



Assessment of the Greenhouse Gas Mitigation Potential of the Nitric Acid Sector in India

Final Report

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Executive Summary

Nitrous oxide (N₂O) is released as a by-product during nitric acid manufacturing process and has a Global Warming Potential (GWP) of 264 (Intergovernmental Panel on Climate Change, 2013). It is at present one of the most significant Ozone Depleting Substances (ODS) and Greenhouse Gases (GHG) released into the atmosphere. The global N₂O emissions are increasing and studies indicate that its overall concentration in the atmosphere will increase by 100% in 2050 (United Nations Environment Programme, 2013). It is estimated that global pre-2020 N₂O abatement potential is approximately 200 million t CO₂e and it is likely to reach 500 million t CO₂e until 2030, which is nearly 1% of the emissions gap for the global 2°C temperature cap (BMUB, 2015).

Nearly 3.78% of the total global N₂O emissions are attributed to the nitric acid production facilities (United Nations Environment Programme, 2013). Clean Development Mechanism (CDM) and Joint Implementation (JI) under the United Nations Framework Convention on Climate Change (UNFCCC) enabled increased penetration of N₂O abatement technologies in nitric acid plants across both the developed and the developing countries. As of April 2016, 97 nitric acid N₂O abatement projects are registered with UNFCCC.

There are twelve¹ operating nitric acid plants in India with a total production potential of 1.7 million tonnes per annum. In India, about two-thirds of the nitric acid is channelised for production of nitro-phosphates and ammonium nitrate (AN). The remaining is used for production of concentrated nitric acid (CNA) and other chemical products like dyes, paints etc. Until recently, calcium ammonium nitrate (CAN) used as a fertiliser, was one of the key products of nitric acid. However, the Ammonium Nitrate Rules, 2012 have diminished the demand for CAN and AN as fertilisers. As a result production of CAN was reduced to zero in FY 2014-15. AN continues to be produced for use as an explosive. Thus, in the present scenario, nitro-phosphates are the key fertiliser products of nitric acid in India.

The existing policy regime in India is structured to promote the use of urea which does not require nitric acid as input feed. There is a growing concern among environmentalists and agriculturists regarding the imbalanced use of fertilisers. Policy reforms to rectify this market distortion are not expected before the start of the next decade. Thus, the short-term nitric acid production is expected to stay at the current levels in the country.

The magnitude of N₂O emissions from the nitric acid sector may find its relevance in India's ambitious commitment to reduce the carbon intensity of its economy by 33-35% by 2030. While the mitigation-related Intended Nationally Determined Contributions (INDCs) submitted by India to the UNFCCC remain free from any sector-specific obligation, it would be of interest to India to capture the low-hanging fruits of abatement first. Factors like the limited

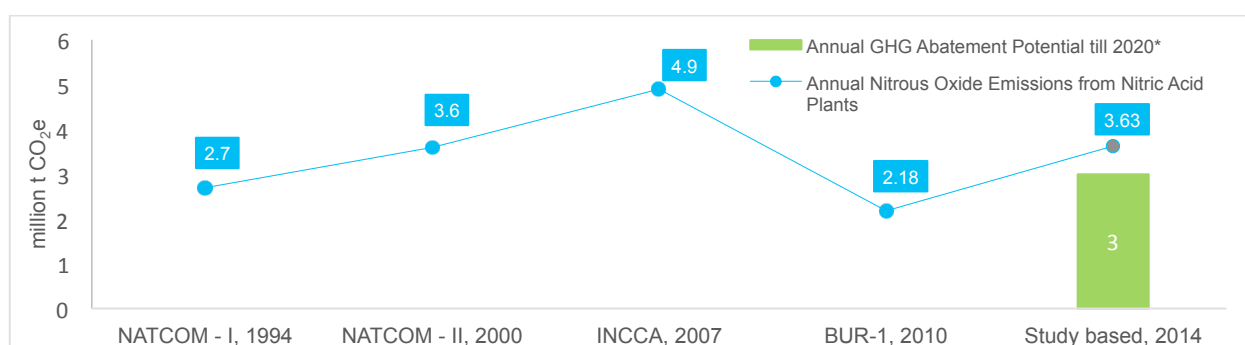
¹ These twelve plants exclude four plants under the control of Ministry of Defense, Government of India.

spread of the sector, availability of a tested, and relatively straight-forward technology, and fairly competitive cost of abatement, further make the sector of particular interest for GHG abatement programmes and schemes.

In 2007, nitric acid production from India contributed 4.9 million t CO₂e of GHG emissions (Indian Network for Climate Change Assessment, 2010). At present there are no regulations for N₂O abatement in India, and all N₂O abatement projects have been implemented considering support from CDM. Three companies from India have collectively registered eight CDM projects: one by Gujarat Narmada Valley Fertilizer Company Limited (GNFCL), two by Rashtriya Chemicals and Fertilizers Limited (RCFL), and five by Deepak Fertilisers and Petrochemicals Corporation Limited (DFPCL). As a result of implementation of abatement technologies in five of the eight registered plants, N₂O emissions from nitric acid production in India reduced to 2.18 million t CO₂e in 2010 (Ministry of Environment, Forests and Climate Change, 2015).

Based on activity data of FY 2014-15, nitric acid production in India is expected to result in **annual N₂O emissions of about 3.63 million t CO₂e**. The **annual GHG abatement potential from the sector is estimated to be 3 million t CO₂e** based on secondary catalyst use in all plants, except the one at National Fertilizers Limited (NFL) where tertiary abatement is deemed more suitable. However, the use of the conservative default baseline emission factor values mandated by the applicable methodology ACM0019, provides a much lower CER generation potential. **Between July 2016 and December 2020, the total CER generation potential from all nitric acid plants in India is about 4.97 million CERs**. Figure 1 presents the N₂O emissions from nitric acid sector in India as reported by various sources for different assessment years.

Figure 1: Estimated Nitrous Oxide Emissions from Nitric Acid Plants in India



* Assuming no capacity addition till 2020

Although most of the registered projects have been issued CERs, none of these have been able to engage in CER transactions as most of the issuances were closer to the end of the first commitment period. As a result, the capital investment made for implementing the mitigation infrastructure and CDM related procedures has not been recovered so far. RCFL is known to have removed secondary catalysts from their nitric acid plants, and in the absence of additional

financial support, the abatement benefits from GNFCL's and DFPCL's projects are expected to continue only until the remaining lifetime of the already installed catalysts.

Germany has launched the 'Nitric Acid Climate Action Group (NACAG)', to advance climate action to curb N₂O emissions during the production of nitric acid. The principal idea behind the NACAG is to increase pre-2020 mitigation of N₂O from nitric acid production and incentivize long term sectoral transformation. It provides an excellent opportunity for bi-lateral cooperation – with a win-win for both the parties by incentivising continuation of abatement activities which at present are at a risk of closure.

India's climate policy has so far been mainly driven by the urgent need to address the energy security challenge for its fast-growing economy – with GHG abatement as a by-product of various energy related schemes. Limited attention has been given to industrial gases abatement projects. NACAG steers the attention of policy makers towards a sector, the GHG abatement potential of which has not been acknowledged through a dedicated policy/scheme. For projects that are implemented but are at a risk of discontinuation, NACAG provides an interim relief until domestic policies around the same are formulated and implemented.

Managing N₂O emissions from the sector in the post-2020 period is both, a challenge and an opportunity, for India. The emissions can be reduced by 60-90% with the use of available abatement technologies. Effective utilisation of the opportunity requires multi-dimensional deliberations that include political, technical, financial, trade and economic aspects. Synergies could be drawn with the Montreal Protocol. On the domestic front, lessons are to be learnt from the success of the Perform, Achieve and Trade (PAT) scheme. The fungibility among tradable commodities generated as a result of various domestic schemes/measures can be explored. It is also equally important to engage with project developers to incorporate their perspective in the overarching policy framework that may establish a long term sustainable regime for GHG abatement from industrial gases.

This report encapsulates the current status and future outlook of the sector and the GHG abatement potential thereof, along with the industry perspectives on (i) technical feasibility and financial viability of the abatement technologies, and (ii) efficacy and challenges associated with the available market-based GHG mitigation mechanisms. The report provides estimates of the GHG mitigation potential from the sector under different growth scenarios and also puts forth recommendations to ensure operational excellence through reduced GHG emissions from the business operations. The key findings from this study would be instrumental in bringing a semblance of perspectives of all relevant stakeholders in order to develop an effective, credible and transparent framework for supporting N₂O abatement in India, both in the pre and post-2020 period.

Acknowledgements

Deloitte Touché Tohmatsu India LLP (DTTILLP) thankfully acknowledges the support extended by all stakeholders in this study. Inputs from all experts, project developers and technology suppliers, were valuable for developing the research methodology as well as drawing meaningful conclusions from the information collected.

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Industry insights provided by Mr. Anil Kumar V. Patil, Director, (P&K), Department of Fertilisers, Ministry of Chemicals and Fertilisers, Dr. S. Nand, Dy. Director General, Fertiliser Association of India, and Dr. D. S. Yadav, Director, Marketing, Fertiliser Association of India are deeply acknowledged.

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Introduction

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) is implementing the project 'Global Carbon Markets' on behalf of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) with the overarching target to explore possibilities for German enterprises to use existing and emerging carbon market instruments for the implementation of mitigation activities. The tasks undertaken in this project are aligned with the Indian climate policies and programmes (National Action Plan on Climate Change, Low-Carbon Strategies for Inclusive Growth etc.). This assignment in particular is part of the recently launched Nitric Acid Climate Action Group (NACAG) which aims to transform the nitric acid (HNO_3) sector. The group essentially contemplates the abatement of nitrous oxide (N_2O) which is produced as a by-product during the nitric acid production process.

Nitrous oxide (N_2O) is one of the potent Greenhouse Gases² (GHG). Its Global Warming Potential (GWP) is 264 and even small volumes of uncontrolled emissions contribute significantly to the anthropogenic emissions basket. The global N_2O emissions in 2010 were estimated at 1399.2 million t CO_2e , of which 52.8 million t CO_2e (3.78%) was contributed by nitric acid production facilities (United Nations Environment Programme, 2013). As of April 2016, 97 nitric acid N_2O abatement projects are registered with United Nations Framework Convention on Climate Change (UNFCCC).

The demand for nitric acid has been growing in the Asia-Pacific region mainly principally due to the growth in the fertiliser sector. India is expected to follow a similar growth trajectory with primary consumption of nitric acid in fertiliser production followed by its use in production of explosives, dye intermediates and various allied organic chemicals.

Indian fertiliser manufacturing companies participated in development and registration of GHG mitigation projects during the past decade. Several fertiliser producing companies have registered their nitric acid production facilities with UNFCCC. Though most of these registered facilities reported that there was no transaction of emission reductions to the Annex-1 countries from their registered projects due to reduction in demand of emission reduction after the end of first commitment period (i.e. December 2012).

India submitted its Intended Nationally Determined Contributions (INDCs) in October 2015 in the run up to Conference of Parties (COP 21) in Paris. The INDCs have set an ambitious target to reduce the emissions intensity of its GDP between 33 to 35 % by 2030 against 2005 level. While the target is not assigned to any particular sector, the agriculture sector has been specifically excluded from mitigation obligations. The National Mission on Sustainable Agriculture, one of the nine missions under the National Action Plan on Climate Change (NAPCC), is India's key armament to confront the climate change challenge in the agriculture

² The GWP of N_2O has undergone a downward revision from 310 to 264

sector. The mission focuses on adaptation rather than mitigation. Though several states have launched policies and programs for modernization of the agriculture sector, yet the impact has been limited. Also, the recent focus on increasing agricultural throughput may further trigger the demand of fertilisers in the country.

One key impediment limiting nitric acid growth in the short term is the existing arrangement of policy support for fertilisers which is structured to promote use of urea (which does not use nitric acid as input feed). New policy developments targeted to reverse urea consumption trend (discussed in detail later in the report) are expected to cause noteworthy market transformations in the in the next decade. The sector, therefore, is of particular relevance to the Indian scenario in the long-term (by virtue of its projected magnitude in the medium to the long-term), even though current N₂O emissions from the sector are low.

This study reports on the present level of nitric acid production in India, key growth drivers and their impact on production, the existing abatement activities, possible additional opportunities of abatement, and future sustenance of abatement initiatives with an overarching goal of N₂O abatement from India. Further, the study provides an estimate of the associated N₂O emissions in the short, medium and long term, and the investment required to tap the GHG emissions from the sector. The non-financial challenges for implementation of N₂O abatement technologies are also discussed in the report. The findings of the study will feed into the context for establishing a dialogue between the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the Indian Government in pushing the agenda of NACAG in India.

The specific objectives of the study are to:

- Delineate the structure of nitric acid sector in India, including identification of the key players, installed capacity, production levels, key users, technology used, key financial parameters etc.
- Outline the policy and regulatory environment for nitric acid, and related sectors
- Analyse the existing portfolio of N₂O abatement CDM projects from the nitric acid production, including registration and issuance status, applicable methodologies, project performance, limitations and barriers in the sector, and CER generation potential until 2020
- Estimate the present and the future (2020, 2030 and 2040) N₂O emissions from the nitric acid sector in India, under various growth scenarios, and estimate the potential abatement achievable through the use of available abatement technologies
- Compare the technologies available for abatement on their key performance parameters, including cost effectiveness
- Review and recommend policy initiatives to promote adoption of N₂O abatement technologies by nitric acid producers in India

1. Overview of the Nitric Acid Sector in India

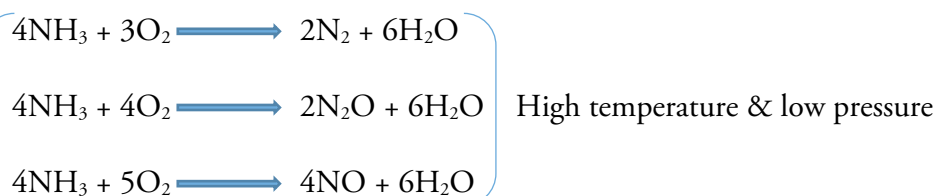
This chapter presents information on nitric acid production in India. The facts and figures pertaining to installed capacity, annual production, captive consumption and sales, status of N₂O abatement technologies and future outlook have been gathered through primary survey³ and corroborated through secondary sources, wherever available. The sources are indicated in relevant sections of the report.

Nitric acid is an inorganic chemical with a variety of productive applications, including nitrogen based fertilisers, explosives, and speciality chemicals such as polyurethane intermediaries, dyes and pharmaceuticals. In India, the principal use of nitric acid is for fertiliser production. Thus traditionally the fertiliser units have been producing nitric acid for their captive consumption as well as for open market sales. Nitric acid is produced essentially as weak nitric acid (WNA) and concentrated nitric acid (CNA). The production of nitric acid is reported at 100% concentration.

1.1 Structure of the Nitric Acid Sector in India

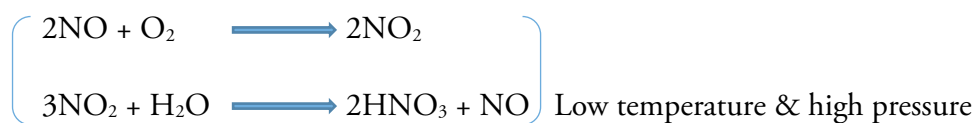
1.1.1 Nitric Acid Production Technology

WNA is produced through a two-step chemical process of oxidation and absorption. In the oxidation phase, ammonia (NH₃) is oxidized at a high temperature over the catalyst into nitric oxide (NO). As the gases cool, the NO is oxidized into nitrogen dioxide (NO₂). In addition to this, it also results in formation of nitrous oxide (N₂O), water (H₂O) and nitrogen (N) (European Fertilizer Manufacturers' Association, 2000).



³ Nitric acid producers, technology suppliers and industry experts

In absorption phase, the nitrogen dioxide (NO₂) reacts with water to form nitric acid (HNO₃).



N₂O, which is produced during the oxidation phase is a potent Greenhouse Gas (GHG) that is released into the atmosphere as part of the production process. It is recognised as one of the six GHGs in the Kyoto Protocol. The choice of nitric acid production technology also determines the amount of N₂O released during the production process. Various technologies are available for the abatement of N₂O during WNA production process. However, in India, such technologies have not been implemented outside the purview of CDM as there are no regulations regarding N₂O emissions from the sector.

There are three technologies for WNA production which are employed globally (European Fertilizer Manufacturers' Association, 2000):

- **High Pressure Mono Pressure⁴ (HP):** Oxidation and absorption steps take place at pressure between 6.5 and 13 bar
- **Medium Pressure Mono Pressure⁵ (MP):** Oxidation and absorption steps take place at pressure between 1.7 and 6.5 bar
- **Dual Pressure (DP):** Absorption takes place at a higher pressure than the oxidation (between 1.7 and 6.5 bar for the oxidation stage and between 6.5 and 13 bar for the absorption stage)

Medium pressure and dual pressure plants are known to emit less N₂O per tonne of nitric acid produced compared to high pressure plants (IPCC, 2006). Apart from specific N₂O emissions, there are several factors that determine the choice of nitric acid production technology. Medium pressure and high pressure plants are preferred for capacity below 500 tonnes per Day (TPD), while dual pressure plants are suitable for plants with capacity more than 500 TPD (ThyssenKrupp India, Stakeholder Consultation, 29 February 2016).

Dual pressure plants require higher capital investment compared to mono pressure plants, but the incremental cost gets recovered during the operational period as dual pressure plants have lower operating costs (low ammonia and catalyst consumption). Well maintained nitric acid plants have a lifetime of more than 30 years. In comparison to other technologies, high pressure plants usually have a shorter lifetime (ThyssenKrupp India, Stakeholder Consultation, 29 February 2016).

⁴ Also called High Pressure Plants

⁵ Also called Medium Pressure Plants

Concentrated nitric acid (CNA) or fuming nitric acid is another commercial form of nitric acid which is produced using WNA as the input feed. The process involves increasing the concentration of nitric acid to 99% and above in stand-alone CNA plants. This conversion of WNA to CNA does not involve release of N₂O.

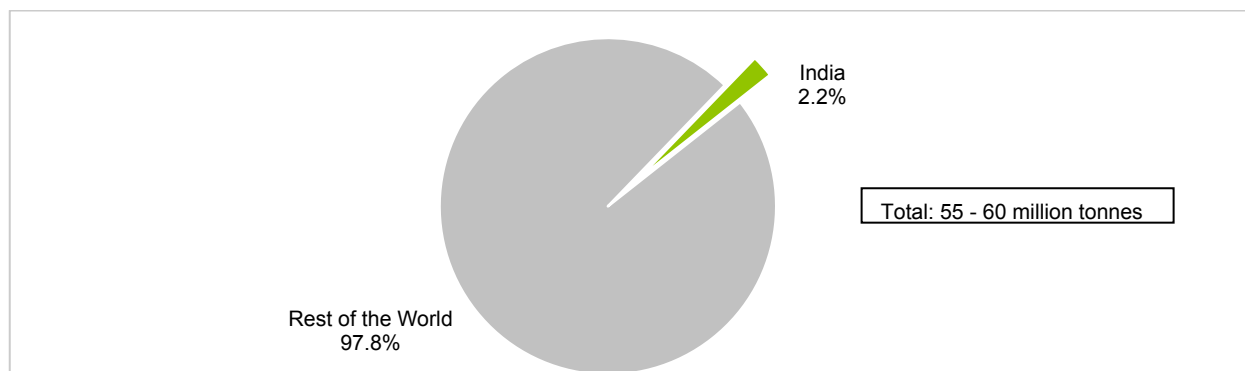
In addition to this, the HOKO process technology for production of CNA which is now obsolete, did not use WNA as the feed-stock. In India, Hindustan Organic Chemicals Limited (HOCL) is the only producer using HOKO process for production of dinitrogen tetroxide (N₂O₄) which yields CNA as a by-product (ThyssenKrupp India, Stakeholder Consultation, 29 February 2016). For the purpose of this assignment, HOCL plant is excluded from the scope of the study as:

- (i) The process does not emit N₂O, and
- (ii) The technology is obsolete, and therefore irrelevant for the scope of the study.

1.1.2 Nitric Acid Production

Global annual nitric acid production is estimated to be at 55-60 million tonnes (Kamphus, 2014), (RSC and Reckitt Benkisser, n.d), of which India contributes about 2.2% (Figure 2). Europe, China and North America are other major producers of nitric acid accounting for about 84% of the global production.

Figure 2: India's Share in Global Nitric Acid Production



The total installed capacity of WNA in India is 5152 TPD (excluding production facilities owned/ operated by Ministry of Defence and its affiliates⁶). Plant-wise information on vintage, technology used, technology supplier and capacity of nitric acid plants in India is provided in Table 1. In India, the fertiliser industry controls about 98% of WNA production capacity. The remaining 2% of the production capacity is controlled by STL, which produces explosives.

⁶ Secondary sources indicate that there are four nitric acid plants under the administrative control of Ministry of Defense, Government of India at Ordnance Factory Itarsi, Ordnance Factory Bhandara, Ordnance Factory Kirkee and Indian Cordite Factory. This information could not be corroborated with primary surveys.

Table 1: WNA Plants in India (Installed Capacity and Technology Suppliers)

Capacity (TPD of 100% Nitric Acid)	No. of Reactors	Process	Year of Commissioning	Licensor	Engineering
Deepak Fertilisers and Petrochemicals Corporation Limited (DFPCL), Taloja					
300	1	HP	1992	Weatherly Inc., USA	
300	1		1992	-do-	-do-
300	1	MP	2000	Uhde	Jacobs
450	1	DP	2009	-do-	Uhde
750	1	HP	2011	-	Weatherly Inc.
Gujarat Narmada Valley Fertilizers Company Limited (GNFCL), Bharuch					
750 (revamped to 900)	1	DP	1991	Krupp /Uhde	Uhde India
300 (revamped to 360)	1	MP	2011	Uhde	-do-
National Fertilizers Limited (NFL), Nangal					
560	8	MP	1961	Pintch Demag	-
Rashtriya Chemicals and Fertilizers Limited (RCFL), Trombay					
352	1	HP	1965/1999/2005	Chemico /Uhde ⁷	Uhde
750	1	MP	1978	-	-
Gujarat State Fertilizers & Chemicals Limited, India (GSFCL), Vadodara					
30	2	DP		-	-
Smartchem Technologies* (STL), Srikakulam					
80 (revamped to 100)	1		-	-	PDIL
Fertilisers and Chemicals Travancore Limited (FACT), Kochi					
15	Not Operational				

Source: Compiled from stakeholder consultations with nitric acid producing companies, sector experts and technology suppliers

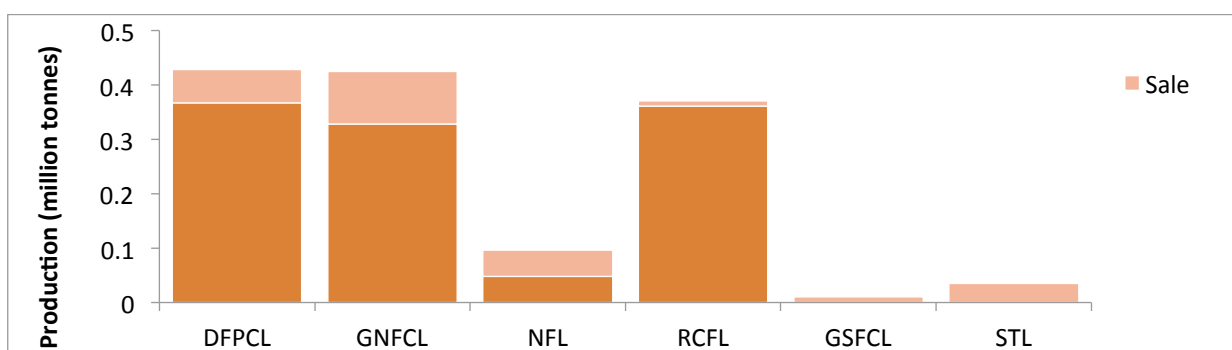
Notes

- HP stands for High Pressure Mono Pressure; MP stands for Medium Pressure Mono Pressure; and DP stands for Dual Pressure
- All plants are operating at 100% throughput except NFL which is operating at 30%.
- FACT has a WNA production facility which is non-operational at present.
- HOCL is not included in the above table as it does not produce WNA and thereby, does not emit N₂O
- "*" sign indicates non-fertiliser producing company.

India's present installed capacity has the potential of producing 1.7 million tonnes of nitric acid annually. In FY 2014-15⁸, the annual production was 1.3 million tonnes. Figure 3 provides a plant-wise break-up of nitric acid production and sale in FY 2014-15.

⁷ Chemico plant built in 1965 was dismantled, and Uhde built a new plant in 2 stages (1999 and 2005)

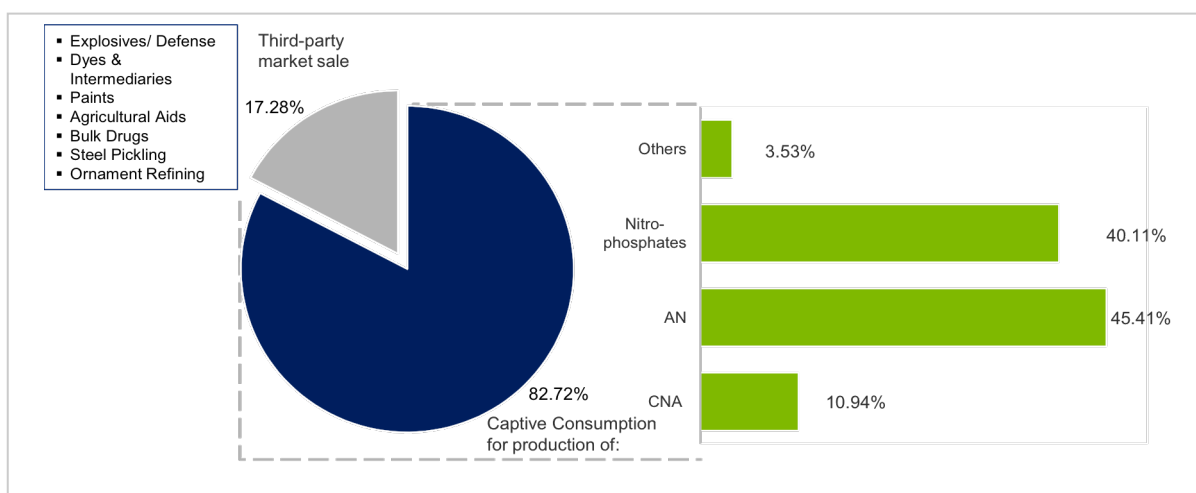
Figure 3: Nitric Acid Production and Sale in India (FY 2014-15)



1.1.3 Industries that use Nitric Acid

Table 2 shows the distribution of product mix confirming large portion of nitric acid consumption within fertiliser industries themselves. Though DFPCL has the largest installed capacity, it observed a reduced production due to non-availability of natural gas during past financial year. GSFCL and NFL sold 100% of their production in the open market. In FY 2014-15, approximately 83% of the nitric acid produced in India was used for captive consumption and the balance 17% was sold in the open market (Figure 4).

Figure 4 WNA Use in India (FY 2014-15)



In FY 2014-15, GNFC held the largest share in WNA market (42.5%) followed by DFPCL (26.9%) and NFL (21.2%). WNA is principally used for production of nitro-phosphates, AN and CNA, while DFPCL uses WNA only for production of AN.

⁸ Financial year in India is from April to March

Nitric Acid for Fertiliser Production

Table 2 WNA Plants in India (Production and Use, FY 2014-15)

S. No.	Company and Plant	Production Potential at 100% Nitric Acid [@] (tonnes)	Actual Production (tonnes)	Sale (tonnes)	Captive Consumption (tonnes) for			
					CNA Production	AN Production	Nitro-phosphate Production	Others
1.	DFPCL	693000	428662	61314	0	367348*	0	0
2.	GNFCL	422400	425173	96977 [#]	116370	24245	196225	0
3.	NFL	184800	48299	48399	-	-	-	139.59 [^]
4.	RCFL	363660	371090	10334 [#]	-	91443	230429	37,456 [§]
5.	GSFCL	16500	10900	10900	-	-	-	-
6.	STL	35000	35000	-	-	-	-	-
Total		1715360	1319124	227935	116370	483036	426654	37456

Source: Compiled from stakeholder consultations and published annual reports

Notes:

@ Based on installed capacity and 330 operating days per annum

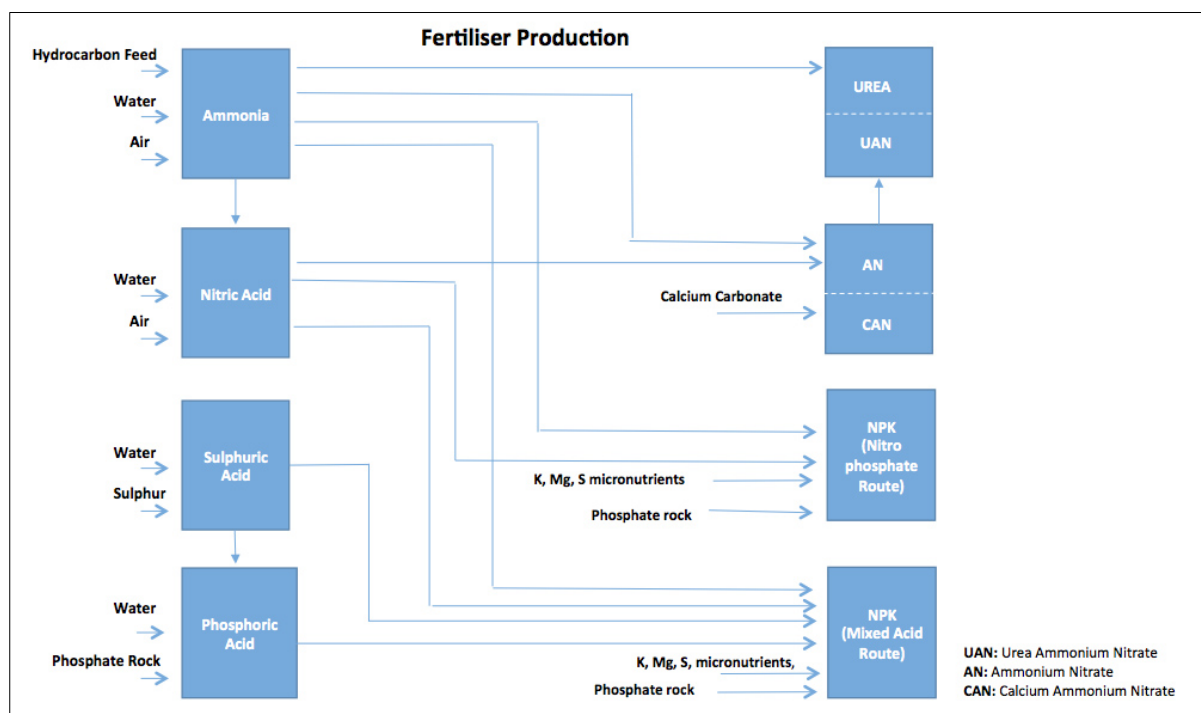
* Estimated based on the preliminary information that DFPCL is using nitric acid for production of AN explosive

^ For production of sodium nitrate/nitrite

Cumulative value for nitric acid of various concentrations. However, the production value is reported for 100% nitric acid. Therefore, sum of values listed as nitric acid sold and that used for captive production do not tally with total production.

§ For sodium nitrate/nitrite and concentrated nitric acid

Figure 5: Schematic Representation of Fertiliser Production

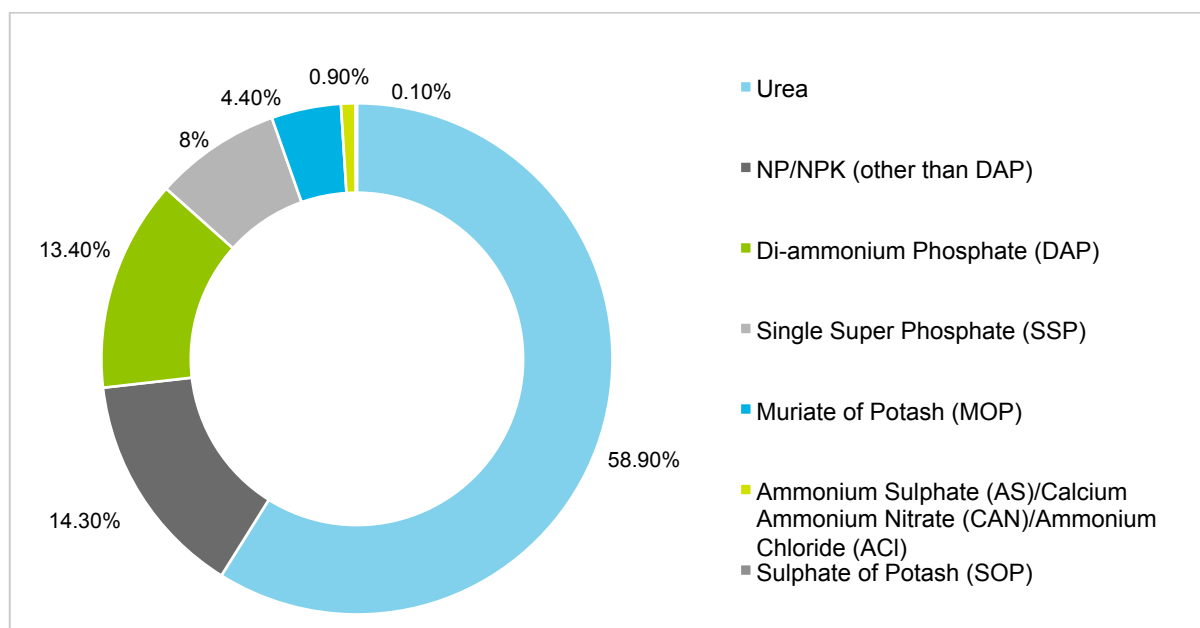


Source: EFMA (European Fertilizer Manufacturers' Association, 2000)

Figure 5 is a graphical representation of fertiliser production using various acids as feedstock. Nitric acid is used for the production of ammonium nitrate (AN), calcium ammonium nitrate (CAN) and NPK through both phosphate and mixed acid route.

India's fertiliser market is dominated by urea because of excessive subsidy on it while other fertilisers are covered under the NBS Scheme (Refer section 1.3.2 for details). Figure 6 presents the market share of various fertilisers in India in 2013-14.

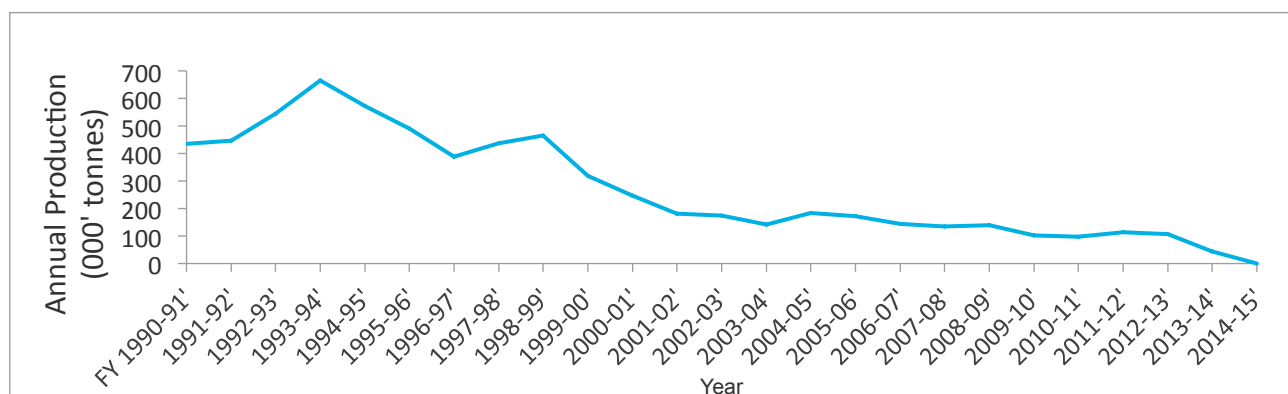
Figure 6: Market Share of various Fertilisers in India, FY 2013-14



Source: FAI (Fertiliser Association of India, 2014)

Globally, the principal fertilisers produced using nitric acid are nitro-phosphates, calcium ammonium nitrate (CAN) and ammonium nitrate (AN). However, in India, CAN production has dwindled since FY 2000-2001 and a reduction in production has been recorded on an annual basis. Figure 7 shows the trend in CAN production over the past 25 years. As per the latest statistics, CAN production has reduced to zero (Fertiliser Association of India, 2015). This could possibly be attributed to Ammonium Nitrate Rules, 2012, making AN and CAN less favourable and accessible for farmers. AN continues to be used as an explosive by industries including mining and quarries with requisite licensing/registrations.

Figure 7: CAN Production in India



Source: FAI (Fertiliser Association of India, 2015)

In FY 2014-15, about a third of the total nitric acid produced in India was used for the production of nitro-phosphates. Considering the current activism directed at promotion of balanced fertilisation thereby moving away from the extensive use of urea, it is likely that nitro-phosphates will emerge as one of the key fertilisers in India in the medium to long term, thereby driving up the demand for nitric acid.

1.1.4 Import/Export Statistics

At present, there is no import/export of nitric acid in the country. Even globally, import or export of nitric acid is not a common practice as nitric acid requires specialised arrangements for long distance transportation.

1.1.5 Turnover and GDP Share

About 83% of nitric acid is consumed for captive purposes by the fertiliser manufacturing facilities while 17% is sold in open market with different concentrations.

- Assuming an average sale price of INR 20,000⁹ per tonne¹⁰, the revenue from third party sale is estimated at INR 4,558.70 million (or € 67.77 million¹¹) for 227,935 tonnes of nitric acid sold in the market in FY 2014-15.
- Cost of production for 1,094,872 tonnes of nitric acid consumed in captive is estimated as INR 19,707.71 million (€ 292.96 million)¹².

⁹ For currency figures, commas have been used as thousand separator.

¹⁰ In FY 2014-15, 227935 tonnes of nitric acid was sold in the market at a price ranging between INR 18,000 (267.57 Euros) per tonne to INR 23,000 (341.90 Euros) per tonne resulting in revenue for the companies from third party sales.

¹¹ Based on Euro conversion rate as on 31st March 2015: 1 Euro = INR 67.27.

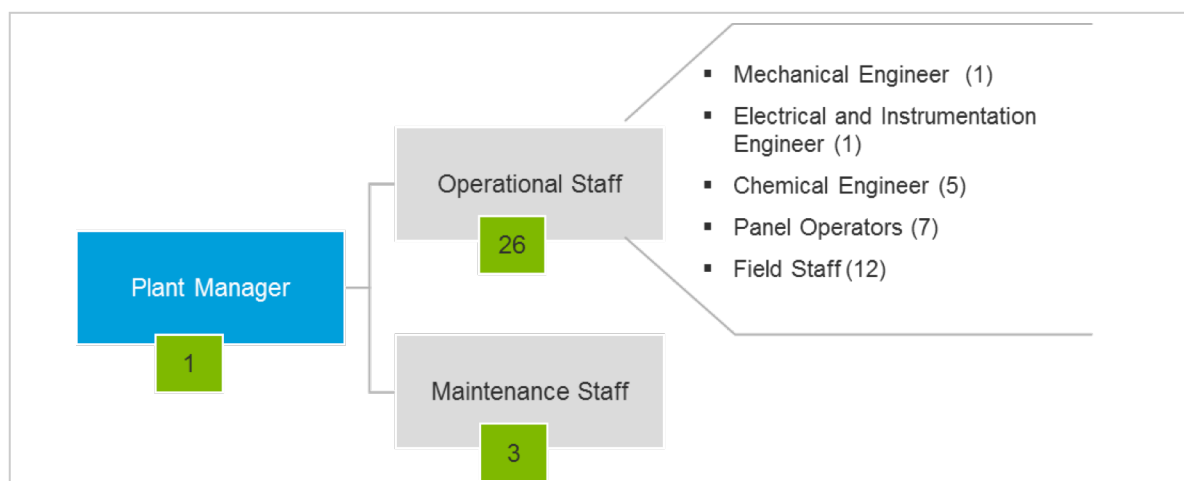
¹² Basis discussions with industry experts, for captive consumption, the cost of production is assumed as 90% of the selling price.

Based on last year's production the approximate turnover stands at INR 24,266.41 million (€ 360.73 million). The sector turnover will exceed INR 25,000 million if the installed capacity is utilised to its full capacity. The Indian GDP for 2014 was \$ 2,066.90 billion. The direct contribution of nitric acid production in the national GDP is estimated at INR 18382.57 million (€ 273.26 million) or 0.015% of the national GDP. The contribution will increase significantly if the indirect contribution to the agriculture sector is included in the estimation.

1.1.6 Employment/Operational Manpower Requirements

The manpower requirement is more or less constant irrespective of size of unit. The stakeholder consultations revealed that approximately 30 full-time employees are required to run a nitric acid plant. Their distribution is presented in Figure 8.

Figure 8: Operational Manpower Requirements for Nitric Acid Plants



There are 12 operational WNA plants in the country¹³. Assuming the same manpower requirement for 12 operational facilities and excluding administrative staff (which are common manpower for other units/departments) of the plant, the sector will provide a direct full time employment to nearly 360 persons.

1.1.7 Institutional Set-up of the Sector

To understand the sector dynamics, stakeholders were identified and consultations were been carried out. This ensured optimised time spent on primary information collection relevant to the study. The stakeholders of the nitric acid sector were classified as:

Primary stakeholders: Those who are directly affected by the project, either as the designated

¹³ Excluding those under Ministry of Defence, Government of India and the non-operation FACT plant.

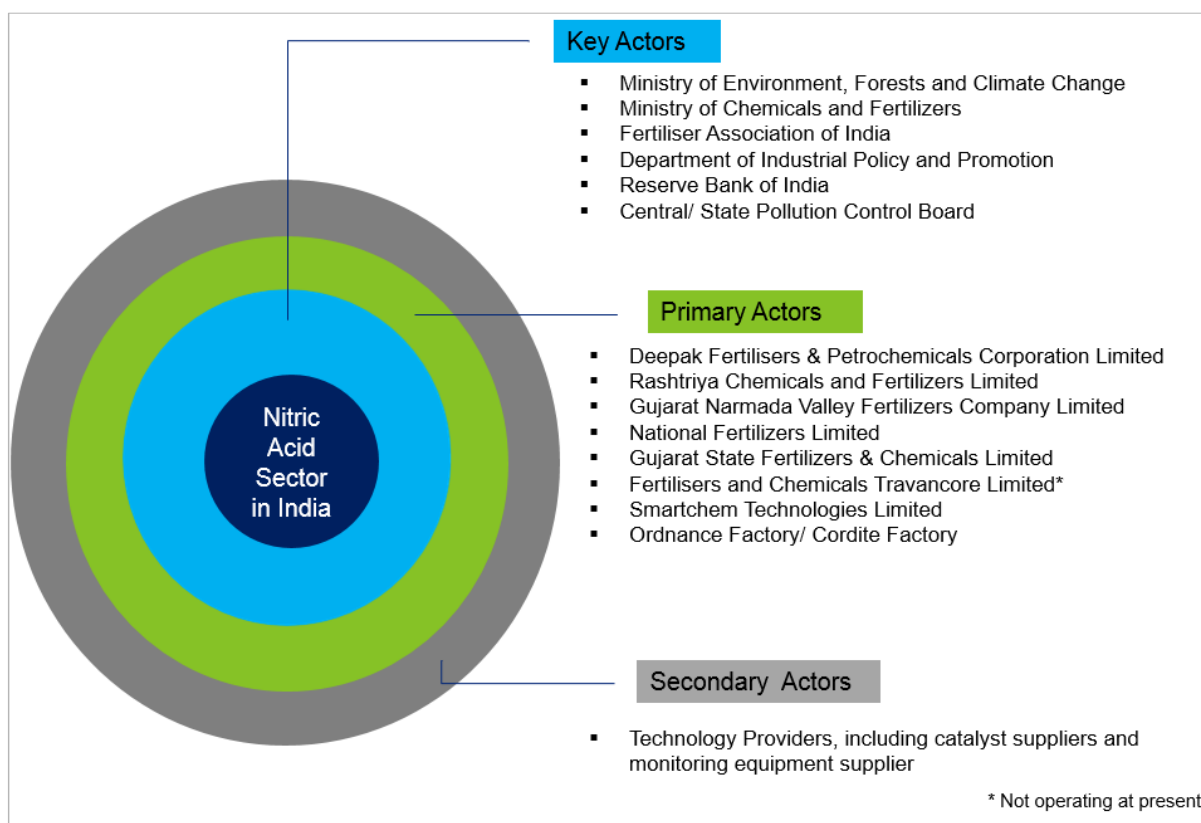
beneficiaries, or because they stand to gain/lose power and privilege as a result of the project. For GHG abatement in the nitric acid sector, nitric acid manufacturers are the primary actors, as they are directly affected by the project. The investment costs for the abatement technology would be borne by the manufacturers (unless supported by the government or an international protocol). They are also key implementers of the project in terms of adopting the abatement technology.

Secondary stakeholders: Those whose involvement in the project is only indirect or temporary, as is the case, for instance, with service providers. Technology providers (monitoring equipment suppliers and catalyst suppliers), though, have a recurring involvement with the project implementers and are involved only indirectly in the process of tapping the GHG potential.

Key stakeholders: Those who are able to use their skills, knowledge or position to significantly influence a project/intervention. These actors may have policy/regulatory influence. In case of the nitric acid sector, several government/semi-government agencies are involved in a regulatory role for the setting-up and operation of nitric acid plants. Nitric acid producing companies are under the control of Ministry of Chemicals and Fertilisers (MoCF). The Fertiliser Association of India (FAI) is a non-profit and non-trading company, functioning as a representative body bringing together all concerned with the production, marketing and use of fertilisers. Since most of the nitric acid production capacity is held with fertiliser producing companies, these two agencies have a key role to play in the overall institutional set-up for the nitric acid sector in India. Several other government agencies are also regulating the nitric acid sector. The Department of Industrial Policy and Promotion (DIPP), Ministry of Commerce and Industry is the prime regulatory body for setting up of nitric acid plants in India. Although industrial licensing is not required for nitric acid plants, certain upstream and downstream industries like coal, oil, explosives, drugs and pharmaceuticals are compulsorily required to obtain industrial licenses. Like several other production facilities, nitric acid plants are also required to obtain registration number from DIPP/GoI.

Consent to Establish, Consent to Operate, Factory License are required to be obtained at the relevant milestones/stages from the respective State Pollution Control Boards (SPCB). Nitric acid plants are also required to obtain environmental clearance from the Ministry of Environment Forests and Climate Change (MoEF&CC); and other compliance with relevant regulations of the respective SPCBs are also mandatory. The approval as per the Indian Boiler Regulations is required before commencement of installation of boilers. Additionally, approval from the Reserve Bank of India is also required where license/proprietary equipment is procured from an international licensor (due to transaction/payments in foreign exchange). Figure 9 presents graphical representation of the stakeholders of the nitric acid sector.

Figure 9: Stakeholders of Nitric Acid Sector in India



1.2 Overall Environmental Impact of the Nitric Acid Production Process and Raw Material Extraction

1.2.1 Raw Material Extraction

Ammonia and water are used as raw materials for production of WNA. Ammonia in turn is produced using 'steam reforming' of natural gas or gasification of oil/coal/naphtha. Considering India's energy security challenges, conservation of energy and thus, efficient use of ammonia is of utmost importance. Primary catalyst in 95%-5% composition (platinum-rhodium) are known to reduce ammonia consumption, thereby leading to resource conservation. The industry preference for this catalyst (in view of low ammonia consumption) needs to be further ascertained.

1.2.2 Hazardous Waste Generation

Spent catalysts used in production process are classified as hazardous waste as per the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2015. Disposal of the spent catalyst should be as per the procedures for management defined in Chapter II of the rules (MoEF&CC, 2015). Further, WNA is used to produce concentrated nitric acid by a general

concentration process. Weak sulphuric acid (WSA) or concentrated sulphuric acid (CSA) is produced as a by-product of the concentration process (RCFL stakeholder consultation, 8 February 2016). WSA finds limited industrial use, and must be disposed off as per the governing regulations.

1.2.3 Energy Consumption

Nitric acid plants consume electricity for operation. Electricity consumption is the highest for high pressure plants (13 kWh / t HNO₃), followed by medium pressure (9 kWh / t HNO₃) and dual pressure plants (8.5 kWh / t HNO₃) (ThyssenKrupp India, Stakeholder Consultation, 5 April 2016).

Apart from electricity, nitric acid production process also consumes additional energy as steam. The production process, being exothermic in nature generates energy as heat which is used to produce steam. Steam consumption (and hence energy consumption) is the highest for high pressure plants (1.53 x 10⁻⁴ kWh / t HNO₃), while medium and dual pressure plants require the same amount of steam (3.84 x 10⁻⁵ kWh / t HNO₃). Medium pressure plants yield maximum energy as output steam (6.1 X 10⁻⁴ kWh / t HNO₃) with the maximum amount of energy as output steam, followed by dual (5.23 X 10⁻⁴ kWh / t HNO₃) and high pressure (4.44 X 10⁻⁴ kWh / t HNO₃) plants (ThyssenKrupp India, Stakeholder Consultation, 4 April 2016).

1.2.4 Emissions from WNA Production

N₂O Emissions: The amount of N₂O produced depends upon oxidation conditions, composition and age of the primary catalyst, and burner design (Mainhardt, 2006). Generally, dual pressure and medium pressure plants emit less N₂O and less NO_x as compared to high pressure plants as lower pressure favours oxidation of ammonia to NO gas (IPCC, 2006).

Table 3 provides a comparison of the emission factors for different nitric acid plants reported by different sources:

Table 3: N₂O Emission Factors

S.No.	Technology	IPCC, 2006 (IPCC, 2006)	Rao et al (Rao, Qureshi, & Devotta, 2004)	Indian CDM registered projects	Reported by tKIS (ThyssenKrupp Industrial Solutions, 2016)
		kg N ₂ O / t HNO ₃			
1.	High Pressure Mono Pressure	9.00 ± 40%	1.54 – 4.13	3.40 – 12.50	10 – 20
2.	Medium Pressure Mono Pressure	7.00 ± 20%	6.48 – 13.79	5.11 – 11.90	6 – 7.50
3.	Dual Pressure	-	0.24 – 0.57	6.20	-

At present, there are no regulations for N₂O emissions in India. Further, N₂O abatement technologies require additional investment, which is perceived as a burden by the nitric acid producers. Hence, N₂O abatement is generally not a consideration while designing nitric acid plants in India.

Other Emissions: WNA production also leads to emissions of NO_x (NO and NO₂). Oxides of nitrogen, and specifically NO₂, are pollutants. In India, the regulatory limits for NO_x from nitric acid plants have been defined (CPCB, 2000), and plants have implemented measures to comply with the limits. Existing regulations for NO_x depend upon the limits prescribed by the different states, as well as the date of commissioning of the plant. For a new plant, the norms/regulatory limit for NO_x are taken into account. Nitric acid plants may also indirectly generate emissions of carbon dioxide (CO₂), and methane (CH₄) by consuming steam (or heat) or electricity produced through the combustion of fossil fuels (US EPA, 2016), during start-up. This is common for plants with steam powered compressors, which require the use of natural gas at start-up.

Apart from the direct environmental impacts of nitric acid production, studies also point out to the damaging downstream impacts of the nitric acid sector through over-use of fertilisers. It has been observed that incorrect use of fertilisers in India is leading to deterioration in soil health (Bera, 2015). The undissolved portions of phosphorous and potassium fertilisers are often absorbed in the soil, and affect its chemical and biological properties (Mullins, n.d). Further, industrial waste from fertiliser/chemical production may consist of a variety of chemicals, which are toxic for living beings (Prajapati, Sharma, & Tiwari, 2010).

1.3 Policy and Regulatory Environment

Since the fertiliser industry is the key producer as well as consumer of nitric acid, regulations/policies related to the fertiliser sector which in-turn impact the production of nitric acid, are of relevance to this study. Some of these regulations/policies are:

1.3.1 Non GHG - Mitigation-related Policies in India: The Perform Achieve and Trade (PAT) Scheme

The Indian fertiliser plants are some of the best performers in terms of energy consumption per unit of production (Fertiliser Association of India, 2015). The fertiliser sector in India is covered under the PAT scheme and four of the five top nitric acid producing companies in India are listed as 'Designated Consumers' (DCs) which mandates the reduction of Specific Energy Consumption (SEC). These companies were given energy reduction targets under Cycle 1 of the PAT scheme, which have been achieved. The PAT Cycle 2 will be implementing next level of SEC reduction targets (Bureau of Energy Efficiency, n.d).

1.3.2 Nutrients Based Subsidy (NBS) Scheme

At present, urea is the only controlled fertiliser in India and is sold at a uniform sale price (Damodaran, 2015). Decontrolled phosphatic and potassic fertilisers are sold with a fixed subsidy irrespective of the selling price. This fixed subsidy on non-urea fertilisers is referred to as Nutrient Based Subsidy (NBS) (Dey, 2014). The NBS introduced in 2010 passes on the increased cost of production to the consumers in case of non-urea fertilisers. Since urea prices are kept fixed, farmers are inclined towards using more urea. As a result, the NBS scheme from 2010 failed to promote balance fertilisation (Bera, 2015). Because of the disproportionately higher demand for urea against other fertilisers, manufacturers are currently not encouraged to produce nitro-phosphates, the key fertiliser category using nitric acid. This has limited the growth prospects of nitric acid production in India. The government is putting in place a New Pricing Scheme (NPS) for urea manufacturing units to encourage investment in the sector (Mukherjee, 2015).

The government is also planning to de-regulate urea in a phased fashion (Damodaran, 2015). The process is expected to go slow to ensure that the fertiliser prices stay affordable for a majority of the farmers. In this direction, the government has already initiated introduction of a uniform gas price for urea plants through gas pooling to help move towards a single urea price, and subsequent decontrol. Additionally, the government is also reported to be working on Direct Benefit Transfer (DBT) to farmers to facilitate the decontrolling process for urea (Damodaran, 2015).

Thus, in the medium to long-term, a more balanced demand for fertilisers propelled through favourable policy reforms is likely to increase the demand for nitric acid in India.

1.3.3 Ammonium Nitrate Rules, 2012

Globally, CAN and AN are two of the principal fertilisers produced using nitric acid as the input feed. While AN is used both as a fertiliser and an explosive, CAN finds exclusive use as fertiliser. The use of both these products as fertilisers in India mandates a license issued by Petroleum and Explosives Safety Organization (PESO). As a result, both the demand and the production of CAN has reduced to zero. Similarly, requirement of license for the use of AN as a fertiliser also have a backward impact on nitric acid demand.

Other regulations pertaining to the environmental impacts of nitric acid plants are discussed in section 1.2.

1.3.4 National/International Initiatives to Limit N₂O Emissions

Multilateral Accords

Nitrous oxide (N₂O) is one of the six GHGs covered under the Kyoto Protocol of the UNFCCC. Both CDM and JI aimed at reducing N₂O emissions from nitric acid and adipic acid production. N₂O abatement projects from adipic acid plants are however not eligible for trading under the EU ETS since May 2013 (European Commission, 2011). Apart from contributing to global warming, N₂O also depletes the stratospheric ozone. At present, N₂O is not recognized as an 'Ozone Depleting Substance' under the Montreal Protocol, though it is mentioned in the Vienna Convention for the Protection of the Ozone Layer (United Nations Environment Programme, 2013).

Trading Schemes – Other Countries

The Australian Emissions Reduction Fund came into legislative effect in 2014. The fund provides incentives for emissions reduction activities across the Australian economy. N₂O abatement projects are covered under the Australian Emissions Reduction Fund (EDF, CDC Climat Research, IETA, 2014).

The Climate Action Reserve (formerly the California Climate Action Registry) launched in 2008 is a national voluntary offset programme focused on the US carbon market. The programme is applicable to N₂O abatement projects in nitric acid plants (Climate Action Reserve, 2011). The Reserve is an approved programme under the VCS. At present there are six nitric acid N₂O abatement projects listed on the Reserve. The reductions verified under the Reserve protocols and registered as 'Climate Reserve Tonnes' are eligible to be converted to Verified Carbon Units (VCUs).

China had recently launched pilot Emissions Trading Scheme in seven cities - Beijing, Chongqing, Guangdong, Hubei, Shanghai, Shenzhen and Tianjin. Out of these seven pilots, N₂O is covered as a GHG only under the Chongqing ETS pilot, while other pilots only include CO₂ (Ecofys, 2015). A review of Intended Nationally Determined Contributions (INDCs) submitted by the BRICS nations reveal that none of these nations, with the exception of China, has specifically targeted reduction of GHG emissions from industrial processes. In addition, China's INDC also makes a specific reference to reducing N₂O from farmland (Department of Climate Change, NDRC, PRC, 2015).

Indian Regulations

There are no regulations pertaining to N₂O emissions from nitric acid production in India. Since N₂O abatement technologies require additional investment, nitric acid plants in India have not implemented N₂O abatement measures, except where supported by CDM. A summary of status of N₂O abatement measures implemented by nitric acid plants in India is presented in Table 4.

1.4 Analysis of Existing Portfolio of CDM Projects

As of April 2016, there are 97 nitric acid N₂O abatement projects registered under CDM which represent 1.26% of all registered CDM projects globally. However, the reduction potential of these projects is substantial due to the high GWP of N₂O. They represent 4% of the total CERs issued till January 2016 (CDM/JI Pipeline Analysis and Database, 2016).

1.4.1 Overview of Applicable CDM Methodologies for N₂O Abatement

The N₂O abatement projects at nitric acid plants availing CDM benefits are using one of the three methodologies – AM0034, AM0028 or ACM0019¹⁴ (CDM/JI Pipeline Analysis and Database, 2016).

AM0034 (withdrawn)

The projects using secondary catalysts for N₂O abatement in plants that started commercial operation before 2006 could use AM0034. As per the methodology, the baseline campaign is run only once before the implementation of the CDM project and the resulting baseline emission rates are then used for all subsequent project campaigns.

In case a new type of primary gauze was installed for a project campaign, AM0034 required the baseline campaign to be repeated and a new baseline emission factor to be established. However, project developers also had the option of applying the default emission factor provided by IPCC (4.5 kg N₂O / t HNO₃). The methodology was withdrawn and replaced by ACM0019 (CDM Methodologies Panel, 3 June 2011), (CDM Methodologies Panel, 9 May 2013). The projects registered using AM0034 will continue to use it until the end of crediting period (10 years fixed crediting) or the renewal of initial crediting period (21 years renewed every 7 years).

AM0028 (no longer applicable to nitric acid plants)

This methodology was applicable to tertiary N₂O abatement projects in both nitric acid and caprolactam plants. The baseline emissions under AM0028 are measured with each project campaign¹⁵, unlike AM0034 (CDM EB 60, Annex 2, 2011). However, in order to adopt a common approach for both technologies (secondary catalyst and tertiary abatement), AM0028 was revised to limit its applicability only to caprolactam plants, and ACM0019 was developed to be also applicable to tertiary N₂O abatement projects in nitric acid plants (CDM Methodologies Panel, 9 May 2013).

¹⁴ Another methodology, AM0051, has not been applied by any project so far. The methodology suggests a technology to measure baseline emissions in the ammonia oxidation reactor. Technical experts agree that currently it is not technically feasible to install such a measuring device.

¹⁵ N₂O concentration is measured both at the inlet and outlet of the destruction facility.

ACM0019

ACM0019, currently applicable under the CDM, establishes default baseline emission factors which are below the commonly observed emission factors in plants without secondary or tertiary abatement. The default emission factors vary on a yearly basis starting from 3.7 kg N₂O / t HNO₃ for 2013, and decreasing progressively to 2.5 kg N₂O / t HNO₃ in 2020. The default emission factor remains 2.5 kg N₂O / t HNO₃ 2020 onwards (CDM EB 73, Annex 7, 2013). Since the default emission factors are conservative, CDM projects using ACM0019 yield less CERs per tonne of HNO₃ production when compared to the previously applicable AM0034 and AM0028.

For tertiary N₂O abatement projects, any remaining N₂O emissions from the project plant and CO₂ emissions arising from the operation of the tertiary N₂O abatement system are included as project emissions under the methodology (CDM EB 73, Annex 7, 2013).

In India, all N₂O abatement projects at nitric acid plants use a secondary catalyst. There is no tertiary N₂O abatement project in India. Thus, all N₂O abatement projects in India either use AM0034¹⁶ or ACM0019.

1.4.2 N₂O Abatement Projects in India

In India, CDM has been the key driver for implementation of N₂O abatement projects in nitric acid plants. These projects used secondary catalysts for abatement of N₂O. As of April 2016, India has eight registered CDM projects that abate/have potential to abate N₂O emissions from the nitric acid production, distributed across three manufacturing facilities - DFPCL (5 projects), GNFCL (1 project) and RCFL (2 projects). Additionally, there is one N₂O abatement project under validation at GNFCL¹⁷. The estimated ex-ante emission reduction potential from this project is 0.11 million t CO₂e per year¹⁸.

Table 4 provides a summary of implementation status of these projects.

¹⁶ Projects that are already registered using AM0034 shall continue to accrue CERs as per the same during their crediting period.

¹⁷ <http://cdm.unfccc.int/Projects/Validation/DB/EBJW63OTGQBR9SS08PVHY1DJQ1RLHL/view.html>

¹⁸ The PDD hosted for validation provided ER potential was based on the incorrect plant capacity. The same has been apportioned to the actual plant size as gathered through stakeholder consultation.

Table 4: Implementation Status of N₂O Abatement Technologies in Nitric Acid Plants in India (Registered)

S. No.	Project Developer	UNFCCC Ref.	Catalyst Implementation Date	CERs issued	Present Status
1.	GNFCL	2550	November 2007	41493	Catalyst in use
2.	DFPCL	2493	April 2010	417238	Catalyst in use
3.	DFPCL	8729			Not implemented
4.	DFPC	2997	June 2010	185677	Catalyst in use
5.	DFPCL	8731			Not implemented
6.	DFPCL	8595			Not implemented
7.	RCFL	2792	March 2009	341446	Catalyst removed in February 2015.
8.	RCFL	2801	June 2009	703285	Catalyst removed in June 2014.
Total				1689139	

Source: Compiled from the data available on UNFCCC website and stakeholder consultations

The stakeholders represented that no CER transactions have been completed with Annex-1 buyers though in few projects the buyer DNA approval appears on the UNFCCC web page.

1.4.3 Limitations, Barriers and Opportunities for CDM in this Sector

Stakeholder consultations suggest that the CDM framework and procedures are perceived to be lengthy and cumbersome by nitric acid producers. The failure of the CER market has generated a sentiment of distrust as the companies have lost the capital investment made for implementation of N₂O abatement measures.

The monitoring procedures as per CDM methodologies are also perceived to be complicated and costly. ACM0019 requires the use of the European Standard EN 14181 (2004) 'Stationary source emissions - Quality assurance of automated measuring systems' for installing and operating the Automated Monitoring System (AMS) for N₂O emissions. Salient features of the standard EN14181 are provided in Box 2, Chapter 2. The stakeholders have revealed that the technical capacity to execute monitoring and calibration requirement as per the standard EN14181 is limited in India. This limitation drives up the cost of project operation. RCFL has reported additional expenditure on monitoring system operation as one of the reasons for discontinuation of N₂O abatement activity. Although ACM0019 was a long leap in simplifying

CDM registration procedures, project developers seek further simplification of the monitoring and issuance procedures, while maintaining credibility and quality of emission reductions generated. An approach to balance the two seemingly contradictory interests may require to be developed.

1.5 Conclusion

Nitric acid production in India is an organised business with the major players operating large fertiliser units. Nearly 83% of nitric acid is consumed in-house by fertiliser companies while close to about 17% is sold to third parties.

The present regulations in India do not mandate N₂O abatement during nitric acid production, yet several large nitric acid producers have registered their projects with UNFCCC for possible additional revenue stream through transaction of CERs. Few registered projects have implemented secondary catalyst based reduction technologies, while two companies have reportedly abandoned their GHG abatement infrastructure. None of the registered projects has approached the CDM Executive Board for issuance of CERs in recent past.

The companies are aware of the benefits of GHG emission reduction and the abatement potential of their nitric acid production facilities. However, technical support as well as financial commitment to mainstream their mitigation efforts would be required.

The next chapter presents a detailed analysis of the past performance of nitric acid production, installed capacity and the realisable GHG abatement potential available in the country.

2. GHG Abatement Potential in Nitric Acid Sector in India

The total installed capacity of nitric acid in India is about 5152 TPD. At present few of the nitric acid production facilities are operating at partial load due to fluctuating in-house fertiliser product mix and third party demand for nitric acid. In addition to production, there are other factors such as age of plant, production technology and abatement efficiency that will result in the estimation of GHG abatement potential from nitric acid production facilities. This chapter covers relevant aspects pertaining to possible GHG reduction potential as well as expected change in potential due to future production of nitric acid under various scenarios.

2.1 Baseline Process Emissions from the Indian Nitric Acid Sector (Scope 1 N₂O emissions)

There are several sources that have reported on N₂O emissions from India. The information on N₂O emissions is available between 1994 and 2010 reported by NATCOM and Biennial Update Report. A summary of N₂O emissions from nitric acid production in India is presented in Table 5. During 1994–2007, N₂O emissions from nitric acid production increased by 81%. Between 2007 and 2010, N₂O emissions from nitric acid production decreased by 57%, reaching even below the 1994 levels. There are no specific reasons presented in the Biennial Update Reports (BUR) for this, though it could be linked to:

- Reduction in GWP value used for N₂O from 310 (IPCC, 1996) to 298 (IPCC, 2007) to 264 (IPCC, 2013)
- Implementation of CDM supported N₂O abatement technologies in 5 WNA plants between 2007 and 2010 (Refer Table 4)

Table 5: Trends in N₂O Emissions from Nitric Acid Plants in India

Source	Year of Publication	Assessment year	Total Emissions (million t CO ₂ e)	N ₂ O Emissions from Nitric Acid Plants (million t CO ₂ e)	Percentage of N ₂ O Emissions from Nitric Acid out of Total Emissions	Reference
NATCOM - I	2004	1994	1228.5	2.7	0.21%	(Sharma, Bhattacharya, & Garg, 2006)
NATCOM - II	2012	2000	1301.2	3.6	0.27%	(Ministry of Environment and Forests, 2012)
INCCA	2010	2007	1727.7	4.9	0.28%	(Indian Network for Climate Change Assessment, 2010)
BUR-1	2016	2010	2136.8	2.18*	0.10%	(Ministry of Environment, Forests and Climate Change, 2015)

*Possible reasons for reduction in emissions from the plants are discussed in Section 2.1.

2.2 GHG Abatement Potential and Costs of Alternative Technologies

2.2.1 N₂O Abatement Technologies for Nitric Acid Plants

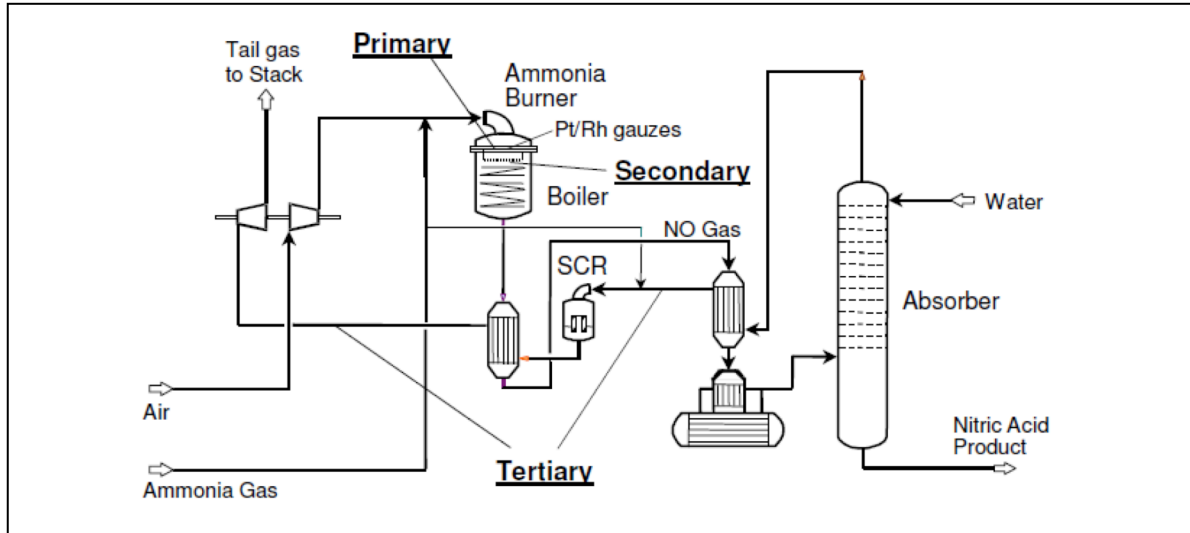
Nitric acid production industry is continuously implementing measures to increase the production through process improvement. Some of these measures also reduce N₂O emissions (CDM Methodologies Panel, 3 June 2011). A number of N₂O abatement technologies have been implemented during last decade. CDM/ JI have played a crucial role in increasing the penetration of these technologies, both in developing as well as developed countries. N₂O abatement measures in nitric acid plants were first implemented in Europe. Both Yara International ASA and BASF are known to have developed and implemented N₂O abatement technologies much earlier than CDM /JI framework was executed (Connock, 2008). However, the technical know-how and implementation remained limited until CDM/JI incentivised uptake of N₂O abatement measures.

N₂O abatement technologies are broadly classified into (IPCC, 2006):

- **Primary abatement:** Includes measures that affect the formation of N₂O during the catalytic oxidization of ammonia (Ministry of Housing, Netherlands, 2001)

- **Secondary abatement:** Includes measures that remove N_2O in the burner after the ammonia oxidation catalyst
- **Tertiary abatement:** Includes measures that remove N_2O from the tail gas

Figure 10: Nitrous Oxide Abatement Process



Source: Groves and Frank, 200919

Primary Abatement Measures

Primary catalyst is a prerequisite for nitric acid production plants, as it is required for oxidation of ammonia to NO gas. Timely replacement of the primary catalyst facilitates oxidation of ammonia, thereby reducing N_2O emissions (Connock, 2008). Catalyst replacement is required more frequently in high pressure plants (once in 3-4 months) as compared to dual pressure and medium pressure plants (once in 6 months). Therefore, high pressure plants have a higher downtime (4 X 2 days = 8 days, as compared to 2 x 2 days = 4 days for medium pressure plants) (ThyssenKrupp, Stakeholder Consultation, 19 February 2016). Primary catalysts in 95%-5% composition (Platinum-Rhodium) are known to reduce N_2O emissions (Kamphus, 2014). Modification of composition and geometry of platinum based catalysts can reduce N_2O emissions by 30-50%. Alternative catalysts yielding 80-90% reduction in N_2O are also reported to have been used in some plants. (Ministry of Housing, Netherlands, 2001). Heraeus' *FTCplus* system is one such example of primary N_2O abatement technology (Connock, 2008). Alternative oxidation catalysts like Co_3O_4 or two-step catalysts are known to reduce N_2O emissions, but generally have a low NO yield which increases ammonia requirement for nitric acid production.

N_2O is unstable at temperatures of 850-950°C. Therefore, N_2O emissions can also be reduced to 70-85% by increasing the residence time of gases at such elevated temperatures enabled through

¹⁹ Groves, M. & Frank, C. (EnviNOx®: Process for N_2O and NO_x Abatement in Nitric Acid Plants – Setting emission standards for nitric acid plants, Uhde GmbH, Dortmund, Germany, 2009)

extension of the reaction chamber behind the catalyst. This measure has a co-benefit of increasing the NO yield²⁰ (Kamphus, 2014).

Secondary Abatement Measures

Secondary abatement requires installing a N₂O destruction catalyst below the primary catalyst inside the oxidation reactor (Connock, 2008). This catalyst decompose N₂O into N₂. Abatement efficiency of the secondary catalysts varies from about 50% to over 90%, and depends on the design and operating conditions of the nitric acid plant as well as on how the secondary catalyst is installed (Kollmuss & Lazarus, 2010). Secondary N₂O abatement technology gained extensive market share in the last decade mainly due to the impetus provided by CDM (Refer Box 1). These technologies are proprietary, and are sold or leased to nitric acid plants. The secondary abatement technology has proven to provide a reliable and environmentally safe way for reducing N₂O. The secondary catalyst itself is easily installable during a routine plant shut-down and gauze change (CDM PDD, Ref 2943, 2010). Use of secondary catalyst does not require additional energy or lead to additional GHG emissions. However, the operational efficiency of catalyst reduces with time and thus, the secondary catalyst is required to be replaced at appropriate intervals to ensure optimum performance (ThyssenKrupp India, Stakeholder Consultation, 29 February 2016).

Box 1: Secondary Catalyst based Technologies

Heraeus, Johnson Matthey, BASF and Umicore are the principal suppliers of secondary catalyst based N₂O abatement technologies.

Heraeus offers two kinds of secondary catalysts – Rashchig Ring type and Pellet type. The former is mainly used in medium pressure plants, and provides a very low pressure drop. The latter is more suitable for low pressure plants, and where the space available for secondary catalyst is only a few millimetres. The catalysts can achieve abatement efficiency of 85-95% depending upon the process and design conditions.

Johnson Matthey has developed its own catalyst based on the Amoxis® catalyst. Additionally, it also markets N₂O abatement catalyst from Yara (YARA 58 Y 1® catalyst system). Abatement efficiency of over 90% can be achieved with both the catalysts. Both the catalysts have been used in nitric acid plants in developing countries with support from CDM.

The secondary catalysts of BASF have also been used in several developing countries apart from being used in its own plants in Europe. The technology at BASF uses different catalyst types and geometries, which allows the technology to be applied to different plant types by adapting to the available pressure drop and installation height.

Umicore markets its N₂O abatement secondary catalyst by the name of MultiComb GreenLine. The catalyst is highly porous, which allows to minimize pressure drops. Additionally, an optimal surface to volume ratio enables high N₂O abatement efficiency. The technology guarantees a minimum percentage of N₂O emission reduction, irrespective of the total N₂O content in the process gas.

Source: (Connock, 2008)

²⁰ NO yield is the highest at ammonia to air ratio of 9.5-10.5% percent, pressure of 1 bar and temperature of 750 - 900°C.

Indian projects have reported varying levels of abatement efficiencies. The secondary catalyst supplied by BASF to GNFCL is guaranteed to destruct a minimum of 63% (CDM PDD, Ref 2550, dated 2009) of the N₂O formed during the reactions in the Ammonia Oxidation Reactor (AOR), when replaced as prescribed. Installed in 2007, the catalyst is reported to have abatement efficiency of 50% at present. The same BASF catalyst has been reported to yield abatement efficiency as high as 81% in RCFL's HP plant for one of its monitoring periods²¹. The technology supplied by Johnson Matthey Plc and adopted by DFPCL, the YARA 58 Y 1[®] catalyst system, reduced 80-90% of baseline N₂O emissions.

Tertiary N₂O Abatement Technologies

Tertiary technologies are installed downstream of the absorption tower and are based on either thermal or catalytic decomposition of N₂O. Tertiary abatement is highly effective at minimising N₂O emissions (over 90% in most cases) (Kollmuss & Lazarus, 2010) (IPCC, 2006) (Kamphus, 2014) and do not interfere with the nitric acid production process. However, it warrants higher operating temperature which may require additional fuel consumption to heat up the tail gas. Some technologies/variants may require additional hydrocarbon (as reducing agents) use.

Tertiary abatement may include the use of the following technologies:

- **Non-Selective Catalytic Reduction (NSCR) Technology:** Non-Selective Catalytic Reduction (NSCR) technology was widely installed in nitric plants built in the 1970s. In the process of destroying NO_x, NSCR systems also destroy 80-90% of the N₂O (Mainhardt, 2006). However, NSCR units are generally not preferred in modern plants because of high energy costs (Kollmuss & Lazarus, 2010) (IPCC, 2006). NSCR technologies require the installation of a complete catalyst container between the absorption column and the stack, as well as a re-heating system which may cause significant downtime of the plant during construction and commissioning (Murali, Fukuda, & Brandt, CDM PDD, Ref 2943, 2010). In India it is unlikely that the nitric acid plants that are already in compliance with the prevailing NO_x regulations would invest in the installation of NSCR technology for N₂O or NO_x abatement.
- **Regenerative Thermal Oxidizer (RTO):** CTP GmbH, Austria has designed a Regenerative Thermal Oxidizer for tertiary abatement of N₂O. The decomposition reaction is non-catalytic and does not require any addition of reducing agent. The RTO is electrically heated. Based on the regenerative heat exchange principle, one or more heat exchangers packed with ceramic honeycombs transfer heat to the entering flue gas, thus applying the stored energy of the blocks. The hot flue gas flows into the combustion chamber where the N₂O is destroyed by high temperature. After cycling the flow, the blocks are reloaded by storing the energy of the hot purified gas. CTP's first thermal N₂O abatement system has been operating successfully in France since August 2010. The project was developed as a JI project. RTO

²¹ between July 2010 to December 2010

unit's thermal decomposition efficiency is expected to vary from 90 to 97% (CDM PDD, Ref 8668, 2012) (CTP, n.d).

- **EnviNO_x**: ThyssenKrupp Industrial Solutions (Uhde) has developed a tertiary N₂O abatement technology called EnviNO_x, which combines N₂O removal process with DeNO_x stage using Iron-Zeolite catalysts. The technology is applicable on industrial scale and has been used successfully in Borealis AG HNO₃ Plant Line E and in some developing countries with CDM support. The technology is available in a number of variants with provisions for either stand-alone N₂O abatement by catalytic decomposition to N₂, or catalytic decomposition of N₂O combined with catalytic reduction of NO_x, or catalytic reduction of N₂O and NO_x. Tertiary N₂O abatement through catalytic reduction using EnviNO_x requires a high tail gas temperature. If temperatures are lower than 350°C, methane is required as a reducing agent for N₂O abatement. As a result, the process emits some CO₂. However, the amount of CO₂ is very less, and hence DeN₂O treatment results in net reduction in GHGs in t CO₂e. The technology results in very high N₂O abatement efficiency (~98-99%).

The comparative advantages and disadvantages of the tertiary abatement technologies over secondary catalyst based technologies are given in Table 6.

Table 6: Comparison of Secondary Catalyst Based Technologies and Tertiary Abatement Technologies

Parameter	Secondary Catalyst Based Technologies	Tertiary Abatement Technologies
N ₂ O Abatement Efficiency	Typically 50-80%, although some projects have also reported over 90% abatement efficiency (CDM Monitoring Report – Ref 2550, 2012), (Connock, 2008) (Debor, Schmidt, & Velsen-Zerweck, 2010)	High (more than 90%, reaching 100% in some cases ²²) in most cases (Debor, Schmidt, & Velsen-Zerweck, 2010), (Connock, 2008), (ThyssenKrupp Industrial Solutions, 2016) (Groves & Sasonow, 2009)
Capital Investment	Comparatively lower	Higher (Refer Section 2.2.6)
Catalyst Life	2-4 years	10 years
On-line Monitoring of Real-time N ₂ O Abatement	Not possible. N ₂ O abatement estimated by comparison against a fixed baseline campaign.	Possible (ThyssenKrupp, Stakeholder Consultation, 29 February 2016)
Impact on Production	At times pressure drops observed inside AOR leading to loss of production.	Being an end-of-pipe solution, does not interfere with the production process. (ThyssenKrupp Industrial Solutions, 2016) (Groves & Sasonow, 2009).
Synergies with NO _x Reduction		Where EnviNO _x systems are used, N ₂ O and NO _x reduction can be combined in a single reactor vessel (Groves & Sasonow, 2009). In such cases, DeNO _x units need

²² In some cases, abatement efficiency as low as 50% has also been reported

Parameter	Secondary Catalyst Based Technologies	Tertiary Abatement Technologies
		to be tweaked and enabled with an N ₂ O abatement catalyst to double up as a 'DeN ₂ O' unit. The incremental cost involved with this change is affordable by most nitric acid producers (ThyssenKrupp India, Stakeholder Consultation, 29 February 2016).
Cost of Abatement	€ 0.44–0.88 / t CO ₂ e ²³ (ThyssenKrupp Industrial Solutions, 2016).	€ 0.33 / t CO ₂ e ²⁴ (ThyssenKrupp Industrial Solutions, 2016).
Pay-back Period (if supported by CDM or a similar mechanism)	Generally the pay-back period is longer as compared to tertiary abatement technologies.	Shorter pay-back period due to higher abatement efficiency, despite relatively higher capital costs.
Adaptability/Compatibility with nitric acid Plants	Some modifications are required in the basket structure which can be managed during the routine plant shut down.	In some cases, implementation of the technology requires some modifications in the nitric acid plant (Groves & Sasonow, 2009), (ThyssenKrupp India, Stakeholder Consultation, 29 February 2016).
Associated Downtime	Lower as compared to tertiary abatement technologies. (ThyssenKrupp India, Stakeholder Consultation, 29 February 2016).	Higher due to longer reactor replacement time.
Additional Inputs	No such requirement.	Required additional energy or methane as reducing agent (Groves & Sasonow, 2009).

Note: The advantages and disadvantages enlisted above are typical observations for the two technologies, and should not be generalised. The choice/suitability/performance of a technology depends on specific plant characteristics and circumstances.

Tertiary abatement technologies have not been implemented in India, even though CDM baseline and monitoring methodology is available. Requirement of modifications in the existing nitric acid plants, and a significantly higher capital cost are the major barriers for its uptake by Indian companies.

²³ Based on typical values for abatement and technology costs over a 10 year period shared by ThyssenKrupp Industrial Solutions.

²⁴ For EnviNOx. Typical assumptions over a 10 year period.

Box 2: Monitoring Equipment and Standards Related to Monitoring of N₂O Emissions

CDM methodologies require the use of the European Standard EN 14181 (2004) 'Stationary source emissions - Quality assurance of automated measuring systems' or any more recent version as a guideline for installing and operating the Automated Monitoring System (AMS) for the monitoring of N₂O emissions in the nitric acid plant. In addition to the concentration of N₂O, total gas volume flow measurement also needs to be certified according to EN14181 (Kamphus, 2014). EN14181 standard describes the quality assurance procedures needed to assure that an Automated Measuring System (AMS) or Continuous Emission Monitoring System (CEMS) installed to measure emissions to air is capable of meeting the uncertainty requirements on measured values given by legislation, e.g. EU Directives, national legislation, and/or the Environment Agency (Source Testing Association, 2016).

Three different Quality Assurance Levels (QAL1, QAL2, and QAL3) are defined to achieve this objective. QAL 1 covers the suitability of an AMS for its measuring task (e.g. before or during the purchase period of the AMS), the validation of the AMS following its installation, and the control of the AMS during its ongoing operation on an industrial plant (Source Testing Association, 2016).

Similarly, QAL 2 describes the procedure to calibrate the CEMS once it has been installed, using Standard Reference Method (SRMs) and then to verify whether it still meets the required uncertainty allowances once installed (Source Testing Association, 2016). QAL2 tests are to be performed at least every 5 years according to EN 14181 (Source Testing Association, 2016).

QAL 3 describes the procedure to maintain and demonstrate the required quality of the Continuous Emissions Monitoring System (CEMS) during its normal operation by checking the zero and span readings (Source Testing Association, 2016). With this documentation it can be demonstrated that the AMS is in control during its operation so that it continues to function within the required specifications (Kamphus, 2014).

2.2.2 Barriers to Implementation of N₂O Abatement Technologies

A review of information available from secondary sources has been carried out to understand barriers to implementation of N₂O abatement projects in India.

- None of the N₂O abatement technology options are expected to generate any financial or economic benefits. Further, there are no regulations mandating the use of N₂O abatement technologies in India. With India having committed to reducing the carbon intensity of its economy by 33-35% by the end of the next decade (MoEF&CC, 2015), it is expected that N₂O emissions from nitric acid sector being low-hanging fruit for GHG abatement may be regulated in future, either through novel market-based mechanisms, or through mandatory compliance directives. Early movers for N₂O abatement technologies are thus expected to gain competitive advantage in terms of exposure to technology and monitoring systems by participating in the NACAG.
- Primary and secondary abatement technologies are installed inside the Ammonia Oxidation Reactor. If not correctly designed and installed, they may interfere with the

production process, leading to deterioration of product quality or a loss of production output (CDM PDD, Ref 1119, 2007).

- There is a possibility of leaching of the secondary catalyst (CDM PDD, Ref 2792, dated 2012) which can get deposited in downstream equipment, leading to either a shut-down of the plant for the cleaning of equipment or a long-term effect such as increasing the corrosion rate of equipment.
- The heat generated in a secondary catalyst may affect the uneven basket expansion leading to shut down for basket modifications/strengthening (CDM PDD, Ref 2792, dated 2012).
- Tertiary abatement technologies usually necessitate modifications in the existing nitric acid plants. This limits the willingness of the companies to implement such technologies owing to increased costs and downtime (ThyssenKrupp India, Stakeholder Consultation, 29 February 2016).

2.2.3 Other Considerations for N₂O Abatement Technologies

Secondary catalysts used for N₂O abatement are classified as hazardous waste, and need to be managed as per the existing regulations. In India, BASF has entered into contractual obligation to take back the spent catalyst from both the companies using its technology. RCFL has removed the secondary catalyst, while GNFCL is still continuing with the catalyst installed initially. BASF and RCFL are still discussing modalities of executing the said contractual obligation. BASF plans to engage some local companies that are involved in recycling/safe disposal of catalysts. Until such time the spent catalysts removed by RCFL are being stored in special cases.

Secondary abatement technology warrants catalyst to be installed in each of the reactors. This is expected to have additional cost implications for basket modifications and possibly increased requirement of secondary catalyst by weight. Such additional costs would need to be assessed and evaluated on a case to case basis as it may not be suitable for production units with multiple burners/reactors. For instance, NFL has 8 burners for a 560 TPD plant, which may require 8 catalyst beds for effective GHG reduction thereby rendering it unviable. Tertiary abatement technologies, on the other hand, being end-of-pipe solutions are not governed/restricted by number of reactors installed.

2.2.4 Outlook for N₂O Abatement Technologies in India

N₂O abatement in India has been done through implementation of secondary catalyst from various technology suppliers. Stakeholder consultations indicated following factors contributed to decision making process:

- Capital investment
- Design process/changes required to be carried out in the plant
- Plant downtime
- Additional energy/material cost during operation
- Abatement efficiency/monitoring
- Recurring expenditure

While few companies have made investments on secondary catalysts, none of the projects have carried out replacement of catalyst resulting in reduced abatement efficiency. Also, issued CERs from these projects have not been transacted so far, participating companies have not recovered capital investment. For possible revival of N₂O abatement opportunities in nitric acid production, financial support is this expected not only for the recurring expenditure for replacement of catalyst but also for the capital investment made during implementation.

However, since the sector is organized and is largely government controlled, it could be easy for the government to pursue initiatives to reduce GHGs from this sector, especially because:

- It is a low-risk sector in terms of guaranteed emission reductions - The technology is available, has been used earlier, and is fairly straightforward, and as such there is no particular risk of failure
- Abatement potential from individual entity is fairly large so there is a clear possibility of greater results with less efforts
- Cost per unit abatement is very competitive when compared to most other sectoral initiatives)

The Government of India is considering changes in the urea policy through appropriate adjustment in fertiliser subsidies along with DBT pilot to ensure in time payment to industry to help improve the financial strength of companies. It is possible that in the long term companies may voluntarily implement N₂O abatement in response to increased awareness of climate change, and in order to maintain their identity as responsible corporate citizens.

2.2.5 N₂O Abatement Potential from India

Table 7 presents the estimated volume of CERs assuming implementation of secondary catalyst based technologies in all plants, except NFL²⁵. The projects have been categorised depending upon the present status of projects:

- CER generation potential from registered and implemented projects wherein only monitoring and issuance cycle related CDM procedures need to be followed. All projects in this cluster have fixed crediting periods, ending before December 2020. These projects, therefore, would not generate CERs beyond the end of their crediting periods under the exiting CDM procedures.
- The second cluster comprises of plants that require investments for both, technology implementation either for revival of abandoned abatement infrastructure or for setting up of infrastructure afresh, and UNFCCC related procedures either for renewal of crediting period, or for monitoring and issuance cycle, or both.
- The third cluster comprise of plants that have had no activity for N₂O abatement i.e. neither the project is registered with the UNFCCC nor have any investments been made for implementing the technology in the plant.

CER potential from each of these units has been estimated with consideration to the (i) end of existing crediting periods, (ii) time lag for renewal of the crediting period where applicable and registration of new project activities, and (iii) time lag for technology implementation and equipment calibrations.

Plants which are currently not registered with the UNFCCC or would be applying for renewal of crediting period, would necessarily have to use ACM0019 which provides conservative default values for the baseline N₂O emission factor. Thus, the CERs accruable by such projects are not the same as GHG abatement achieved. The actual GHG abatement is much higher. Table 7 also provides the GHG abatement potential from each plant estimated on the basis of actual or vintage/technology equivalent baseline emission factors.

The annual GHG abatement potential from nitric acid plants stands at 3 million t CO₂e. Considering 4.5 years remaining up till December 2020, the total GHG abatement potential is estimated to be 13.5 million t CO₂e between July 2016 and December 2020. The CER generation potential for the same period is estimated to be 4.97 million CERs.

²⁵ Secondary catalyst based abatement may not be technically feasible for NFL

Table 7: Total GHG Abatement and CER Generation Potential from Indian Nitric Acid Plants (up to 2020)

Company	Unit	Installed Capacity (TPD)	Time left to generate CERs until 2020 (months)	CER Generation Potential until 2020 (number)	N ₂ O Emission per Tonne of Nitric Acid Production (kg N ₂ O / t HNO ₃)	Annual GHG Abatement Potential (t CO ₂ e)	GHG Abatement Potential until 2020 (t CO ₂ e)
GNFCL	Unit 1	900	40	1082078	6.20	332947	1498262
DFPCL	Unit 1	300	45	831277	8.58	221674	997533
DFPCL	Unit 3	300	51	561140	5.11	132033	594149
Total from registered and operational projects				2474495		686654	3089943
RCFL	Unit 1	352	48	301909	12.50	447305	2012873
RCFL	Unit 2	750	48	643272	11.90	901968	4058856
DFPCL	Unit 2	300	54	205186	3.40 [^]	50908	229086
DFPCL	Unit 4	450	54	332750	3.40 [^]	81910	368595
DFPCL	Unit 5	750	54	512893	3.40 [^]	127272	572724
Total from registered and not implemented/ discontinued projects				1996100		1609363	7242134
NFL	Unit 1	560	45	219548	11.90	553628 [#]	2491326 [#]
GSFCL	Unit 1	30	45	16877	6.20	10247	46112
STL	Unit 1	100	45	56258	5.11	28152	126684
GNFCL	Unit 2	360	45	203295	6.22	113000	508500
FACT	Unit 1	15	-	-	12.50	10330	46485
Total from non-registered projects				495979		715358 [#]	3219107 [#]
Total for all plants				4966574		3011375 [#]	13551183 [#]

represents values with use of tertiary abatement technology in NFL

Notes:

CER generation potential:

- Based on secondary catalyst based technologies, except for NFL where tertiary abatement technology (with 95% abatement efficiency) has been considered.
- CER potential for registered projects is based on PDD estimates. For non-CDM projects, Baseline EF is as per ACM0019 version 02 and abatement efficiency is assumed to be 63% (Except NFL). GWP value of 264 has been applied.
- For unregistered projects, crediting period is assumed to start in April 2017.
- DFPCL's non-implemented projects are assumed to start accruing CERs July 2016 onwards.
- Registered and operating projects are assumed to start accruing CERs July 2016 onwards, with consideration to calibration requirements to be conducted before start of the campaign.
- 2nd crediting period assumed to start on 01 January 2017. GWP and baseline EF are revised during CP renewal period, while abatement efficiency remains as envisaged at the time of PDD for CP1.
- FACT is not included for estimation of CER generation potential as it is not operating.

GHG Abatement Potential:

- Based on secondary catalyst use. ER potential for CDM candidate/ registered projects is based on PDD estimates. For non-CDM projects, Baseline EF estimated based on plants using similar vintage and technology, and abatement efficiency of 63%. NFL plant is assumed to operate at 100%.

[^] The prescribed EF may vary annually based on the provisions of ACM0019. For the purpose of estimation of GHG abatement potential, prescribed value for 2015 has been used.

Analysis of the above table reveals that nearly 90% of the total estimated volume CERs will come from registered projects and balance 10% will be contributed by unregistered projects. Figure 11 represents the distribution of the total CER generation potential up to 2020. Additionally, considering that the transaction costs and transaction timelines associated with the registered and operating projects are the least, this set of plants could be placed on priority for perusal under the NACAG in India.

Figure 11: CER Generation Potential from Nitric Acid Plants up to 2020

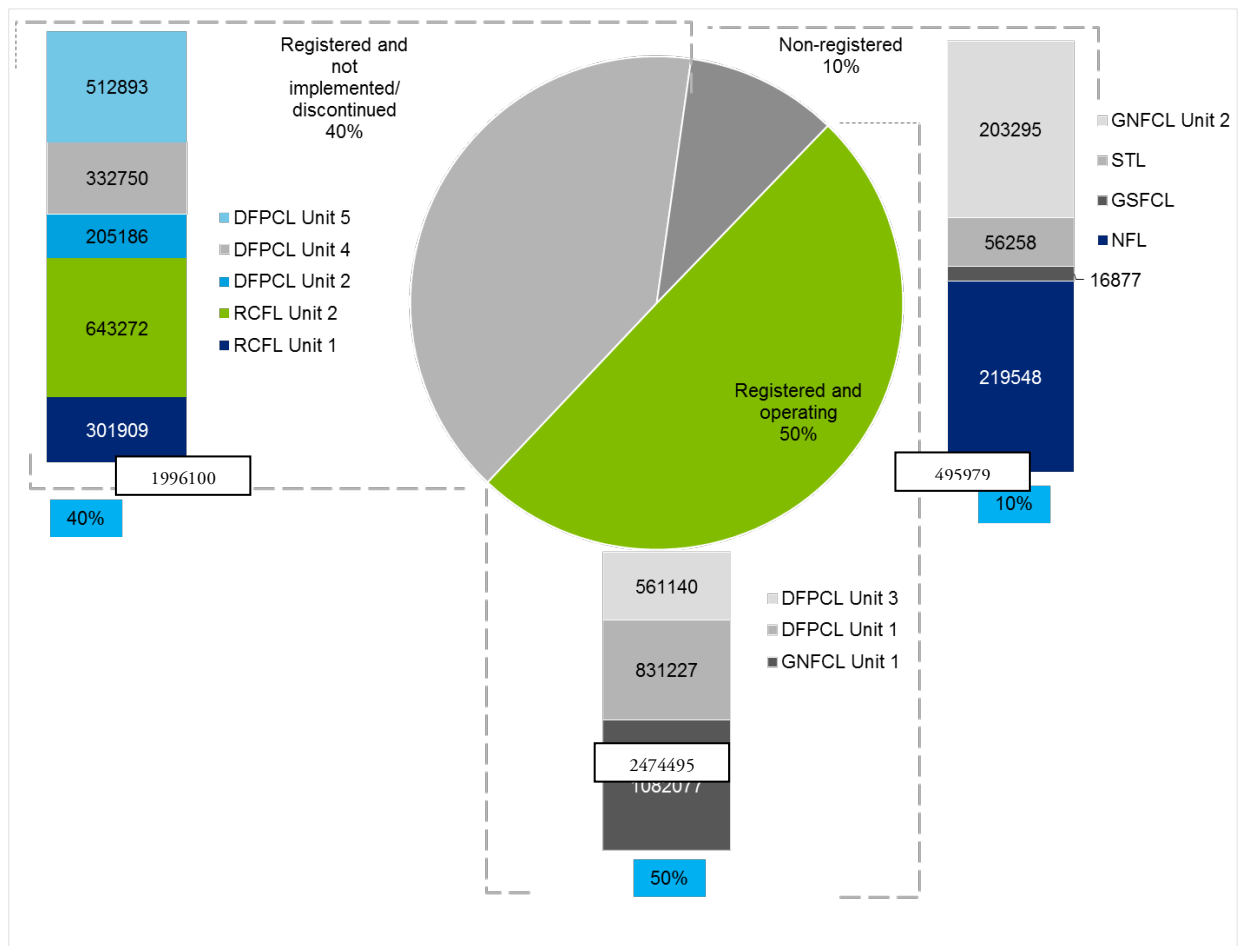
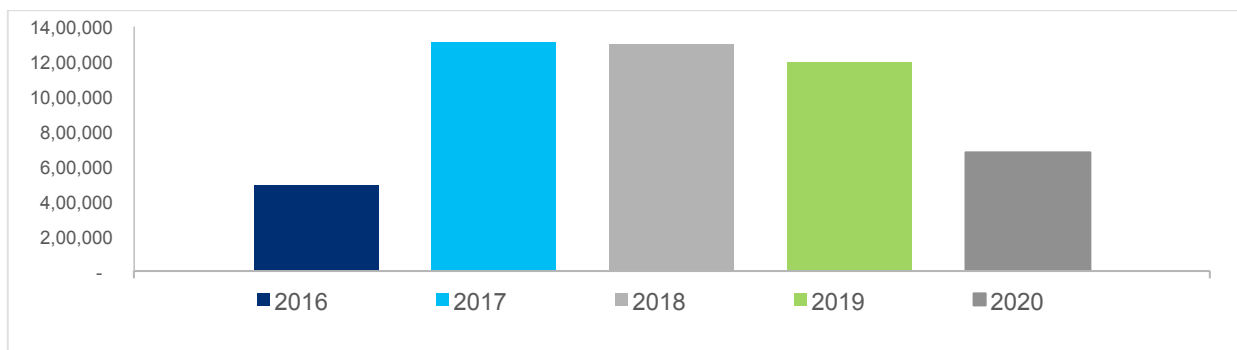


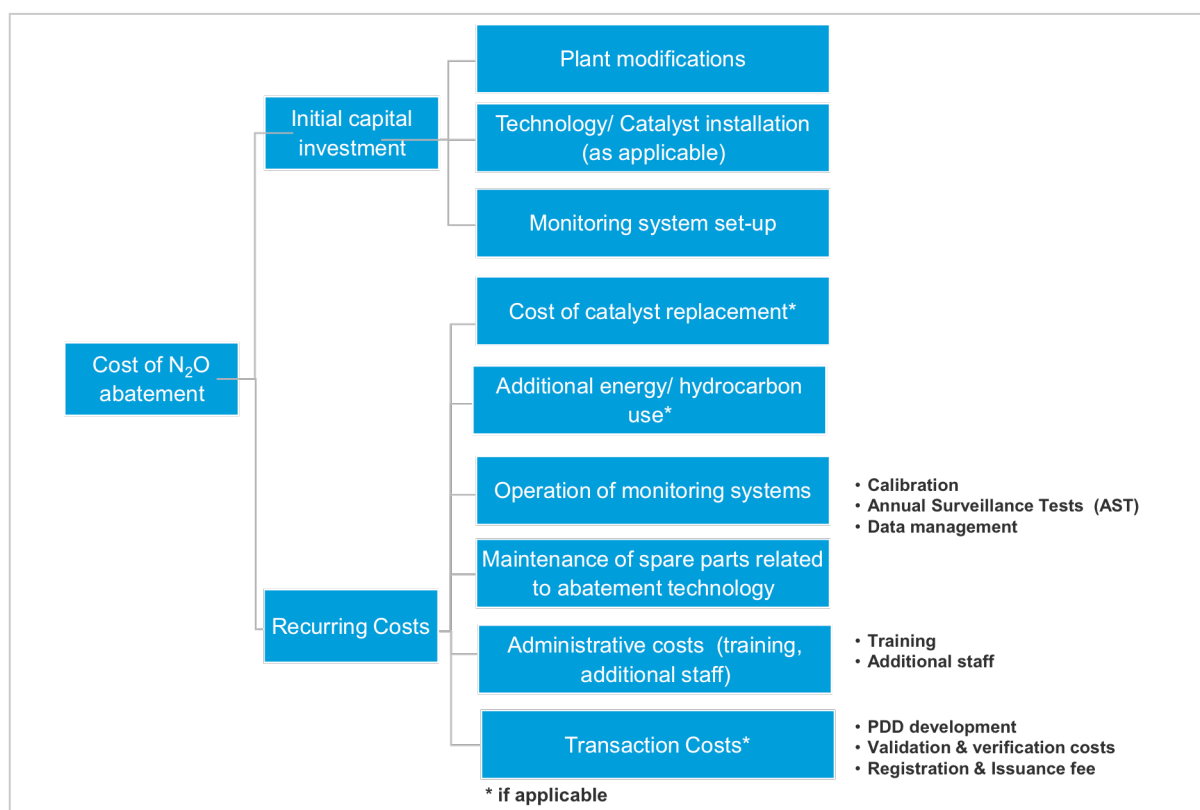
Figure 12: Annual CER Generation Potential from Nitric Acid Plants up to 2020



2.2.6 Cost of Mitigation Technologies

Abatement technologies require two-fold investment, initial capital investment and recurring costs. Figure 13 is a graphical representation of the cost heads associated with implementation of N₂O abatement technologies.

Figure 13: Cost associated with Implementation of Abatement Technologies



Secondary Catalyst Based Technologies

Indian projects have reported capital investment ranging from INR 19.4 million (€ 0.28 million)²⁶ (CDM PDD, Ref 2792, dated 2012) to INR 46.94 million (€ 0.69 million) (CDM PDD, Ref 2550, dated 2009) depending upon plant size and choice of secondary catalysts. For secondary catalysts, recurring cost of catalyst is linked to useful life of the catalyst, linked to production of nitric acid. Additionally, costs related to operation and maintenance of monitoring systems also add to the recurring costs. For Indian projects, estimates for recurring costs range from INR 6.4 million (€ 0.095 million) to INR 7.32 million (€ 0.11 million). The total costs over a period of 10 years range from INR 82.8 million²⁷ (€ 1.38 million) (CDM PDD, Ref 2997, 2010) to INR 193 million (€ 2.87 million) (CDM PDD, Ref 2801, 2009).

²⁶ Conversion rate: INR 67.21 = 1 Euro, for 2009

²⁷ Conversion rate: INR 60 = 1 Euro, for May 2010.

Tertiary Catalyst Based Technologies

No Indian project has been registered using tertiary abatement technologies, the analysis has thus been carried out on the basis of publically available information. A project in Zimbabwe (CDM PDD, Ref 6483, 2012) reports for the following costs for a 281 TPD plant²⁸:

- Investment cost²⁹ of implementation of NSCR DeNO_x technologies with simultaneous N₂O abatement - INR 8.8 million³⁰ (€ 0.19 million).
- Investment costs for tertiary catalyst based N₂O abatement – INR 82.5 million (€ 1.90 million).

Although exact estimates on operating costs of the above mentioned technologies is not available, NSCR technology is known to incur high operation costs due to high energy requirements (IPCC, 2006).

An alternate - EnviNO_x technology indicates capital investment of INR 122 million (€ 1.63 million) per plant. Additionally, operating costs are estimated to be about INR 7.2 million (€ 0.096 million) per year (ThyssenKrupp Industrial Solutions, 2016). EnviNO_x technology is reported to cost INR 23.9 (0.319 €) per t CO₂e. The same source reports cost of secondary catalyst based abatement as INR 32.8 – 65.75 (0.44 -0.88 €) per t CO₂e.

Other factors that may impact total incremental costs for implementation of secondary/tertiary abatement technologies include:

- **Cost escalation:** The capital cost of equipment as well as catalyst is recording a steady increase (8% annually)
- **Lost revenue from decreased production:** Improper installation may result in reduced throughput due to pressure drop inside the AOR (CDM PDD, Ref 2943, 2010) (RCFL recorded reduced production and as there was no CDM benefit from the use of catalyst, they decided to remove catalyst (RCFL, Stakeholder Consultation, 8 February 2016). This is applicable only for secondary catalyst based technologies.
- **Increased plant maintenance costs:** Leaching of catalyst may enhance corrosion of downstream equipment (CDM PDD, Ref 2792, dated 2012). This is also applicable only for secondary catalyst based technologies.
- **Costs for disposal/recycling of used catalyst:** Spent catalysts is classified as a hazardous waste in India and needs to be disposed as per the governing legislations (MoEF&CC, 2015). Arranging/outsourcing disposal may entail additional costs. For existing Indian projects the related costs are to borne by the technology supplier as per the contract.

²⁸ The project includes two plants of 281 TPD each. Costs have been apportioned accordingly.

²⁹ Excluding technical and maintenance costs

³⁰ Conversion rate INR 66 = USD 1

2.2.7 Considerations beyond Technological Measures

Some policy and non-technical measures to facilitate uptake of N₂O abatement technologies in India include:

- Easy financing options can be made available for prospective project developers in the form of soft loans, interest-free loans etc.
- Custom/import duty on technologies for N₂O abatement and monitoring should be waived-off.
- Tax-incentives should be provided to nitric acid producers investing in N₂O abatement technologies.
- Introduction of N₂O tax for nitric acid producing companies may serve as an incentive to implement N₂O abatement activities.
- Research and Development on N₂O abatement technologies should be promoted/financed with the aim to develop a cheaper indigenous technology.
- Mandating disclosure of process emissions from nitric acid plants may also promote adoption of sustainable business practices like N₂O abatement technologies in the long term.

2.3 Future Outlook (2020/2030/2040) of Indian Nitric Acid Sector and Industries using Nitric Acid

2.3.1 Sector Growth/Planned Capacity Additions

The present production of nitric acid in India is majorly consumed in fertiliser industry which consumes nearly 83% of the produce, while about 17% is sold in open market for other uses. The third party sale component has been witnessing an annual growth of 11-14%. Demand from downstream sectors is likely to be the key trigger for future increase in production, as well as for new capacity additions. At present, two new nitric acid plants (1 x 800 TPD and 1 x 350 TPD) are known to be in pipeline.

The Fertiliser Sector

The present policy environment in India is not very conducive for fresh investments in the fertiliser sector³¹ as a whole. For the purpose of this study, discussions have been limited to nitric acid based fertilisers i.e. Nitro phosphates, AN and CAN. The recent regulatory developments related to AN and CAN are expected to have a direct bearing on the nitric acid demand. On the other hand, the Government is taking measures towards deregulation of urea, which is a

³¹ A study by Shakti Sustainable Energy Foundation observed that the current policy environment in India presently is not favorable for new investments in fertilisers. While there have been addition to capacity since 1999 in India, six plants have closed down since 2011.

noteworthy development (refer section 1.3.2) indicating increased demand for Nitro-phosphates in the future. Thus, in the medium to long term, a balanced demand for fertilisers in India is expected.

Further, India's domestic policy initiatives such as the Food Security Bill and the National Mission on Sustainable Agriculture focusing on enhancing agricultural output imply that there would be a substantive increase in total fertiliser demand in the coming years. Production of nitric acid based fertilisers is therefore expected to increase proportionately.

Chemical Sector

The Indian chemical sector has grown from \$ 30 billion (Export-Import Bank of India, 2007) in 2007 to \$ 100 Billion in 2010 and is contributing 7% of India's GDP (Indian Chemical Industry – 'XIIth Five Year Plan', 2012-2017, 2012). With the current initiatives of industry and government, the Indian chemical industry is expected to grow at 11% per annum (or at a rate of 15% per annum in an optimistic scenario) by 2017 (Indian Chemical Industry – 'XIIth Five Year Plan', 2012-2017, 2012).

Nitric acid is also used in small quantities of as an intermediate in the polymer industry (The Essential Chemical Industry Online, 2016). Growth estimates, available for polymers specifically, state that the demand for polymers is expected to grow by 8-10% with healthy growth in industries such as clothing, automobiles etc. (Make in India, 2016).

In view of the above sectoral scenario, a small component of demand increase may come from the chemical sector.

Pharmaceutical Sector

The Indian pharmaceuticals market is expected to expand at a CAGR of 23.9% (Corporate Catalyst India Private Limited, 2015) to reach \$ 55 billion by 2020. As nitric acid is used for production of pharmaceuticals, its demand from the pharmaceutical sector is also expected to grow in the short term.

In view of the above projections and discussions, it can be inferred that the fertiliser sector would continue to be the major user of nitric acid. Chemical and pharmaceutical sectors will also contribute to growth of nitric acid production in India in the short term. While the demand for nitric acid from the fertiliser sector is not expected to increase significantly in the short term, if the possible policy reforms in the fertiliser sector materialise, these are expected to provide a push to the demand in the medium to long term,

To summarise,

- Captive consumption of nitric acid in fertiliser industry has not recorded any significant growth in the country as production of CAN has stopped since the last financial year. Also, production of urea, a highly subsidised and hence the most preferred fertiliser in

India, does not require nitric acid as input feed. Thus, captive consumption of nitric acid for fertiliser production is expected to increase only when urea is included in Nutrition Based Subsidy (NBS) basket which will result in a balanced demand for various fertilisers, thereby increasing the demand for Nitro-phosphates that require nitric acid for production

- The third party sales are recording a steady growth between 11-14% with slight regional variation as most of the non-fertiliser producing users of nitric acid source it from the nearest fertiliser producers
- Stakeholder consultations indicate additional capacity of 1150 TPD to be implemented in FY 2020-21, thereby ensuring that the demand of nitric acid is contained

2.3.2 Future Scenarios

Three scenarios have been developed to project the growth trajectory of nitric acid production in India, and to estimate the emissions and abatement potential using different technologies.

Scenario 1: Business As Usual (BAU) Scenario: Nitric Acid Production Capacity grows at a CAGR of 1.4 %.

Between FY 1991 and 2016, nitric acid production capacity in India increased at a CAGR of 1.4%. The period before that has been excluded for CAGR calculation as it was only in 1991 that economic reforms led to liberalization of the Indian economy. The scenario assumes that the same trend shall continue in the long term (FY 2022-2041) as well. The planned capacity additions are expected to become operational in FY 2022. The BAU thus follows the historical growth trajectory.

Scenario 2: Pessimistic Scenario: Captive Consumption grows at a CAGR of 0%; Third Party Sale grows at a CAGR of 3.5%.

This scenario assumes that a restrictive policy/market environment in the fertiliser industry caps the production of nitric acid based fertilisers at the present levels, and growth in third party sale is the only driver for increasing nitric acid production capacity. Based on the data for FY 2015, only 17.27% of the total nitric acid production was channelized for third party market sales. Of the third party buyers of nitric acid, the explosives industry is one of the key players. During the period FY 2007-2012, the market for explosive nitrate mixture in India grew at a CAGR of 3.5% (Research & Markets, 2012). Thus, the scenario further assumes that nitric acid sale to all third parties grow at a CAGR of 3.5%.

Scenario 3: Optimistic Scenario: Captive Consumption grows at a CAGR of 1.4%; Third Party Sale grows at a CAGR of 14%.

This represents an optimistic scenario for growth of nitric acid sector in India. The scenario assumes that both captive consumption and third party sale of nitric acid grow without disruption, i.e. captive consumption component grows at BAU CAGR of capacity addition (1.4

%) despite policy reforms in the fertiliser sector and third party sale component grows at 14% (higher-end of the growth range of 11-14 % of nitric acid sales to third parties).

Table 8 summarizes the growth rates assumed under various scenarios.

Table 8: Growth Rates assumed under various Scenarios

Scenario	Assumed CAGR	
	Captive Use	Market Sale
Scenario 1: BAU	1.4%	
Scenario 2: Pessimistic	0	3.5%
Scenario 3: Optimistic	1.4%	14%

Assumptions used for estimation of abatement potential

(i) For the period FY 2016 – FY 2021, abatement potential has been estimated as follows:

(a) CDM (registered/candidate) units:

- Abatement potential through the use of secondary catalysts:
While all projects are based on abatement through use of secondary catalyst, these projects report varying values of abatement efficiency of secondary catalysts (%), GWP and baseline EF in the PDD for estimating expected emission reductions. For each unit, expected annual emission reductions as reported in the PDD have been considered as its abatement potential. For projects using ACM0019, expected emission reductions for FY 2015 has been used. For projects currently under CDM-validation, updated information on capacity of the plant has been considered, and the PDD estimates have been apportioned accordingly.
- Abatement potential through the use of tertiary abatement technologies:
Abatement potential has been calculated based on CDM PDD data/values as equivalent abatement achievable through tertiary abatement technologies with 90% abatement efficiency.

(b) Non-CDM units/projects

Baseline emissions have been assumed based on the reported EF of nitric acid plants of comparable vintage and technology in India. Global Warming Potential (GWP) of Nitrous Oxide (N₂O) has been sourced from IPCC's Fifth Assessment Report (264 times that of Carbon Dioxide) (IPCC, 2013).

- Abatement potential through the use of secondary catalysts:
Abatement efficiency of 63% has been applied to estimate abatement potential through use of secondary catalyst.

- Abatement potential through the use of tertiary abatement technologies:
Abatement efficiency of 90% has been applied to estimate abatement potential through use of tertiary abatement technologies.

(ii) For the period FY 2022 onwards, abatement potential has been calculated as follows:

- Baseline emission factor, as provided in approved methodology ACM0019 (CDM EB 73, Annex 7, 2013), has been used as it represents the most conservative emission factor (2.5 kg N₂O / t HNO₃).
- Global Warming Potential (GWP) of Nitrous Oxide (N₂O) has been sourced from IPCC's Fifth Assessment Report (264 times that of Carbon Dioxide) (IPCC, 2013).
- Production capacity - Known capacity additions in the pipeline are assumed to start operation in FY 2022. Plants reaching the end of their operational lifetime are assumed to be replaced with plants of equivalent capacities without technological upgradation.
- Abatement efficiency of secondary catalyst has been assumed to be 63%, while that of tertiary abatement technologies has been assumed to be 90%.

(iii) Other assumptions used for calculation of abatement potential and the associated costs are tabulated in Table 9 (on the following page).

Table 9: Key Assumptions for Calculation of Abatement Potential and Associated Costs

S.No.	Assumption	Value	Unit	Basis	Remarks
1	Number of operating days in a year	330.00	days	Stakeholder consultation	Conservative assumption
2	Capacity of new units (2021 onwards)	750.00	TPD	Stakeholder consultation	Assumed to be the same irrespective of the plant size
3	Capital investment ³² required for secondary catalyst	46.94	million INR/ unit	CDM Ref 2550	
4	Life of secondary catalyst	2	years	CDM Ref 2550	
5	Operating costs (abatement through secondary catalyst)	0	million INR/ unit/ annum	CDM Ref 2550	
6	Capital investment ³³ for tertiary abatement technologies	165.00	million INR/ unit	CDM Ref 6483	
7	Operating costs (abatement through tertiary abatement)	6.59	million INR/ unit/ annum	Assumption ³⁴	
8	Life of catalyst	8	years	Conservative Assumption	
9	Cost Escalation	8.00	% per annum	Assumed	No escalations on the Capex until FY 2021-22. No escalation has been assumed for O&M until FY 2015-16
10.	Operating load	100.00	%	Normative	

2.3.3 Results

Table 10 gives estimated production capacity in FY 2020-21, FY 2030-31 and FY 2040-41 under each of the three scenarios.

Table 10: Estimated Production Capacity under various Scenarios

Year	Nitric Acid Production Capacity (TPD)		
	FY 2020-21	FY 2030-31	FY 2040-41
Scenario 1: BAU	5152.00	7253.06	8334.91
Scenario 2: Pessimistic	5152.00	6400.00	6400.00
Scenario 3: Optimistic	5152.00	9605.69	20275.79

³² Covers operation cost of initial two years

³³ Covers operation cost of initial eight years

³⁴ The PDD does not provide information on operating costs. For the purpose of this study, operating costs have been assumed as 15.9% of capital costs.

Figure 14 shows the growth of N₂O emissions from nitric acid production under BAU and optimistic scenario through FY 2040-41. A sharp decline in emissions is observed in FY 2021-22, despite new capacity additions, owing to a shift to the most conservative EF for estimation of emissions FY 2021-22 onwards. Actual emissions from the production process, based on actual baseline EFs for the existing units³⁵ are represented in through a solid line in the figure.

Figure 14: Growth of N₂O emissions under BAU and Optimistic Scenarios

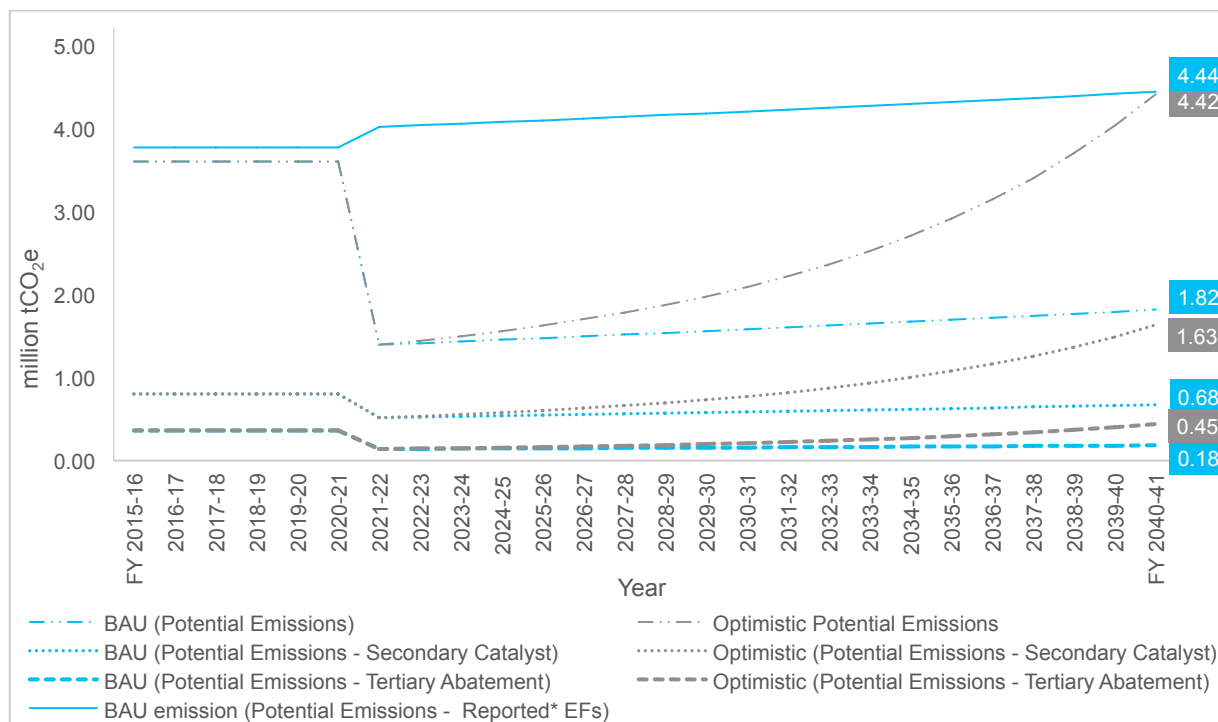


Table 11 (on the next page) summarises the projected annual emissions and abatement potential estimated for FY 2020-21, FY 2030-31 and FY 2040-41 under the three scenarios

³⁵ For plants where actual baseline EFs have not been reported, EF of comparable vintage and technology has been used.

Table 11: Projected Annual Emissions and Abatement Potential estimated under various Scenarios

million t CO₂e

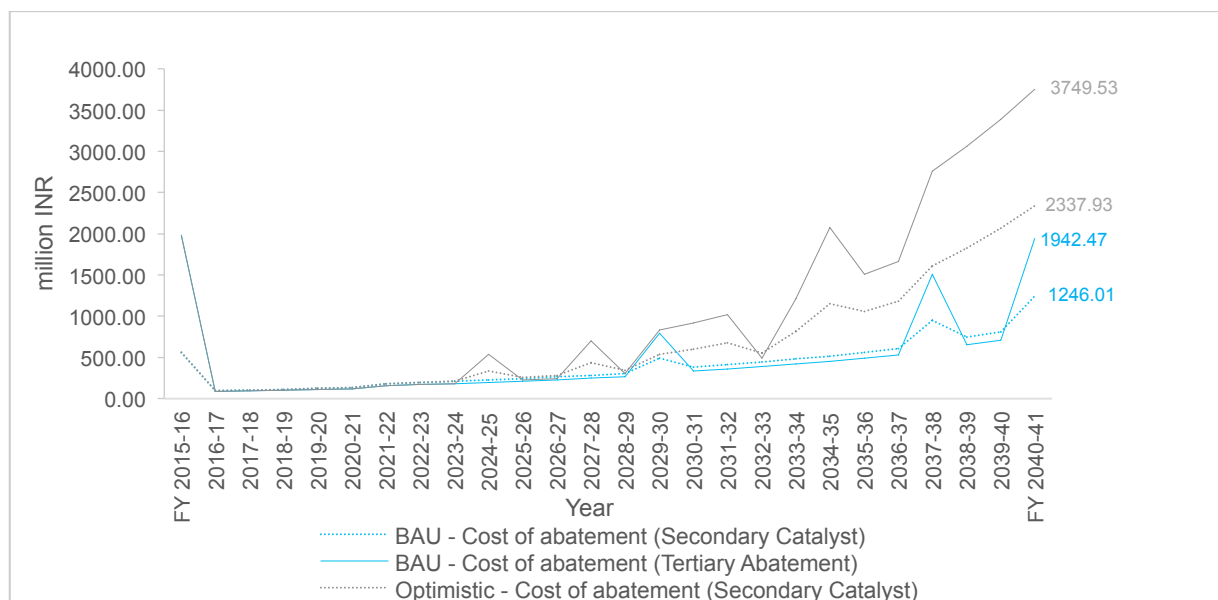
Year	FY 2020-21	FY 2030-31	FY 2040-41
Scenario 1: BAU			
Total Emissions - without abatement technology	3.63	1.58	1.82
Total Emissions - with secondary catalyst	0.82	0.58	0.68
(Emissions Abated)	(2.81)	(1.00)	(1.14)
Total Emissions - with tertiary abatement technologies	0.37	0.16	0.18
(Emissions Abated)	(3.26)	(1.42)	(1.63)
Scenario 2: Pessimistic			
Total Emissions - without abatement technology	3.63	1.39	1.39
Total Emissions - with secondary catalyst	0.82	0.51	0.51
(Abatement)	(2.81)	(0.88)	(0.88)
Total Emissions - with tertiary abatement technologies	0.37	0.14	0.14
(Emissions Abated)	(3.26)	(1.25)	(1.25)
Scenario 3: Optimistic			
Total Emissions - without abatement technology	3.63	2.09	4.42
Total Emissions - with secondary catalyst	0.82	0.77	1.63
(Emissions Abated)	(2.81)	(1.32)	(2.78)
Total Emissions - with tertiary abatement technologies	0.37	0.21	0.45
(Emissions Abated)	(3.26)	(1.88)	(3.97)

Using the cost estimates provided in Table 9, the total estimated expenditure required up to FY 2021, FY 2031 and FY 2041 is summarized in Table 12. Distribution of cost over the years due to recurring expenditures, and capital investment with each capacity addition is shown in Figure 15.

Table 12: Estimated Cumulative Cost under various Scenarios

Year	million INR (million € ³⁶)			
	FY 2015-16	FY 2020-21	FY 2030-31	FY 2040-41
Scenario 1: BAU				
Total Cost of Abatement -secondary catalyst	563.28 (7.49)	1,133.51 (15.08)	3,903.40 (51.92)	1,0670.77 (141.92)
Total Cost of Abatement - tertiary abatement technologies	1,980.00 (26.33)	2,481.11 (33.00)	5,278.71 (70.21)	1,2746.02 (169.52)
Scenario 2: Pessimistic				
Total Cost of Abatement -secondary catalyst	563.28 (7.49)	1,133.51 (15.08)	3,719.70 (49.47)	9,303.09 (123.73)
Total Cost of Abatement - tertiary abatement technologies	1,980.00 (26.33)	2,481.11 (33.00)	4,753.81 (63.23)	9,660.39 (128.48)
Scenario 3: Optimistic				
Total Cost of Abatement -secondary catalyst	563.28 (7.49)	1,133.51 (15.08)	4,507.00 (59.94)	17,788.27 (236.58)
Total Cost of Abatement - tertiary abatement technologies	1,980.00 (26.33)	2,481.11 (33.00)	6,760.71 (89.92)	2,7681.54 (368.16)

Figure 15: Distribution of Annual Costs for Abatement using Secondary Catalysts and Tertiary Abatement Technologies (BAU and Optimistic Scenario)



³⁶ Euro to INR conversion rate as on 31st March 2016: 1 Euro = INR 75.188

As is clear from the above discussions, tertiary abatement technologies though involve a significantly higher cost of implementation, are able to achieve higher abatement as compared to secondary catalysts. To compare cost efficiency of the two measures, cost of abatement per t CO₂e for each of the two technologies is provided in Table 13.

Table 13: Cost per t CO₂e Abatement using Secondary and Tertiary Abatement Technologies

Particulars	Secondary Catalyst	Tertiary Abatement Technologies
Total abatement up to FY 2041 (BAU) (million t CO ₂ e)	37.00	48.16
Total cost up to FY 2041 (BAU) (million INR)	10670.77	12746.02
Cost per unit (INR/ t CO ₂ e)	288.44	263.85
Cost per unit (€/ t CO ₂ e)	3.87	3.54

While on an annual basis the significant cost difference observed in Figure 15 can be attributed to the difference in capital investment associated with two technologies, analysis suggests that the cost of abatement (per t CO₂e) over long term is comparable for both technologies (less than 10% variation). This could be attributed to the higher abatement achieved with tertiary catalysts.

Over a long term, the increased capital costs of tertiary abatement technology gets adjusted by higher abatement over time. In short term, however, the variation in cost per unit abatement is more pronounced (0.90 €/ t CO₂e and 1.69 €/ t CO₂e for secondary catalysts and tertiary abatement technologies respectively up to 2020; and 2.0 €/ t CO₂e and 2.5 €/ t CO₂e for secondary catalysts and tertiary abatement technologies respectively up to 2030). Eventually, the cost per unit abatement for tertiary abatement technologies becomes more attractive than that for secondary abatement technologies (as shown in Table 13). Thus for short to medium term, secondary abatement technologies are cost effective.

2.4 Conclusion

N₂O emissions from nitric acid plants contribute only a small percentage to India's total GHG inventory. Nonetheless, by virtue of its projected magnitude the sector is of relevance to the Indian scenario in the medium to long term. CDM and JI have played a crucial role in increasing the penetration of N₂O abatement technologies, both in developing as well as developed countries. At present, the N₂O abatement potential from the sector in India stands at 3 million t CO₂e with the use of secondary catalysts in all plants except NFL, where tertiary abatement technology may be more suitable.

It is important to mention that the estimated CER potential from India projects between July 2016 and December 2020 is about 4.97 million t CO₂e which is based on the applicable

UNFCCC approved methodologies that have gone conservative over time, the actual abatement for the same duration estimated using the actual project baseline established before registration, is about 13.55 million t CO₂e. The values presented in table 13 can be adjusted appropriately in order to understand the actual benefit to the environment from implementation of N₂O abatement activities in India. The estimated investment required for interventions is approximately INR 600 million (€ 8 million) up to 2020³⁷.

The next chapter details out four case studies that presents in-depth analysis of the business case for N₂O abatement in India. The studies covered

- GNFL: Company with two projects (one operating with catalyst)
- RCFL: Company with two projects (both operating after abandoning operational catalysts)
- DFPCL: Largest nitric acid producer in the country
- NFL: Oldest nitric acid producer in the country with technical challenges around secondary catalyst

³⁷ Assuming tertiary abatement technology for NFL, and secondary catalyst use in other units.

3. GHG Abatement – Case Studies

3.1 Case Study 1: Successful N₂O Abatement Project

3.1.1 Introduction

GNFCL is a joint sector enterprise promoted by the Government of Gujarat and GSFCL. It was set up in Bharuch, Gujarat in 1976. Over the years, GNFCL has diversified into chemicals/petrochemicals, fertilisers, energy sector, electronics/telecommunications and Information Technology.

It has two nitric acid plants. A 750 TPD dual pressure plant (WNA I) has been revamped to increase its capacity to 900 TPD. Another 300 TPD medium pressure plant (WNA II) has been revamped to 360 TPD. In FY 2014-15, the total nitric acid production was 425173 tonnes, of which 336840 tonnes was consumed in captive for production of nitro-phosphates (58.3%), CNA (34.5%) and ammonium nitrate (7.2%). The balance was sold to third parties (GNFC Annual Report - FY 2014-15, 2015). Another 360 TPD WNA plant is in pipeline to cater to the increased demand for production of CNA.

In 2007, GNFCL had installed a German patent BASF secondary catalyst (O3-85 Extruded Stars 6mm) under the primary catalyst in WNA I, with envisaged benefits from CDM. By composition of weight BASF catalysts have 20% CuO, 16% ZnO, plus AL₂O₃ and promoters. The extrudates are in 6mm star shaped form and ring tablets 5 x 5 x 2.5 mm tablets. The catalyst needs to be poured from drums and raked level into burner basket located directly under platinum gauze. The sole purpose of the secondary catalyst is to decompose N₂O into N₂ and O₂. BASF guaranteed N₂O destruction of minimum 63% leading to total CER generation potential of 3.3 million t CO₂e over the 10 year crediting period. (CDM PDD, Ref 2550, dated 2009). This N₂O abatement measure by GNFCL is also registered as CDM project under ACM0034.

Investment in the project activity includes installation and engineering costs associated with shipping, construction and commissioning of the secondary catalyst. On-going costs include replacement costs for the secondary catalyst and regular maintenance and supervision costs at the project site. Itemised costs are provided in Table 14.

Table 14: Capital Cost for the Project Activity as reported by GNFCL

S.No.	Detail	Cost (million INR)
1	Cost of CEMS analyser, related service charges	25.34
2	Custom Duty for import of analyser	2.42
3	Cost of 1870 kg Type 03-85-SS6 secondary catalyst	14.64
4	Custom duty for the import of secondary catalyst	4.54
5	Custom duty	-
6	Expected cost of registration	-
7	Cost of infrastructure	-
	Initial cost of project activity	46.94

Source: (CDM PDD, Ref 2550, dated 2009)

GNFCL has reported that the secondary catalysts installed at WNA I in 2007 is still in use. No monitoring reports have been submitted to UNFCCC for the period beyond January 2010. The project is at a risk of discontinuation as the abatement efficiency has reduced significantly.

Although GNFCL had initiated the process of implementing N₂O abatement measure at WNA II as a CDM project, the initiative was abandoned on account of failure of CDM market, thus plugging the only revenue stream incentivizing implementation of the measure. The project can be revived if adequate financial support is provided. GNFCL has indicated that it would consider use of secondary and tertiary abatement technologies on WNA II and the upcoming WNA III, provided financial support is received. However, technical feasibility of installing tertiary catalyst based system needs to be analyzed in consultation with the technology suppliers.

Details regarding the key parameters and CDM status of the projects are provided in Table 15 (on the following page).

Table15: Key Parameters and CDM Status of GNFCL's N₂O Abatement Projects

Particulars	WNA I	WNA II
CDM Reference No.	2550	-
Registration Status	Registered	Under Validation
Registration Date	29 th October 2009	-
Crediting Period	29 th October 2009 – 28 th Oct 2019 (Fixed)	-
Envisaged Abatement Efficiency of the Catalyst	63%	63%
Methodology	AM0034 Version 03.0.0.	At present - AM0034 Version 03.0.0. To be revised to ACM0019.
Baseline EF	6.20 kg N ₂ O / t HNO ₃	6.22 kg N ₂ O / t HNO ₃
Annual Average ER potential (t CO ₂ e)	332947	130000
Date of Installation of Secondary Catalyst	21 st November 2007	-
Catalyst Replaced	No	NA
Issuance Status	Issued	NA
Number of Issuances	1	NA
CERs Issued	41493	NA
Observed Abatement Efficiency of the Catalyst	-50%	NA

NA - Not Applicable

Source: Compiled from UNFCCC approved PDD and MR, and stakeholder consultations.

3.1.2. GHG Potential

The already registered N₂O abatement project at WNA I has a crediting period up to October 2019. Assuming WNA II applies ACM0019 with a crediting period start date in April 2017, GNFCL's total CER generation potential up to 2020 is provided in Table 16. Since WNA I is already registered with secondary catalyst use, and feasibility of secondary catalyst use in WNA II has already been established, the case study presented does not discuss CER generation potential through tertiary abatement technologies.

Table 16: CER Generation Potential from GNFC's WNA plants

Year	Annual CER generation potential (with secondary catalyst)		
	WNA I	WNA II	WNA III
2016	166474	0	0
2017	332947	44626	0
2018	332947	55534	0
2019	249710	53551	0
2020	0	49584	0
Total (up to 2020)	1285373		

Notes:

For WNA I: Annual CER generation potential provided in the registered PDD, apportioned to the remaining time (starting July 2016) in the current year.

For WNA II and WNA III:

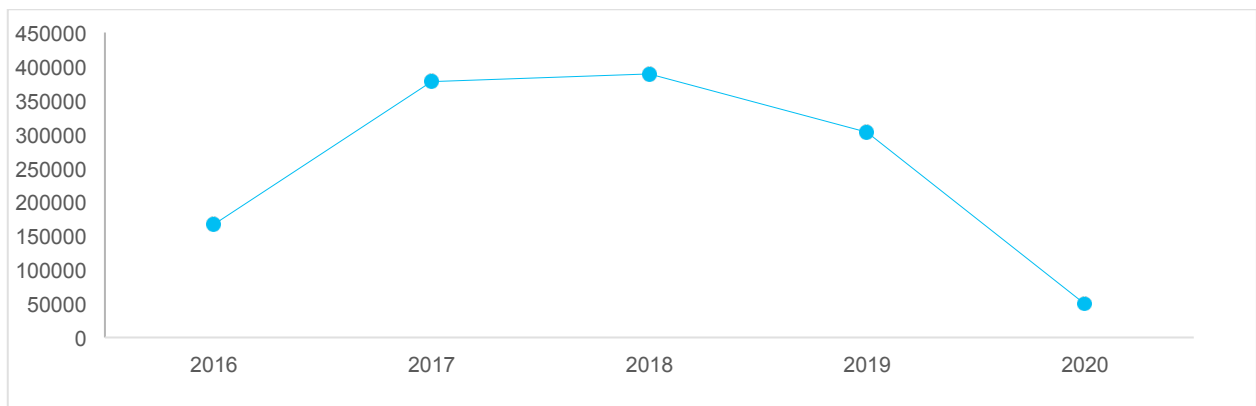
(1) The following assumptions have been used to estimate CER generation potential:

- Secondary catalyst abatement efficiency: 63%
- WNA III commissioning date: FY 2021-22
- Annual nitric acid plant operation days: 330
- Baseline EF for WNA II – conservative defaults provided in ACM0019, version 2
- GWP of N2O – 264 times that of CO2

(2) Potential CERs for WNA II & III have been calculated as:

• CER = Installed capacity (TPD) x Number of operational days in a year x Baseline emission factor (t N2O / t HN03) x Abatement efficiency (%) x GWP x Proportion of year under the assumed crediting period.³⁸

Figure 16 CER Generation Potential from GNFC's WNA Plants



³⁸ i.e. for a project activity with the expected crediting period start date as April 2017, the annual emissions for 2017 been multiplied by a factor of 3/4.

3.1.3 Technology: Availability & Feasibility

There are secondary and tertiary catalyst based technologies available for GHG abatement. As stated earlier, WNA I is already operating with secondary catalyst at 50% abatement efficiency. Although GNFCL had plans to install secondary catalyst on WNA II as well, the initiative was abandoned. GNFCL has indicated that it is open to installing tertiary abatement technologies at WNA II and III, provided the requisite financial support is provided. However, a detailed assessment of feasibility of tertiary abatement technology for the two plants needs to be conducted in consultation with the technology suppliers.

ThyssenKrupp Uhde is the technology supplier for both WNA I and WNA II. Considering ThyssenKrupp Uhde is also the technology supplier for a tested and successful tertiary abatement technology – EnviNO_x – it may be a good opportunity to initiate discussions with the technology supplier, especially for WNA III so that design modifications (if required) can be incorporated since the inception stage.

Additionally, since the performance of an abatement technology may vary with specific plant conditions, it is important to conduct a comparative analysis of the investment and returns for each technology to be able to identify the most suitable technology for each plant.

Environmental and allied statutory clearances also need to be considered for successful implementation of GHG abatement at WNA II and III.

3.1.4 CDM Registration

Both secondary and tertiary technologies at WNA II are eligible for registration with the UNFCCC. For WNA III, design characteristics/tender documents need to be studied to ensure that N₂O abatement measures at the plant would be eligible for registration.

Both the plants would necessarily have to use ACM0019 irrespective of the choice of technology, as AM0034 has now been withdrawn, while AM0028 is no longer applicable to nitric acid plants. ACM0019 adopts a conservative approach for the estimation of GHG emission reduction potential from nitric acid production facilities. The actual GHG abatement is expected to be much higher compared to the abatement potential estimated through ACM0019.

3.1.6 Timeline

The following timelines have been considered for estimation of CER generation potential:

WNA I: Project is already registered and implemented. Although the installed catalyst is abating N₂O, CER accrual is assumed to start from July 2016 to provide adequate time-frame to calibrate the monitoring equipment in use. There is an additional requirement to revise the PDD to reflect changes in the project design from the registered PDD (plant capacity has been

increased since the time of registration). However, as per the existing CDM procedures, the process can be done in parallel with verification and issuance activity.

WNA II:

- Contract between NACAG and GNFCL: June 2016
- Feasibility study for tertiary infrastructure: 60 days
- PDD development: 30 days
- DNA approval: Parallel activity with validation
- Project validation: 90 days
- Registration with UNFCCC: 90 days

Project Implementation, testing and calibration: parallel with CDM procedural timelines. The accrual of emission reductions can start from the date of registration of project with UNFCCC or the date of implementation of the project (whichever is later).

WNA III: Project commissioning – FY 2021-22

3.1.7 Key findings

Up to 2020, CER generation potential from secondary catalyst use as WNA I & II is 1.28 million t CO₂e. The company has already made capital investment for one of its facilities, while for the second facility capital investment will be carried out on the basis of firm opportunity for transaction of emission reductions.

Since GNFCL has already implemented an N₂O abatement project in WNA I, it is technically equipped to manage/oversee implementation and monitoring of the measure. It is also well appraised of the CDM procedures and requirements, and has already completed the issuance cycle.

3.2 Case Study 2: Registered and discontinued N₂O Abatement Project

3.2.1 Introduction

RCFL is a public sector undertaking of Government of India. The company was formed in 1978 consequent to the reorganization of Fertiliser Corporation of India (FCI). The Government of India holds 80% of share capital of RCFL (March 2013 filing to SEBI). RCFL is 4th largest producer of urea in the country. The production is managed through 2 locations namely Trombay (within municipal limits of Mumbai) and Thal (100 km south of Mumbai). RCFL is engaged in manufacturing and marketing of ammonia, urea, ANP, methanol, nitric acid, formic acid and sulphuric acid.

RCFL is operating two nitric acid plants – a 352 TPD High Pressure plant, and another 750 TPD Medium Pressure plant. Both the plants together can provide a maximum throughput of 1200 TPD (98 TPD higher than the installed capacity). In FY 2014-15, the total nitric acid production at was 371090 tonnes (at 100% concentration) (RCF Ltd, Annual Report - FY 2014-15, 2015), of which 359328 tonnes was consumed in captive, and the balance was sold to third-parties. Most (64%) of the WNA consumed in captive was used for the production of nitro-phosphates (64.12%), and the remaining for the production of ammonium nitrate (25.46%), sodium nitrate/nitrite and CNA (10.42%).

Table 17 Key Parameters and Status of RCFL's N₂O Abatement Projects

Item	352 TPD High Pressure Plant	750 TPD Medium Pressure Plant
CDM Reference No.	2792	2801
Registration Status	Registered	Registered
Registration Date	20 th November 2009	29 th November 2009
Crediting Period	20 th November 2009 – 19 th November 2016 (Renewable)	29 th November 2009 – 28 th November 2016 (Renewable)
Envisaged abatement efficiency of the catalyst	89.5%	89.5%
Methodology	AM0034 ver. 3	AM0034 ver. 3
Baseline EF	0.0125 t N ₂ O / t HNO ₃	0.0119 t N ₂ O / t HNO ₃
Annual Average ER Potential (1 st crediting Period) (t CO ₂ e)	447305	901968
Date of Installation of Secondary Catalyst	30 th March 2009	Not known
Cost	Project Cost - INR 19.4 million; Annual cost of catalysts replacement and maintenance of the monitoring systems - INR 6.4 million	Project Cost - INR 37.6 million; Annual cost of catalysts replacement and maintenance of the monitoring systems - INR 15.6 million.
Issuance Status	Issued	Issued
Number of Issuances	3	4
CERs Issued	0.34 million	0.70 million
Monitoring Reports in the Issuance Pipeline	Awaiting issuance request for the 4 th and 5 th monitoring period (32 months in total) with 799776 MERs	Awaiting issuance request for the 5 th monitoring period (15 months) with 480840 MERs
Monitored Abatement Efficiency of the Catalyst	81% (as reported for the period 8 th July 2010 – 4 th December 2010)	55% for campaigns 5, 6 and 73% for campaign 7 (fourth monitoring period – 1 st December 2010 to 7 th September 2011) consists of 3 campaigns)

Source: Compiled from UNFCCC approved PDD and MR, and stakeholder consultations.

In 2009, RCFL had installed secondary catalyst just below the primary catalyst in both the plants. The technology is based on selective reduction of N₂O. The catalyst facilitates conversion/reduction of N₂O to harmless N₂ formation in an exothermic reaction. The secondary catalysts were procured from BASF against a capital cost and 11% of CER sharing arrangement. These N₂O abatement measures are also registered as CDM projects with renewable crediting periods (CDM PDD, Ref 2792, dated 2012), (Nair P. M., 2009). Details regarding the key parameters and CDM status of the projects are provided in the Table 17 (on previous page).

RCFL has reported that secondary catalyst was removed from the MP plant in June 2014, followed by removal of secondary catalyst from the HP plant in February 2015.

3.2.2 GHG Potential

Performance of secondary catalysts through the verified monitoring reports against which the issuances have been carried out by UNFCCC were reviewed.

352 TPD unit: AM0034 (Ver. 3) Registered PDD with 447305 t CO₂e per year potential

Duration for Monitoring	HN03 Production	Operational Hours	GHG (t CO ₂ e)
20th November 2009 – 12th February 2010	28812.98	1928	85469
13th February 2010 – 7th July 2010	44666.01	2861	130778
8th July 2010 – 4th December 2010	45619.96	2873	136762

Approximate GHG abatement in 1 year = (85469+130778+136762)* (12/12.5) = 338888.6 t CO₂e in about 306 days of plant operation

750 TPD unit: AM0034 (Ver. 3) Registered PDD with 901968 t CO₂e per year potential

Duration for Monitoring	HN03 Production	Operational Hours	GHG (t CO ₂ e)
29th November 2009 – 25th February 2010	62280.45	1770	156486
26th February 2010 – 3rd September 2010	125149.7	4013	186209
4th September 2010 – 30th November 2010	62094.50	1989	108447

Approximate GHG abatement in 1 year = (156486+186209+108447) = 451142 t CO₂e in about 323 days of plant operation

Analysis:

- Total nitric acid produced by RCFL in monitoring year = 368623.60 tonnes approximately; while for FY 2014-15 it was 369662 tonnes i.e. the annual production is constant for past 5 years and the units are operating for more than 300 days in a year.

- The cumulative annual GHG abatement potential identified in the registered PDDs of RCFL is 1349273 t CO₂e whereas the actual reduction as per the verified monitoring report is 790030.6 t CO₂e which is approximately 58.5% of estimated potential
- The reduced GHG potential is because of lower nitric acid production compared to estimates presented in respective PDDs as well as lower N₂O emissions during actual monitoring period
- During the stakeholder consultation, it was informed that the third party demand for nitric acid is increasing at about 10% and the balance available capacity is sufficient to cater to such demand. The third party sales amount to 2.79% of the total nitric acid produced by RCFL.

Both the registered projects are nearing the completion of their first crediting period, and are currently operating without the secondary catalyst. CER generation potential from both the projects, assuming renewal of crediting period using ACM0019, and revival of the implemented technology is provided in Table 18.

Table 18 CER Generation Potential from RCFL's WNA Plants

Year	Annual CER Generation Potential (with secondary catalyst)	
	352 TPD High Pressure Plant	750 TPD Medium Pressure Plant
2016	0	0
2017	82339	175438
2018	76850	163742
2019	74105	157894
2020	68616	146198
Total (up to 2020)		945181

Notes:

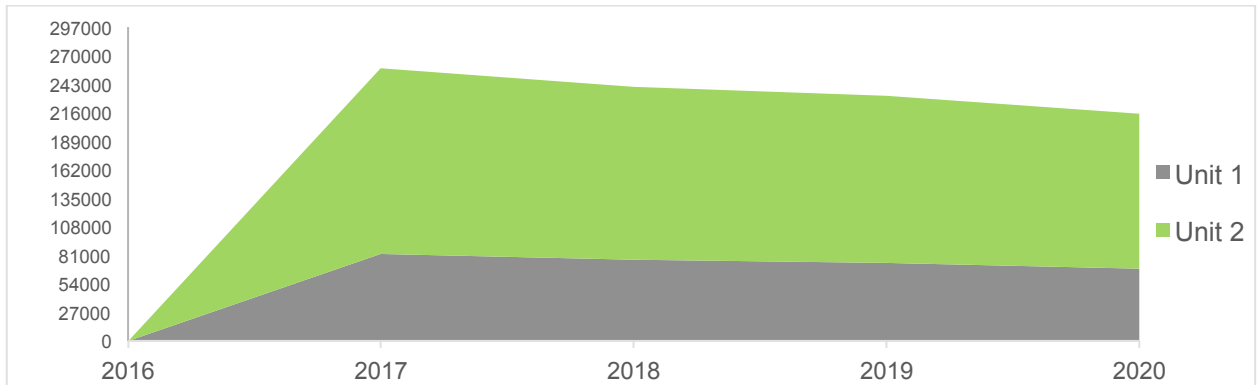
(1) The following assumptions have been used to estimate CER generation potential:

- Secondary catalyst abatement efficiency: 89.5%
- Crediting period renewal date: 01 January 2017
- Date of re-installation of secondary catalysts: 01 January 2017
- Annual nitric acid plant operation days: 330
- Baseline EF- conservative defaults provided in ACM0019, version 2
- GWP of N₂O – 264 times that of CO₂

(2) Potential CERs have been calculated as:

- CER = Installed capacity (TPD) x Number of operational days x Baseline emission factor (t N₂O / t HNO₃) x Abatement efficiency (%) x GWP

Figure 17 CER Generation Potential from RCFL's WNA Plants



Since the secondary catalyst supplied by BASF to RCFL is envisaged to yield a high abatement efficiency, use of tertiary abatement technology is not expected to increase the GHG abatement potential significantly. Nonetheless, discussions with the technology suppliers would provide a more accurate estimation of the specific abatement potential of the two plants through the use of tertiary abatement technologies.

3.2.3 Technology: Availability and Feasibility

During the stakeholder consultation, it was reported that the two catalysts were performing at 80% (high pressure) and 65% (medium pressure) respectively before they were taken out. It was also reported that there is no technical reason for discontinuing GHG abatement and the principal decision was based on absence of transaction opportunities for the issued volumes.

The removed/dismantled catalysts are stored within the premise of RCFL while other infrastructure has been made offline, which requires revival, testing and calibration for proper operational efficiency.

RCFL could also undertake a detailed techno-financial analysis to determine the feasibility of implementing tertiary abatement technology. Such an analysis would also reveal incremental costs and benefits associated with the use of such technologies considering the specific plants parameters and design.

3.2.4 CDM Registration

Both the projects are eligible to apply for renewal of the crediting period. However, in this case, the methodology ACM0019 would necessarily have to be applied to both projects. For this reason, the CER generation potential from the two projects in the second crediting period would be significantly lower than that in the first crediting period.

The second crediting period is expected to start on 1st January 2017. There is a possibility of reviving project implementation as soon as the contract with NACAG is executed. In this case, some CERs can be accrued for the small period between July 2016 and November 2016. Since

monitoring periods across two different crediting periods cannot be combined in a single monitoring report, this would add on to the additional transaction costs associated with an independent monitoring and verification event for this short period. The estimates provided in Table 18 therefore, assume start date of CER accrual to coincide with the start date of second crediting period.

If tertiary abatement technology is deemed to be feasible for RCFL's plants, and is implemented, CDM procedures would require a fresh validation and registration of the projects. This would entail further extension of the CDM timelines, as well as additional transaction costs for validation and registration. For this reason, time lines provided in the following section consider only revival of the secondary catalyst based abatement as the PDD is registered with the same technology.

3.2.5 Timeline

The following time estimates have been considered:

- Contract between NACAG and RCFL: June 2016
- PDD revision: 30 days
- Validation of Renewal of crediting period: 60 days
- Renewal of crediting period with UNFCCC: 90 days
- Project Implementation, testing and calibration: parallel with CDM procedural timelines. The accrual of emission reductions can start from the date of registration of project with UNFCCC or the date of implementation of the project (whichever is later) – Assumed to be 1st January 2017.

3.2.6 Key findings

RCFL has expressed its interest in reviving its secondary catalyst based N₂O abatement projects, however, RCFL does not foresee much incentive in reviving the projects, unless the associated costs are paid upfront and monitoring and verification processes are made cost and time efficient. With use of secondary catalysts, CER generation potential from RCFL's WNA plants stand at 0.94 million CERs (until the end of this decade), while the actual abatement is much higher.

Feasibility of implementing tertiary abatement technologies at the two plants can also be studied. However, implementing tertiary abatement technologies may negatively impact CDM timelines, as well as increase the associated transaction costs. Considering that secondary catalysts have performed reasonably well at RCFL's plants in the past, it may not be attractive to pursue tertiary abatement technologies.

Further, since RCFL has already implemented N₂O abatement projects, which have been issued CERs for multiple time periods, it is believed that RCFL is technically equipped, and experienced to manage/oversee implementation and monitoring of the measure.

3.3 Case Study 3: Planned N₂O Abatement Project

3.3.1 Introduction

DFPCL was set up in 1979 as an ammonia manufacturing company. It is currently a publicly listed company and is among the country's leading producers of industrial chemicals and fertilisers. Its industrial chemicals unit is located at Taloja, which manufactures a variety of products – including nitric acid. The nitric acid complex at DFPCL is the largest of its kind in all of Asia.

DFPCL is operating five nitric acid plants with a combined capacity of 2100 TPD (2 x 300 TPD + 1 x 750 TPD High Pressure units; 1 x 450 TPD Dual Pressure Unit, and 1 x 300 TPD Medium Pressure units). In FY 2014-15, the total WNA production at was 428662 tonnes, of which 61314 tonnes was sold to third-parties, and the remaining was consumed in captive (DFPCL Annual Report - FY 2014-15, 2015).

In 2010, DFPCL had installed a pelletised catalyst (secondary catalyst) underneath the precious metal gauzes of the plant (secondary catalyst) just below the primary catalyst in its WNA I (300 TPD HP) and WNA III (300 TPD MP) plants. The secondary catalyst technology in use, YARA 58 Y 1° catalyst system, has been developed by YARA International ASA (Norway) and is marketed exclusively by Johnson Matthey plc. The YARA 58 Y 1° abatement catalyst is made of cylindrical pellets containing cobalt as an active ingredient, and like other secondary catalysts, reduces N₂O levels in the gas mix resulting from the ammonia oxidation reaction by facilitating conversion of N₂O to N₂ (CDM PDD, Ref 2997, 2010), (CDM PDD, Ref 2943, 2010). The catalyst has been tried and tested in a number of nitric acid plants in Europe. The abatement efficiency has been shown to be more than 80%. If operated properly, the secondary catalyst system has a lifetime of several campaigns and may reduce N₂O emissions to a level satisfactorily below the baseline for about two years, before the catalyst material needs to be replaced (CDM PDD, Ref 2997, 2010). The catalyst does not contaminate the nitric acid produced in the respective nitric acid plant, neither with Cobalt nor with any of the other catalyst materials. These N₂O abatement measures are also registered as CDM projects with crediting periods ending in April 2020 and October 2020 for WNA I and WNA III respectively.

Table 19: Key Parameters and Status of DFPCL's N₂O Abatement Projects

Item	WNA I	WNA II	WNA III	WNA IV	WNA V
CDM Reference No.	2943	8729	2997	8731	8595
Registration Status	Registered	Registered	Registered	Registered	Registered
Registration Date	9 th April 2010	18 th December 2012	11 th October 2010	18 th December 2012	10 th December 2012
Crediting Period	9 th April 2010 – 8 th April 2020 (Fixed)	1 st January 2013 – 31 st December 2022 (Fixed)	11 th October 2010 – 10 th October 2020 (Fixed)	1 st January 2013 – 31 st December 2022 (Fixed)	1 st January 2013 – 31 st December 2022 (Fixed)
Envisaged Abatement Efficiency of the Catalyst	80-90%	80-90%	80-90%	80-90%	80-90%
Methodology	AM0034 version 03.0.0.	ACM0019 version 01.0.0.	AM0034 version 03.0.0.	ACM0019 version 01.0.0.	ACM0019 version 01.0.0.
Baseline EF t N ₂ O / t HNO ₃	0.00858	0.0034 – 0.0025 (as per ACM0019)	0.00511	0.0034 – 0.0025 (as per ACM0019)	0.0034 – 0.0025 (as per ACM0019)
Annual Average ER Potential	221674	50908	132033	81910	127272
Date of Installation of Secondary Catalyst	6 th April 2010	-	14 th June 2010	-	-
Catalyst Replaced	No	NA	No	NA	NA
Cost	INR 97 million (including cost of catalyst replacement, basket modifications and AMS purchase and maintenance).	NA	INR 97 million (including cost of catalyst replacement, basket modifications and AMS purchase and maintenance).	NA	NA
Issuance Status	Issued	NA	Issued	NA	NA
Number of Issuances	5	NA	4	NA	NA
CERs issued	417238	NA	185667	NA	NA

Source: Compiled from UNFCCC approved PDD and MR, stakeholder consultations.

Additionally, DFPCL's WNA II (300 TPD HP) WNA IV (450 TPD Dual Pressure) and WNA V (750 TPD HP) are also registered as CDM projects using secondary catalyst for N₂O abatement, although none of latter plants have actually implemented N₂O abatement. Details regarding the key parameters and CDM status of the projects are provided in Table 19. The catalysts installed in the year 2010, are still in use. No monitoring reports have been submitted to UNFCCC for the period beyond February 2013 for WNA I and March 2013 for WNA III.

Since the catalysts were supplied on a lease basis by Johnson Matthey plc, DFPCL is required to pay a regular lease fee – which includes the cost of continued operation and regular replacement of the catalysts. At the end of useful lifetime of the catalyst, Johnson Matthey will take back the catalyst for recycling/ disposal according to EU regulations (CDM PDD, Ref 2997, 2010).

3.3.2 GHG Potential

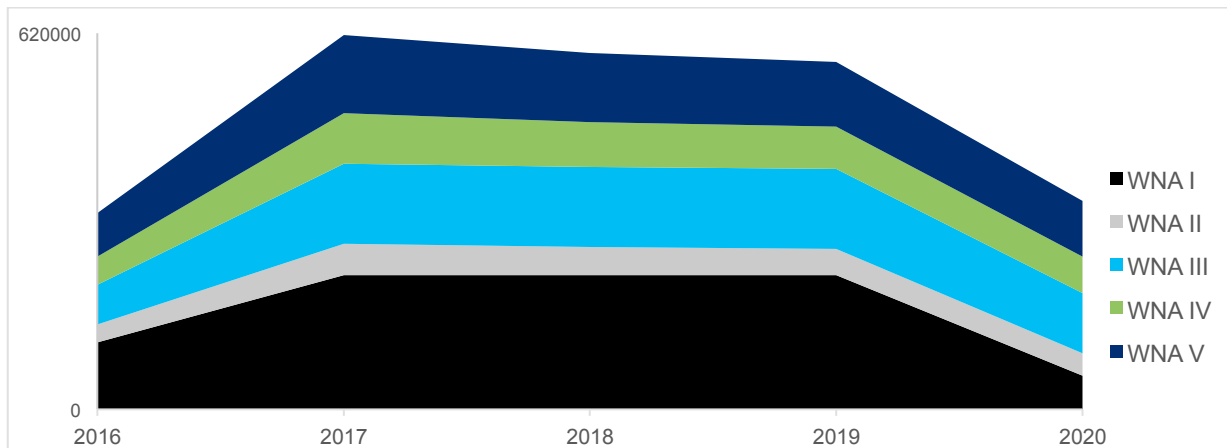
All the registered projects have opted for a fixed crediting period. WNA I and WNA III have crediting periods ending in April 2020 and October 2020 respectively. The other three projects have crediting periods extending beyond 2020. With the ex-ante emission reduction estimates provided in the registered PDD, the CER generation potential from all of DFPCL's WNA plants is provided in Table 20.

Table 20: CER Generation Potential from DFPCL's WNA Plants

Year	Annual CER Generation Potential (with secondary catalyst)				
	WNA I	WNA II	WNA III	WNA IV	WNA V
2016	110837	28700	66017	45823	71749
2017	221674	51499	132033	82795	128747
2018	221674	45599	132033	73944	113996
2019	221674	42648	132033	69519	106621
2020	55418	36740	99025	60669	91870
Total	2443336				

Source: UNFCCC registered PDDs

Figure 18 CER Generation Potential from DFPCL's WNA Plants



Since the secondary catalysts supplied by Johnson Matthey are reported to yield a high abatement efficiency, use of tertiary abatement technology is not expected to increase the GHG abatement potential significantly. Nonetheless, discussions with the technology providers would provide a more accurate estimation of the specific abatement potential of the two plants through the use of tertiary abatement technologies.

3.3.3 Technology: Availability and Feasibility

Secondary catalysts are reported to be performing well at DFPCL's WNA I and WNA III. RCFL could also undertake a detailed techno-financial analysis to determine the feasibility of implementing tertiary abatement technology. Such an analysis would also reveal incremental costs and benefits associated with the use of such technologies considering the specific plants parameters and design.

Environmental and allied statutory clearances also need to be considered for successful implementation of tertiary N₂O abatement.

3.3.4 CDM Registration

All the projects are registered – WNA I and WNA III are already accruing CERs; while WNA II, WNA IV and WNA V are ready to start accruing CERs as soon as the technology is implemented. None of the projects have opted for renewable crediting period, and hence no activity is required for the same. The projects would accrue CERs up to the end of their crediting period. The figures mentioned in the Table 20 have been apportioned accordingly.

If tertiary abatement technology is deemed to be feasible for DFPCL's plants, and is implemented, CDM procedures would require a fresh validation and registration of the projects. This would entail further extension of the CDM timelines, as well as additional transaction costs

for validation and registration. Therefore, tertiary abatement technology has not been considered as an option for this case.

3.3.5 Timeline

For the purpose of estimation of CER generation potential the contract between NACAG and DFPCL is expected to be executed by June 2016. For the non-implemented projects, project Implementation, testing and calibration can be carried out in parallel so that all projects can start accruing CERs July 2016 onwards.

3.3.6 Key findings

DFPCL could be one of the key partners for NACAG in India, since DFPCL's plants have a cumulative capacity of 2100 TPD, and that all plants are equipped to accrue CERs as soon as the necessary legal and technical arrangements are put in place. The total CER generation potential from all of DFPCL's WNA plants is 2.44 million CERs between July 2016 and December 2020.

It may also be of interest to study the feasibility of implementing tertiary abatement technologies in the five plants. However, implementing tertiary abatement technologies would involve a fresh registration procedure and negatively impact CER delivery timelines. It would also increase the associated transaction costs. Thus, it may not be attractive to pursue tertiary abatement in this case.

Further, since the company has already implemented N₂O abatement projects, which have been issued CERs multiple times, it is believed that it is technically equipped, and experienced to manage/oversee implementation and monitoring of the measure.

3.4 Case Study 4: No N₂O Abatement Technology in Place

3.4.1 Introduction

NFL is one of the oldest fertiliser producers in the country. It has 5 gas based manufacturing facilities (2 in Punjab – Nangal and Bhatinda, 1 in Haryana – Panipat and 2 in Madhya Pradesh – Vijapur). The company was incorporated in 1974 and the Nangal facility of Fertilizer Corporation of India (FCI) was transferred to NFL. NFL is engaged in manufacturing and marketing of urea, neem-coated urea, bio-fertilisers (solid & liquid) and other allied Industrial products like nitric acid, ammonium nitrate & ammonium nitrite, sodium nitrite and sodium nitrate etc.

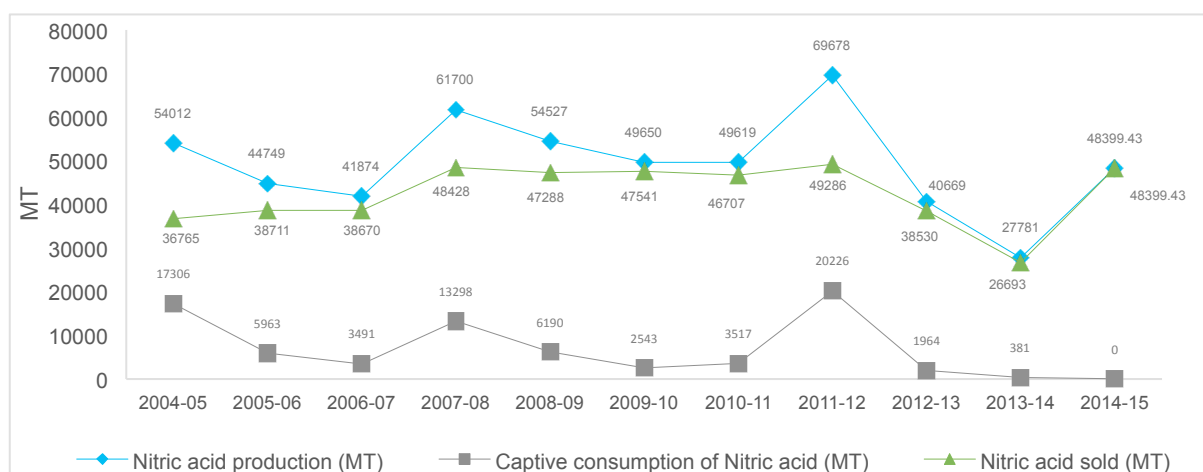
The nitric acid production facility at NFL Nangal was implemented in 1961 by FCI through technology from Pintch Demag. The facility was essentially conceived for captive consumption and small portions were sold out to third parties. With increased production of urea and change in regulations around production of ammonium nitrate and nitrite, the captive consumption of nitric acid reduced at the Nangal facility and the company started producing nitric acid for open market/third party sales. The open market sale are driven by regional demand resulting the reduced production of nitric acid.

The NFL nitric acid production facility operates at 3.25 bar (medium pressure) and has an installed capacity of 560 TPD. The total installed capacity is divided into 2 streams of 280 TPD and each stream has 4 burners (70 TPD per burner). The Nangal facility considered possible emission reduction opportunities through abatement of nitrous oxide released into atmosphere during production of nitric acid in 2005. A PDD³⁹ was prepared and submitted to UNFCCC in July 2005, and the company discussed possibility of GHG abatement during the first commitment period of the Kyoto Protocol with a few project developers.

The draft PDD was prepared based on ex-ante information available at the plant without applying/proposing a new methodology. The CDM project development was abandoned due to technical issues (concerns regarding cost effective application of secondary catalyst) and absence of UNFCCC approved CDM methodology. In addition to this, the nitric acid production facility was operating at partial load resulting in reduced GHG abatement achievable and hence, reduced interest of the investors in the plants' potential.

Over the past decade, captive consumption of the nitric acid produced has gone down; the company is able to operate only one stream (280 TPD) at part load for third party sale. The average operational utilization of the nitric acid facility is about 30%.

Figure 19: Nitric Acid Production and Use Trends at NFL



³⁹https://cdm.unfccc.int/filestorage/F/S/_/FS_955501000/NFL%20PDD%20version%201%20DNV%20one%20sample%20point.pdf?t=SIV8bzVrZTFvfDBZGmuz5xhMrmIPiYT5eZMo

During the stakeholder consultation, it was informed that the nitric acid production at NFL is expected to go up with increased demand from third party. At present 30% of the nitric acid is sold to explosive industries while balance is sold to trading companies (suppliers to steel pickling, ornamental refining and production of potassium nitrate). The demand is expected to grow gradually with annual increase in third party sales between 10-14%.

3.4.2 GHG Potential

NFL is the oldest operating plant in India, and is expected to have a very high baseline emission factor. However, ACM0019 (the methodology applicable at present, prescribes use of conservative default emission factor for estimation of expected CERs. The actual abatement is expected to be much higher.

Table 21 presents the CER generation potential, as well as the GHG abatement potential from the plant.

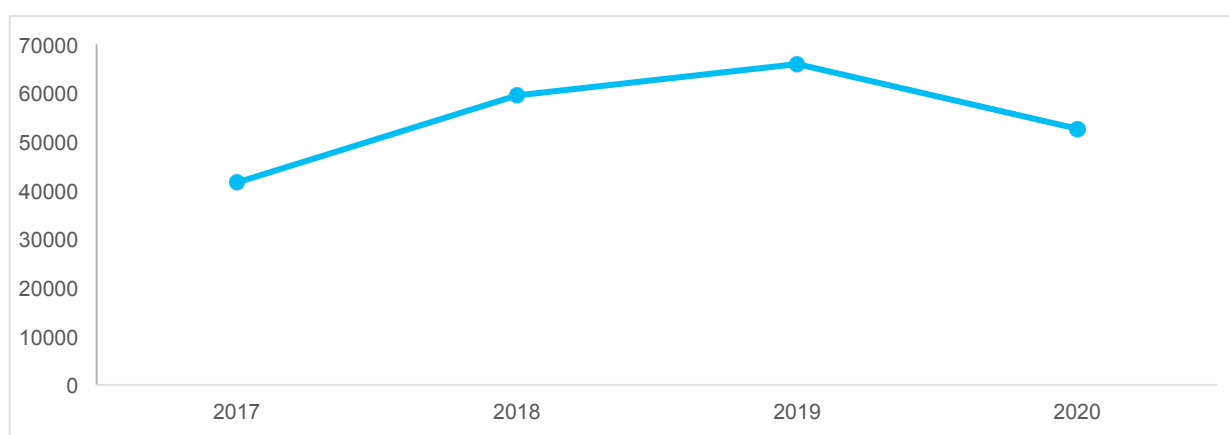
Table 21: CER Generation Potential from NFL's WNA Plant

Year	Annual CER Generation Potential (with secondary catalyst)	Annual GHG Abatement Potential (with tertiary abatement technology)
2017	41538	164767
2018	59445	252642
2019	65920	290539
2020	52645	334119
Total	219548	1042067

Assumptions

- Production increases at 15% per annum from the base year i.e. 2014-15 (48,399 tonnes)
- Abatement efficiency: 95%; GWP 264; baseline EF as per ACM0019.
- Estimated annual nitric acid plant operation days: 330
- Start of crediting period: April 2017

Figure 20: CER Generation Potential from NFL's WNA Plants



3.4.3 Technology: Availability & Feasibility

During the earlier analysis of possible use of secondary catalyst at NFL Nangal in 2005, it was discovered that secondary abatement technology may not be viable because the plant has 8 burners of 70 TPD each and thus, if secondary catalyst based technology is implemented, the secondary catalyst would have to be installed in each of the individual burners.

In principle, tertiary catalyst based technologies are now available and have been successfully implemented at several facilities across the world. Initial discussions with technology suppliers have revealed that the present exhaust/tail pipe gas temperature at the facility is between 170 – 180°C (as opposed to the desired temperature of 350°C). This requires additional investment of simultaneous consumption of fuel which will add to additional operational expenditure beyond the cost of catalyst.

Thus, the following aspects need to be considered for implementation of tertiary abatement technology at its WNA plant:

- Technical feasibility for tertiary catalyst infrastructure
- Identification of technology supplier for tertiary catalyst
- Capital investment
- Operational expenditure (recurring) - cost of catalyst and fuel
- Gas allocation to Nangal facility/availability of fuel
- Environmental and allied statutory clearances

A detailed feasibility assessment would be able to identify the exact technology that would be most suitable for the plant specific circumstances.

3.4.4 CDM Registration

ACM0019 is applicable to the N₂O abatement project at the WNA plant. In 2005, it had considered implementing N₂O abatement technology in its nitric acid plant with support from CDM. It had also developed and submitted a PDD without using/proposing a new methodology. NFL did not pursue the project further mainly because of technical issues with secondary catalyst use (concerns regarding cost implications for implementing the technology in each of the 8 burners) and low production of nitric acid (plant is operating at partial load leading to reduced GHG abatement potential for investors) and reduced captive consumption of nitric acid in NFL. Yet, the previous exercise has helped NFL in identification of possible technology that may work in its plant, and has exposed the relevant staff to the specific requirements of CDM procedures.

ACM0019 adopts a conservative approach for the estimation of GHG emission reduction potential. Considering that NFL is the oldest operating plant in India, the actual GHG abatement from the plant is expected to be much higher than its CER generation potential.

3.4.5 Timelines

The following time estimates have been considered:

CDM due diligence (starting July 2016):

- Feasibility study for tertiary infrastructure 60 days
- PDD development 90 days
- DNA approval Parallel activity with validation
- Project validation 120 days
- Registration with UNFCCC 90 days

The accrual of emission reductions can start from the date of submission of the final documents for registration to the UNFCCC or the date of implementation of the project (whichever is later).

Project Implementation, testing and calibration can be conducted in parallel with CDM due diligence to maximize the volume of CERs generated/available for transaction from the project before 2020. The accrual can thus commence from April 2017 (FY 2017-18).

3.4.6 Key findings

NFL Nangal facility may possibly become the first facility in the country to apply tertiary catalyst based GHG reduction technology. If implemented the technology would continue to reduce GHG emissions beyond 2020 (systems generally have a lifetime of about 10 years) at minimum operational cost (cost of fuel and monitoring) even in the absence of additional financial support.

3.5 Conclusion

The case studies revealed that about 90% of the possible emission reduction opportunities from India are available with registered projects from three companies. All registered projects have implemented/intend to implement secondary catalyst for GHG abatement. The companies with registered projects can operationalize GHG mitigation in a relatively shorter time and optimize the volume of CERs that can be made available for transaction under the NACAG.

For NFL, although secondary catalyst use has been acknowledged as an unviable option, identification of a suitable tertiary abatement technology may require a further rigorous feasibility assessment exercise. Which may result in additional capital investment and time. In addition to this the NFL nitric acid unit is operating since 1961, which may result in complications during implementation of GHG abatement infrastructure unless confirmed otherwise by technology provider.

4. Recommendations

Based on the insights gained during the study and interactions with the various stakeholder groups, the following recommendations are made.

For India

Multi-lateral Frameworks

- The INDC submitted by India to the UNFCCC does not bind it to any sector specific mitigation contribution (MoEF&CC, 2015). However, the emission reduction opportunity through N₂O abatement from nitric acid production is a low hanging fruit for the country and appropriate provisions can enable uptake of abatement technologies ensuring long term GHG reduction from the sector. It is recommended that a policy framework to tap the GHG mitigation potential of the sector is identified and incorporated in the revised INDCs slated to be submitted in 2018.
- The Montreal Protocol has been very successful in reducing the production and consumption of Ozone Depleting Substances (ODS). Given the N₂O threat to the ozone layer, there is a case for including N₂O within the protocol, or a separate provision should be made to curb emissions of N₂O (United Nations Environment Programme, 2013). The MoEF&CC may consider engaging with the international agencies to address this issue.
- MoCF may consider development of a Nationally Appropriate Mitigation Action (NAMA) to appropriately capture the N₂O abatement opportunity. Since the monitoring and reporting is possible in line with the international standards, the NAMA can be domestic or internationally supported.

Bilateral Frameworks

- Participation in the NACAG is an opportunity for India to address the ozone depletion and climate change mitigation simultaneously. NACAG through the BMUB may consider engaging with the MoEF&CC to provide immediate technical and financial support for the N₂O abatement initiative to capture the available mitigation potential until a domestic policy initiative for long term abatement of N₂O from nitric acid production is developed.

- Exploring opportunities for south-south cooperation to initiate/finance R&D on low-cost N₂O abatement technologies, including implementation of demonstration projects, is another area for action by India. In addition to this, India may also explore synergies that can be worked out in ‘cap and trade’ schemes in other countries or regions.

Domestic Programs

- Section 135 of the Companies Act, 2013 mandates all companies having net profit of INR 50 million or turnover of INR 10000 million or more, or net worth of INR 5000 million or more during any financial year to constitute a Corporate Social Responsibility Committee of the Board to ensure that in each financial year the company spends at least 2% of its average net profits on CSR activities enumerated in Schedule VII of the Act. Ensuring environmental sustainability is one of the prescribed CSR activities as per Schedule VII. Considering that the most of the nitric acid producing companies are covered by the Companies Act⁴⁰, and that N₂O abatement projects have direct benefits towards environmental sustainability, there is a case for nitric acid producing companies employing their CSR budget for implementing N₂O abatement. Table 22 presents the CSR budget of the key nitric acid manufacturing companies for FY 2014-15. The cumulative budget of these entities may not suffice to sustain N₂O abatement across the sector. However, CSR funds from other companies may be directed to the sector to fill in the gap.

Table 22 CSR Funds Available with Nitric Acid Producing Companies

S. No.	Company Name	CSR Funds Available (million INR)
1.	GNFCL	83.99
2.	DFPCL	39.70
3.	RCFL	80.20
4.	NFL	8.91
5.	GSFCL	114.78
	Total	328

The Ministry of Corporate Affairs (MoCA) may consider notifying N₂O abatement as one of the permissible activities under CSR which will not only pave the way for such investments by companies, but will also enable other companies to support such environmentally benign initiatives.

⁴⁰ In FY 2014-15, only one of the four major nitric acid producing company reported losses

- Government of India has launched several domestic schemes such as Renewable Energy Certificates, PAT, Green Bonds etc. in its endeavor to move towards a low-carbon economy. With a clear synergy amongst these schemes and GHG abatement, the government may actively engage to explore avenues for interlinking of these schemes, and where possible, establish fungible transaction instruments applicable to N₂O abatement interventions. A move in this direction would create a market for the product of N₂O abatement, thereby opening opportunities for project developers to recover the investments incurred for implementation of technology.
- The MoCF may consider setting up a special task force to assess the technical and financial feasibility of N₂O emission reduction measures across all sectors, fertilisers and otherwise. The recommendations of the task force should feed into the revision of INDCs with sector-specific action plans for GHG abatement. Further, a consortium of sectoral experts from key sectors contributing N₂O emissions like energy, waste and nitric acid may be formed to devise an action plan for the reduction in N₂O emissions in a phased manner.
- Nitric acid production and consumption is expected to increase in the medium to long term. Policy makers may consider setting up of nitrogen use efficiency standards as part of the National Action Plan for Climate Change (NAPCC) through the National Mission on Sustainable Agriculture.

Sectoral Policies

- The fertiliser sector expects rationalisation of subsidy on various products which can foster long term growth including the increase in domestic production. Deregulation of petroleum products has set an example in the country resulting in significant reduction of subsidy burden. Given that 70% of the production cost of fertilisers is attributed to the input fuel, and at present the international petroleum prices are significantly low, the government can use this opportunity to deregulate the fertiliser sector. The process is expected to improve the financial health of the companies enabling them to undertake N₂O abatement measures without any external financial support.

Institutional Reforms

- Standardised simplified procedures for monitoring of N₂O abatement with conservative default values should be developed to help bring down costs associated with monitoring of emissions.
- Capacity building initiatives may be undertaken to develop locally available manpower to carry out calibration and monitoring as per EM14181. This will reduce third party monitoring expenditures.

For the BMUB

- There is a clear interest in NACAG in India, both from nitric acid producers as well as technology suppliers. The BMUB may consider utilising this opportunity. The key characteristics of the sector such as regulated operations, readily available abatement opportunity, exposure to abatement technology and CDM procedures, are all aligned with the interest of the BMUB. The BMUB may pursue the Government of India to join NACAG, and parallelly engage with various stakeholders.
- Once India joins NACAG, implementation of umbrella contracts with technology suppliers, DoEs and consultants may be considered to reduce the transaction costs and time.
- An international N₂O abatement 'Programme of Activities' (PoA) under the CDM could be initiated with GIZ/BMUB as the Coordinating and Managing Entity (CME). New/unregistered project activities can join in the PoA as Component Project Activities (CPAs).
- Considering the finance-related apprehensions of nitric acid producers in India, most of which have already sunk investments into N₂O abatement projects, the BMUB may consider development of tailor-made CER pricing solutions for each project activity.

For Nitric Acid Producers

- Considering that secondary abatement technologies have been successfully implemented in India, it is recommended that project developers may adopt such technologies wherever feasible.

5. Conclusion

The Indian nitric acid sector offers a significant GHG mitigation potential at a low cost. Between July 2016 and December 2020, the sector can provide about 4.97 million CERs in a cost effective manner while the actual abatement is about 13.55⁴¹ million t CO_{2e} during the same duration. The sector is regulated and a majority of players operate under a government controlled environment (MoCF, Government of India). The demand for nitric acid is expected to grow in the medium to long term, which may further increase the GHG contribution from India.

The previous N₂O abatement interventions have provided the necessary exposure pertaining to technology, CDM due diligence, monitoring and transaction of the generated CERs. The knowledge base has spread across the sector and almost every player has some experience of carbon markets and allied opportunities made available to developing countries through the Kyoto Protocol. However, the crash in CER prices observed towards the end of the first commitment period, resulted in diminished CER transaction opportunities, and has placed these projects at a risk of being abandoned. Also, the law of the land does not warrant GHG abatement through N₂O reduction opportunities.

It is generally expected that over a period of time, technological advancements may autonomously reduce N₂O emissions from nitric acid production and that setting up of new units will result in lower GHG emissions. Yet specifically in India there are facilities which are more than 50 years old and are still operating, albeit at lower operational efficiencies. None of the operating units, new or old, has any financial incentive to invest in GHG abatement technologies. While CDM provided a market-based mechanism to support such interventions, the long term solution to ensure that the sector operates with the minimum contribution to the GHG emissions is very much in the hands of policy makers.

The NACAG provides an excellent opportunity for the participating developing countries to consider N₂O reductions in their national mitigation agenda. For countries like India, where abatement opportunity from the nitric acid sector has not been captured either through domestic regulations, or through the INDCs, the NACAG can provide the much-needed financial and technical support to push for an industry-wide transformation. For India in particular, nitric acid N₂O abatement projects offer an important opportunity for bi-lateral cooperation as a significant

⁴¹ On the basis of actual baseline campaign run at various production facilities in India

abatement potential can be realized at a relatively lower investment through a stabilized and effective technology targeted at a relatively concentrated sector. The emission reductions achieved through N₂O abatement can be transparently measured and offer an effective means towards domestic targets. Thus, if there is an agreement between participating ministries from both sides (BMUB and MoEF&CC), it is possible to turn around the abatement opportunities into realizable potential.

Unlike renewable energy generation projects, where emission reductions are inherent to regular project operations, industrial gases abatement projects require additional investments over and above those required for production. Recovery of abatement expense is necessary for such interventions, especially where the implemented abatement measure does not offer additional revenue sources. Therefore, international CER procurement programs must cater to such initiatives that are at risk of being abandoned. The NACAG can offer an immediate solution for addressing N₂O abatement from the nitric acid sector until the next decade, thus providing the national governments a window to formalize a policy around the same. Further, unlike the market-based mechanisms wherein price discovery was beyond the control of investor, the NACAG offers a sector-wide opportunity to ensure that both capital and operational investments are recovered against the sale of CERs thus generated, through tailor-made CER pricing solutions.

Beyond NACAG's intended time-frame (up to 2020), it is imperative that adequate support is provided to the project proponents through dedicated financial streams that are made available through international arrangements or through appropriate provisions in the host country's policy framework. The decision makers can draw synergies from the Montreal Protocol which has resulted in a technology shift in refrigeration sector. There are opportunities to leverage the existing regulations and mechanisms for addressing specific challenges of N₂O abatement from the sector. Specifically for India, provisions of Section 135 of the Companies Act 2013 provide opportunity to channelise Corporate Social Responsibility (CSR) funds for addressing financial challenges associated with the long term implementation of N₂O abatement technologies. Trade fungibility among the existing domestic schemes like Renewable Purchase Obligation (RPO), Renewable Energy Certificates (RECs), PAT, Green Bonds etc. may be explored as a step towards finding a long term mitigation solution.

Annexures

Annex I: List of Abbreviations

ACI	Ammonium Chloride
AMS	Automated Monitoring System
AN	Ammonium Nitrate
AOR	Ammonia Oxidation Reactor
AR	Assessment Report
AS	Ammonium Sulphate
BEE	Bureau of Energy Efficiency
BUR	Biennial Update Report
CAGR	Compounded Annual Growth Rate
CAN	Calcium Ammonium Nitrate
CDM	Clean Development Mechanism
CEMS	Continuous Emissions Monitoring System
CER	Certified Emission Reduction
CH ₄	Methane
CME	Coordinating and Managing Entity
CMIE	Centre for Monitoring Indian Economy
CNA	Concentrated Nitric Acid
CoP	Conference of Parties
CP	Crediting Period
CPA	Component Project Activities
CSR	Corporate Social Responsibility
DAP	Di-ammonium Phosphate
DC	Designated Consumers
DFPCL	Deepak Fertilisers and Petrochemicals Corporation Limited
DP	Dual Pressure
DoE	Designated Operational Entity

EPC	Engineering, procurement, and construction
ETS	Emissions Trading Scheme
EU	European Union
FACT	Fertilizers and Chemicals Travancore Limited
FAI	Fertilizer Association of India
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNFCL	Gujarat Narmada Valley Fertilizer Company Limited (now renamed to Gujarat Narmada Valley Fertilizers & Chemicals Limited)
GoI	Government of India
GSFCL	Gujarat State Fertilizer Corporation
GWP	Global Warming Potential
HFC	Hydro Fluorocarbons
HNO ₃	Nitric Acid
HP	High Pressure Mono Pressure
IFFCO	Indian Farmers Fertiliser Cooperative Limited
INCCA	Indian National Climate Network Assessment
INDCs	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
KRIBHCO	Krishak Bharati Cooperative Limited
LULUCF	Land Use, Land Use Change, and Forestry
MoCA	Ministry of Corporate Affairs
MoCF	Ministry of Chemicals and Fertilisers
MoEF	Ministry of Environment, Forests (now renamed to Ministry of Environment, Forests and Climate Change)
MoEF&CC	Ministry of Environment, Forests and Climate Change
MOP	Muriate of Potash
MP	Medium Pressure Mono Pressure
N ₂ O	Nitrous oxide
NACAG	Nitric Acid Climate Action Group

NAMA	Nationally Appropriate Mitigation Action
NAPCC	National Action Plan on Climate Change
NATCOM	National Communication
NBS	Nutrient Based Scheme
NFL	National Fertilizers Limited
NH ₃	Ammonia
NMEEE	National Mission on Enhanced Energy Efficiency
NMSA	National Mission on Sustainable Agriculture
NO	Nitrogen oxide
NO _x	Oxides of Nitrogen
N-P-K	Nitrogen-Phosphate-Potassium
NSCR	Non-Selective Catalytic Reduction
ODS	Ozone Depleting Substances
O&M	Operation and Maintenance
PAT	Perform Achieve and Trade
PDD	Project Design Document
PoA	Programme of Activities
RCFL	Rashtriya Chemicals & Fertilizers Limited
REC	Renewable Energy Certificates
RPO	Renewable Purchase Obligation
RTO	Regenerative Thermal Oxidizer
SEC	Specific Energy Consumption
SOP	Sulphate of Potash
SSP	Single Super Phosphate
t CO ₂ e	tonnes of CO ₂ equivalent
tKIS	Thyssenkrupp Industrial Solutions Ltd
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WNA	Weak Nitric Acid

Annex II: Glossary of Terms

Annex I Countries – The industrialised countries (and those in transition to a market economy) which took on obligations to reduce their greenhouse gas emissions under the United Nations Framework Convention on Climate Change.

Approved Methodology – A methodology that has been approved by the Executive Board of the UNFCCC for application to CDM project activities or CPAs. Approved methodologies are publicly available on the UNFCCC CDM website.

Business-As-Usual (BAU) – A scenario used for projections of future emissions assuming no action, or no new action, is taken to enhance or limit sector growth.

CAGR – The compound annual growth rate is calculated by taking the n th root of the total percentage growth rate, where n is the number of years in the period being considered.

Carbon Credits – Tradeable permits that aim to reduce greenhouse gas emissions by giving them a monetary value.

Carbon Dioxide Equivalent (CO₂e) – A simple way to place emissions of various climate change agents on a common footing to account for their effect on climate. It describes, for a given mixture and amount of greenhouses, the equivalent weight of carbon dioxide that would have the same global warming ability, when measured over a specified timescale.

Certified Emission Reduction (CER) – Emission reductions from CDM project activities in accordance with the CDM rules and requirements, which are expressed in units equal to one metric tonne of carbon dioxide equivalent, calculated using global warming potentials defined by Decision 2/CP.3 of the United Nations Framework Convention on Climate Change or as subsequently revised in accordance with Article 5 of the Kyoto Protocol.

Clean Development Mechanism (CDM) – One of the three market-based mechanisms under the Kyoto Protocol to the United Nations Framework Convention on Climate Change, whereby developed countries may finance greenhouse gas emission-avoiding projects in developing countries, and receive credits for doing so, which they may apply towards meeting mandatory limits on their own emissions.

Coordinating and Managing Entity (CME) - An entity authorized by all participating host country DNAs involved in a particular PoA and nominated in the Modalities of Communication statement as the entity that communicates with the Board and the secretariat, including on matters relating to the distribution of CERs, tCERs or ICERs, as applicable.

Component Project Activity (CPA) - A single measure, or a set of interrelated measures under a PoA, to reduce GHG emissions by sources or result in net anthropogenic GHG removals by sinks, applied within a designated area defined in the baseline methodology(ies).

Crediting Period – The period in which verified and certified GHG emission reductions or removals by sinks attributable to a CDM project activity or CPA, as applicable, can result in the issuance of CERs from that CDM project activity or CPA. The time period that applies to a crediting period for a CDM project activity or CPA, and whether the crediting period is renewable or fixed, is determined in accordance with the CDM rules and requirements.

Designated Operational Entity (DoE) – An entity designated by the CMP, based on a recommendation by the Board, as qualified to validate proposed CDM project activities and PoAs, as well as verify and certify reductions in anthropogenic emissions by sources of GHG and net anthropogenic GHG removals by sinks.

Emission Factor (EF) – A representative value that related the quantity of a pollutant released to the atmosphere with the activity associated with its release.

Global Warming Potential (GWP) – A relative index that enables comparison of the climate effect of the emissions of various greenhouse gases (and other climate changing agents). Carbon dioxide, the greenhouse gas that causes the greatest anthropogenic radiative forcing because of its overwhelming abundance, is chosen as the reference gas. GWP is also defined as an index based on the radiative forcing of a pulsed injection of a unit mass of a given well-mixed greenhouse gas in the present-day atmosphere, integrated over a chosen time horizon, relative to the radiative forcing by a unit mass of carbon dioxide over the same time horizon. The GWPs represent the combined effect of the differing atmospheric lifetimes (i.e., how long these gases remain in the atmosphere) and their relative effectiveness in altering the energy balance at the tropopause. The Kyoto Protocol uses GWPs from pulse emissions over a 100-year time horizon.

Issuance – The instruction by the Board to the CDM Registry Administrator to issue a specified quantity of CERs, ICERs, or tCERs for a project activity or PoA, as applicable, into the pending account of the Board in the CDM registry, for subsequent distribution to accounts of project participants in accordance with the CDM rules and requirements.

Joint Implementation (JI) – Projects that allow a country with an emission reduction or limitation commitment under the Kyoto Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission reduction or emission removal project in another Annex B Party. Each ERU is equivalent to one tonne of CO₂, which can be counted towards meeting its Kyoto target.

Kyoto Protocol – The international Treaty intended to reduce greenhouse gas emissions. It adds additional provisions to the United Nations Framework Convention on Climate Change.

Monitoring Report – A report prepared by a project participant which sets out the GHG emission reductions or net GHG removals of an implemented registered CDM project activity or PoA for a particular monitoring period.

Montreal Protocol – An international treaty governing the protection of stratospheric ozone. The Montreal Protocol on Substances That Deplete the Ozone Layer and its amendments

control the phase-out of ODS production and use. Under the Montreal Protocol, several international organisations report on the science of ozone depletion, implement projects to help move away from ODS, and provide a forum for policy discussions. In addition, the Multilateral Fund provides resources to developing nations to promote the transition to ozone-safe technologies. The full text of the Montreal Protocol is available from the United Nations Environmental Programme (UNEP).

Nationally Appropriate Mitigation Action (NAMA) – Climate change mitigation measures proposed by developing country governments to reduce emissions below 2020 business-as-usual levels and to contribute to domestic sustainable development. NAMAs can take the form of regulations, standards, programs, policies or financial incentives.

Nitrogen Use Efficiency (NUE) - A measure of performance in converting inputs of nitrogen compounds into useful products. There are several ways of expressing NUE, with the simplest being the amount of nitrogen in a product divided by the amount of nitrogen used, often expressed as a percentage.

Non-Annex I Countries – A group of developing countries that have signed and ratified the United Nations Framework Convention on Climate Change. They do not have binding emission reduction targets.

Ozone Depleting Substance (ODS) – A substance contributing to ozone (O₃) depletion in the Earth's atmosphere. These substances are listed in the Montreal Protocol which is designed to phase out their production and consumption.

Programme of Activity (PoA) – A voluntary coordinated action by a private or public entity which coordinates and implements any policy/measure or stated goal (i.e. incentive schemes and voluntary programmes), which leads to anthropogenic GHG emission reductions or net anthropogenic GHG removals by sinks that are additional to any that would occur in the absence of the PoA, via an unlimited number of CPAs.

Registration –The formal acceptance by the Board of a CDM project activity or PoA validated by a DOE as a CDM project activity or PoA, as applicable. Registration is the prerequisite for the verification, certification and issuance of CERs, ICERs or tCERs, as applicable, related to that CDM project activity or PoA.

Renewable Energy Certificates (REC) – A certificate that is proof that one megawatt-hour (MWh) of electricity was generated from a renewable energy resource. Once the electricity provider has fed the electricity into the grid, the Renewable Energy Certificate (REC) they received can then be sold on the open market as a commodity. Because of the additional cost for producing "green" energy, the RECs provide an additional income stream to the energy provider, thus making it a bit more attractive to produce.

Renewable Purchase Obligation (RPO) – An instrument designed to encourage generation of electricity by increasing its demand through mandating purchase of renewable energy in a certain prescribed proportion.

Scenario – A description of how the future may unfold based on ‘if-then’ propositions. Climate change scenarios typically include an initial socio-economic situation and a description of the key driving forces and future changes in emissions, temperature, or other climate change-related variables.

Secondary N₂O Abatement – Installation of a catalyst inside the ammonia burner unit with the sole purpose of removing N₂O emissions from the stream.

Tertiary N₂O abatement – Installation of an abatement system in the tail-gas leaving the absorption column of a nitric acid plant to destroy the N₂O generated in the ammonia burner unit.

Urea – A reactive nitrogen form, urea (or carbamide) is an organic compound with the chemical formula (NH₂)₂CO.

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