Monitoring report form for CDM project activity
(Version 07.0)

Complete this form in accordance with the instructions attached at the end of this form.

MONITORING REPORT		
Title of the project activity	Reduction of N2O emissions from the new nitric acid plant #5 of Hu-Chems Fine Chemical Corp.	
UNFCCC reference number of the project activity	6637	
Version number of the PDD applicable to this monitoring report	1.4	
Version number of this monitoring report	01.1	
Completion date of this monitoring report	05/03/2020	
Monitoring period number	18th monitoring period	
Duration of this monitoring period	28/10/2019 – 02/02/2020	
Monitoring report number for this monitoring period	N/A	
Project participants	Hu-Chems Fine Chemical Corp. Carbon Climate Protection GmbH	
Host Party	Republic of Korea	
Applied methodologies and standardized baselines	ACM0019 v1 (N_2O abatement from nitric acid production) No standardized baseline applicable.	
Sectoral scopes	5 – Chemical industries	
Amount of GHG emission reductions or net anthropogenic GHG removals achieved by the project activity in this monitoring period	Amount achieved before 1 January 2013	Amount achieved from 1 January 2013
	N/A	84,219 tCO_2e
Amount of GHG emission reductions or net anthropogenic GHG removals estimated ex ante for this monitoring period in the PDD	77,933 tCO_2e	

SECTION A. Description of project activity

A.1. General description of project activity

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The project participants have implemented the project activity for the purpose of GHG emission reduction by catalytic N_2O destruction in its nitric acid (furthermore called "NA") plant 5 in Yeosu, Republic of Korea. The project is categorized as large-scale project under sectoral scope 5 – Chemical Industries. The Host Party for the project activity is the Republic of Korea. The project activity includes development, design, engineering, procurement, finance, construction, operation and maintenance of a system for catalytic decomposition of N_2O in the NA plant 5 of Hu-Chems Fine Chemical Corp. (furthermore called "Hu-Chems").

In this project, Hu-Chems installed an EnviNOx® system for catalytic decomposition of NO_x and N_2O additionally to the equipment at the NA manufacturing plant. The project activity reduces the GHG emissions, which would otherwise be released to the atmosphere, if the project was not implemented. The EnviNOx® process used in the NA plant 5 is based on the catalytic decomposition of nitrous oxide (N_2O) and the catalytic reduction of NO_x (NO and NO_2) with ammonia (NH_3). This process works very well at temperatures above about 425°C. The reactions take place over two iron zeolite catalyst beds.

A.2. Location of project activity

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Country (Host Party): Republic of Korea
Province: Jeollanam-do
Town: Yeosu, 7-6, Wollae-dong
Unique geographic coordinates: Longitude 127.74158 E, Latitude: 34.84583 N

A.3. Parties and project participants

Parties involved	Project participants	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
Republic of Korea (Host Party)	Hu-Chems Fine Chemical Corp.	No
Austria	Carbon Climate Protection GmbH	No

A.4. References to applied methodologies and standardized baselines

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Applied methodology: ACM0019, version 1 ("N_2O abatement from nitric acid production")[1]

ACM0019 refers to "Tool to determine the mass flow of a greenhouse gas in a gaseous stream", version 02.0.0[2], thus the tool is applied in this project activity. Furthermore, the methodology refers to "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion". Since no fossil fuels are used in the project activity, it is neglected and not mentioned anymore throughout this document.
No standardized baselines are used according to the applied methodology.

A.5. Crediting period type and duration

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Type of crediting period:	Fixed
Starting date of the crediting period:	25/02/2013 (changed from 01/09/2012)
End date of the crediting period:	24/02/2023 (changed from 31/08/2022)
Duration of the fixed crediting period:	10 years

SECTION B. Implementation of project activity

B.1. Description of implemented project activity

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(a) Description of the installed technology, technical processes and equipment

General description:

Nitrous oxide (N_2O) is an unwanted, invisible and previously neglected by-product of the manufacture of NA. It is formed alongside the main, desired product nitric oxide (NO) during the catalytic oxidation of ammonia in air over noble metal gauzes. The production of NA takes place in three main process steps as indicated by the following reactions:

1. Ammonia (NH_3) combustion to form nitric oxide (NO)[3]:

   $4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$ (main reaction 1)

   Simultaneously nitrous oxide (N_2O), nitrogen (N) and water (H_2O) are formed as well, in accordance with the following equations:

   $4\ NH_3 + 3\ O_2 \rightarrow 2\ N_2 + 6\ H_2O$ (side reaction 1)
   $4\ NH_3 + 4\ O_2 \rightarrow 2\ N_2O + 6\ H_2O$ (side reaction 2)

   NO yield mainly depends on pressure and temperature in the ammonia oxidation process and is usually in a range of 95% to 97%.

2. NO is oxidised to nitrogen dioxide (NO_2):

   $2\ NO + O_2 \rightarrow 2\ NO_2$ (main reaction 2)

[1] http://cdm.unfccc.int/methodologies/DB/MNMFNF10VUEOJACEIRX3EHYC9QXGDC
[2] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-08-v2.0.0.pdf
[3] Ammonia is reacted with air on noble metal catalyst in the oxidation section of NA plants. Nitric oxide and water are formed in this process according to the above mentioned main equation.

3. (According to the technical process) Absorption of NO_2 in water to form NA (HNO_3):

   $3\ NO_2 + H_2O \rightarrow 2\ HNO_3 + NO$ (main reaction 3)
   (NO is oxidised to NO_2 according to main reaction 2)

When leaving the ammonia oxidation reactor, there is no relevant loss of N_2O in the tail gas section unless an N_2O destruction facility is installed. N_2O that leaves the ammonia oxidation reactor is thus discharged to atmosphere in the tail gas and has no economic value.

Project specific description:

- Principles of the EnviNOx® process

The EnviNOx® process used in Hu-Chems´ NA plant #5 is based on the catalytic decomposition of nitrous oxide (N_2O) and the catalytic reduction of NO_x (NO and NO_2) with ammonia (NH_3). Catalytic decomposition of N_2O occurs when the N_2O is split into its constituent elements by contact with a catalyst. A catalyst is a material, which accelerates the speed of the reaction without itself being transformed or consumed by the reaction. This process works well at temperatures above 425°C.

The reactions take place over two iron zeolite catalyst beds. In the first bed N_2O is catalytically decomposed into its elements:

$$2\ N_2O \rightarrow 2\ N_2 + O_2$$

This rate of this reaction is enhanced by high concentrations of NO_X. Before the tail gas enters the second catalyst bed, a small quantity of ammonia vapour is added. In the second bed a large part of the NO_x is reduced with ammonia according to such reactions as:

$$6\ NO_2 + 8\ NH_3 \rightarrow 7\ N_2 + 12\ H_2O$$
$$6\ NO + 4\ NH_3 \rightarrow 5\ N_2 + 6\ H_2O$$
$$NO + NO_2 + 2\ NH_3 \rightarrow 2\ N_2 + 3\ H_2O$$
$$4\ NO + O_2 + 4\ NH_3 \rightarrow 4\ N_2 + 6\ H_2O$$

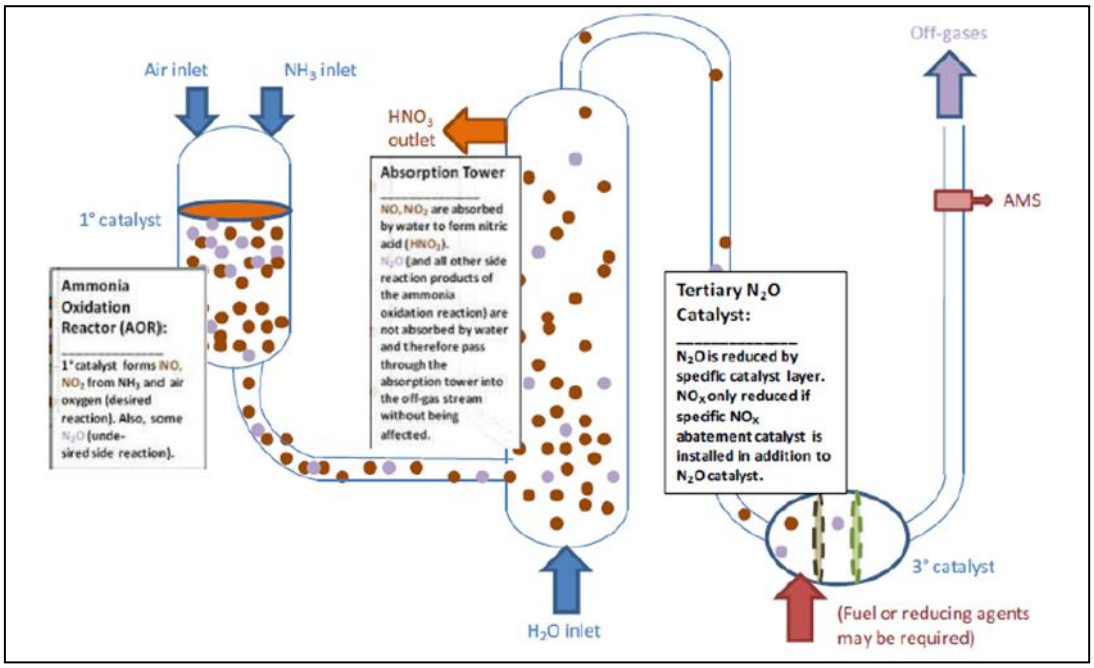
Some further destruction of N_2O also occurs. All the above reactions are exothermic and cause a temperature rise over the EnviNOx® reactor. The consumption of ammonia corresponds to the stoichiometric ratio given in the reaction equations above and does not differ significantly from the consumption of a conventional DeNOx unit.

- Technology employed by the project activity

Hu-Chems installed an EnviNOx® system for catalytic decomposition of NO_x and N_2O additionally to the equipment at NA manufacturing plant #5. The project activity reduces the GHG emissions, which would otherwise be released to the atmosphere, if the project was not implemented.

- Location of the EnviNOx® system

The EnviNOx® system is located in the tail gas stream at the position with the highest tail gas temperature in the NA production process.



Project boundary

(b) Information on the implementation and actual operation of the project activity, including relevant dates

The project has been fully implemented and is operated as per the registered PDD with all physical features in place (technology, project equipment, monitoring and metering equipment). The monitoring is done according to the applied methodology ACM0019, v1 and the monitoring plan. The EnviNOx® system at Hu-Chems´ NA plant #5 was installed in February 2013 and the starting date of normal operation of the project activity was 25/02/2013.

During this monitoring period several observations were made, which have been analysed in detail as described hereunder. It should be noted that actual hours as given in the Excel book attached to this MR are to be read as follows: e.g. 01/01/2020, 01:00 summarizes the hour from 01/01/2020 00:00 to 01:00. The time as given in the tables below is expressed in this regard.:

- Downtimes of the NA plant (and EnviNOx® system)

During below mentioned periods the EnviNOx® system was out of operation due to the given reason. No emission reductions are claimed during these downtimes.

Start Date & Time		End Date & Time		Observation & Reason
04/11/2019	01:00	06/11/2019	22:00	NA plant shutdown (Gauze change)

- Other relevant observations

During below mentioned periods observations related to the operation of the AMS have been made. It shall be noted that during these periods the NA plant as well as the EnviNOx® system were in normal operation and emission reductions have been conservatively determined as described in section *C.4 Systematic Measures* of this Monitoring Report (MR), fully in line with the applied methodology and the registered monitoring plan.

Start Date & Time		End Date & Time		Observation, Reason & Conservative Action
06/11/2019	22:00	07/11/2019	00:00	Observation: N_2O outlet concentration out of range Reason: No/low reducing agent's input to EnviNOx® unit after NA plant shutdown Conservative action: Recalculation of $v_{i,t,db}$ by equating N_2O outlet concentration with upper range of N_2O inlet concentration

19/11/2019	10:00	19/11/2019	15:00	Observation: Fluctuation of N_2O concentration Reason: Monthly health check by EMERSON Conservative action: Recalculation of $v_{i,t,db}$ by applying max. value of MP in acc. with ACM0019 v1 & the PDD
18/12/2019	10:00	18/12/2019	15:00	Observation: Fluctuation of N_2O outlet concentration Reason: Monthly health check by EMERSON Conservative action: Recalculation of $v_{i,t,db}$ by applying max. value of MP in acc. with ACM0019 v1 & the PDD
22/01/2020	09:00	22/01/2020	14:00	Observation: Fluctuation of N_2O outlet concentration Reason: Monthly health check & quarterly inspection by EMERSON Conservative action: Recalculation of $v_{i,t,db}$ by applying max. value of MP in acc. with ACM0019 v1 & the PDD

- Calibration and Maintenance

The maintenance methods and procedures as well as the calibration scheme for monitoring instruments used for CDM Monitoring have been incorporated as part of the ISO 9001 procedures, and form an integral part of the systems and procedures of Hu-Chems. QA/QC of monitoring equipment is in full compliance with the monitoring methodology and the monitoring plan of the registered PDD. Detailed information on exchange and/or calibration of instruments is mentioned under section *D.2*.

As further pointed out in section *C.3* the project participants have contracted EMERSON Process Management Korea (EPMK) to execute monthly onsite health checks and/or quarterly onsite inspection visits. System components, sampling system, analysers/measurement devices and the automated monitoring system required for the monitoring of the CDM project are covered by these contracts. Regular health check and inspection visit services, respectively, have been conducted by EPMK in November, December 2019 and January 2020, which attested good condition and availability of the system (i.e. sampling system, analyser as well as AMS hard- and software and total Delta V). Records of conducted maintenance activities and other performed services related to calibration and maintenance are available and submitted to the DOE for verification.

B.2. Post-registration changes

B.2.1. Temporary deviations from the registered monitoring plan, applied methodologies, standardized baselines or other methodological regulatory documents

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No such temporary deviations occurred in this monitoring period.

B.2.2. Corrections

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No such corrections occurred in this monitoring period, neither to any previous monitoring periods.

B.2.3. Changes to the start date of the crediting period

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No such changes occurred in this monitoring period.
Already before the start of this monitoring period, the start date of the crediting period has been changed from 01/09/2012 (indicated date in the PDD) to 25/02/2013 (start of regular operation of the EnviNOx® system). This change was approved by the UNFCCC Secretariat and made visible on the relevant project view page.

B.2.4. Inclusion of monitoring plan

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No such inclusions occurred in this or any previous monitoring period.

B.2.5. Permanent changes to the registered monitoring plan, or permanent deviation of monitoring from the applied methodologies, standardized baselines, or other methodological regulatory documents

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No such permanent changes occurred in this or any previous monitoring period.

B.2.6. Changes to project design

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No such changes occurred in this or any previous monitoring period.

B.2.7. Changes specific to afforestation or reforestation project activity

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N/A

SECTION C. Description of monitoring system

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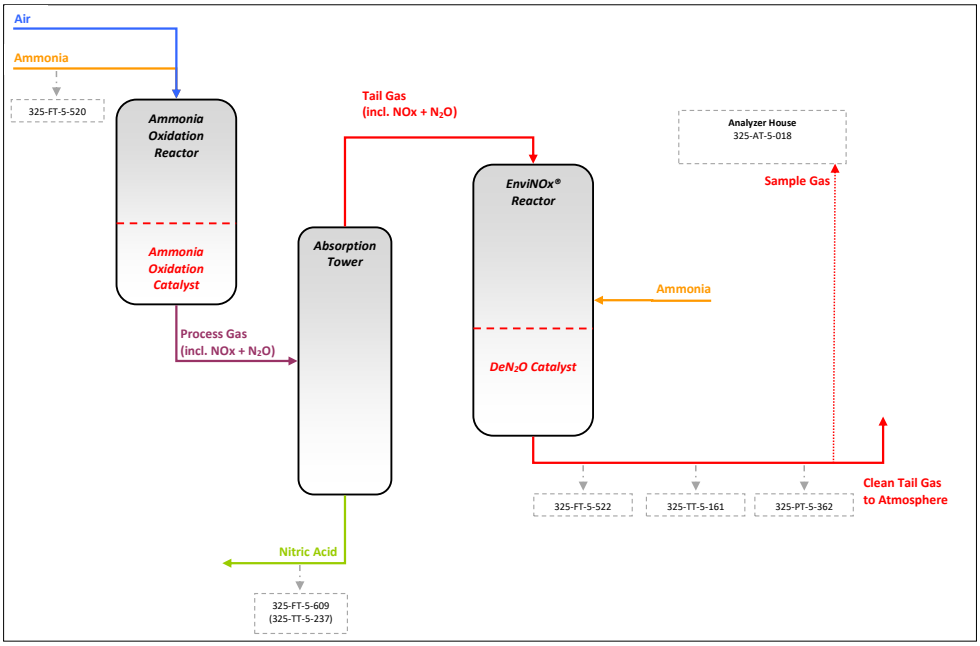
(1) Information flow

The instruments transmitters continuously provide a 4 – 20 mA analogue signal according to range and units configured. These signals are transmitted to I/O cards (analogue input/output cards) and collected by the Delta V processor. Resulting digital values are made available in the network to be further processed (e.g. in controller blocks, calculation of other variables) and are stored as raw data in the protected continuous historian server.

Modifications of the Delta V, which are protected by security levels by the supplier, are tracked by a Version Control Tool.

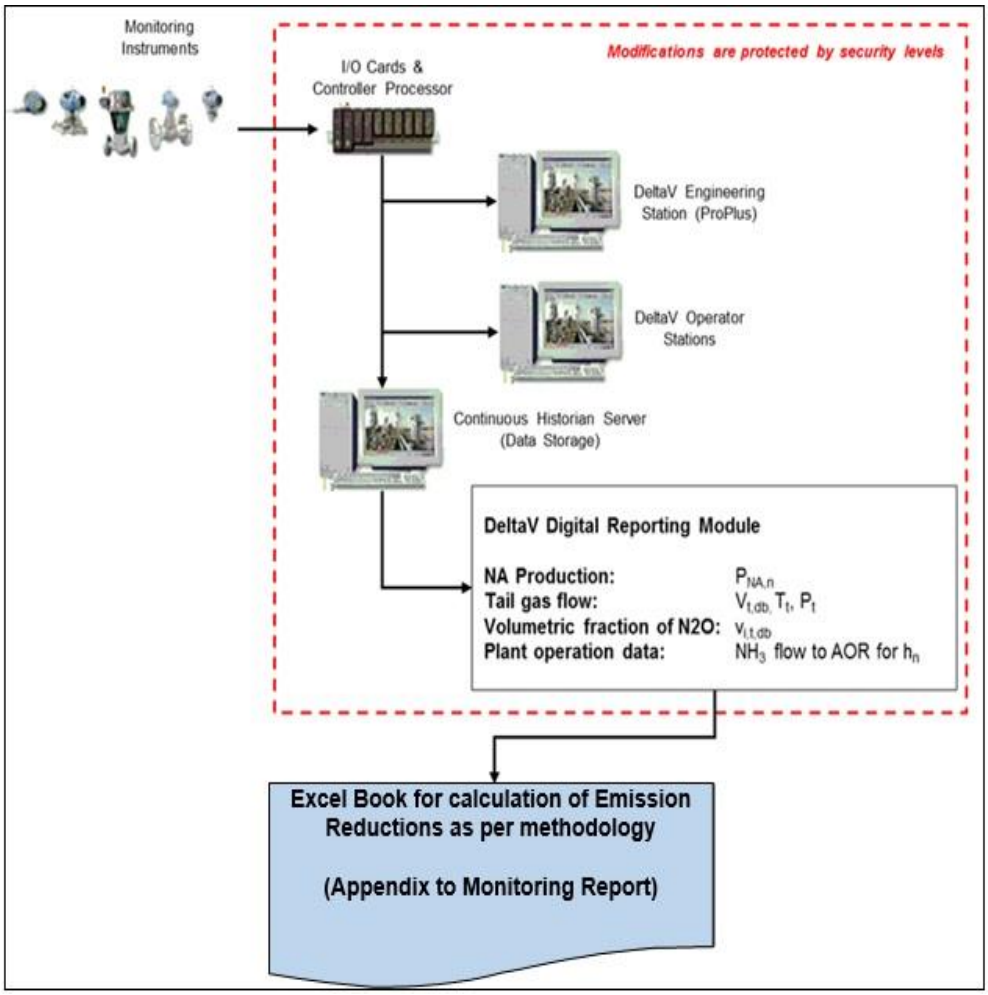


Line diagram of NA plant #5 & CDM project equipment

The reporting module of the Delta V system automatically generates aggregated daily reports based on the stored raw data from the continuous historian server. Daily reports contain following data relevant for calculation of claimed emission reductions (hourly values):

- NA production ($P_{NA,n}$)
- Operating parameter of the NA plant (NH_3 flow to AOR for determining h_n)
- Volumetric flow, temperature and pressure of the tail gas stream ($V_{t,db}$, T_t, P_t)
- Volumetric fraction of N_2O in the tail gas stream ($v_{i,t,db}$)

Relevant parameters as mentioned above are exported from the digitally available daily reports to an excel book (as attached to this MR) for presentation of required parameters and calculation of emission reductions according to formulae as required. Details on source of data of all relevant parameters can be found in the respective parameter tables in section *D*.



Information flow diagram

The information flow (including data generation, aggregation, recording, calculation and reporting) fully complies with the applied methodology ACM0019, v1, registered PDD and monitoring plan.

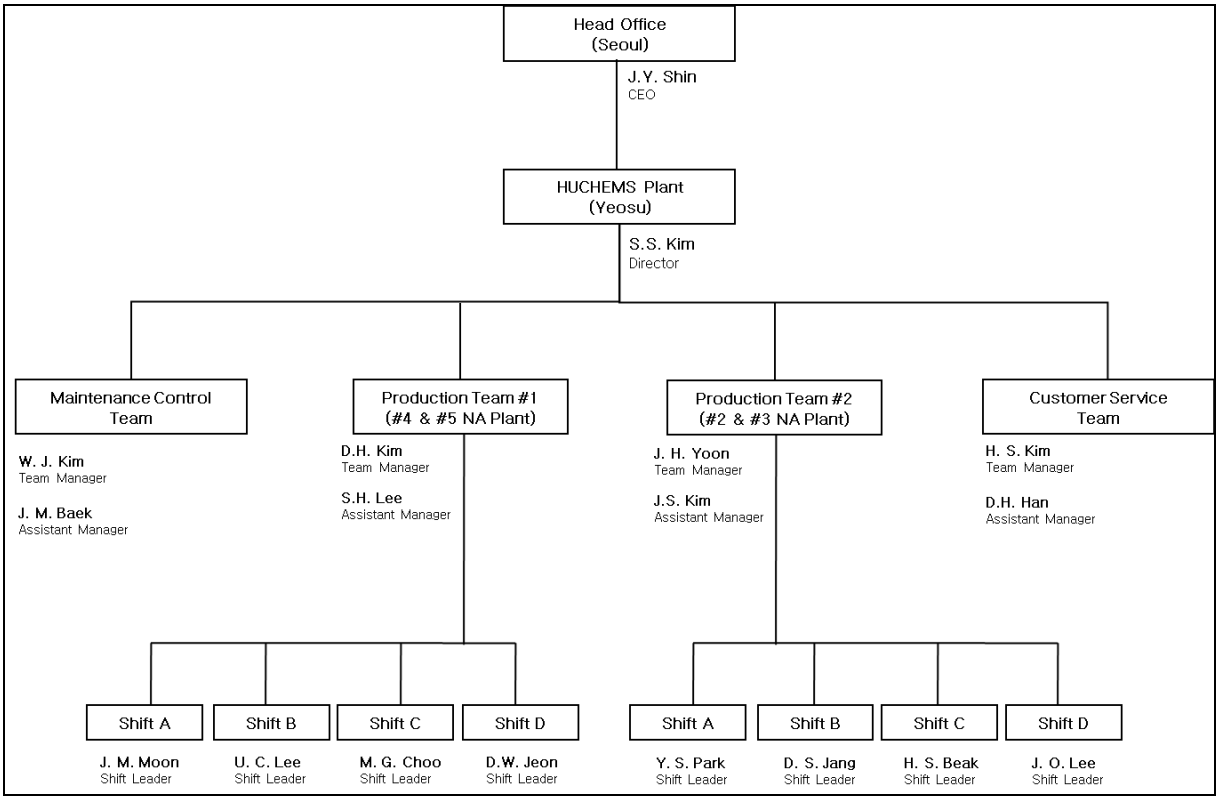
(2) Roles and responsibilities of personnel

Project operator is Hu-Chems Fine Chemical Corp. Hu-Chems operates several production units, which produce fine chemical products. Hu-Chems is ISO 9001 and 14001 certified and received the Korean safety and health management system certificate (KGS 18001 & OHSAS 18001). The company has received the Grand Prize of Korea Valuable Management Award in 2005, the President of Korea's medal in an Energy Saving Promote Contest as well as the Korean Marketing Best Award (KMAC) in 2004 as well as other awards.

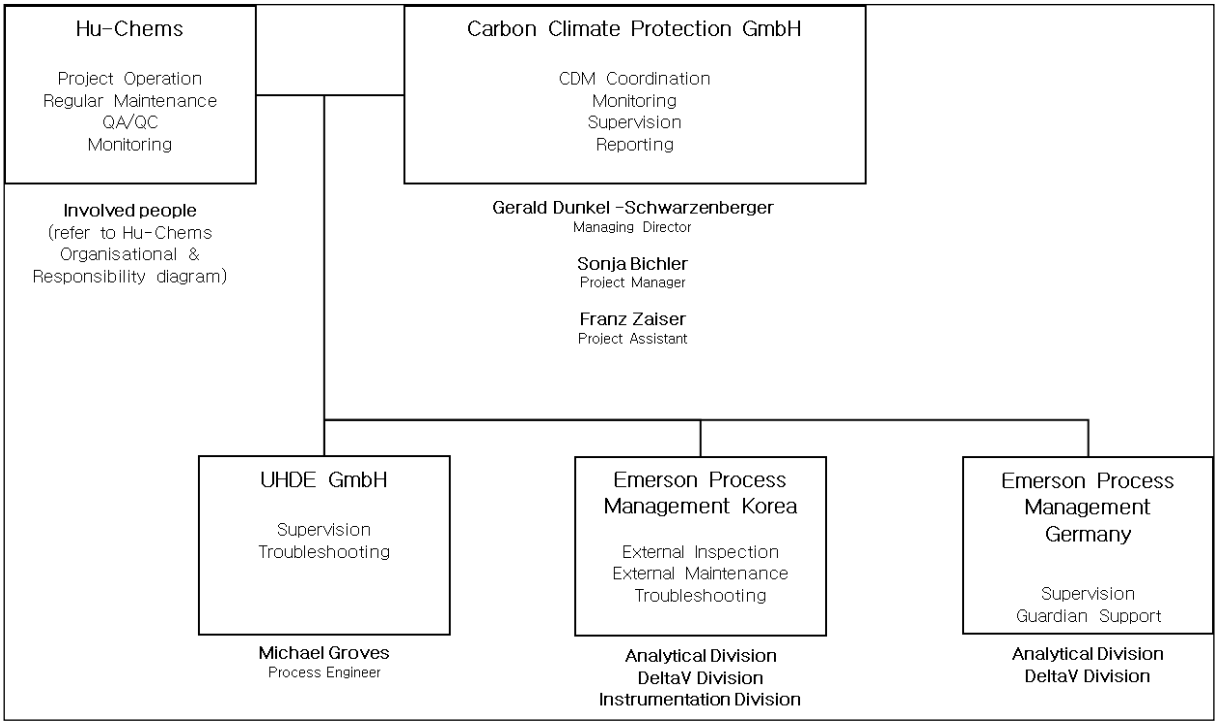
The operating and maintenance personal of the EnviNOx® system have been trained by the technology provider UHDE and the supplier of the digital process control system (Delta V, M/s. process management). Further, Hu-Chems has established internal training plans on the CDM procedures, operation of the EnviNOx® system and the monitoring system to train staff who is

assigned to the project during the crediting period. Training records are available and submitted to the DOE for verification.

CARBON Climate Protection GmbH (CCP) is responsible for supervision and checks of monitoring and reporting data. Furthermore, CCP prepares the MR and supporting documents and arranges additional double-checks of data and information. CCP gives its approval on the supporting documents as well as the MR before submitting it to the respective DOE for verification.



Hu-Chems organisational & responsibility diagram



CDM project: involved entities & project responsibilities

(3) Back up plans / Emergency procedures for monitoring system
Back up plan for measuring system / Periodically observation of automated monitoring system

- EnviNOx® – automatic DCS system

The EnviNOx® system is designed for automatic operation so that activities by the operation personnel are not required during normal operation. However, all alarms and any action taken by the operating personnel ("events") are automatically logged at the computer station (Alarm & Event List) of the DCS system. All alarm & event log sheets are exported and therefore digital available (Excel Files) and can be analysed and evaluated. Malfunction of system components is indicated on the operator console in the control room as an alarm. Occurrence of such an alarm requires the operator to immediately take measures to remedy the problem. This is done by informing Hu-Chems instrument department and CCP. It is then decided whether the problem can be fixed immediately by Hu-Chems or whether external support is required.

- Back up – regular onsite inspection

In addition to the automatic error indication by the automatic DCS system, the project operator Hu-Chems is carrying out visual onsite analyser cabinet inspections as well as related installations on a shift basis (3 times daily). Relevant data related to the analyser and sampling system are logged on the ISO Document HCSEF-448-1 "CDM Analyser/Reactor Check List". Actions are defined in case of abnormal observations. Further Hu-Chems is carrying out visual onsite checks of the EnviNOx® reactor and tail gas line as well as related installations once per day. Relevant data are logged on the ISO document HCSEF-448-1 "CDM Analyser/Reactor Check List". Actions are defined in case of abnormal observations.

- Back up – system support & preventive maintenance → Delta V

The Delta V automatic measuring system (AMS) used for plant operation and CDM monitoring was designed by the company EMERSON, the main supplier of components related to the monitoring system. In order to ensure maximum availability of the Delta V AMS and to prevent deficient handling of data, Hu-Chems has contracted EPMK to execute monthly onsite health checks and/or quarterly onsite inspection visits. Furthermore, a 24-hours emergency service and the 24-hours Delta V guardian support are covered by the contract. The contracted services comprise error diagnostics, measures for system stability, updates as well as preventive maintenance for the Delta V system and related technical components. Health check reports and inspection visit reports are available and submitted to the DOE for verification.

- Back up – support & preventive maintenance → EnviNOx® system, analyser, instruments

Main instruments for CDM monitoring (i.e. sampling system, continuously measuring non-dispersive-infrared analyser used for N_2O detection, etc.) were designed and supplied by the company EMERSON, the main supplier of components related to the monitoring system. In order to enable high levels of availability and accuracy of instruments, Hu-Chems has contracted EPMK to execute monthly onsite health checks and/or quarterly onsite inspection visits. Furthermore, a 24-hours emergency service is covered by the contract. The contracted regular, services comprise error diagnostics of analysers, component updates of the analysers and the sampling system, in-depth inspections of analysers and the sampling system as well as preventive maintenance services for the analysers, the sampling system and technical components/instruments of the CDM monitoring system. The contract was coming into force after the start-up period of the project activity. Exception handling for CDM monitoring instruments is covered by the 24-hours emergency service with guaranteed short-term onsite availability of EPMK experts. Health check reports and inspection visit reports are available and submitted to the DOE for verification.
Supervision is done based on the daily reports by the technology provider UHDE and EMERSON.

- Back up – calibration and general maintenance → instruments

In order to safeguard availability and accuracy of instruments, the project participants have mandated EPMK to execute regular calibration services and regular general maintenance services for all related monitoring instruments on a regular basis (adapted to the annual shutdown and

maintenance schedule of the NA plant). The service inter alia consists, besides calibrations, of hardware and connection maintenance as well as software checks and error diagnostics. Service reports of performed services and calibration records are submitted to the DOE for verification.

- Back up – onsite spare part stock

As further important contribution to the availability of the monitoring system (e.g. in the event of failure of the measuring equipment), Hu-Chems stores a comprehensive range of spare parts at the project site. The types and amount of stored spare parts meet the recommendations of the supplier. The majority of spare part types are re-purchased after consumption some other spare part types are re-purchased after their stock has reached a defined reorder level. In both cases Hu-Chems is following the recommendation of the supplier. The spare part stock includes inter alia filter elements, valves and pressure controllers for the sample handling system and filter elements, analysis cells (crucial part for analysers), flow sensors and several electrical parts for the analysers. An overview on available parts is made available to the DOE for verification.

- Back up – certified standard gases

Pressure levels of standard gases used for the regular, automatic calibration of the analyser are constantly monitored during the regular onsite inspection. Spare bottles of test gases are purchased in proper time. Specifications and certification of test gases are made available to the DOE for verification.

- Back up – procedures

In addition to the quality control and quality assurance procedures according to the Hu-Chems quality management system and in order to avoid possible failures of the automated monitoring system, procedures are implemented for the project activity. The approach was to ensure immediate response to such special events in the system. The following table summarizes the periodical observations of the AMS:

Organiza-tion	Action	Frequency	Output
Delta V	Events & Alarm List	Continuously	Txt- & Excel files
Hu-Chems	Shift Inspection	3 times per day	Protocol/Check List
Hu-Chems	Daily Inspection	Daily	Protocol/Check List
UHDE	Supervision	Daily	Plausibility check
EPMK	Health check of AMS (Hard- & Software) and Health check of Sampling & Analyser system	Monthly	Health Check Report
EPMK	Health check of AMS (Hard- & Software) and Inspection of Sampling & Analyser system	Quarterly	Inspection Report
EPMK	General Maintenance & Calibration Service of instruments	Regularly, adopted to annual shutdown schedule of plant	Service Report & Calibration records

All resulting documents are analysed and evaluated by Hu-Chems under support of CCP. In case of any upcoming problem or failure of the EnviNOx® system and/or the automated monitoring system Hu-Chems immediately takes measure to remedy the problem. The provider of the AMS is available 24 hours a day via hotline. Furthermore, EPMK is committed to be onsite within 24 hours.

(4) Systematic measures for QA for monitoring data during AMS down times

In order to ensure data quality, back up plans (see above) are in place. In case of (scheduled or unscheduled) AMS down times (or parts thereof), demonstration of normal plant operation and estimation of emission reductions are conservatively conducted according to the methodology and the monitoring plan. Related data and documents are provided to the DOE for verification, if applicable in the covered monitoring period.

SECTION D. Data and parameters

D.1. Data and parameters fixed ex ante

Data/Parameter	$EF_{default,y}$
Unit	$kgN_2O/tHNO_3$
Description	Default N_2O baseline emissions factor in the calendar year y of the monitoring period n
Source of data	According to the PDD / ACM0019 v1
Value(s) applied	Year: Emission factor (kgN_2O/HNO_3) 2012: 3.90 2013: 3.70 2014: 3.50 2015: 3.40 2016: 3.20 2017: 3.00 2018: 2.80 2019: 2.70 2020: 2.50 2021: 2.50 2022: 2.50 …: … Year n: 2.50
Choice of data or measurement methods and procedures	Specified in the methodology
Purpose of data/parameter	Calculation of baseline emissions
Additional comments	The decrease in the value for the baseline emission factor over time is to reflect the technological development.

Data/Parameter	GWP_{N2O}
Unit	tCO_2e/tN_2O
Description	Global warming potential of N_2O valid for the commitment period
Source of data	According to the PDD / ACM0019 v1
Value(s) applied	298
Choice of data or measurement methods and procedures	None
Purpose of data/parameter	Calculation of project emissions
Additional comments	Valid from 01/01/2013 onwards as per relevant CDM EB decision. The value applicable before that date (310 tCO_2e/tN_2O) is not applicable to this project activity, since physical emission reduction has started in February 2013.

Parameters from "Tool to determine the mass flow of a greenhouse gas in a gaseous stream"

Data/Parameter	R_u
Unit	$Pa.m^3/kmol.K$
Description	Universal ideal gases constant
Source of data	According to the PDD / "Tool to determine the mass flow of a greenhouse gas in a gaseous stream"
Value(s) applied	8,314
Choice of data or measurement methods and procedures	Specified in the tool
Purpose of data/parameter	Calculation of project emissions
Additional comments	-

Data/Parameter	MM_i
Unit	kg/kmol
Description	Molecular mass of greenhouse gas i
Source of data	According to the PDD / "Tool to determine the mass flow of a greenhouse gas in a gaseous stream"
Value(s) applied	44.02
Choice of data or measurement methods and procedures	Specified in the tool
Purpose of data/parameter	Calculation of project emissions
Additional comments	Value is applicable for N_2O.

D.2. Data and parameters monitored

Data/Parameter	$P_{NA,n}$
Unit	$tHNO_3$
Description	Nitric acid produced in the monitoring period n
Measured/calculated/ default	Measured
Source of data	Production reports (based on measurements from PP) NA flow and density are measured with a coriolis flowmeter, temperature with a temperature measurement and concentration is determined based on measured parameters. Values are sent to the DCS (control room), and the NA production (as 100% HNO_3) is calculated based on mass flow and HNO_3 concentration. Final production values are exported in production reports through the Delta V System. Please refer to section *C.1 Information Flow* of this MR.
Value(s) of monitored parameter	**114,831** An excel book containing recorded hourly values is attached to this MR.
Monitoring equipment	Meter location: Located in the NA line, downstream of the absorption tower. **325-FT-5-609** Type: Coriolis flow meter Accuracy class: ± 0.10% of rate Calibration frequency: 60 months Serial number: 14739187 Date of last calibration: 09/05/2019 (Validity: 08/05/2024) **325-TT-5-237** Type: Temperature transmitter Accuracy class: ±0.14°C + (±0.02% of span) Calibration frequency: 24 months Serial number: C2M408098 Date of last calibration: 09/05/2019 (Validity: 08/05/2021)
Measuring/reading/recording frequency	Measuring: Continuously Reading: Every 10 seconds Recording: Hourly
Calculation method (if applicable)	N/A
QA/QC procedures	The maintenance methods and procedures for monitoring instruments used for CDM Monitoring have been incorporated as part of the ISO 9001 procedures of Hu-Chems. Accordingly, calibration and maintenance are part of regular QA/QC of the NA plant (please refer to section *C.3*). Please refer also to section *C.3. Back Up plans / Emergency procedures for monitoring system* of this MR and respective sub-items *Back Up Plans for measuring systems / Periodically observation of the AMS*.
Purpose of data/parameter	Calculation of baseline emissions

Additional comments	Parameter is automatically monitored.

Data/Parameter	**h_n**
Unit	N/A
Description	Number of hours of operation in a monitoring period n
Measured/calculated/ default	Measured
Source of data	Measuring device (Please refer to monitoring equipment below and to section *C.1 Information Flow* of this MR.) The flow of NH_3 to the ammonia oxidation reactor indicates the operational status. In case, the volume flow of NH_3 to the ammonia oxidation reactor lies above the threshold of 500 Nm^3/h during an hour, the reactor is considered in operation. This check is traceably incorporated in the excel book attached to this MR.
Value(s) of monitored parameter	**2,283** An excel book containing recorded hourly values is attached to this MR.
Monitoring equipment	Meter location: Located in the ammonia supply line, upstream of the ammonia oxidation reactor. **325-FT-5-520** Type: Coriolis flow meter Accuracy class: ± 0.35% Calibration frequency: 60 months Serial number: 14288859 Date of last calibration: 09/05/2019 (Validity: 08/05/2024)
Measuring/reading/recording frequency	Measuring: Continuously Reading: Every 10 seconds Recording: Hourly
Calculation method (if applicable)	N/A
QA/QC procedures	The maintenance methods and procedures for monitoring instruments used for CDM Monitoring have been incorporated as part of the ISO 9001 procedures of Hu-Chems. Accordingly, calibration and maintenance are part of regular QA/QC of the NA plant (please refer to section *C.3*). Please refer to section *C.3. Back Up plans / Emergency procedures for monitoring system* of this MR and respective sub-items *Back Up Plans for measuring systems* / *Periodically observation of the AMS*.
Purpose of data/parameter	Calculation of baseline and project emissions
Additional comments	N/A

Parameters from "Tool to determine the mass flow of a greenhouse gas in a gaseous stream"

Data/Parameter	**$V_{t,db}$**
Unit	m^3 dry gas/h
Description	Volumetric flow of the gaseous stream in time interval t on a dry basis
Measured/calculated/ default	Measured
Source of data	Measuring device (Please refer to monitoring equipment below and to section *C.1 Information Flow* of this MR.)
Value(s) of monitored parameter	**258,709** The value represents an average over the MP. An excel book containing recorded hourly values is attached to this MR.

Monitoring equipment	Meter location: Located in the stack at the end of the tail gas line. **325-FT-5-522** Type: Differential pressure transmitter Accuracy class: < 2.0% of measuring range Calibration frequency: 60 months (QAL2 reference measurement) Serial number: 1230726 Date of last QAL 2: 23/08/2019 – 26/08/2019 (Validity: 22/08/2024)
Measuring/reading/recording frequency	Measuring: Continuously Reading: Every 1 second Recording: Hourly
Calculation method (if applicable)	N/A
QA/QC procedures	The maintenance methods and procedures for monitoring instruments used for CDM Monitoring have been incorporated as part of the ISO 9001 procedures of Hu-Chems. Accordingly, calibration and maintenance are part of regular QA/QC of the NA plant (please refer to section *C.3*). QA/QC procedures consider requirements per EN 14181. Calibration against a primary device provided by an independent accredited laboratory follows EN 14181 requirements (QAL2 reference measurement). Please refer also to section *C.3. Back Up plans / Emergency procedures for monitoring system* of this MR and respective sub-items *Back Up Plans for measuring systems / Periodically observation of the AMS*.
Purpose of data/parameter	Calculation of project emissions
Additional comments	N/A

Data/Parameter	$v_{i,t,db}$
Unit	m^3 gas i/m^3 dry gas
Description	Volumetric fraction of greenhouse gas i in a time interval t on a dry basis
Measured/calculated/ default	Measured
Source of data	Measuring device (Please refer to monitoring equipment below and to section *C.1 Information Flow* of this MR.)
Value(s) of monitored parameter	**$2.55*10^{-5}$** The value represents an average over the MP. An excel book containing recorded hourly values is attached to this MR.
Monitoring equipment	Meter location: Sample take-off is located in the stack at the end of the tail gas line and leads (via sample gas line) to the locked analyser house where analyser and standard gases for calibrations are installed. **325-AT-5-018** Type: NDIR Analyser Accuracy class: ±1% (zero/span) Calibration frequency: 60 months (QAL2 reference measurement) Serial number: 393709203380368 Date of last QAL 2: 23/08/2019 – 26/08/2019 (Validity: 22/08/2024)
Measuring/reading/recording frequency	Measuring: Continuously Reading: Every 1 second Recording: Hourly
Calculation method (if applicable)	N/A

QA/QC procedures	The maintenance methods and procedures for monitoring instruments used for CDM Monitoring have been incorporated as part of the ISO 9001 procedures of Hu-Chems. Accordingly, calibration and maintenance are part of regular QA/QC of the NA plant (please refer to section *C.3*). QA/QC procedures consider requirements per EN 14181. Calibration against a primary device provided by an independent accredited laboratory follows EN 14181 requirements (QAL2 reference measurement). EPMK has been mandated to conduct monthly analyser health checks and quarterly inspection checks to ensure good instrument condition. Please refer to section *C.3. Back Up plans / Emergency procedures for monitoring system* of this MR and respective sub-items *Back Up Plans for measuring systems / Periodically observation of the AMS*.
Purpose of data/parameter	Calculation of project emissions
Additional comments	N/A

Data/Parameter	**T_t**
Unit	K
Description	Temperature of the gaseous stream in time interval t
Measured/calculated/ default	Measured
Source of data	Measuring device (Please refer to monitoring equipment below and to section *C.1 Information Flow* of this MR.)
Value(s) of monitored parameter	**409.97** The value represents an average over the MP. An excel book containing recorded hourly values is attached to this MR.
Monitoring equipment	Meter location: Located in the stack at the end of the tail gas line **325-TT-5-161** Type: Temperature transmitter Accuracy class: ±(0.30 + 0.0050|t|) Calibration frequency: 24 months Serial number: 1230727 Date of last calibration: 09/05/2019 (Validity: 08/05/2021)
Measuring/reading/recording frequency	Measuring: Continuously Reading: Every 1 second Recording: Hourly
Calculation method (if applicable)	N/A
QA/QC procedures	The maintenance methods and procedures for monitoring instruments used for CDM Monitoring have been incorporated as part of the ISO 9001 procedures of Hu-Chems. Accordingly, calibration and maintenance are part of regular QA/QC of the NA plant (please refer to section *C.3*). Please refer to section *C.3. Back Up plans / Emergency procedures for monitoring system* of this MR and respective sub-items *Back Up Plans for measuring systems / Periodically observation of the AMS*.
Purpose of data/parameter	Calculation of project emissions
Additional comments	N/A

Data/Parameter	**P_t**
Unit	Pa
Description	Pressure of the gaseous stream in time interval t
Measured/calculated/ default	Measured
Source of data	Measuring device (Please refer to monitoring equipment below and to section *C.1 Information Flow* of this MR.)

Value(s) of monitored parameter	**101,287** The value represents an average over the MP. An excel book containing recorded hourly values is attached to this MR.
Monitoring equipment	Meter location: Located in the stack at the end of the tail gas line. **325-PT-5-362** Type: Pressure transmitter Accuracy class: < 2.0% of measuring range Serial number: 1230980 Calibration frequency: Monthly Calibration has been conducted monthly according to the monitoring plan. The first calibration relevant for this MP was on 04/10/2019. Validity is always until the next month after calibration.
Measuring/reading/recording frequency	Measuring: Continuously Reading: Every 1 second Recording: Hourly
Calculation method (if applicable)	N/A
QA/QC procedures	The maintenance methods and procedures for monitoring instruments used for CDM Monitoring have been incorporated as part of the ISO 9001 procedures of Hu-Chems. Accordingly, calibration and maintenance are part of regular QA/QC of the NA plant (please refer to section *C.3*). Please refer to section *C.3. Back Up plans / Emergency procedures for monitoring system* of this MR and respective sub-items *Back Up Plans for measuring systems / Periodically observation of the AMS*.
Purpose of data/parameter	Calculation of project emissions
Additional comments	N/A

Data/Parameter	**$C_{H2O,t,db,n}$**
Unit	mg H_2O/m^3 dry gas
Description	Moisture content of the gaseous stream at normal conditions in time interval t
Measured/calculated/ default	Measured
Source of data	Measurements according to the USEPA CF42 method 4 – Gravimetric determination of water content
Value(s) of monitored parameter	**6,000** (equivalent to 0.006 kg H_2O/m^3 dry gas)
Monitoring equipment	As per USEPA CF42 method 4 – Gravimetric determination of water content (performed by the qualified, external entity)
Measuring/reading/recording frequency	As per the PDD measurements coincide with the calibration of the flow-meter to measure the volume flow of stack gas (i.e. QAL 2 reference measurements). Last repeated measurements were conducted during last QAL 2.
Calculation method (if applicable)	N/A
QA/QC procedures	According to standard USEPA CF42 method 4
Purpose of data/parameter	Calculation of project emissions

Additional comments	As per the applied "Tool to determine the mass flow of a greenhouse gas in a gaseous stream" flow and volumetric fraction may be measured on a dry or wet basis. The tool covers possible measurement combinations, providing 6 different calculation options to determine the mass flow of a particular greenhouse gas (option A to F). As described in the PDD, the option chosen for this project is option A requiring to demonstrate that the gaseous stream is dry, whereas the tool suggests two ways to do this: (a) Measure the moisture content of the gaseous stream ($C_{H2O,t,db,n}$) and demonstrate that this is less or equal to 0.05 kg H_2O/m^3 dry gas; or (b) Demonstrate that the temperature of the gaseous stream (T_t) is less than 60°C (333.15 K) at the flow measurement point. In the case of this project activity, the first way (a) has been chosen. The measured value as described above shows that the moisture content of the gaseous stream is below the threshold value of 0.05 kg H_2O/m^3 dry gas.

D.3. Implementation of sampling plan

>>
No sampling plan is applicable to this project activity.

SECTION E. Calculation of emission reductions or net anthropogenic removals

All references to used formulae and methods follow ACM0019 v1, applicable tools and the project documentation (PDD, monitoring plan) and are transparently shown in the excel book attached to this MR. This excel book contains recorded monitored data, a comprehensive calculation of baseline emissions, project emissions and emission reductions with actual values (formulae of calculation are shown in the spreadsheet cells for ease of assessment).

E.1. Calculation of baseline emissions or baseline net removals

>>
Baseline emissions are calculated by the following equation:

$$BE_n = P_{NA,n} * EF_{BL,N2O,n} * GWP_{N2O} * 10^{-3}$$

Where:

BE_n	=	Baseline emissions in monitoring period *n* (tCO_2e)
$P_{NA,n}$	=	Nitric acid produced in the monitoring period *n* ($tHNO_3$)
$EF_{BL,N2O,n}$	=	Baseline N_2O emission factor for nitric acid production in the monitoring period *n* (kgN_2O / $tHNO_3$)
GWP_{N2O}	=	Global Warming Potential of N_2O valid for the commitment period

The values for the present period are:

BE_n *)	**$P_{NA,n}$**	**$EF_{BL,N2O,n}$**	**GWP_{N2O}**
tCO_2e	$tHNO_3$	kgN_2O / $tHNO_3$	tCO_2e / tN_2O
89,978	114,831	2.70 (2019) 2.50 (2020)	298

**) Value is conservatively rounded down.*

Determination of the baseline N_2O emission factor

The baseline N_2O emission factor in the monitoring period n ($EF_{BL,N2O,n}$) is determined as a default emission factor $EF_{default,y}$ given for each calendar year y (available from the PDD / methodology):

$$EF_{BL,N2O,n} = EF_{default,y}$$

$EF_{default,y}$ is 2.70 $kgN_2O/tHNO_3$ for the year 2019 and 2.50 $kgN_2O/tHNO_3$ for the year 2020 (refer to the parameter tables under section *D.1*).

E.2. Calculation of project emissions or actual net removals

>>

Project emissions are calculated by the following equation:

$$PE_n = PE_{N2O,n} + PE_{CO2,tertiary,n}$$

Where:

PE_n	=	Project emissions in monitoring period *n* (tCO_2e)
$PE_{N2O,n}$	=	Project emissions of N_2O from the project plant in monitoring period *n* (tCO_2e)
$PE_{CO2,tertiary,n}$	=	Project emissions of CO_2 from the operation of the tertiary N_2O abatement facility in monitoring period *n* (tCO_2)

As clearly described in the PDD, the project emissions of CO_2 from the operation of the tertiary N_2O abatement facility ($PE_{CO2,tertiary,n}$) are set to zero due to the absence of this emission source in the project activity.

The values for the present period are:

PE_n	**$PE_{N2O,n}$**	**$PE_{CO2,tertiary,n}$**
tCO_2e	tCO_2e	tCO_2e
5,759	5,759	0

Project emissions of N_2O from the project plant ($PE_{N2O,n}$) are calculated by the following equation:

$$PE_{N2O,n} = (Q_{N2O,tailgas,n} + Q_{N2O,by-pass,n}) * GWP_{N2O}$$

Where:

$PE_{N2O,n}$	=	Project emissions of N_2O from the project plant in monitoring period n (tCO_2e)
$Q_{N2O,tail\ gas,n}$	=	Amount of N_2O released through the tail gas of the project plant to the atmosphere in monitoring period n (tN_2O)
$Q_{N2O,by-pass,n}$	=	Amount of N_2O released through the by-pass to a tertiary N_2O abatement system to the atmosphere in monitoring period n (tN_2O)
GWP_{N2O}	=	Global Warming Potential of N_2O valid for the commitment period

As clearly described in the PDD, the amount of N_2O released through the by-pass to a tertiary N_2O abatement system to the atmosphere ($Q_{N2O,by-pass,n}$) is set to zero due to the absence of this emission source in the project activity.

The values for the present period are:

$PE_{N2O,n}$ **)	**$Q_{N2O,tailgas,n}$**	**$Q_{N2O,by-pass,n}$**	**GWP_{N2O}**
tCO_2e	tN_2O	tN_2O	tCO_2e / tN_2O
5,759	19.32	0	298

***) Value is conservatively rounded up.*

Determination of $Q_{N2O,tail\ gas,n}$

The amount of N_2O released through the tail gas of the project plant to the atmosphere ($Q_{N2O,tail\ gas,n}$) is "Tool to determine the mass flow of a greenhouse gas in a gaseous stream", whereas following provisions apply:

- Throughout the crediting periods of the project activity, the N_2O concentration and volume or mass flow of the tail gas are to be monitored continuously. The monitoring system is to be installed and maintained throughout the crediting period based on the European Norm 14181, or any more recent update of that standard;
- The monitoring system should provide separate hourly average values for the N_2O concentration and the volume or mass flow of the tail gas based on 2 seconds (or shorter) interval readings that are recorded and stored electronically. These N_2O data sets shall be identified by means of a unique time / date key indicating when exactly the values were observed;
- The correction factors derived from the calibration curve of the QAL 2 audit for the monitoring components as determined during the QAL 2-test in accordance with EN14181 must be applied to both the N_2O concentration and the volume or mass flow of the tail gas. This can either be applied automatically to the raw data recorded by the data storage system at the plant or it can be applied to the calculated hourly averages as part of the calculation of project emissions;
- If data for either the N_2O concentration or the volume or mass flow of the tail gas are not available for more than 1/3 of any hour while the plant was in operation, the value for that hour shall be replaced with the maximum value of N_2O concentration or volume or mass flow of the tail gas observed during the monitoring period. If data for neither the N_2O concentration nor the volume or mass flow of the tail gas are available for more than 1/3 of any hour while the plant was in operation, the maximum value of mass flow of N_2O calculated during the monitoring period shall be applied to any such hour. Values observed during five operating hours before and after a plant start-up and shut-down shall not be used for the determination of the maximum values;

The monitoring system as well as calculations and consideration of QAL 2 calibration curve are fully implemented, the monitoring system are in full compliance with these provisions.

As furthermore stated in the PDD following the "Tool to determine the mass flow of a greenhouse gas in a gaseous stream" the mass flow of greenhouse gas i in the gaseous stream in time interval t ($F_{i,t}$) is calculated based on measurements of

(a) the total volume flow or mass flow of the gas stream;
(b) the volumetric fraction of the gas in the gaseous stream; and
(c) the gas composition and water content.

The flow and volumetric fraction may be measured on a dry basis or wet basis. The tool covers the possible measurement combinations, providing six different calculation options to determine the mass flow of a particular greenhouse gas (Option A to F). As described in the PDD the option chosen for this project activity is Option A requiring to demonstrate that the gaseous stream is dry, whereas the tool suggests two ways to do this:

(a) Measure the moisture content of the gaseous stream ($C_{H2O,t,db,n}$) and demonstrate that this is less or equal to 0.05 kg H_2O/m^3 dry gas; or
(b) Demonstrate that the temperature of the gaseous stream (T_t) is less than 60°C (333.15 K) at the flow measurement point.

In the case of this project activity option (a) was chosen. Repeated measurements in line with the USEPA CF42 method 4 were conducted during last QAL 2 and showed that the moisture content of the gaseous stream ($C_{H2O,t,db,n}$) is clearly below the threshold value of 0.05 kg H_2O/m^3 dry gas.

Summarized, $Q_{N2O,tailgas,n}$ is calculated as per the equation below following Option A of the tool as mentioned above:

$$Q_{N2O,tailgas,n} = \sum_{h=1}^{h=h_n} F_{N2O,tailgas,h} * 10^{-3}$$

Where:

$Q_{N2O,tail\ gas,n}$	=	Amount of N_2O released through the tail gas of the project plant to the atmosphere in monitoring period *n* (tN_2O)
$F_{N2O,tail\ gas,h}$[4]	=	Mass flow of N_2O in the gaseous stream of the tail gas in the hour *h* (kgN_2O/h)
h_n	=	Number of hours in monitoring period *n* during which the plant was in operation

The result of $Q_{N2O,tailgas,n}$ over the monitoring period is basically the sum over hourly values of calculated mass flow of N_2O ($F_{N2O,tailgas,h}$).

The values for the present period are:

$Q_{N2O,tailgas,n}$	**$\sum F_{N2O,tailgas,h}$**
tN_2O	kgN_2O
19.32	19,322

The hourly values of $F_{N2O,tailgas,h}$ are calculated as per following formulae:

$$F_{i,t} = V_{t,db} * v_{i,t,db} * \rho_{i,t}$$

With

$$\rho_{i,t} = \frac{P_t * MM_i}{R_u * T_t}$$

Where:

$F_{i,t}$	=	Mass flow of greenhouse gas i in the gaseous stream in time interval t (kg gas/h)
$V_{t,db}$	=	Volumetric flow of the gaseous stream in time interval t on a dry basis (m^3 dry gas/h)
$v_{i,t,db}$	=	Volumetric fraction of greenhouse gas i in the gaseous stream in a time interval t on a dry basis (m^3 gas i/m^3 dry gas)
$\rho_{i,t}$	=	Density of greenhouse gas i in the gaseous stream in time interval t (kg gas i/m^3 gas i)
P_t	=	Absolute pressure of the gaseous stream in time interval t (Pa)
MM_i	=	Molecular mass of greenhouse gas i (kg/kmol)
R_u	=	Universal ideal gases constant (Pa.m^3/kmol.K)
T_t	=	Temperature of the gaseous stream in time interval t (K)

For calculation of $F_{N2O,tailgas,h}$ as well as application of calibration curves or corrections to data in case of observations and events (as described in section *B.1.*) on an hourly basis please refer to the excel book, which is attached to this MR.

E.3. Calculation of leakage emissions

>>

According to the methodology any leakage emissions sources are deemed to be negligible.

[4] $F_{N2O,tail\ gas,h}$ corresponds to the parameter $F_{i,t}$ of the "Tool to determine the mass flow of a greenhouse gas in a gaseous stream".

E.4. Calculation of emission reductions or net anthropogenic removals

	Baseline GHG emissions or baseline net GHG removals (t CO_2e)	Project GHG emissions or actual net GHG removals (t CO_2e)	Leakage GHG emissions (t CO_2e)	GHG emission reductions or net anthropogenic GHG removals (t CO_2e)		
				Before 01/01/2013	From 01/01/2013	Total amount
Total	89,978	5,759	0	N/A	84,219	84,219

**) Note that actual calculation of emissions reductions as presented in chapters E.1 to E.4 has been done in the excel book. Rounding in chapters E.1 to E.4 has just been done for ease of presentation. Please note that conservative rounding has been made for final ER_y calculation only. This can be traced in the excel book attached to this MR.*

E.5. Comparison of emission reductions or net anthropogenic removals achieved with estimates in the registered PDD

Amount achieved during this monitoring period (t CO_2e)	Amount estimated ex ante for this monitoring period in the PDD (t CO_2e)
84,219	77,933

E.5.1. Explanation of calculation of "amount estimated ex ante for this monitoring period in the PDD"

>>

The following data were applied for the ex-ante calculation of emission reduction:

- Nameplate capacity: 1,150 MTPD HNO_3
- Yearly operation: 345 days
- Estimated yearly nitric acid production: 396,750 tHNO_3/a;
- Estimated tail gas flow rate: 223,260 m^3 dry gas/h;
- N_2O outlet concentration of tail gas flow: 44 ppmv;
- No fossil fuels are used for the operation of the tertiary N_2O abatement facility;

For year 2019 the PDD states an estimated emission reduction of 298,797 tCO_2e and for year 2020 274,198 tCO_2e, corresponding estimation of "Amount estimated ex ante for this MP in the PDD" (for 98 days): **77,933 tCO_2e**

E.6. Remarks on increase in achieved emission reductions

>>

During this monitoring period the actual emission reductions are higher than the corresponding ex-ante estimation according to the PDD (based on conservative assumptions) due to the following:

- Higher efficiency of the EnviNOx® unit during this MP compared to the ex-ante estimation, which came up with lower project emissions;
- Lower N_2O emissions of the EnviNOx® unit during this MP compared to the ex-ante estimation;
- Less NA plant shutdowns or downtimes of the EnviNOx® unit during this MP compared to the ex-ante estimation;
- Moreover, it is noticed that the baseline emissions in this MP are higher than compared to the ex-ante estimation.

E.7. Remarks on scale of small-scale project activity

>>
N/A

Appendix 1. Excel book for claiming Emission Reductions

An excel book containing monitored data and calculations of baseline emissions, project emissions and emission reductions was submitted to the DOE:

HUC-6637_MP#18_UNFCCC_v1.0_CONFIDENTIAL.xlsx

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Document information

Version	*Date*	*Description*
07.0	31 May 2019	Revision to: • Ensure consistency with version 02.0 of the “CDM project standard for project activities” (CDM-EB93-A04-STAN); • Add a section on remarks on the observance of the scale limit of small-scale project activity during the crediting period; • Add "changes specific to afforestation or reforestation project activity" as a possible post-registration changes; • Clarify the reporting of net anthropogenic GHG removals for A/R project activities between two commitment periods; • Make editorial improvements.
06.0	7 June 2017	Revision to: • Ensure consistency with version 01.0 of the “CDM project standard for project activities” (CDM-EB93-A04-STAN); • Make editorial improvements.
05.1	4 May 2015	Editorial revision to correct version numbering.
05.0	1 April 2015	Revisions to: • Include provisions related to delayed submission of a monitoring plan; • Provisions related to the Host Party; • Remove reference to programme of activities; • Overall editorial improvement.

Version	*Date*	*Description*
04.0	25 June 2014	Revisions to: • Include the Attachment: Instructions for filling out the monitoring report form (these instructions supersede the "Guideline: Completing the monitoring report form" (Version 04.0)); • Include provisions related to standardized baselines; • Add contact information on a responsible person(s)/ entity(ies) for completing the CDM-MR-FORM in A.6 and Appendix 1; • Change the reference number from *F-CDM-MR* to *CDM-MR-FORM*; • Editorial improvement.
03.2	5 November 2013	Editorial revision to correct table in page 1.
03.1	2 January 2013	Editorial revision to correct table in section E.5.
03.0	3 December 2012	Revision required to introduce a provision on reporting actual emission reductions or net GHG removals by sinks for the period up to 31 December 2012 and the period from 1 January 2013 onwards (EB 70, Annex 11).
02.0	13 March 2012	Revision required to ensure consistency with the "Guidelines for completing the monitoring report form" (EB 66, Annex 20).
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