilizer nitrates, Fertilizer Science and Technology series, Vol 4, New York, Basel, 1985.

[7] P. Gry, Program to reduce NOx emissions of HNO3 plants with selective catalytic reduction, International conference on Industrial Atmospheric Pollution – NOXCONF 2001, Collection of papers, Session 8, Paris, 21-22 March 2001.

$$QI_{N2O,y} = \sum_{i}^{n} F_{TI,i} \times CI_{N2O,i} \times M_i \qquad \text{Equation (22)}$$

Where:

$QI_{N2O,y}$	=	Quantity of N$_2$O emissions at the inlet of the destruction facility in year y (t N$_2$O)
$F_{TI,i}$	=	Volume flow rate at the inlet of the destruction facility during interval i (m^3/h)[8]
$CI_{N2O,i}$	=	N$_2$O concentration a destruction facility inlet during interval i (tN$_2$O/m^3)
M_i	=	Length of measuring interval i (h)
i	=	Interval
n	=	Number of intervals during the year

66.   The quantity of N$_2$O in the gas flow between the ammonia oxidation reactor and the absorption column in year y is calculated based on continuous measurement of the gas volume flow rate and the N$_2$O concentration in the product stream from the ammonia oxidation. Therefore, the quantity of the N$_2$O produced by ammonia oxidation is given by:

$$QA_{N2O,y} = \sum_{i}^{n} F_{AI,i} \times CA_{N2O,i} \times M_i \qquad \text{Equation (23)}$$

Where:

$QA_{N2O,y}$	=	Quantity of N$_2$O in the gas flow between the ammonia oxidation reactor and the absorption column in year y (tN$_2$O)
$F_{AI,i}$	=	Volume flow rate of the product stream of the ammonia oxidation reactor during interval i (m^3/h)
$CA_{N2O,i}$	=	N$_2$O concentration in the product stream of the ammonia oxidation reactor during interval i (tN$_2$O/m^3)
M_i	=	Length of measuring interval i (h)
i	=	Interval
n	=	Number of intervals during the year

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[8] $FT_{1,i}$ and $CI_{N2O,i}$ should be measured simultaneously and at same basis (wet or dry) and values should be expressed on the same basis (wet or dry) and should be corrected to normal conditions (101.325 kPa, 0 deg C) . If the instrument (or measurement system) uses the algorithm to convert actual conditions to normal conditions, the proper source of such algorithm should be used (e.g. based on procedures of EN14181). For all the cases, either manual or algorithm-based conversion of actual conditions to normal conditions, the temperature and pressure of actual conditions of gas should be recorded.

67. The volume flow rate of the product stream of the ammonia oxidation reactor during interval i , $F_{AI,i}$ is calculated from the volume flow rates of ammonia and air to the ammonia oxidation reactor:

$$F_{AI,i} = 0.975\left(A_{OR,i} + Air_{OR,i}\right)$$

Equation (24)

Where:

$F_{AI,i}$ =   Volume flow rate of the product stream of the ammonia oxidation reactor during interval i (m^3/h)

$A_{OR,i}$ =   Actual ammonia input to oxidation reactor during interval i (m^3/h)

$Air_{OR,i}$ =   Actual air input to oxidation reactor during interval i (m^3/h)[9]

68. The total quantity of N$_2$O in the product flow between the absorption column and the HPO® process area in year y is calculated based on the annual liquid volume flow and a conservative determination of the N$_2$O concentration in the process liquid. Therefore the quantity of the N$_2$O exiting the absorption column in the process liquid is given by:

$$QP_{N20,y} = \sum_{i}^{n} F_{PI,y} \times CP_{N2O,y}$$

Equation (25)

Where:

$QP_{N20,y}$ =   Quantity of N$_2$O in the product flow from the absorption column to the HPO® process area in year y (t N$_2$O)

$F_{PI,y}$ =   Volume of product liquid flow in year y (m^3)

$CP_{N2O,y}$ =   N$_2$O concentration in the product liquid (tN$_2$O/m^3)

If,

$$P_{projectcalc,y} \geq P_{productcalc,max}$$

Equation (26)

Then

$$BE_{N2O,y} = min\left(EF_{N2O,IPCC}; SEcalc_{N2O,y}\right) \times P_{productcalc,max}$$

Equation (27)

Where:

$BE_{N2O,y}$ =   Baseline emissions of N$_2$O in year y (tN$_2$O)

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[9] *Air$_{OR,I}$* and *CA$_{N2O,I}$* should be measured and expressed at wet bases and should be corrected to normal conditions (101.325 kPa, 0 deg C). If the instrument (or measurement system) uses the algorithm to convert actual conditions to normal conditions, the proper source of such algorithm should be used (e.g. based on procedures of EN14181). For all the cases, either manual or algorithm-based conversion of actual conditions to normal conditions, the temperature and pressure of actual conditions of gas should be recorded.

$EF_{N2O,IPCC}$	=	Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N$_2$O emission process (in this case a high-pressure nitric acid plant); 5.4 kgN$_2$O/t Product
$SEcalc_{N2O,y}$	=	Specific N$_2$O emissions per unit of calculated nitric acid production in year y (tN$_2$O/t Product)

69.   The specific N$_2$O emissions per unit of output of nitric acid equivalent are defined as:

$$SEcalc_{N2O,y} = \frac{min\{QI_{N2O,y}; (QA_{N2O,y} - OP_{N2O,y})\}}{P_{productcalc,y}}$$

Equation (28)

Where:

$SEcalc_{N2O,y}$	=	Specific N$_2$O emissions per unit of calculated nitric acid production in year y (tN$_2$O/t Product)

5.4.2. Case 2: Legal regulations for N$_2$O are implemented

70.   Emissions at the time the regulation has to be implemented. Depending on the character of the regulation the adjustment is done as shown below:

5.4.2.1.   Case 2.1: Regulation setting of a threshold for an absolute quantity of N$_2$O emissions per nitric acid or caprolactam production plant over a given time period

71.   Baseline N$_2$O emissions are limited by the absolute quantity of N$_2$O emissions given by the regulation. If the measured baseline N$_2$O emissions are exceeding the regulatory limit, then measured baseline N$_2$O emissions are substituted by the regulatory limit.

72.   This leads to the following condition:

<mark>For a nitric acid plant,</mark>

<mark>$BE_{N2O,y} = min\{QR_{N2O,y}; QB_{N2O,y}; SE_{N2O,y} \times P_{product,max}\}$</mark>   <mark>(28)</mark>

(a)   For a caprolactam plant using the Raschig process,

$$BE_{N2O,y} = min\{OR_{N2O,y}; OB_{N2O,y}; EF_{N2O,IPCC} \times P_{product,max}; SE_{N2O,y} \times P_{product,max}\}$$

Equation (29)

(b)   For a caprolactam plant using the HPO® process,

<mark>$$BE_{N2O,y} = min \begin{cases} OR_{N2O,y}; \\ QI_{N2O,y}; \\ QA_{N2O,y} - QP_{N2O,y}; \\ EF_{N2O,IPCC} \times P_{productcalc,max}; \\ SE_{N2O,y} \times P_{productcalc,max} \end{cases}$$</mark>

$$BE_{N2O,y} = min \begin{cases} QR_{N2O,y}; \\ QI_{N2O,y}; \\ QA_{N2O,y} - QP_{N2O,y}; \\ EF_{N2O,IPCC} \times P_{productcalc,max}; \\ SEcalc_{N2O,y} \times P_{productcalc,max} \end{cases}$$

Equation (30)

Where:

$OB_{N2O,y}$	=	Quantity of N$_2$O emissions from ammonia oxidation at the inlet of the destruction facility in year y (tN$_2$O)
$QR_{N2O,y}$	=	Regulatory limit of N$_2$O emissions in year y (tN$_2$O)
$BE_{N2O,y}$	=	Baseline emissions of N$_2$O in year y (tN$_2$O)
$SE_{N2O,y}$	=	Specific N$_2$O emissions per unit of output of ~~nitric acid or~~ caprolactam in year y (tN$_2$O/t Product)
$P_{product,max}$	=	Design capacity (t Product)
$SEcalc_{N2O,y}$	=	Specific N$_2$O emissions per unit of calculated nitric acid production in year y (tN$_2$O/t Product)
$P_{productcalc,max}$	=	On-site design capacity of calculated nitric acid production (t-HNO$_3$)
$EF_{N2O,IPCC}$	=	Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N$_2$O emission process

73. $QB_{N2O,y}$, $SE_{N2O,y}$ and $SEcalc_{N2O,y}$ are defined according to the instructions under Case 1 above.

5.4.2.2.   Case 2.2: Regulation setting of a threshold for specific N$_2$O emissions per unit of product:

74.   This leads to the following condition:

(a)   For a ~~nitric acid plant or~~ a caprolactam plant using the Raschig process,

$$BE_{N2O,y} = min \begin{cases} RSE_{N2O} \times P_{product,y} \\ OB_{N2O,y} \\ SE_{N2O,y} \times P_{product,max} \\ EF_{N2O,IPCC} \times P_{product,max} \end{cases}$$

Equation (31)

(b)   For a caprolactam plant using the HPO® process,

~~(*) For Raschig process only~~

$$BE_{N2O,y} = min \begin{cases} RSE_{N2O} \times P_{product,y}; \\ QI_{N2O,y}; \\ QA_{N2O,y} - QP_{N2O,y}; \\ SEcalc_{N2O,y} \times P_{productcalc,max}; \\ EF_{N2O,IPCC} \times P_{productcalc,max} \end{cases} \qquad \text{Equation (32)}$$

Where:

$SE_{N2O,y}$	=	Specific N_2O emissions per unit of output of nitric acid or caprolactam in year y (tN_2O/t Product)
RSE_{N2O}	=	Regulatory limit of N_2O emissions per unit of output of nitric acid or caprolactam (tN_2O/t Product)
$BE_{N2O,y}$	=	Baseline emissions of N_2O in year y (tN_2O)
$P_{product,y}$	=	Production of nitric acid or caprolactam in year y (t Product)
$OB_{N2O,y}$	=	Quantity of N_2O emissions from ammonia oxidation at the inlet of the destruction facility in year y (t N_2O)
$SEcalc_{N2O,y}$	=	Specific N_2O emissions per unit of calculated nitric acid production in year y (tN_2O/t Product)
$P_{productcalc,max}$	=	On-site design capacity of calculated nitric acid production (t HNO_3)
$EF_{N2O,IPCC}$	=	Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N_2O emission process

75. $QB_{N2O,y}$, $SE_{N2O,y}$ and $SEequiv_{N2O,y}$ are defined according to the instructions under Case 1 above.

5.4.2.3. Case 2.3: Regulation setting of a threshold for N_2O concentration in the tail gas.

76. This leads to the following condition:

(a) For a nitric acid plant or a caprolactam plant using the Raschig process,

$$BE_{N2O,y} = min \begin{cases} QB_{N2O,y}; \\ \sum_i CR_{N2O,i} \times F_{TG,i} \times M_i; \\ SE_{N2O,y} \times P_{product,max}; \quad \text{(Only for Raschig process)} \\ EF_{N2O,IPCC} \times P_{product,max} \end{cases} \qquad \text{Equation (33)}$$

(b) For a caprolactam plant using the HPO® process,

$$BE_{N2O,y} = min \begin{cases} QI_{N2O,y}; \\ QA_{N2O,y} - QP_{N2O,y}; \\ \sum_i CR_{N2O,i} \times F_{TG,i} \times M_i; \\ SEcalc_{N2O,y} \times P_{productcalc,max} \\ EF_{N2O,IPCC} \times P_{productcalc,max} \end{cases} \qquad \text{Equation (34)}$$

Where:

$CR_{N2O,i}$ = Regulatory limit for specific N$_2$O concentration during interval i (tN$_2$O/m^3)

$BE_{N2O,y}$ = Baseline emissions of N$_2$O in year y (tN$_2$O)

$F_{TG,i}$ = Volume flow rate at the exit of the destruction facility during interval i (m^3/h)

M_i = Length of measuring interval i (h)

i = Interval

$QB_{N2O,y}$ = Quantity of N$_2$O emissions from ammonia oxidation at the inlet of the destruction facility in year y (t N$_2$O)

$SEcalc_{N2O,y}$ = Specific N$_2$O emissions per unit of calculated nitric acid production in year y (tN$_2$O/t Product)

$P_{productcalc,max}$ = On-site design capacity of calculated nitric acid production (t HNO$_3$)

$EF_{N2O,IPCC}$ = Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N$_2$O emission process

77. $QB_{N2O,y}$, $SE_{N2O,y}$ and $SEcalc_{N2O,y}$ are defined according to the instructions under Case 1 above.

78. Change in NO$_X$ or N$_2$O regulations will automatically cause a re-assessment of the baseline scenario.

5.5. Procedures used to determine the permitted operating conditions of the ~~nitric acid or~~ caprolactam production plant in order to avoid "overestimation of emission reductions

79. In order to avoid that the operation of the ~~nitric acid or~~ caprolactam production plant is manipulated in a way to increase the N$_2$O generation, thereby increasing the CERs, the following procedures relating to the operating temperature and pressure and the use of ammonia oxidation catalysts shall be applied.

5.5.1. Operating temperature and pressure of the ammonia oxidation reactor (AOR)

80. If the actual average daily operating temperature or pressure in the ammonia oxidation reactor (T_g and P_g) are outside a "permitted range" of operating temperatures and pressures ($T_{g,hist}$ and $P_{g,hist}$), the baseline emissions are calculated for the respective time

period based on lower value between (a) the conservative IPCC default values of the latest IPCC GHG Inventory Guidelines accepted by the IPCC[10] for the equivalent N_2O emission process, "$EF_{N2O,IPCC}$". ~~For nitric acid plants, $EF_{N2O,IPCC}$ = 4.5kgN_2O/tonne of nitric acid~~, for caprolactam using the Raschig process, $EF_{N2O,IPCC}$ = 5.4kgN_2O/tonne of caprolactam, and for a caprolactam plant using the HPO® process, $EF_{N2O,IPCC}$ = 5.4 kgN_2O/tonne of calculated nitric acid production, all conservatively applying the IPCC default values.(b) SE_{N2O},y and (c) any related value as a result of legal regulations (e.g. $RSE_{N2O,y}$).

81. $EF_{N2OIPCC}$ = Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N_2O emission process

82.   Required monitoring parameters:

(a) $T_{g,d}$ Actual operating temperature AOR on day d (°C);

(b) $P_{g,d}$ Actual operating pressure AOR on day d (Pa);

(c) $T_{g,hist}$ Historical operating temperature range AOR (°C);

(d) $P_{g,hist}$ Historical operating pressure range AOR (Pa).

83.   In order to determine the "permitted range" of the operating temperature and pressure in the ammonia oxidation reactor, the project applicant has the obligation to determine the operating temperature and pressure range by:

(a)   Firstly, data on historical temperature and pressure ranges; or, if no data on historical temperatures and pressures are available; then

(b)   Secondly, by range of temperature and pressure stipulated in the operating manual for the existing equipment; or, if no operating manual is available or the operating manual gives insufficient information; then

(c)   Thirdly, by literature reference (e.g. from *Ullmann's Encyclopedia of Industrial Chemistry, Fifth, completely revised edition*, Volume A 17, VCH, 1991, P. 298, Table 3. or other standard reference work or literature source).

84.   If historical data on daily operating temperatures and pressures are available (i.e. case a), statistical analysis shall be used for determining the permitted range of operating temperature and pressure. To exclude the possibility of manipulating the process, outliers of historical operating temperature and pressure shall be eliminated by statistical methods. Therefore, the time series data are interpreted as a sample from a stochastic variable. All data that are part of the 2.5% Quantile or that are part of the (100-2.5)% Quantile of the sample distribution are defined as outliers and shall be eliminated. The permitted range of operating temperature and pressure is then calculated based on the remaining historical minimum and maximum operating conditions.

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[10] According to pre-publication draft 2006 IPCC Guidelines accepted by the 21st Session of the IPCC, the conservative IPCC default value of Nitric Acid Plants is based on the default emission factor for low-pressure plants (5kgN2O/tonne of nitric acid, accounting for 10% uncertainty factor), whereas for high-pressure plants used by caprolactam plants using both Raschig and HPO® processes, emissions are 9 kgN2O/tonne of nitric acid, accounting for 40% uncertainty factor.

5.5.2. Composition of ammonia oxidation catalyst

85. The plant operator is allowed to use compositions of ammonia oxidation catalysts that are common practice in the region or have been used in the ~~nitric acid or~~ caprolactam production plant during the last three years without limitation of N$_2$O baseline emissions.

86. In case the ~~nitric acid or~~ caprolactam production plant operator wishes to change to a composition not used during the last three years, but is common practice in the region and supplied by a reputable manufacturer, or if it corresponds to a composition that is reported as being in use in the relevant literature, the plant operator is allowed to use these ammonia oxidation catalysts without limitation of N$_2$O baseline emissions.

87. In case the ~~nitric acid or~~ caprolactam production plant operator changes the composition of ammonia oxidation catalysts and the composition is not common practice in the region and not reported as being in use in the relevant literature, the project applicant has to demonstrate (either by economic or other arguments) that the choice of the new composition was based on considerations other than an attempt to increase the rate of N$_2$O production. If the project applicant can demonstrate appropriate and verifiable reasons, the plant operator is allowed to use new ammonia oxidation catalysts without limitation of N$_2$O baseline emissions.

88. ~~The first composition of ammonia oxidation catalyst used during the crediting period shall be of the same kind of catalyst composition already in operation in the specific nitric acid or caprolactam production plant. This is to avoid gaming at the beginning of the project activity.~~

89. In case the ~~nitric acid or~~ caprolactam production plant operator changes the composition of ammonia oxidation catalysts and the composition is not common practice in the region and not reported as being in use in the relevant literature, and the project applicant cannot demonstrate appropriate and verifiable reasons for this.

90. Baseline emissions are limited to the maximum specific N$_2$O emissions of previous periods (~~tN$_2$O/tHNO3 for nitric acid,~~ tN$_2$O/tCaprolactam for the Raschig process or tN$_2$O/tonne of calculated nitric acid production for the HPO® process), documented in the verified monitoring reports.

91. Required monitoring parameters:

    (a)   *Gsup*   Supplier of the ammonia oxidation catalyst;

    (b)   *Gsup,hist*   Historical supplier of the ammonia oxidation catalyst;

    (c)   *Gcom*   Composition of the ammonia oxidation catalyst;

    (d)   Gcom,hist   Historical composition of the ammonia oxidation catalyst;

    (e) $SE_{N2O,y}$ Specific N$_2$O emissions per ton of product of nitric acid or caprolactam in year *y* (tN$_2$O/t Product).

5.5.3. Ammonia flow rate to the ammonia oxidation reactor

92. If the actual daily ammonia flow rate exceeds the (upper) limit on maximum historical daily permitted ammonia flow rate, the baseline emissions for this operating day are

calculated based on the conservative IPCC default values and are limited by the legal regulations. The upper limit on ammonia flow should be determined based on:

(a)   Historical operating data on maximum daily average ammonia flow; or, if not existing; on

(b)   Calculation of the maximum ammonia flow rate allowed as specified by ammonia oxidation catalyst manufacturer or on typical catalyst loadings; or, if not existing;

(c)   Based on the literature;

(d)   Ammonia flow rate specified by the ammonia oxidation reactor manufacturer.

93.   If the daily ammonia input to the oxidation reactor exceeds the limit on permissible ammonia input, baseline N$_2$O emissions are capped at conservative IPCC default values, $EF_{N2O,IPCC}$.

94.   Required monitoring parameters on daily basis:

(a) $A_{OR,d}$ Actual ammonia input to oxidation reactor (tNH$_3$/day);

(b) $A_{OR,hist}$ Maximum historical ammonia input to oxidation reactor (tNH$_3$/day).

5.6.   Leakage

95.   Each N$_2$O destruction technology works best over a particular range of tail gas temperatures.

96.   Depending on the mode of operation, additional tail gas heating could be required upstream of the destruction facility. Appropriate tail gas temperature at the inlet of the N$_2$O destruction facility could either be obtained due to external energy sources (e.g. additional heat exchanger) or by adjustments of the internal energy flow. In other words, the increased tail gas temperature at the inlet of the N$_2$O destruction facility may require additional external energy, but the additional energy might be recovered before the tail gas is released to the atmosphere (e.g. tail gas turbine to generate electricity, kinetic energy or other).

97.   On condition that an energy converter (e.g. tail gas turbine) is installed at the end of the pipe, the installation of the N$_2$O destruction facility will not result in significant additional energy consumption at the nitric acid or caprolactam production plant and therefore no leakage is expected.

98.   Leakage emissions need only be analyzed if the project activity does not involve any energy recovery from the tail gas. If an installation for energy utilization at the end of the pipe is missing, leakage is given by:

$$LE_y = LE_{s,y} + LE_{TGU,y} + LE_{TGH,y}$$ Equation (35)

Where:

LE_y =   Leakage emissions in year y (t CO$_2$e)

$LE_{s,y}$ =   Emissions from net change steam export (t CO$_2$e)

$LE_{TGU,y}$	=	Emissions from net change in tail gas utilization (t CO$_2$e)
$LE_{TGH,y}$	=	Emissions from net change in tail gas heating (t CO$_2$e)

99.   Each component is calculated as follows:

$$LE_{s,y} = (ST_{BL} - ST_{PR}) \times M_y/\eta_{ST} \times EF_{ST}$$ Equation (36)

Where:

$LE_{s,y}$	=	Emissions from net change steam export (t CO$_2$e)
ST_{BL}	=	Baseline steam export (MW)
ST_{PR}	=	Project steam export (MW)
M_y	=	Operating hours in year y (h)
η_{ST}	=	Efficiency of steam generation (%)
EF_{ST}	=	Fuel emissions factor for steam generation (t CO$_2$e/MWh)

$$LE_{TGU,y} = (EE_{BL} - EE_{PR}) \times M_y/\eta_r \times EF_r$$ Equation (37)

Where:

$LE_{TGU,y}$	=	Emissions from net change in tail gas utilization (t CO$_2$e)
EE_{BL}	=	Baseline energy export from tail gas utilization (MW)
EE_{PR}	=	Project energy export from tail gas utilization (MW)
M_y	=	Operating hours in year y (h)
η_r	=	Efficiency of replaced technology (%)
EF_r	=	Fuel emissions factor for replaced technology (t CO$_2$e/MWh)

$$LE_{TGH,y} = \left(EI_{TGH,y}/\eta_{TGH}\right) \times EF_{TGH}$$ Equation (38)

Where:

$LE_{TGH,y}$	=	Emissions from net change in tail gas heating (t CO$_2$e)
$EI_{TGH,y}$	=	Energy input for additional tail gas heating (MWh/yr)
η_{TGH}	=	Efficiency of additional tail gas heating (%)
EF_{TGH}	=	Emissions factor for additional tail gas heating (t CO$_2$e/MWh)

100.   The effect of the modifications on the energy balance (e.g. steam export) of the ~~nitric acid or~~ caprolactam production plant can be assessed by carrying out standard thermodynamic and heat transfer calculations. Since the overall effect is considered small, and the modifications adopted are highly project-specific, the calculation of the effects will be considered on a case-by-case basis at the project stage.

5.7. Emission reductions

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

$$ER_y = BE_y - PE_y - LE_y$$

Equation (39)

Where:

ER_y	=	Emissions reductions of the project activity during the year *y* (t CO$_2$e)
BE_y	=	Baseline emissions during the year *y* (t CO$_2$e)
PE_y	=	Project emissions during the year *y* (t CO$_2$e)
LE_y	=	Leakage emissions in year *y* (t CO$_2$e)

5.8. Data and parameters not monitored

Data / Parameter table 1.

Data / Parameter:	EF_{NH3}
Data unit:	T CO$_2$e/tNH$_3$
Description:	Ammonia Production GHG Emission Factor
Source of data:	IPCC
Measurement procedures (if any):	-
Any comment:	A default factor of 2.14 tCO$_2$e/tNH$_3$ is suggested (GEMIS 4.2)

Data / Parameter table 2.

Data / Parameter:	EF_{HC}
Data unit:	T CO$_2$e/tHC
Description:	Hydrocarbon CO$_2$ emissions factor
Source of data:	IPCC
Measurement procedures (if any):	-
Any comment:	The hydrocarbon CO$_2$ emission factor is given by the molecular weights and the chemical reaction when hydrocarbons are converted (e.g. where CH$_4$ is used as hydrocarbon, each converted tonne of CH$_4$ results in 44/16 tonnes of CO$_2$, thus the hydrocarbon emission factor is 2.75)

Data / Parameter table 3.

Data / Parameter:	Type HC
Data unit:	-

Description:	Type of hydrocarbon
Source of data:	Hydrocarbon supplier
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 4.

Data / Parameter:	$P_{product,hist}$
Data unit:	T
Description:	Design Capacity
Source of data:	Manufacturer's specifications
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 5.

Data / Parameter:	$T_{g,hist}$
Data unit:	°C
Description:	Historical operating temperature range of the ammonia oxidation reactor
Source of data:	Production reports/manufacturer's specifications
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 6.

Data / Parameter:	$P_{g,hist}$
Data unit:	Pa
Description:	Historical operating pressure range of the ammonia oxidation reactor
Source of data:	Production reports/manufacturer's specifications
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 7.

Data / Parameter:	$G_{sup,hist}$
Data unit:	-
Description:	Historical supplier of ammonia oxidation catalyst
Source of data:	Annual reports, Supplier information

Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 8.

Data / Parameter:	$G_{com,hist}$
Data unit:	-
Description:	Historical composition of the ammonia oxidation catalyst
Source of data:	Supplier information
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 9.

Data / Parameter:	$A_{OR,max}$
Data unit:	tNH$_3$/year
Description:	Maximum historical ammonia input to oxidation reactor
Source of data:	Production reports/manufacturer's specifications/literature
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 10.

Data / Parameter:	ST_{BL}
Data unit:	MW
Description:	Baseline Steam Export
Source of data:	Project operator and/or technology provider (PDD)
Measurement procedures (if any):	-
Any comment:	Calculated based on ex post estimation (PDD)

Data / Parameter table 11.

Data / Parameter:	η_{ST}
Data unit:	%
Description:	Steam Generation Efficiency
Source of data:	Manufacturer information
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 12.

Data / Parameter:	EE_{BL}
Data unit:	MW
Description:	Baseline Energy Export from Tail Gas Utilization
Source of data:	Project operator and/or technology provider (PDD)
Measurement procedures (if any):	Calculated, based on ex ante estimation (PDD)
Any comment:	-

Data / Parameter table 13.

Data / Parameter:	η_r
Data unit:	%
Description:	Efficiency of technology replaced
Source of data:	Manufacturer information
Measurement procedures (if any):	Calculated, based on ex ante estimation (PDD)
Any comment:	-

Data / Parameter table 14.

Data / Parameter:	η_{TGH}
Data unit:	%
Description:	Efficiency of additional tail Gas Heating
Source of data:	Manufacturer information
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 15.

Data / Parameter:	$P_{product,max}$
Data unit:	t Product
Description:	Design capacity of nitric acid or caprolactam production
Source of data:	Project operator and/or technology provider
Measurement procedures (if any):	-
Any comment:	-

6. Monitoring methodology

6.1. Archival of monitoring information

102. All data collected as part of monitoring should be archived electronically and be kept at least for two years after the end of the last crediting period. One hundred per cent of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted with calibrated measurement equipment according to relevant industry standards.

103. The accuracy of the N$_2$O emissions monitoring results is to be ensured by installing a monitoring system that has been certified to meet (or exceeds) the requirements of the prevailing best industry practice or monitoring standards in terms of operation, maintenance and calibration. The latest applicable European standards and norms (EN 14181) could be used as the basis for selecting and operating the monitoring system.

104. In addition, the monitoring provisions in the relevant applicable tools apply.

Figure 3: Project boundary (destruction facility in pressure zone, tail gas turbine upstream)
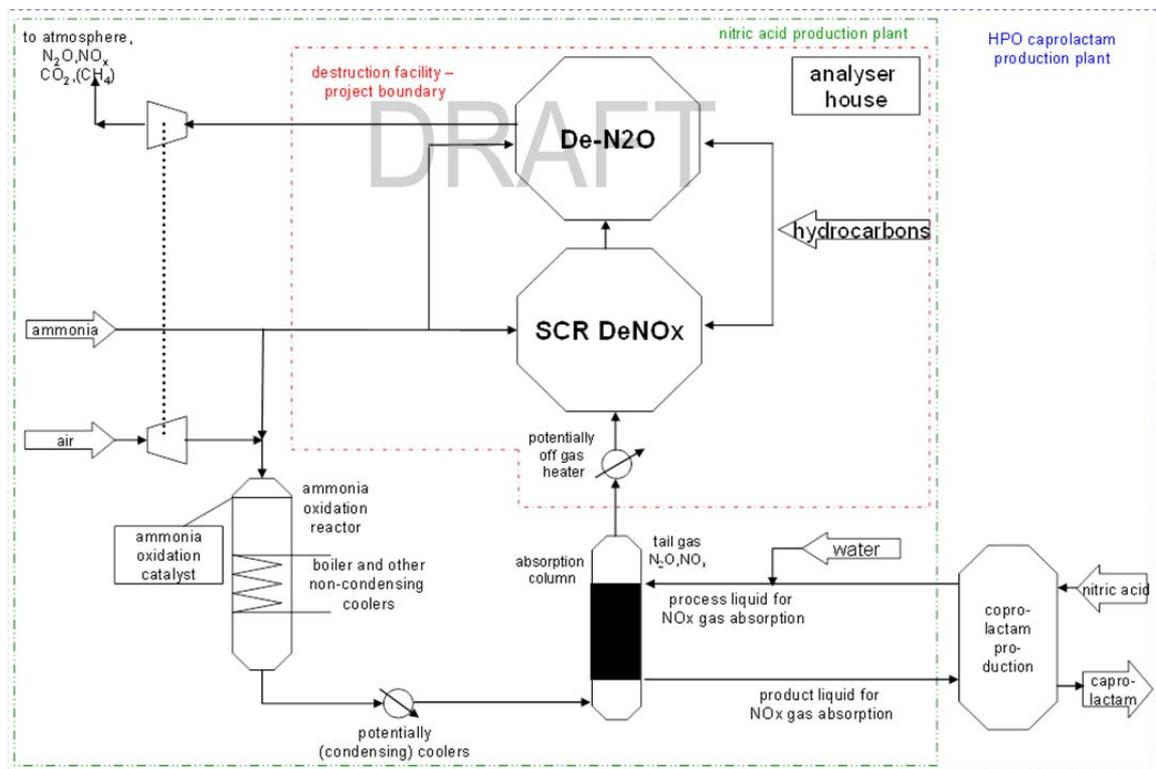
Figure 4: Project boundary (destruction facility outside pressure zone, tail gas turbine downstream)
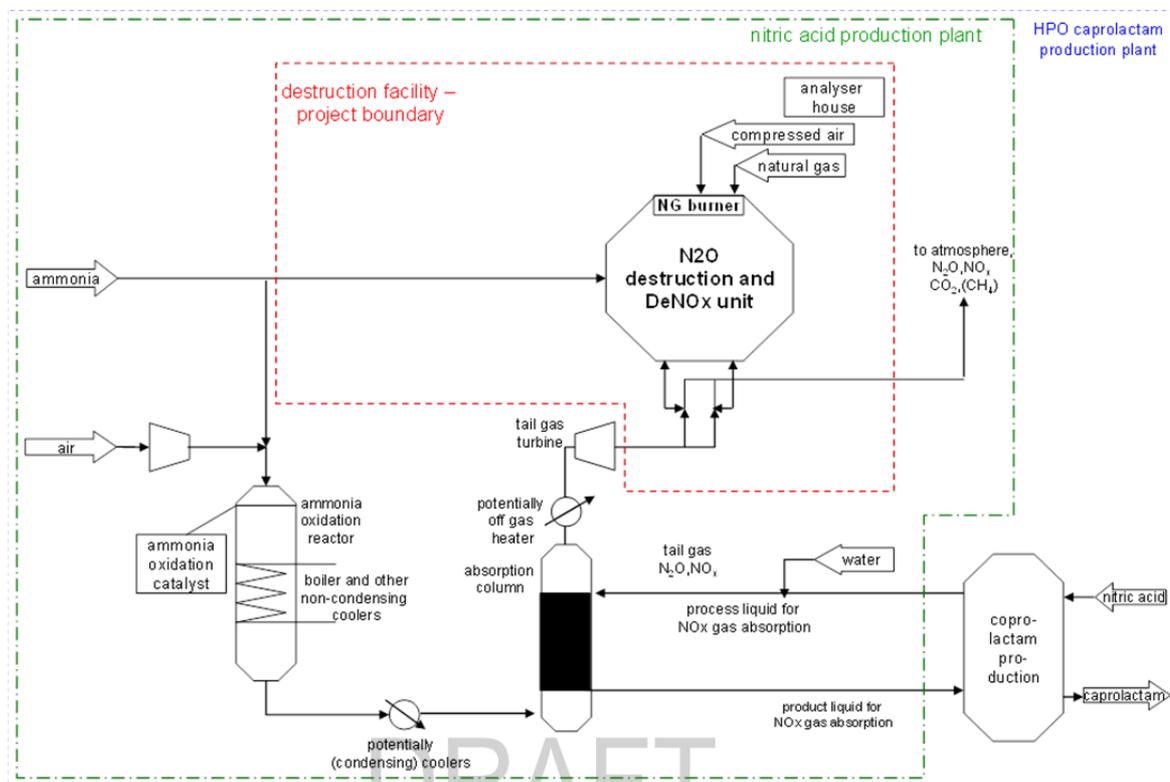
105.   The value adopted for Quantity of N$_2$O at the inlet of the destruction facility should be calculated considering conservatively the error included in the measurement.

106.   Note:

(a)   AI: Measurement for the concentration of N$_2$O;

(b)   FI: measurement for total flow rate;

(c)   PI: measurement for pressure;

(d)   TI: measurement for temperature.

6.2.   Determination of conversion rates of hydrocarbons

107.   Hydrocarbons can be used as reducing agent and/or re-heating the tail gas. In the case of hydrocarbons with one carbon atom in the molecule (CH$_4$), the hydrocarbon is mainly converted to CO$_2$, while some remains intact. Hydrocarbon reducing agents with two or more carbon atoms in the molecule are completely converted to water, carbon monoxide and carbon dioxide (H$_2$O, CO, CO$_2$).

108.   If methane (CH$_4$) is present in the reducing agent and/or re-heating the tail gas, as with natural gas, a part leaves the N$_2$O destruction facility unconverted and is emitted to atmosphere. The fraction of unconverted methane depends on the amount of methane supplied to the reactor, the reactor operating temperature, and the quantity of catalyst supplied.

6.2.1. Case 1: Fraction of methane not converted will be measured

109. In order to measure the fraction of unconverted methane, an additional analyser is required. If the project-specific costs of this analyser for CH$_4$ are not unreasonable the methodology recommends the installation of the analyser.

6.2.2. Case 2: Fraction of methane not converted will not be measured due to unreasonable costs

110. A conservative baseline approach is required, as follows:

(a) If hydrocarbons with two or more carbon atoms are present as reducing agent:

(i) In order to apply a conservative baseline approach the fraction of unconverted hydrocarbons is zero: (OXIDHC = 100%). Hence, reducing agent GHG emissions are calculated based on the hydrocarbon CO$_2$ emission factor;

(b) If methane is present in the reducing agent and/or re-heating the tail gas, for example; as with natural gas:

(i) In order to apply a conservative baseline approach the fraction of unconverted hydrocarbon is 100% (OXIDCH4 = 0%). Hence, reducing agent GHG emissions are calculated based on the Global Warming Factor of the hydrocarbon.

111. The option to be adopted shall be decided on a case-by-case basis.

6.3. Data and parameters monitored

6.3.1. Project emissions

Data / Parameter table 16.

Data / Parameter:	$F_{TE,i}$
Data unit:	m³/h
Description:	Volume flow rate at the exit of destruction facility during interval i
Source of data:	Measurements by project participants
Measurement procedures (if any):	Flow meter
Monitoring frequency:	Continuously. Recording frequency: daily
QA/QC procedures:	Refer to QA/QC procedures cited below. FTI Both parameters shall be cross-checked to ensure that no leak of N$_2$O is taking place. In case of discrepancy, conservative calculation of emission reduction shall be provided
Any comment:	Flow should be expressed in normal conditions. Flow metering system will automatically record volume flow adjusted to standard temperature and pressure

Data / Parameter table 17.

Data / Parameter:	$CO_{N2O,i}$
Data unit:	tN_2O/m^3
Description:	N_2O concentration at destruction facility outlet
Source of data:	Measurements by project participants
Measurement procedures (if any):	Gas chromatography in the 0–5000 ppm range, or non-dispersion infrared absorption <mark>analyzer</mark>analyser
Monitoring frequency:	Continuously. Recording frequency: daily
QA/QC procedures:	Gas chromatography shall be subjected to relevant QA/QC scheme consistent with the procedures listed below, with respect to equipment certification, installation and performance
Any comment:	Should be expressed in normal conditions. In case non-dispersion infrared absorption analyzer is used, it shall be checked by sampling by gas chromatography periodically

Data / Parameter table 18.

Data / Parameter:	M_i
Data unit:	H
Description:	Measuring Interval
Source of data:	Measurements by project participants
Measurement procedures (if any):	Measuring device. Data management system
Monitoring frequency:	Continuously. Recording frequency: daily
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 19.

Data / Parameter:	$Q_{NH3,y}$
Data unit:	tNH_3
Description:	N_2O destruction facility: Project Ammonia Input (as gas or in solution)
Source of data:	Measurements by project participants
Measurement procedures (if any):	Measuring device
Monitoring frequency:	Continuously. Recording frequency: monthly
QA/QC procedures:	-
Any comment:	Measured, in case no SCR DeNO$_X$-unit is installed in the baseline scenario

Data / Parameter table 20.

Data / Parameter:	$Q_{HC,y}/Q_{CH4,y}$
Data unit:	m^3
Description:	Hydrocarbon input (reducing agent and/or re-heating the tail gas)
Source of data:	Measurements by project participants
Measurement procedures (if any):	Monitoring device
Monitoring frequency:	Continuously. Recording frequency: daily
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 21.

Data / Parameter:	ρ_{HC}/ρ_{CH4}
Data unit:	t/m^3
Description:	Hydrocarbon density
Source of data:	Certificate hydrocarbon supplier or default value
Measurement procedures (if any):	Monitoring device.
Monitoring frequency:	Recording frequency: yearly
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 22.

Data / Parameter:	$OXID_{HC}$
Data unit:	%
Description:	Hydrocarbon oxidation factor
Source of data:	Measurements by project participants
Measurement procedures (if any):	Measuring device
Monitoring frequency:	Continuously. Recording frequency: daily
QA/QC procedures:	-
Any comment:	-

6.3.2. Baseline emissions

Data / Parameter table 23.

Data / Parameter:	$P_{product,y}$
Data unit:	~~tHNO3 or~~ tCaprolactam.
Description:	~~Plant output of HNO3~~ or Caprolactam
Source of data:	Production reports
Measurement procedures (if any):	-
Monitoring frequency:	Recording frequency: daily
QA/QC procedures:	Cross – check of production, marketing and stock change data. Measurement devices such as weighbridge can be subjected to QA/QC scheme consistent with the procedures listed below, with respect to equipment certification, installation and performance
Any comment:	-

Data / Parameter table 24.

Data / Parameter:	$CI_{N2O,i}$
Data unit:	tN$_2$O/m^3
Description:	N$_2$O concentration at N$_2$O destruction facility inlet
Source of data:	Measurements by project participants
Measurement procedures (if any):	Gas chromatography in the 0-5000 ppm range or non-dispersion infrared absorption ~~analyzer~~analyser
Monitoring frequency:	Continuously. Recording frequency: daily
QA/QC procedures:	Gas chromatography shall be subjected to relevant QA/QC scheme consistent with the procedures listed below, with respect to equipment certification, installation and performance
Any comment:	Should be expressed in normal conditions. In case non-dispersion infrared absorption analyzer is used, it shall be checked by sampling by gas chromatography periodically

Data / Parameter table 25.

Data / Parameter:	$F_{TI,i}$
Data unit:	m³/h
Description:	Volume flow rate at the inlet of destruction facility during interval i
Source of data:	Measurements by project participants
Measurement procedures (if any):	Flow meter

Monitoring frequency:	Continuously. Recording frequency: daily
QA/QC procedures:	Refer to QA / QC procedures cited below. FTI Both parameters shall be cross-checked to ensure that no leak of N$_2$O is taking place. In case of discrepancy, conservative calculation of emission reduction shall be provided
Any comment:	Flow should be expressed in normal conditions. Flow metering system will automatically record volume flow adjusted to standard temperature and pressure

Data / Parameter table 26.

Data / Parameter:	$A_{OR,i}$
Data unit:	m³/h
Description:	Actual ammonia input to oxidation reactor during interval i
Source of data:	Measurements by project participants
Measurement procedures (if any):	Flow meter
Monitoring frequency:	Continuously. Recording frequency: daily
QA/QC procedures:	-
Any comment:	Flow should be expressed in normal conditions

Data / Parameter table 27.

Data / Parameter:	$Air_{Or,i}$
Data unit:	m³/h
Description:	Actual air input to oxidation reactor during interval i
Source of data:	Measurements by project participants
Measurement procedures (if any):	Flow meter
Monitoring frequency:	Continuously. Recording frequency: daily
QA/QC procedures:	-
Any comment:	Should be measured and expressed at wet bases and should be corrected to normal conditions (101.325 kPa, 0 deg C)

Data / Parameter table 28.

Data / Parameter:	$CA_{N2O,i}$
Data unit:	tN$_2$O/m^3
Description:	N$_2$O concentration in the product stream of the ammonia oxidation reactor during interval i
Source of data:	Measurements by project participants

Measurement procedures (if any):	Gas chromatography in the 0-5000 ppm range or non-dispersion infrared absorption ~~analyzer~~analyser
Monitoring frequency:	Continuously. Recording frequency: daily
QA/QC procedures:	-
Any comment:	Should be expressed in normal conditions. In case non-dispersion infrared absorption analyzer is used, it shall be checked by sampling by gas chromatography periodically

Data / Parameter table 29.

Data / Parameter:	$CP_{N2O,y}$
Data unit:	tN_2O/m^3
Description:	N_2O concentration in the product liquid
Source of data:	Measurements by project participants
Measurement procedures (if any):	Use the maximum possible N_2O concentration given the characteristics of the product liquid
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	Determine solubility of N_2O using a sample of the product liquid. Use a standard laboratory technique for this purpose such as RSKSOP-175[11]

Data / Parameter table 30.

Data / Parameter:	$F_{PI,y}$
Data unit:	m^3
Description:	Volume of product liquid flow in year y
Source of data:	Production reports
Measurement procedures (if any):	-
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	Since the quantity of N_2O in the product liquid is very low, the amount of product liquid flow is to be determined from standard reports on the production process

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[11] U.S. Environmental Protection Agency, 1994, RSKSOP 175 rev. no. 2, Sample preparations and calculations for dissolved gas analysis in water samples using a GC headspace equilibration technique: U.S. Environmental Protection Agency Test Methods, Region 1, 14 p.

Data / Parameter table 31.

Data / Parameter:	$QR_{N2O,y}$
Data unit:	tN$_2$O
Description:	Regulation I: annual quantity N$_2$O limited
Source of data:	National legislation
Measurement procedures (if any):	-
Monitoring frequency:	Recording frequency: date of regulation
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 32.

Data / Parameter:	$RSE_{N2O,y}$
Data unit:	tN$_2$O/tHNO$_3$ or tN$_2$O/tCaprolactam
Description:	Regulation II: N$_2$O emissions per unit of nitric acid or Caprolactam
Source of data:	National legislation
Measurement procedures (if any):	-
Monitoring frequency:	Recording frequency: date of regulation
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 33.

Data / Parameter:	$CR_{N2O,i}$
Data unit:	tN$_2$O/m^3
Description:	Regulatory limit for specific N$_2$O concentration during interval i
Source of data:	National legislation
Measurement procedures (if any):	-
Monitoring frequency:	Recording frequency: date of regulation
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 34.

Data / Parameter:	$T_{g,d}$
Data unit:	°C

Description:	Actual operating temperature ammonia oxidation reactors on day d
Source of data:	Measurements by project participants
Measurement procedures (if any):	Measuring device
Monitoring frequency:	Continuously
QA/QC procedures:	Pressure gauges subjected to QA / QC scheme consistent with the procedures listed below, with respect to equipment certification, installation and performance
Any comment:	-

Data / Parameter table 35.

Data / Parameter:	$P_{g,d}$
Data unit:	Pa
Description:	Actual operating pressure ammonia oxidation reactors on day d
Source of data:	Measurements by project participants
Measurement procedures (if any):	Measuring device
Monitoring frequency:	Continuously
QA/QC procedures:	Pressure gauges subjected to QA/QC scheme consistent with the procedures listed below, with respect to equipment certification, installation and performance
Any comment:	-

Data / Parameter table 36.

Data / Parameter:	Reg_{NOx}
Data unit:	tNOx/m³
Description:	National regulation on NO$_X$ emissions
Source of data:	National regulations, Ministry of Environment
Measurement procedures (if any):	-
Monitoring frequency:	Recording frequency: date of regulation
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 37.

Data / Parameter:	G_{sup}
Data unit:	-
Description:	Supplier of the ammonia oxidation catalyst
Source of data:	Supplier information
Measurement procedures (if any):	-
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 38.

Data / Parameter:	G_{com}
Data unit:	-
Description:	Composition of the ammonia oxidation catalyst
Source of data:	Annual reports, supplier information
Measurement procedures (if any):	-
Monitoring frequency:	Date of changing gauze composition
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 39.

Data / Parameter:	$SE_{N2O,y}$
Data unit:	tN$_2$O/t Product
Description:	Specific N$_2$O emissions per ton of product of nitric acid or caprolactam in year y
Source of data:	Measurements by project participants
Measurement procedures (if any):	-
Monitoring frequency:	Recording frequency: yearly
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 40.

Data / Parameter:	$A_{OR,y}$
Data unit:	tNH$_3$/yr

Description:	Actual ammonia input to oxidation reactor in year y
Source of data:	Measurements by project participants
Measurement procedures (if any):	Calculate from $A_{OR,d}$
Monitoring frequency:	Continuously
QA/QC procedures:	-
Any comment:	-

6.3.3. Leakage emissions

Data / Parameter table 41.

Data / Parameter:	ST_{PR}
Data unit:	MW
Description:	Project Steam Export
Source of data:	Project operator and/or technology provider (PDD)
Measurement procedures (if any):	Calculated based on ex post estimation (PDD)
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 42.

Data / Parameter:	EF_{ST}
Data unit:	tCO₂e/MWh
Description:	Steam Generation Emission Factor
Source of data:	Certificate fuel supplier or default value
Measurement procedures (if any):	Calculated based on ex post estimation (PDD)
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 43.

Data / Parameter:	M_y
Data unit:	h
Description:	Operation hours in year y
Source of data:	Measurements by project participants

Measurement procedures (if any):	Measuring device, Data management system
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 44.

Data / Parameter:	EE_{PR}
Data unit:	MW
Description:	Project Energy Export from Tail Gas Utilization
Source of data:	Project operator and/or technology provider (PDD)
Measurement procedures (if any):	Calculated, based on ex ante estimation (PDD)
Monitoring frequency:	--
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 45.

Data / Parameter:	EF_r
Data unit:	t CO_2e/MWh
Description:	Fuel Emission Factor for replaced technology
Source of data:	Certificate fuel supplier or default value
Measurement procedures (if any):	-
Monitoring frequency:	Yearly
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 46.

Data / Parameter:	$EI_{TGH,y}$
Data unit:	MWh/yr
Description:	Additional Energy Input for Tail Gas Heating
Source of data:	Measuring device or project operator and/or technology provider (PDD)
Measurement procedures (if any):	-
Monitoring frequency:	Recording frequency: monthly

QA/QC procedures:	-
Any comment:	Measured if leakage emissions exceed 2% of total expected emission reductions. Otherwise calculated based on ex post estimation (PDD)

Data / Parameter table 47.

Data / Parameter:	EF_{TGH}
Data unit:	t CO$_2$e/MWh
Description:	Fuel Emission Factor external Tail Gas Heating
Source of data:	Certificate fuel supplier or default value
Measurement procedures (if any):	-
Monitoring frequency:	Recording frequency: yearly
QA/QC procedures:	-
Any comment:	-

6.4. Good monitoring practice and performance characteristics

112. Accuracy of the N$_2$O emissions monitoring results is to be ensured by installing a monitoring system that has been certified to meet or exceed the requirements of the prevailing best industry practice or monitoring standards in terms of operation, maintenance and calibration. The latest applicable European standards and norms (EN 14181) or equivalent standards, which prescribes the features needed for Automated Measuring Systems (AMS) need and how they are to be calibrated and maintained, shall be used as the basis for selecting and operating the monitoring system.

113. The following guidance documents are recommended as references for the Quality Assurance and Control procedures:

    (a) European Standard, Technical Committee Air Quality: Working Document, Air quality – Certification of automated measuring systems (AMS). Part 3: Performance specifications and test procedures for AMS for monitoring emissions from stationery sources, prEN 264022, CEN/TC 264:2005/1;

    (b) European Norm EN 14181: Quality assurance of automated measuring systems, 2004;

    (c) Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety: Bundeseinheitliche Praxis bei der Überwachung der Emissionen. RdSchr. d. BMU v. 13.06.2005 – IG 12 – 45053/5.

114. The European Norm EN 14181 stipulates three levels of quality assurance tests and one annual functional test for AMS which are recommended to be used as guidance regarding the selection, installation and operation of the AMS under the monitoring methodology. The three quality assurance levels (QALs) are as follows:

(a) Quality assurance of tested AMS. AMS must have performance certificate (e.g. MCERTS), with calculation of uncertainty before installation according to approved methods such as ISO 14956 including:

   (i) Standard deviation;

   (ii) Lack of fit (linearity);

   (iii) Repeatability at zero and reference points;

   (iv) Time-dependent zero and span drift;

   (v) Temperature dependence;

   (vi) Voltage fluctuation;

   (vii) Suitability test;

   (viii) Cross sensitivity to likely components of the stack gas;

   (ix) Influence of variations in flow rate on extractive Automated Measuring Systems;

   (x) Response time;

   (xi) Detection limit;

   (xii) Influence of ambient conditions on zero and span readings;

   (xiii) Performance and accuracy;

   (xiv) Availability;

   (xv) Susceptibility to physical disturbances.

   The specific performance characteristics of the monitoring system chosen by the project shall be listed in the Project Design Document. Also, project activities should calculate and show the margins of error for each of the performance characteristics as well as the cumulative error for the complete measuring system.

(b) Quality assurance of installation and calibration of the Automated Measuring System according to the Standard Reference Measurement Method (SRM), determination of the measurement uncertainty/variability of the AMS and inspection of the compliance with the prescribed measurement uncertainties. Such tests must be carried out by organisations that have an accredited quality assurance system such as one according to ISO/IEC 17025 or relevant standards. Items to be considered include the following:

   (i) Selection of the location of measurement;

   (ii) Duly installation of the monitoring equipment;

   (iii) Correct choice of measurement range;

(iv)   Calibration of the AMS using the Standard-Reference-Method (SRM) as guidance;

(v)   Calibration curve either as linear regression or as straight line from absolute zero to centre of a scatter-plot;

(vi)   Calculation of the standard deviation at the 95% confidence interval;

(vii)   Inspection every three years.

(c)   Continuous quality assurance through the local operator/manager (drift and accuracy of the AMS, verification management and documentation);

(i)   Permanent quality assurance during the plant operation by the operating staff;

(ii)   Assurance of reliable and correct operation of the monitoring equipment (maintenance evidence);

(iii)   Regular controls: zero point, span, drift, meet schedule of manufacturer maintenance intervals.

115.   In addition, annual functionality test including SRM measurements to check for uncertainties in the data measured by the AMS. Such tests must be carried out by organisations that have an accredited quality assurance system such as one according to ISO/IEC 17025 or relevant standards.

(a)   Annual confirmation of the calibration curve;

(b)   Validity proof of calibration curves;

(c)   Back-setting of excess meter of invalid calibration range.

116.   Minimum requirements for electronic evaluation units

(a)   Evaluation unit needs to take into account registration, mean average determination, validation, and evaluation;

(b)   The system and concept of emission data processing needs to be described;

(c)   Protocols and out-prints are required.

117.   Downtime of Automated Measuring System

118.   In the event that the monitoring system is down, the lowest between the conservative default value established in the methodology or the last measured byproduct rate (whichever the lower) will be valid and applied for the downtime period for the baseline emission factor, and the highest measured byproduct rate during the project activity will be applied for the downtime period for the campaign emission factor.

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Document information

Version	Date	Description
06.0.0	05 November 2012	MP 58, Annex 3 Revision to: • Remove all references to nitric acid plants; • Change the title from "N_2O destruction in the tail gas of Nitric Acid or Caprolactam Production Plants" to "N_2O destruction in the tail gas of Caprolactam production plants".
05.1.0	15 April 2011	EB 60, Annex 2 Amendment to: • Broaden the applicability allowing thermal decomposition of N_2O; • Editorial improvements.
05	12 February 2010	EB 52, Annex 4 Revision to: • Broaden the applicability of the methodology to cover project activities that use HPO® process for the production of Caprolactam.
04.2	02 August 2008	EB 41, Annex 8 Editiorial revision to: • Add footnote 4 and footnote 5 to clarify that volume of gas and N_2O concentration should be measured simultaneously, and at same basis (wet or dry) and should be expressed at the normal conditions. The clarification made in the monitoring tables of these parameters
04.1	25 January 2007	Equation 8 was modified by removing the term GWP on the lhs of the equation.
04	21 December 2006	EB 28, Annex 11 Conservative default value for oxidation of methane and hydrocarbons that may be used for destruction of NO_X has been amended.
03	01 November 2006	EB 27, Annex 8 Revision to: • Clarify that the phrase "existing nitric acid production facilities installed no later than 31 December 2005" in the applicability conditions should be that a record of commercial production exists before 31 December, 2005.

Version	Date	Description
02	29 September 2006	EB 26, Annex 8
		Revision to:
		• Broaden the applicability of the approved methodology AM0028 to project activities that destroy N$_2$O emissions from process of caprolactam production. The approved methodology was also amended to include the monitoring of N$_2$O using the standard EN1418, which is also used in the approved methodology AM0034.
01	24 February 2006	EB 23, Annex 13
		Initial adoption.

Decision Class: Regulatory
Document Type: Standard
Business Function: Methodology
Keywords: nitrous oxide, animal manure management systems

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