AM0028

Large-scale Methodology

N2O destruction in the tail gas of Caprolactam production plants

Version 06.0

Sectoral scope(s): 05

TABLE OF CONTENTS Page

[1. Introduction 3](#_Toc358026509)

[2. Scope, applicability, and entry into force 3](#_Toc358026510)

[2.1. Scope 3](#_Toc358026511)

[2.2. Applicability 3](#_Toc358026512)

[2.3. Entry into force 3](#_Toc358026513)

[3. Normative references 3](#_Toc358026514)

[4. Definitions 3](#_Toc358026515)

[5. Baseline methodology 3](#_Toc358026516)

[5.1. Project boundary 3](#_Toc358026517)

[5.1.1. Step 1: Identify technically feasible baseline scenario alternatives to the project activity 3](#_Toc358026518)

[5.1.2. Step 2: Eliminate baseline alternatives that do not comply with legal or regulatory requirements: 3](#_Toc358026519)

[5.1.3. Step 3: Eliminate baseline alternatives that face prohibitive barriers (barrier analysis) 3](#_Toc358026520)

[5.1.4. Step 4: Identify the most economically attractive baseline scenario alternative 3](#_Toc358026521)

[5.1.5. Step 5: Re-assessment of baseline scenario in course of proposed project activity’s lifetime 3](#_Toc358026522)

[5.2. Additionality 3](#_Toc358026523)

[5.3. Project emissions 3](#_Toc358026524)

[5.3.1. N2O emissions not destroyed by the project activity 3](#_Toc358026525)

[5.3.2. Project emissions from the operation of the destruction facility 3](#_Toc358026526)

[5.4. Baseline emissions 3](#_Toc358026527)

[5.4.1. Case 1: The most plausible baseline scenario is that no N2O would be abated in the absence of the project activity (i.e. no secondary or tertiary reductions measures and no NSCR De-NOX unit would be installed) 3](#_Toc358026528)

[5.4.2. Case 2: Legal regulations for N2O are implemented 3](#_Toc358026529)

[5.5. Procedures used to determine the permitted operating conditions of the caprolactam production plant in order to avoid “overestimation of emission reductions” 3](#_Toc358026530)

[5.5.1. Operating temperature and pressure of the ammonia oxidation reactor (AOR) 3](#_Toc358026531)

[5.5.2. Composition of ammonia oxidation catalyst 3](#_Toc358026532)

[5.5.3. Ammonia flow rate to the ammonia oxidation reactor 3](#_Toc358026533)

[5.6. Leakage 3](#_Toc358026534)

[5.7. Emission reductions 3](#_Toc358026535)

[5.8. Data and parameters not monitored 3](#_Toc358026536)

[6. Monitoring methodology 3](#_Toc358026537)

[6.1. Archival of monitoring information 3](#_Toc358026538)

[6.2. Determination of conversion rates of hydrocarbons 3](#_Toc358026539)

[6.2.1. Case 1: Fraction of methane not converted will be measured 3](#_Toc358026540)

[6.2.2. Case 2: Fraction of methane not converted will not be measured due to unreasonable costs 3](#_Toc358026541)

[6.3. Data and parameters monitored 3](#_Toc358026542)

[6.3.1. Project emissions 3](#_Toc358026543)

[6.3.2. Baseline emissions 3](#_Toc358026544)

[6.3.3. Leakage emissions 3](#_Toc358026545)

[6.4. Good monitoring practice and performance characteristics 3](#_Toc358026546)

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

Table 1. Methodology key elements

|  |  |
| --- | --- |
| Typical projects | Installation of a catalytic reduction unit to destroy N2O emissions in the tail gas of caprolactam production plants |
| **Type of GHG emissions mitigation action** | 1. GHG destruction.   Catalytic destruction of N2O emissions |

1. Scope, applicability, and entry into force
   1. Scope
2. The proposed methodology is applicable to project activities that destroy N2O emissions either by catalytic or thermal decomposition of N2O in the tail gas of caprolactam production[[1]](#footnote-1) plants (i.e. tertiary destruction).
   1. Applicability
3. The following conditions apply:
   1. The applicability is limited to the existing production capacity measured in tonnes of 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 N2O is generated and not for the process with new ammonia oxidizer. Existing production "capacity" is defined as the design capacity, measured in tonnes of caprolactam per year;
   2. 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;
   3. The project activity will not result in shut down of an existing N2O destruction or abatement facility at the caprolactam production plant;
   4. The project activity shall not affect the caprolactam production level;
   5. The project activity will not cause an increase in NOX emissions;
   6. 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;
   7. The N2O concentration in the flow at the inlet and the outlet of the catalytic N2O destruction facility is measurable. Furthermore, for a caprolactam plant using the HPO® process, the N2O concentration in the gas flow between the ammonia oxidation reactor and the absorption column is also measurable, and the N2O in the product flow from the absorption column to the HPO® process area is quantifiable.
   8. Entry into force
4. The date of entry into force of the revision is the date of the publication of the EB 73 meeting report on 31 May 2013.
5. Normative references
6. This baseline and monitoring methodology is based on the following proposed new methodology:
   1. “NM0111: Baseline Methodology for catalytic N2O destruction in the tail gas of Nitric Acid Plants" submitted by Carbon Projektentwicklung GmbH”.
7. This methodology also refers to the latest approved versions of the following tools:
   1. "Tool for the demonstration and assessment of additionality”;
   2. "Tool to calculate project or leakage CO2 emissions from fossil fuel combustion”.
8. 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) please refer to <http://cdm.unfccc.int/goto/MPappmeth>.
9. Definitions
10. The definitions contained in the Glossary of CDM terms shall apply.
11. Baseline methodology
    1. Project boundary
12. For the purpose of determining project activity emissions, project participants shall include the followings in the project boundary:
    1. N2O concentration in the flow stream of the tail gas;
    2. 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 NOX reduction will not be considered as project emissions;
    3. Hydrocarbons as a reducing agent to enhance the efficiency of a N2O catalytic reduction facility.
13. For the purpose of determining baseline emissions, project participants shall include the following emission sources:
    1. N2O concentration in the flow stream of the tail gas insofar as the N2O is formed in the ammonia oxidation reactor;
    2. 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 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 not be considered.
14. Table 2 and 3 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 baseline emission sources included or excluded from the project boundary

|  |  |  |  |
| --- | --- | --- | --- |
| Source | Gas |  | Justification/Explanation |
| 1. Emissions of N2O as a result of side reaction to the ammonia oxidation in the caprolactam production process | 1. N2O | 1. Included | 1. Main emission source, taking national N2O emission regulations into account |
| 1. In an HPO® caprolactam production process, emissions of N2O as a result of the decomposition of hydroxylamine (hyam) in the absorption column | 1. N2O | 1. Excluded | 1. 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 N2O formation |
| 1. Emissions related to the production of ammonia used for NOX reduction 2. (Attention: Ammonia used for NOX-reduction does not cause GHG emissions, only the production of ammonia causes GHG emissions) | 1. CO2 2. CH4 3. N2O | 1. Included | 1. In case SCR DeNOX 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 NOX reduction. Baseline emissions and project emissions are similar and therefore not considered for calculation. In case no SCR DeNOX-unit is already installed prior to the project start: ammonia input for NOX reduction is considered 0 for baseline emissions |
| 1. N2O emissions from SCR DeNOX-unit | 1. N2O | 1. Excluded | 1. The presence of a SCR DeNOX unit tends to increase the N2O emissions. Therefore the ex post measurement of the baseline emissions at the inlet of the N2O destruction facility represents a conservative determination of the baseline N2O emissions |

Table 3. Overview on project emission sources included or excluded from the project boundary

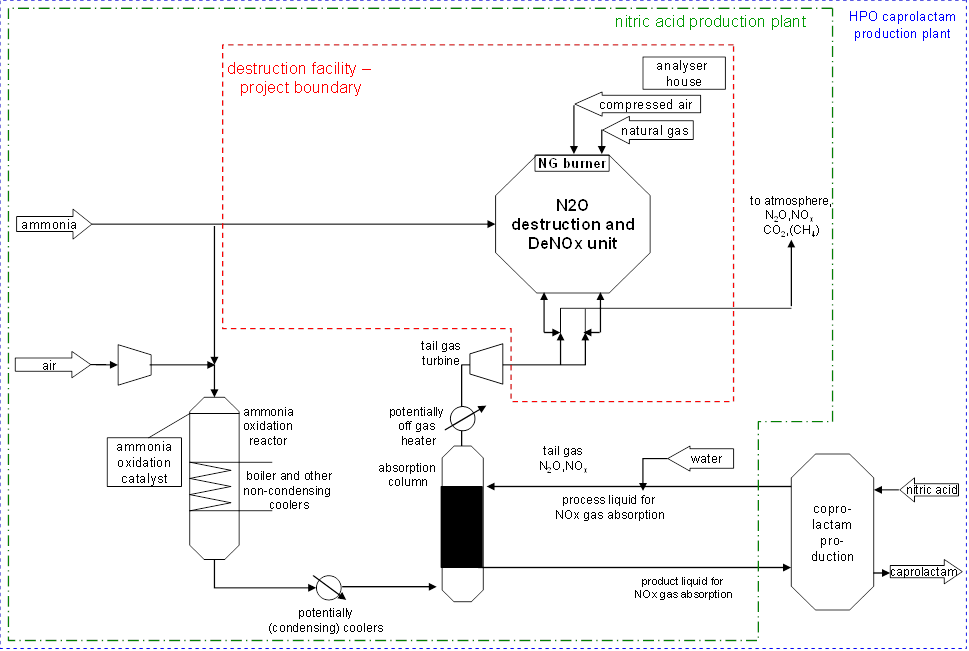
|  |  |  |  |
| --- | --- | --- | --- |
| Source | Gas |  | Justification/Explanation |
| Emissions of N2O as a result of side reaction to the caprolactam production process | N2O | Included | Main emission source, taking national N2O emission regulations into account |
| Emissions related to the production of ammonia used for NOX reduction (Attention: Ammonia used for NOX reduction does not cause GHG emissions, only the production of ammonia causes GHG emissions) | CO2  CH4  N2O | Included | In case SCR DeNOX 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 NOX reduction. Baseline emissions and project emissions are similar and therefore not considered for calculation. In case no SCR DeNOX-unit is already installed prior to the project start: ammonia input for NOX reduction is considered zero for baseline emissions |
| In case of thermal N2O decomposition process installed: Emissions at the project site resulting from fuel combustion to maintain the required temperature in the reaction chamber | CO2 | 1. Included | Thermal destruction of N2O 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 |
| In case of N2O reduction process installed: Emissions at the project site resulting from hydrocarbons used as reducing agent and/or re-heating the tail gas | CH4  and/or  CO2 | 1. Included | Hydrocarbons are used as reducing agent and/or re-heating the tail gas to enhance the efficiency of a N2O catalytic reduction facility. In this case hydrocarbons are mainly converted to CO2, 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 CO2 |
| Emissions from electricity demand | CO2  CH4  N2O | 1. 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 | CO2  CH4  N2O | 1. 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 |

1. As shown in Figure 1 (Destruction facility inside of the pressure zone, tail gas turbine upstream of project) and Figure 2 (Destruction facility not in pressure zone, tail gas turbine located downstream), the spatial extent of the project boundary comprises:
   1. The catalytic N2O destruction facility including auxiliary ammonia and/or hydrocarbon input;
   2. 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
   3. For monitoring purposes only, the caprolactam production plant, to measure the caprolactam output and operating parameters of the ammonia oxidation reactor.

Figure 1. Project boundary (destruction facility in the pressure zone, tail gas turbine upstream)



Figure 2. Project boundary (destruction facility outside pressure zone, tail gas turbine downstream)



* + 1. Step 1: Identify technically feasible baseline scenario alternatives to the project activity

1. The baseline scenario alternatives should include all technically feasible options which are realistic and credible.
   * + 1. Sub-step 1a: The baseline scenario alternatives should include all possible options that are technically feasible to handle N2O emissions. These options are, inter alia:
   1. Status quo: The continuation of the current situation, where there will be no installation of technology for the destruction or abatement of N2O;
   2. Switch to alternative production method not involving ammonia oxidation process;
   3. Alternative use of N2O such as:
      1. Recycling of N2O as a feedstock for the plant;
      2. The use of N2O for external purposes;
   4. Installation of a Non-Selective Catalytic Reduction (NSCR) DeNOX unit;[[2]](#footnote-2)
   5. The installation of an N2O destruction or abatement technology:
      1. Tertiary measure for N2O destruction;
      2. Primary or secondary measures for N2O destruction or abatement.
2. These options should include the CDM project activity not implemented as a CDM project.
   * + 1. Sub-step 1b: In addition to the baseline scenario alternatives of Step 1a, all possible options that are technically feasible to handle NOX emissions should be considered. The installation of a NSCR DeNOX unit could also cause N2O emission reduction. Therefore NOX emission regulations have to be taken into account in determining the baseline scenario. The respective options are, inter alia:
   1. The continuation of the current situation, where either a DeNOX-unit is installed or not;
   2. Installation of a new Selective Catalytic Reduction (SCR) DeNOX unit;
   3. Installation of a new Non-Selective Catalytic Reduction (NSCR) DeNOX unit;
   4. Installation of a new tertiary measure that combines NOX and N2O emission reduction.
      1. Step 2: Eliminate baseline alternatives that do not comply with legal or regulatory requirements:
   5. 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 (N2O), e.g. national or local NOX 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 N2O and NOX emissions;
   6. 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;
   7. 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.
3. The following table shows potential baseline scenarios taking legal or regulatory requirements into account:

Table 4. Potential baseline scenarios taking legal or regulatory requirements

|  |  |  |
| --- | --- | --- |
| Caprolactam production plant in compliance with N2O and NOX regulation | Caprolactam production plant not in compliance with NOX regulation | Caprolactam production plant not in compliance with N2O regulation |
| Continuation Status quo | SCR DeNOX installation N | SCR De-NOX installation that combines N2O and NOX emission reduction |
| Installation of N2O destruction or abatement technology | NSCR De-NOX installation | Installation of N2O destruction or abatement technology |
| Alternative use of N2O | Tertiary measure that combines NOX and N2O emission reduction | Alternative use of N2O |

* + 1. Step 3: Eliminate baseline alternatives that face prohibitive barriers (barrier analysis)
       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:
  1. Investment barriers, inter alia:
     1. Debt funding is not available for this type of innovative project activity;
     2. 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;
  2. Technological barriers, inter alia:
     1. Technical and operational risks of alternatives;
     2. Technical efficiency of alternatives (e.g. N2O destruction, abatement rate);
     3. 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;
     4. Lack of infrastructure for implementation of the technology;
  3. Barriers due to prevailing practice, inter alia:
     1. The project activity is the “first of its kind”: No project activity of this type is currently operational in the host country or region.

1. 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:
   1. Relevant legislation, regulatory information or industry norms;
   2. Relevant (sectoral) studies or surveys (e.g. market surveys, technology studies, etc.) undertaken by universities, research institutions, industry associations, companies, bilateral/multilateral institutions etc.;
   3. Relevant statistical data from national or international statistics;
   4. Documentation of relevant market data (e.g. market prices, tariffs, rules);
   5. 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.;
   6. Documents prepared by the project developer, contractors or project partners in the context of the proposed project activity or similar previous project implementations;
   7. Written documentation of an independent expert judgement from industry, educational institutions (e.g. universities, technical schools, training centers), industry associations and others.
      * 1. 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)
2. If any of the baseline scenario alternatives face barriers that would prohibit them from being implemented, then these should be eliminated.
3. 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.
4. 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.
   * 1. Step 4: Identify the most economically attractive baseline scenario alternative
5. Determine which of the remaining project alternatives that are not prevented by any barrier is the most economically or financially attractive.
6. To conduct the investment analysis, use the following sub-steps:
   * + 1. Sub-step 4a: Determine appropriate analysis method
7. 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).
   * + 1. Sub-step 4b: Option I: Apply simple cost analysis
8. Document the costs associated with alternatives to the CDM project activity and demonstrate that the corresponding activities produce no financial or economic benefits.
   1. 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;
   2. If one or more alternatives generate financial or economic benefits, then the simple cost analysis cannot be used to select the baseline scenario.
      * 1. Sub-step 4c: Option II: Apply investment comparison analysis
9. Identify the financial indicator, such as IRR,[[3]](#footnote-3) NPV, cost benefit ratio, or unit cost of service most suitable for the project type and decision-making context.
10. 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.
11. 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).
12. Assumptions and input data for the investment analysis shall not differ across the project activity and its alternatives, unless differences can be well substantiated.
13. Present in the CDM-PDD submitted for validation a clear comparison of the financial indicator for the proposed project alternative.
14. The alternative that has the best indicator (e.g. highest IRR) can be pre-selected as the most plausible baseline scenario candidate.
    * + 1. Sub-step 4d: Sensitivity analysis (only applicable to Option II)
15. 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 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.
16. 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.
    * 1. Step 5: Re-assessment of baseline scenario in course of proposed project activity’s lifetime
17. At the start of a crediting period, a re-assessment of the baseline scenario due to new or modified NOX or N2O emission regulations should be executed as follows:
    * + 1. Sub-step 5a: New or modified NOX-emission regulations
18. If new or modified NOX 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:
    1. Selective Catalytic Reduction (SCR);
    2. Non-Selective Catalytic Reduction (NSCR);
    3. Tertiary measures incorporating a selective catalyst for destroying N2O and NOX emissions;
    4. Continuation of baseline scenario.
19. 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 5. Potential outcomes of the re-assessment of the baseline scenario (to be in line with NOX regulation)

|  |  |
| --- | --- |
| Consequence (adjusted baseline scenario) | |
| SCR De-NOX installation | Continuation of original (N2O) baseline scenario |
| NSCR De-NOX installation | The N2O emissions outlet of NSCR become adjusted baseline N2O emissions, as NSCR may reduce N2O emissions as well as NOX |
| Tertiary measure that combines NOX and N2O emission reduction | Adjusted baseline scenario results in zero N2O emissions reduction |
| Continuation of original baseline scenario | Continuation of original baseline scenario |

* + - 1. Sub-step 5b: New or modified N2O - regulation

1. 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.
2. 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 DeNOX units).
   1. Additionality
3. 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.
4. 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.
5. 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 NOX 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.
   1. Project emissions
6. 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.
7. Project emissions are defined by the following equation:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Project emissions in year *y* (t CO2e) |
|  | = | Project emissions from N2O not destroyed in year *y* (t CO2e) |
|  | = | Project emissions related to the operation of the destruction facility in year *y* (t CO2e) |

* + 1. N2O emissions not destroyed by the project activity

1. N2O emissions not destroyed by the project activity are calculated based on the continuous measurement of the N2O concentration in the tail gas of the N2O destruction facility and the volume flow rate of the tail gas stream.
2. The emissions of non destroyed N2O are given by:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Project emissions from N2O not destroyed in year *y* (t CO2e) |
|  | = | Project emissions of N2O in year *y* (tN2O) |
|  | = | Global warming potential of N2O = 310 |

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Project emissions of N2O in year *y* (tN2O) |
|  | = | Volume flow rate at the exit of the destruction facility during interval *i* (m3/h)[[4]](#footnote-4) |
|  | = | N2O concentration in the tail gas of the N2O destruction facility during interval *i* (tN2O/m3) |
|  | = | Length of measuring interval *i* (h) |
|  | = | Interval |
|  | = | Number of intervals during the year |

* + 1. Project emissions from the operation of the destruction facility

1. The operation of the N2O 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 N2O.
2. The emissions related to the operation of the N2O destruction facility are given by (1) upstream emissions related to the production of ammonia used as input; (2) on-site emissions due to the hydrocarbons use as input to the N2O destruction facility; and (3) on-site emissions due to the fossil fuel (FF) use (e.g. natural gas, LPG, butane) as input to the N2O destruction facility (thermal decomposition):

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Project emissions related to the operation of the destruction facility in year *y* (t CO2e) |
|  | = | Project emissions related to ammonia input to destruction facility in year *y* (t CO2e) |
|  | = | Project emissions related to hydrocarbon input to destruction facility and/or re-heater in year *y* (t CO2e) |
|  | = | Project emissions related to the combustion of fossil fuels in year *y* (t CO2) |

* + - 1. Ammonia input to the destruction facility
  1. In case an existing SCR DeNOX 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;
  2. Should no SCR DeNOX unit be installed prior to the starting date of the project activity, project emissions related to the production of ammonia are considered as follows:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Project emissions related to ammonia input to destruction facility in year *y* (tCO2e) |
|  | = | Ammonia input to the destruction facility in year *y* (tNH3) |
|  | = | GHG emissions factor for ammonia production (CO2e/tNH3) |

1. Please note: Ammonia input for NOX emission reduction will not cause GHG emissions other than related to the production of ammonia.
2. A default factor of 2.14 t CO2e/tNH3 is suggested (GEMIS 4.2).
   * + 1. Hydrocarbon input
3. Hydrocarbons can be used as reducing agent and/or re-heating the tail gas to enhance the catalytic N2O reduction efficiency. In this case hydrocarbons are mainly converted to CO2 (*HCEC,y),* while some methane remain unconverted to CO2 (*HCENC,y*).
4. The emissions from hydrocarbon input are:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Project emissions related to hydrocarbon input to destruction facility and/or re-heater in year *y* (t CO2e) |
|  | = | Converted hydrocarbon emissions in year *y* (t CO2) |
|  | = | Methane emissions in year *y* (t CO2e) |

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

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Methane emissions in year *y* (t CO2e) |
|  | = | Methane density (t/m3) |
|  | = | Methane used in year *y* (m3) |
|  | = | Global warming potential of methane |
|  | = | Oxidation factor of methane (%) |

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Converted hydrocarbon emissions in year *y* (t CO2e) |
|  | = | Hydrocarbon density (t/m3) |
|  | = | Hydrocarbon, with two or more molecules of carbon, input in year *y* (m3) |
|  | = | Oxidation factor of hydrocarbon (%), with two or more molecules of carbon |
|  | = | Carbon emissions factor of hydrocarbon (tCO2/t HC), with two or more molecules of carbon |

1. The hydrocarbon CO2 emission factor is given by the molecular weights and the chemical reaction when hydrocarbons are converted (e.g. where CH4 is used as hydrocarbon, each converted tonne of CH4 results in 44/16 tonnes of CO2, thus the hydrocarbon emission factor is 2.75).
2. Project emissions are limited to the design capacity of the existing caprolactam production plant. If the actual production of caprolactam (*Pproduct,y*) exceeds the design capacity (*Pproduct,max*) then emissions related to the production above *Pproduct,max* will neither be claimed for the baseline nor for the project scenario.
   * + 1. Combustion of fossil fuels
3. In the thermal N2O 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 (*PEFF,y*) and the respective monitoring shall be done in accordance with the latest “Tool to calculate project or leakage CO2 emissions from fossil fuel combustion”.
4. If no fuel combustion is involved, for example in the case of catalytic N2O destruction, the respective part in equation (4) is set to zero.
   1. Baseline emissions
5. Baseline emissions are given by the following equation:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Baseline emissions in year *y* (t CO2e) |
|  | = | Baseline emissions of N2O in year *y* (tN2O) |
|  | = | Global warming potential of N2O = 310 |

1. Depending on the implementation of regulations on N2O emissions and the character of the regulation, baseline N2O emissions (*BEN2O,y*) are calculated as shown below:
   * 1. Case 1: The most plausible baseline scenario is that no N2O would be abated in the absence of the project activity (i.e. no secondary or tertiary reductions measures and no NSCR De-NOX unit would be installed)
        1. Case 1.1: Caprolactam plants using the Raschig production process
2. In the case of a caprolactam plant using the Raschig process, baseline emissions are limited to the design capacity of the existing caprolactam production plant. If the actual production of caprolactam (*Pproduct,y*) exceeds the design capacity (*Pproduct,max*) then emissions related to the production above *Pproduct,max* will not be claimed for the baseline scenario.
3. *Pproduct,y*  = Production of caprolactam in year *y* (t Product)
4. *Pproduct,max* = Design capacity caprolactam production (t Product)

If,

|  |  |
| --- | --- |
|  |  |

Then,

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Baseline emissions of N2O in year *y* (tN2O) |
|  | = | Quantity of N2O supplied to the destruction facility from ammonia oxidation in year *y* (tN2O) |

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Quantity of N2O supplied to the destruction facility from ammonia oxidation in year *y* (tN2O) |
|  | = | Quantity of N2O emissions at the inlet of the destruction facility in year *y* (tN2O) |

1. The total quantity of N2O supplied to the N2O destruction facility (DF) is calculated based on continuous measurement of the tail gas volume flow rate and the N2O concentration at the inlet of the N2O destruction facility. Therefore the quantity of the N2O at the inlet is given by:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Quantity of N2O emissions at the inlet of the destruction facility in year *y* (tN2O) |
|  | = | Volume flow rate at the inlet of the destruction facility during interval *i* (m3/h)[[5]](#footnote-5) |
|  | = | N2O concentration a destruction facility inlet during interval *i* (tN2O/m3) |
|  | = | Length of measuring interval *i* (h) |
|  | = | Interval |
|  | = | Number of intervals during the year |

If,

|  |  |
| --- | --- |
|  |  |

Then,

|  |  |
| --- | --- |
| for Raschig process |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Baseline emissions of N2O in year *y* (tN2O) |
|  | = | Specific N2O emissions per unit of output product of caprolactam in year *y* (tN2O/t Product) |
|  | = | Design capacity (t Product ) |
|  | = | Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N2O emission process (in this case a high-pressure nitric acid plant); 5.4 kgN2O/t Product |

1. The specific N2O emissions per unit of output of caprolactam are defined as:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Specific N2O emissions per unit of output of caprolactam in year *y* (tN2O/t Product) |
|  | = | Quantity of N2O emissions at the inlet of the destruction facility in year *y* (tN2O) |

* + - 1. Case 1.2: Caprolactam plants using the HPO® production process

1. 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 (*Pproduct,calc,y*) exceeds the design capacity (*Pproduct,calc,max*), then emissions related to the production above *Pproduct,calc,max* will not be claimed for the baseline scenario.
2. *Pproduct,calc, y* = On-site calculated nitric acid production in year *y* (t HNO3)
3. *Pproduct,calc,max* = On-site design capacity of calculated nitric acid production   
   (t HNO3)

|  |  |
| --- | --- |
|  |  |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Actual ammonia input to oxidation reactor in year *y* (tNH3/yr) |
|  | = | Maximum historical ammonia input to oxidation reactor (tNH3/yr) |
|  | = | Molar mass of ammonia = 17 tonnes/Mmol |
|  | = | Molar mass of nitric acid = 63 tonnes/Mmol |
|  | = | Ammonia oxidation reactor oxidation efficiency = 93%[[6]](#footnote-6) |
|  | = | Efficiency of the absorption column = 99%[[7]](#footnote-7) |

If,

|  |  |
| --- | --- |
|  |  |

then

|  |  |
| --- | --- |
|  |  |

and

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | *=* | Quantity of N2O supplied to the destruction facility from ammonia oxidation in year *y* (tN2O) |
|  | *=* | Quantity of N2O emissions at the inlet of the destruction facility in year *y* (tN2O) |
|  | *=* | Quantity of N2O in the gas flow between the ammonia oxidation reactor and the absorption column in year *y* (tN2O) |
|  | *=* | Quantity of N2O in the product flow from the absorption column to the HPO® process area in year *y* (tN2O) |

1. The total quantity of N2O supplied to the N2O destruction facility (DF) is calculated based on continuous measurement of the tail gas volume flow rate and the N2O concentration at the inlet of the N2O destruction facility. Therefore the quantity of the N2O at the inlet is given by:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Quantity of N2O emissions at the inlet of the destruction facility in year *y* (t N2O) |
|  | = | Volume flow rate at the inlet of the destruction facility during interval *i* (m3/h)[[8]](#footnote-8) |
|  | = | N2O concentration a destruction facility inlet during interval *i* (tN2O/m3) |
|  | = | Length of measuring interval *i* (h) |
|  | = | Interval |
|  | = | Number of intervals during the year |

1. The quantity of N2O 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 N2O concentration in the product stream from the ammonia oxidation. Therefore, the quantity of the N2O produced by ammonia oxidation is given by:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Quantity of N2O in the gas flow between the ammonia oxidation reactor and the absorption column in year *y* (tN2O) |
|  | = | Volume flow rate of the product stream of the ammonia oxidation reactor during interval *i* (m3/h) |
|  | = | N2O concentration in the product stream of the ammonia oxidation reactor during interval *i* (tN2O/m3) |
|  | = | Length of measuring interval *i* (h) |
|  | = | Interval |
|  | = | Number of intervals during the year |

1. The volume flow rate of the product stream of the ammonia oxidation reactor during interval *i*, *FAI,i,* is calculated from the volume flow rates of ammonia and air to the ammonia oxidation reactor:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Volume flow rate of the product stream of the ammonia oxidation reactor during interval *i* (m3/h) |
|  | = | Actual ammonia input to oxidation reactor during interval *i* (m3/h) |
|  | = | Actual air input to oxidation reactor during interval *i* (m3/h)[[9]](#footnote-9) |

1. The total quantity of N2O 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 N2O concentration in the process liquid. Therefore the quantity of the N2O exiting the absorption column in the process liquid is given by:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Quantity of N2O in the product flow from the absorption column to the HPO® process area in year *y* (t N2O) |
|  | = | Volume of product liquid flow in year *y* (m3) |
|  | = | N2O concentration in the product liquid (tN2O/m3) |

If,

|  |  |
| --- | --- |
|  |  |

Then

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Baseline emissions of N2O in year *y* (tN2O) |
|  | = | Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N2O emission process (in this case a high-pressure nitric acid plant); 5.4 kgN2O/t Product |
|  | = | Specific N2O emissions per unit of calculated nitric acid production in year *y* (tN2O/t Product) |

1. The specific N2O emissions per unit of output of nitric acid equivalent are defined as:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Specific N2O emissions per unit of calculated nitric acid production in year *y* (tN2O/t Product) |

* + 1. Case 2: Legal regulations for N2O are implemented

1. Emissions at the time the regulation has to be implemented. Depending on the character of the regulation the adjustment is done as shown below:
   * + 1. Case 2.1: Regulation setting of a threshold for an absolute quantity of N2O emissions per caprolactam production plant over a given time period
2. Baseline N2O emissions are limited by the absolute quantity of N2O emissions given by the regulation. If the measured baseline N2O emissions are exceeding the regulatory limit, then measured baseline N2O emissions are substituted by the regulatory limit.
3. This leads to the following condition:
   1. For a caprolactam plant using the Raschig process,

|  |  |
| --- | --- |
|  |  |

* 1. For a caprolactam plant using the HPO® process,

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Quantity of N2O emissions from ammonia oxidation at the inlet of the destruction facility in year *y* (tN2O) |
|  | = | Regulatory limit of N2O emissions in year *y* (tN2O) |
|  | = | Baseline emissions of N2O in year *y* (tN2O) |
|  | = | Specific N2O emissions per unit of output of caprolactam in year *y* (tN2O/t Product) |
|  | = | Design capacity (t Product ) |
|  | = | Specific N2O emissions per unit of calculated nitric acid production in year *y* (tN2O/t Product) |
|  | = | On-site design capacity of calculated nitric acid production  (t-HNO3) |
|  | = | Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N2O emission process |

1. *QBN2O,y*, *SEN2O,y* and *SEcalcN2O,y* are defined according to the instructions under Case 1 above.
   * + 1. Case 2.2: Regulation setting of a threshold for specific N2O emissions per unit of product:
2. This leads to the following condition:
   1. For a caprolactam plant using the Raschig process,

|  |  |
| --- | --- |
|  |  |

* 1. For a caprolactam plant using the HPO® process,

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Specific N2O emissions per unit of output of caprolactam in year *y* (tN2O/t Product) |
|  | = | Regulatory limit of N2O emissions per unit of output of caprolactam (tN2O/t Product) |
|  | = | Baseline emissions of N2O in year *y* (tN2O) |
|  | = | Production of caprolactam in year *y* (t Product) |
|  | = | Quantity of N2O emissions from ammonia oxidation at the inlet of the destruction facility in year *y* (t N2O) |
|  | = | Specific N2O emissions per unit of calculated nitric acid production in year *y* (tN2O/t Product) |
|  | = | On-site design capacity of calculated nitric acid production (t HNO3) |
|  | = | Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N2O emission process |

1. *QBN2O,y*, *SEN2O,y* and *SEequivN2O,y* are defined according to the instructions under Case 1 above.
   * + 1. Case 2.3: Regulation setting of a threshold for N2O concentration in the tail gas.
2. This leads to the following condition:
   1. For a caprolactam plant using the Raschig process,

|  |  |
| --- | --- |
|  |  |

* 1. For a caprolactam plant using the HPO® process,

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Regulatory limit for specific N2O concentration during interval *i* (tN2O/m3) |
|  | = | Baseline emissions of N2O in year *y* (tN2O) |
|  | = | Volume flow rate at the exit of the destruction facility during interval *i* (m3/h) |
|  | = | Length of measuring interval *i* (h) |
|  | = | Interval |
|  | = | Quantity of N2O emissions from ammonia oxidation at the inlet of the destruction facility in year *y* (t N2O) |
|  | = | Specific N2O emissions per unit of calculated nitric acid production in year *y* (tN2O/t Product) |
|  | = | On-site design capacity of calculated nitric acid production (t HNO3) |
|  | = | Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N2O emission process |

1. *QBN2O,y*, *SEN2O,y* and *SEcalcN2O,y* are defined according to the instructions under Case 1 above.
2. Change in NOX or N2O regulations will automatically cause a re-assessment of the baseline scenario.
   1. Procedures used to determine the permitted operating conditions of the caprolactam production plant in order to avoid “overestimation of emission reductions”
3. In order to avoid that the operation of the caprolactam production plant is manipulated in a way to increase the N2O 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.
   * 1. Operating temperature and pressure of the ammonia oxidation reactor (AOR)
4. If the actual average daily operating temperature or pressure in the ammonia oxidation reactor (*Tg* and *Pg*) are outside a “permitted range” of operating temperatures and pressures (*Tg,hist* and *Pg,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]](#footnote-10) for the equivalent N2O emission process, “*EFN2O,IPCC*”. for caprolactam using the Raschig process, *EFN2O,IPCC* = 5.4kgN2O/tonne of caprolactam, and for a caprolactam plant using the HPO® process, *EFN2O,IPCC* = 5.4 kgN2O/tonne of calculated nitric acid production, all conservatively applying the IPCC default values.(b) *SEN2O,y* and (c) any related value as a result of legal regulations (e.g. *RSEN2O,y*).
5. *EFN2OIPCC* = Conservative IPCC default value of the latest IPCC GHG Inventory  
    Guidelines accepted by the IPCC for the equivalent N2O emission process
6. Required monitoring parameters:
   1. *Tg,d* Actual operating temperature AOR on day *d* (°C);
   2. *Pg,d* Actual operating pressure AOR on day *d* (Pa);
   3. *Tg,hist* Historical operating temperature range AOR (°C);
   4. *Pg,hist* Historical operating pressure range AOR (Pa).
7. 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:
   1. Firstly, data on historical temperature and pressure ranges; or, if no data on historical temperatures and pressures are available; then
   2. 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
   3. 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).
8. 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 per cent Quantile or that are part of the (100‑2.5) per cent 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.
   * 1. Composition of ammonia oxidation catalyst
9. 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 caprolactam production plant during the last three years without limitation of N2O baseline emissions.
10. In case the 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 N2O baseline emissions.
11. In case the 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 N2O 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 N2O baseline emissions.
12. In case the 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.
13. Baseline emissions are limited to the maximum specific N2O emissions of previous periods (tN2O/tCaprolactam for the Raschig process or tN2O/tonne of calculated nitric acid production for the HPO® process), documented in the verified monitoring reports.
14. Required monitoring parameters:
    1. *Gsup* Supplier of the ammonia oxidation catalyst;
    2. *Gsup,hist* Historical supplier of the ammonia oxidation catalyst;
    3. *Gcom* Composition of the ammonia oxidation catalyst;
    4. Gcom,hist Historical composition of the ammonia oxidation catalyst;
    5. *SEN2O,y* Specific N2O emissions per ton of product of   
        caprolactam in year *y* (tN2O/t Product).
       1. Ammonia flow rate to the ammonia oxidation reactor
15. 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:
    1. Historical operating data on maximum daily average ammonia flow; or, if not existing; on
    2. Calculation of the maximum ammonia flow rate allowed as specified by ammonia oxidation catalyst manufacturer or on typical catalyst loadings; or, if not existing;
    3. Based on the literature;
    4. Ammonia flow rate specified by the ammonia oxidation reactor manufacturer.
16. If the daily ammonia input to the oxidation reactor exceeds the limit on permissible ammonia input, baseline N2O emissions are capped at conservative IPCC default values, *EFN2O,IPCC.*
17. Required monitoring parameters on daily basis:
    1. *AOR,d* Actual ammonia input to oxidation reactor (tNH3/day);
    2. *AOR,hist* Maximum historical ammonia input to oxidation reactor (tNH3/day).
    3. Leakage
18. Each N2O destruction technology works best over a particular range of tail gas temperatures.
19. 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 N2O 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 N2O 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).
20. On condition that an energy converter (e.g. tail gas turbine) is installed at the end of the pipe, the installation of the N2O destruction facility will not result in significant additional energy consumption at the caprolactam production plant and therefore no leakage is expected.
21. 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:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Leakage emissions in year *y* (t CO2e) |
|  | = | Emissions from net change steam export (t CO2e) |
|  | = | Emissions from net change in tail gas utilization (t CO2e) |
|  | = | Emissions from net change in tail gas heating (t CO2e) |

1. Each component is calculated as follows:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Emissions from net change steam export (t CO2e) |
|  | = | Baseline steam export (MW) |
|  | = | Project steam export (MW) |
|  | = | Operating hours in year *y* (h) |
|  | = | Efficiency of steam generation (%) |
|  | = | Fuel emissions factor for steam generation (t CO2e/MWh) |

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Emissions from net change in tail gas utilization (t CO2e) |
|  | = | Baseline energy export from tail gas utilization (MW) |
|  | = | Project energy export from tail gas utilization (MW) |
|  | = | Operating hours in year *y* (h) |
|  | = | Efficiency of replaced technology (%) |
|  | = | Fuel emissions factor for replaced technology (t CO2e/MWh) |

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Emissions from net change in tail gas heating (t CO2e) |
|  | = | Energy input for additional tail gas heating (MWh/yr) |
|  | = | Efficiency of additional tail gas heating (%) |
|  | = | Emissions factor for additional tail gas heating (t CO2e/MWh) |

1. The effect of the modifications on the energy balance (e.g. steam export) of the 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.
   1. Emission reductions
2. 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:

|  |  |
| --- | --- |
|  |  |

Where:

|  |  |  |
| --- | --- | --- |
|  | = | Emissions reductions of the project activity during the year *y* (t CO2e) |
|  | = | Baseline emissions during the year *y* (t CO2e) |
|  | = | Project emissions during the year *y* (t CO2e) |
|  | = | Leakage emissions in year *y* (t CO2e) |

* 1. Data and parameters not monitored

Data / Parameter table 1.

|  |  |
| --- | --- |
| Data / Parameter: | EFNH3 |
| Data unit: | t CO2e/tNH3 |
| Description: | Ammonia Production GHG Emission Factor |
| Source of data: | IPCC |
| Measurement procedures (if any): | - |
| Any comment: | A default factor of 2.14 tCO2e/tNH3 is suggested (GEMIS 4.2) |

Data / Parameter table 2.

|  |  |
| --- | --- |
| Data / Parameter: | EFHC |
| Data unit: | t CO2e/tHC |
| Description: | Hydrocarbon CO2 emissions factor |
| Source of data: | IPCC |
| Measurement procedures (if any): | - |
| Any comment: | The hydrocarbon CO2 emission factor is given by the molecular weights and the chemical reaction when hydrocarbons are converted (e.g. where CH4 is used as hydrocarbon, each converted tonne of CH4 results in 44/16 tonnes of CO2, 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: | Pproduct,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: | Tg,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: | Pg,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: | Gsup,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: | Gcom,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: | AOR,max |
| Data unit: | tNH3/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: | STBL |
| 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: | ηST |
| Data unit: | % |
| Description: | Steam Generation Efficiency |
| Source of data: | Manufacturer information |
| Measurement procedures (if any): | - |
| Any comment: | - |

Data / Parameter table 12.

|  |  |
| --- | --- |
| Data / Parameter: | EEBL |
| 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: | ηr |
| 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: | ηTGH |
| 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: | Pproduct,max |
| Data unit: | t Product |
| Description: | Design capacity of caprolactam production |
| Source of data: | Project operator and/or technology provider |
| Measurement procedures (if any): | - |
| Any comment: | - |

1. Monitoring methodology
   1. Archival of monitoring information
2. 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.
3. The accuracy of the N2O 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.
4. In addition, the monitoring provisions in the relevant applicable tools apply.

Figure 3. Project boundary (destruction facility in pressure zone, tail gas turbine upstream)

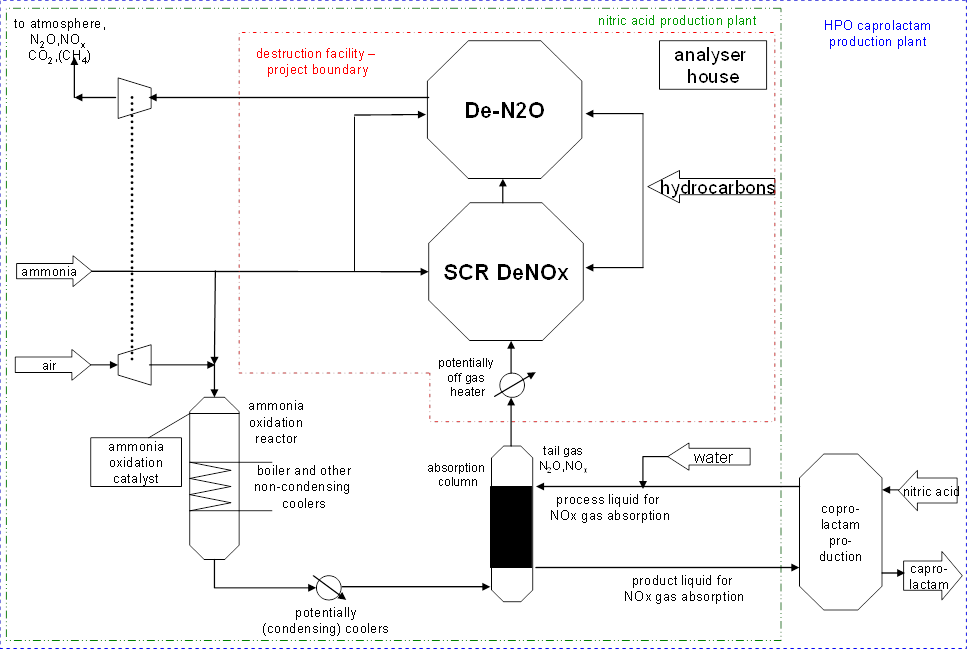
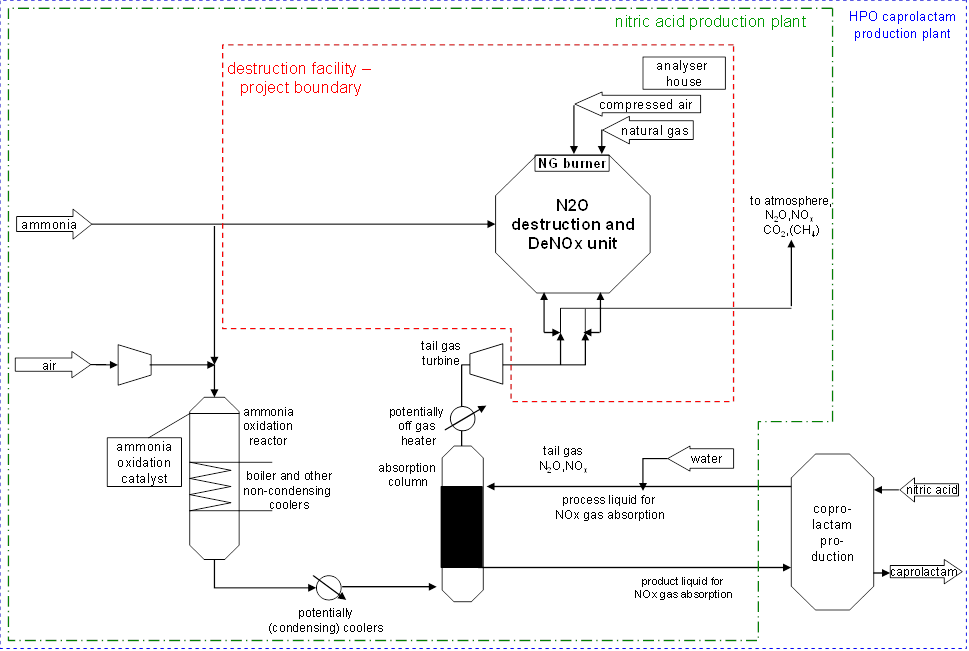


Figure 4. Project boundary (destruction facility outside pressure zone, tail gas turbine downstream)



1. The value adopted for Quantity of N2O at the inlet of the destruction facility should be calculated considering conservatively the error included in the measurement.
2. Note:
   1. AI: Measurement for the concentration of N2O;
   2. FI: measurement for total flow rate;
   3. PI: measurement for pressure;
   4. TI: measurement for temperature.
   5. Determination of conversion rates of hydrocarbons
3. 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 (CH4), the hydrocarbon is mainly converted to CO2, 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 (H2O, CO, CO2).
4. If methane (CH4) is present in the reducing agent and/or re-heating the tail gas, as with natural gas, a part leaves the N2O 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.
   * 1. Case 1: Fraction of methane not converted will be measured
5. In order to measure the fraction of unconverted methane, an additional analyser is required. If the project-specific costs of this analyser for CH4 are not unreasonable the methodology recommends the installation of the analyser.
   * 1. Case 2: Fraction of methane not converted will not be measured due to unreasonable costs
6. A conservative baseline approach is required, as follows:
   1. If hydrocarbons with two or more carbon atoms are present as reducing agent:
      1. 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 CO2 emission factor;
   2. If methane is present in the reducing agent and/or re-heating the tail gas, for example; as with natural gas:
      1. In order to apply a conservative baseline approach the fraction of unconverted hydrocarbon is 100 per cent (OXIDCH4 = 0%). Hence, reducing agent GHG emissions are calculated based on the Global Warming Factor of the hydrocarbon.
7. The option to be adopted shall be decided on a case-by-case basis.
   1. Data and parameters monitored
      1. Project emissions

Data / Parameter table 16.

|  |  |
| --- | --- |
| Data / Parameter: | FTE,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 N2O 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: | CON2O,i |
| Data unit: | tN2O/m³ |
| Description: | N2O 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 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: | Mi |
| 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: | QNH3,y |
| Data unit: | tNH3 |
| Description: | N2O 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 DeNOX*-unit is installed in the baseline scenario |

Data / Parameter table 20.

|  |  |
| --- | --- |
| Data / Parameter: | QHC,y/QCH4,y |
| Data unit: | m3 |
| 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: | ρHC/ρCH4 |
| Data unit: | t/m3 |
| 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: | OXIDHC |
| 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: | - |

* + 1. Baseline emissions

Data / Parameter table 23.

|  |  |
| --- | --- |
| Data / Parameter: | Pproduct,y |
| Data unit: | tCaprolactam. |
| Description: | 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: | CIN2O,i |
| Data unit: | tN2O/m3 |
| Description: | N2O concentration at N2O 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 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: | FTI,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 N2O 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: | AOR,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: | AirOr,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: | CAN2O,i |
| Data unit: | tN2O/m3 |
| Description: | N2O 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 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: | CPN2O,y |
| Data unit: | tN2O/m3 |
| Description: | N2O concentration in the product liquid |
| Source of data: | Measurements by project participants |
| Measurement procedures (if any): | Use the maximum possible N2O concentration given the characteristics of the product liquid |
| Monitoring frequency: | - |
| QA/QC procedures: | - |
| Any comment: | Determine solubility of N2O using a sample of the product liquid. Use a standard laboratory technique for this purpose such as RSKSOP-175[[11]](#footnote-11) |

Data / Parameter table 30.

|  |  |
| --- | --- |
| Data / Parameter: | FPI,y |
| Data unit: | m3 |
| 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 N2O in the product liquid is very low, the amount of product liquid flow is to be determined from standard reports on the production process |

Data / Parameter table 31.

|  |  |
| --- | --- |
| Data / Parameter: | QRN2O,y |
| Data unit: | tN2O |
| Description: | Regulation I: annual quantity N2O 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: | RSEN2O,y |
| Data unit: | tN2O/tCaprolactam |
| Description: | Regulation II: N2O emissions per unit of 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: | CRN2O,i |
| Data unit: | tN2O/m3 |
| Description: | Regulatory limit for specific N2O 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: | Tg,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: | Pg,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: | RegNOx |
| Data unit: | tNOx/m³ |
| Description: | National regulation on NOX 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: | Gsup |
| 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: | Gcom |
| 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: | SEN2O,y |
| Data unit: | tN2O/t Product |
| Description: | Specific N2O emissions per ton of product of 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: | AOR,y |
| Data unit: | tNH3/yr |
| Description: | Actual ammonia input to oxidation reactor in year *y* |
| Source of data: | Measurements by project participants |
| Measurement procedures (if any): | Calculate from *AOR,d* |
| Monitoring frequency: | Continuously |
| QA/QC procedures: | - |
| Any comment: | - |

* + 1. Leakage emissions

Data / Parameter table 41.

|  |  |
| --- | --- |
| Data / Parameter: | STPR |
| 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: | EFST |
| Data unit: | t CO2e/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: | My |
| 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: | EEPR |
| 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: | EFr |
| Data unit: | t CO2e/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: | EITGH,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: | EFTGH |
| Data unit: | t CO2e/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: | - |

* 1. Good monitoring practice and performance characteristics

1. Accuracy of the N2O 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.
2. The following guidance documents are recommended as references for the Quality Assurance and Control procedures:
   1. 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;
   2. European Norm EN 14181: Quality assurance of automated measuring systems, 2004;
   3. 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.
3. 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:
   1. 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:
      1. Standard deviation;
      2. Lack of fit (linearity);
      3. Repeatability at zero and reference points;
      4. Time-dependent zero and span drift;
      5. Temperature dependence;
      6. Voltage fluctuation;
      7. Suitability test;
      8. Cross sensitivity to likely components of the stack gas;
      9. Influence of variations in flow rate on extractive Automated Measuring Systems;
      10. Response time;
      11. Detection limit;
      12. Influence of ambient conditions on zero and span readings;
      13. Performance and accuracy;
      14. Availability;
      15. 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.

* 1. 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:
     1. Selection of the location of measurement;
     2. Duly installation of the monitoring equipment;
     3. Correct choice of measurement range;
     4. Calibration of the AMS using the Standard-Reference-Method (SRM) as guidance;
     5. Calibration curve either as linear regression or as straight line from absolute zero to centre of a scatter-plot;
     6. Calculation of the standard deviation at the 95 per cent confidence interval;
     7. Inspection every three years;
  2. Continuous quality assurance through the local operator/manager (drift and accuracy of the AMS, verification management and documentation);
     1. Permanent quality assurance during the plant operation by the operating staff;
     2. Assurance of reliable and correct operation of the monitoring equipment (maintenance evidence);
     3. Regular controls: zero point, span, drift, meet schedule of manufacturer maintenance intervals.

1. 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.
   1. Annual confirmation of the calibration curve;
   2. Validity proof of calibration curves;
   3. Back-setting of excess meter of invalid calibration range.
2. Minimum requirements for electronic evaluation units
   1. Evaluation unit needs to take into account registration, mean average determination, validation, and evaluation;
   2. The system and concept of emission data processing needs to be described;
   3. Protocols and out-prints are required.
3. Downtime of Automated Measuring System
   1. 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.

- - - - -

Document information

| Version | Date | Description |
| --- | --- | --- |
|  | | |
| 06.0 | 31 May 2013 | EB 73, Annex 5  Revision to:   * Remove all references to nitric acid plants; * Change the title from “N2O destruction in the tail gas of Nitric Acid or Caprolactam Production Plants” to “N2O destruction in the tail gas of Caprolactam production plants” (formally known as "Catalytic N2O destruction in the tail gas of Nitric Acid or Caprolactam Production Plants"). |
| 05.1.0 | 15 April 2011 | EB 60, Annex 2  Amendment to:   * Broaden the applicability allowing thermal decomposition of N2O; * 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 N2O 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 NOX 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. |
| 02 | 29 September 2006 | EB 26, Annex 8  Revision to:   * Broaden the applicability of the approved methodology AM0028 to project activities that destroy N2O emissions from process of caprolactam production. The approved methodology was also amended to include the monitoring of N2O 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 | | |

1. Caprolactam production plants including the ammonia oxidation reactor (AOR) where N2O is generated. [↑](#footnote-ref-1)
2. NSCR: as NSCR DeNOX-unit will reduce N2O emissions as a side reaction to the NOX-reduction. Consequently, new NSCR installation can be seen as alternative N2O reduction technology. [↑](#footnote-ref-2)
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. [↑](#footnote-ref-3)
4. *FTE,i* and *CON2O,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. [↑](#footnote-ref-4)
5. *FTl,i* and *CIN2O,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. [↑](#footnote-ref-5)
6. C. Keleti (ed), Nitric Acid and fertilizer nitrates, Fertilizer Science and Technology series, Vol 4, New York, Basel, 1985. [↑](#footnote-ref-6)
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. [↑](#footnote-ref-7)
8. *FT1,i* and *CIN2O,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. [↑](#footnote-ref-8)
9. *AirOR,I* and *CAN2O,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. [↑](#footnote-ref-9)
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 per cent 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 per cent uncertainty factor. [↑](#footnote-ref-10)
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. [↑](#footnote-ref-11)