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Industrial N_2O Projects Under the CDM: The Case of Nitric Acid Production

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Abstract

This paper evaluates nitric acid projects under the CDM and considers whether they may pose a risk to environmental integrity. The paper finds that the CDM successfully fostered abatement in this sector which previously had not engaged in abatement practices. It further finds that carbon leakage is unlikely for this project type and that there is no evidence that would indicate widespread gaming in order to maximize emissions reductions. The conclusions provide recommendations on how the current nitric acid methodologies could be improved and simplified through the use of a common benchmarking approach.

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Introduction

Over the past years, industrial gas projects implemented under the Clean Development Mechanism (CDM) have come under increased scrutiny, in particular HFC-23 from HCFC-22 production and N_2O from adipic acid and nitric acid production. Although they make up only 2% of the projects in the CDM pipeline, industrial gas projects account for the lion's share of emissions credits or CERs issued under the CDM (74% as of September 2010). With abatement costs that tend to be quite low (EUR 0.1 to EUR 4/tCO_2e) relative to the price of CERs, these projects can generate very large profits that may lead to unintended consequences. An assessment of monitoring data from HFC-23 projects indicated that HCFC-22 plant operators increased their HCFC-22 production and HFC-23 generation in order to maximize revenues from the CDM (Schneider, in press). The EU Commission announced recently that it will propose limits on the use of industrial gas projects for the third trading period of the European Emissions Trading Scheme (ETS), starting in 2013.

This paper addresses the case of nitric acid projects under the CDM, and considers whether these projects pose a risk to environmental integrity. A second paper focuses on adipic acid projects under the CDM, specifically examining carbon leakage issues (Schneider et al, 2010). Both of our papers focus on the question of overall emissions impacts of these project types and discuss policy solutions that could address the identified shortcomings. These papers are meant to contribute to a constructive discussion on how to improve CDM performance by strengthening its environmental integrity and addressing any economic distortions that crediting mechanisms might create.

Nitrous oxide (N_2O) is a powerful greenhouse gas (GHG), with a global warming potential of 310 over a 100-year timeframe and an atmospheric lifetime of 114 years.[1] N_2O emissions account for approximately 9% of global annual GHG emissions, and their atmospheric concentration has increased by 15% since 1750 (IPCC FAR, 2007). Agricultural activity accounts for the large majority of global anthropogenic N_2O emissions. Industrial processes, specifically the manufacture of adipic acid and nitric acid, also generate N_2O as an unwanted by-product during production.

Industrial N_2O projects play a large role in the CDM. To date, almost a quarter of all issued CERs come from industrial N_2O projects. Of those, 85% are from adipic acid projects and 15% from nitric acid projects, as shown in Table 1. These projects make only 3% of the projects registered under the CDM. Nitric acid projects produce on average 1.4 times as many CERs as the average CDM project, whereas adipic projects produce on average 116 times as many CERs[2]. Under Joint Implementation (JI), three adipic acid and 33 nitric acid projects are currently in the pipeline (Table 2). As with CDM, industrial N_2O projects under JI account for about a quarter of total credits issued to date; in the case of JI, however, the crediting of nitric acid projects dominates.

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[1] This GWP value is based on the Second Assessment Report of the IPCC and used during the first commitment period under the Kyoto Protocol until 2010. The GWP in the Fourth Assessment Report is 298.

[2] Based on total projects registered (CDM total: 2344) and total credits issued as of Sept 2010 (CDM total: 430,298,000).

Table 1: N_2O Abatement Projects in the CDM Pipeline as of September 2010.

Project Type	At validation	Registered	Total # of projects	Million credits issued	% of total credits issued
Adipic acid	0	4	4	85.4	19.8%
Nitric Acid	6	57	63	14.7	3.4%
Caprolactam	2	1	3	0	0%
Total N_2O	8	62	70	100.1	23.3%

(Source: UNEP RISOE, Sept 2010)

Figure 1: Industrial N_2O Projects under the CDM

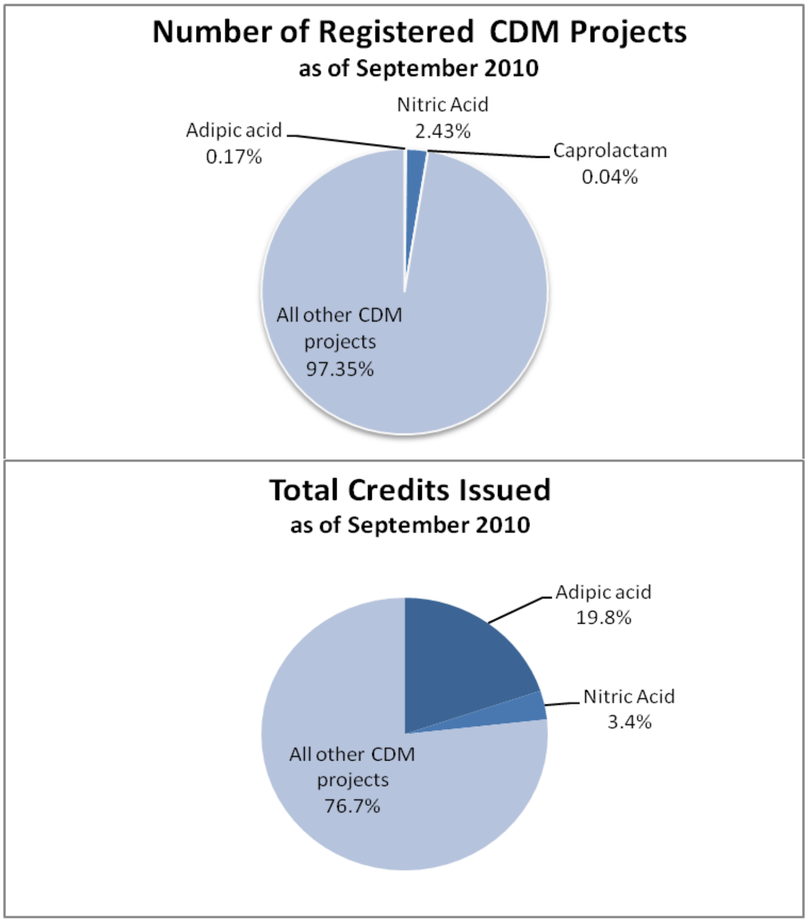

Table 2: N_2O Abatement Projects in the JI Pipeline as of September 1, 2010.

Type	Number of projects	% of total # of projects	Million credits issued	% of total credits issued
Adipic Acid	3	0.9%	0.36	3.6%
Nitric Acid	33	10%	2.23	22.8%
Total N_20	36	11%	2.59	26.5%

(Source: UNEP RISOE, Sept 2010)

This paper analyzes the environmental integrity of nitric acid projects. We first evaluate the potential for carbon leakage for this project type and then evaluate issues related to the determination of baseline emissions and emissions reductions. The conclusions provide recommendations on how the current nitric acid methodologies could be improved.

Global nitric acid production and N_2O abatement

Globally, an estimated 500-600 nitric acid plants are thought to be in operation – approximately 100 of them are located in Europe. It is difficult to get accurate data on the number of plants and the total amount of nitric acid produced annually because these plants are often integrated into larger chemical facilities. Nitric acid (HNO_3) is primarily used to make synthetic fertilizers and explosives. Furthermore, in contrast to adipic acid plants, most of the nitric acid plants are owned by local companies supplying regional markets (N.Serve 2010a; EC 2006, IPCC 2000, 2006). No reliable international statistics are available on the use of targeted[3] N_2O abatement in nitric acid production plants:

- *Europe:* To support the implementation of the "Integrated Pollution Prevention and Control Directive" (EC 2008a), the European Commission (EC) published guidelines in 2007 on Best Available Technologies (BAT) that set a benchmark of 2.5kg of N_2O or less[4] per tonne of nitric acid for existing plants (EC 2006). In order for EU Directives to be enforceable they have to be integrated into national legislation by the respective member states. Not all EU countries have passed legislation and it is unclear how many member states are actually enforcing this directive. This has implications on how baselines are set and emissions reductions are calculated for JI projects and will be discussed in more detail later. Nevertheless, in all EU member countries, except for Greece and Italy, some type of N_2O abatement is either required through an opt-in to the European Union Emissions Trading Scheme (EU-ETS) (Austria, the Netherlands, Norway, United Kingdom) (EC 2008, 2009a), or it is possible to voluntarily abate and earn credits through JI. [5] Furthermore, two (non-JI) pilot projects were implemented in Norway and Austria as part of their national climate policy. All EU nitric acid plants will be included in the third phase of the EU-ETS and benchmark emission levels of around 0.8 kg of N_2O per tonne of nitric acid are currently being discussed between the EU member states and the EU Commission's DG Climate Action (CLIM).

- *United States*: Targeted N_2O abatement in nitric acid plants does not seem to be used in the US (some older plants use NSCR technology, see footnote 3). In 2009, the Carbon Action Reserve, a voluntary US offset program, approved a nitric acid methodology for domestic offset projects

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[3] In many countries, nitric acid plants are required by law to abate their emissions of NO and NO_x emissions. 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 N_2O. However, NSCR units are generally not preferred in modern plants because of high energy costs and are not allowed as abatement technologies for CDM or JI projects (EPA 2010).

[4] BAT was set at 1.85 kg N_2O/tonne 100 % nitric acid for existing plants yet industry and one Member State did not agree with these N_2O emission levels and claimed that BAT should be set at 2.5 kg N2O/tonne 100 % nitric acid for existing plants. This issue was not resolved. Therefore individual member states have used either or both levels in their legislation.

[5] Nitric acid plants in Italy, Greece, Croatia, Russia and Japan are not eligible for JI because these countries do not allow for national JI projects to be implemented or have decided not to allocate ERUs to nitric acid JI projects (Russia).

in the US and has currently three projects listed (Climate Action Reserve, 2010). The methodology is largely based on the two CDM methodologies (AM0034 and AM0028).

- *Developing countries:* According to industry experts, nitric acid plants in Non-Annex 1 countries do not currently use targeted N_2O abatement technology outside the CDM.

In summary, it is reasonable to assume that N_2O abatement in nitric acid plants is only very rarely implemented voluntarily and occurs in most cases only if there is regulation or some type of incentive, either through offset programs or emissions trading systems. N_2O regulation for nitric acid plants in developed countries is uncommon to date and does not exist in developing countries. Almost all the existing abatement projects have been implemented through carbon trade programs.

Profitability and the risk of carbon leakage

For many industrial gas CDM projects, revenues from credits (CERs) far outweigh abatement implementation costs. This holds true for nitric acid projects but these projects are considerably less profitable than for example HFC-23 or adipic acid projects.

There are currently two CDM methodologies in use for nitric acid projects: AM0028 for tertiary destruction and AM0034 for secondary destruction of N_2O (see p. 9 for a description of abatement technologies). Each tonne of nitric acid produces on average 2 CERs, [6] yet these numbers vary by a factor of three between 0.5 and 3.8 CERs per tonne of nitric acid produced (*Figure 2*), depending on the type of plant (high, medium, low pressure), the type of destruction – secondary for AM0034 projects (blue in Figure 2) and tertiary for AM0028 projects (green in Figure 2) – and operating conditions (further explained in the next section). At a market price of EUR 13 per CER[7] this results in EUR 7.5 – 49.5 in revenue (average EUR 26) per tonne of nitric acid produced. Abatement costs for nitric acid projects are estimated to be in the range of EUR 1-2 per CER (EPA 2006, Wara 2006, EC 2006). The costs for CDM project implementation (validation, N_2O monitoring, verification, etc.) add another EUR 1-2 per CER, bringing total costs for nitric acid project implementation to EUR 3-4. As a result, net profit for N_2O abatement would appear to range between EUR 9 and 10 per CER at EUR 13 per CER and between EUR 4.5 and-38.1 per tonne of nitric acid produced.[8]

However, project proponents are unlikely to capture the full differential between the costs of creating a CER and their market price: In order to reduce risk and get advance payment, project developers often sell “primary” CERs on a forward basis, i.e. in advance of CERs actually being issued. Generally, primary CER prices are often below the secondary CER price (the 13 EUR value we are using here represents a secondary CER price). In addition, some countries tax CER revenue from N_2O projects (e.g. China 30%, Uzbekistan 80%) this further reduces profits for project developers.

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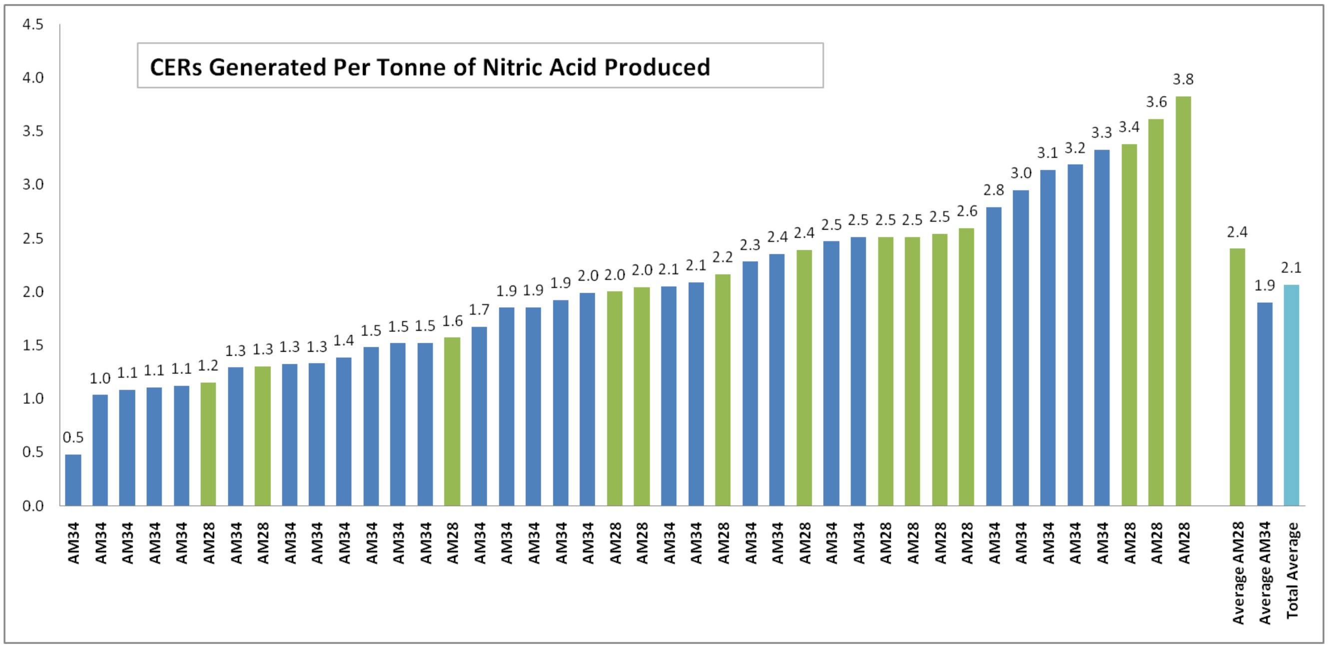
[6] Average baseline emissions are about 8.9kg N_2O per t of nitric acid. Based on N.Serve (2010a) destruction efficiencies for CDM projects range between 70% (AM0034) and 86% (AM0028), with an average destruction efficiency of 75%. This results in: 8.9 kg X 0.75 X 310/1000 = 2 t CO2e or CERs per tonne of nitric acid. The difference between the average of 1.8 CERs shown in figure 2 is due to rounding errors.

[7] Based on secondary CER market prices, Sept 30, 2010 (www.pointcarbon.com)

[8] At a rate of 2 CERs generated per tonne of nitric acid produced, the net profit would range between EUR 18 and 20.

Figure 2: Credits Generated Per Tonne of Nitric Acid Produced
(for Nitric Acid Plants that have submitted mentoring reports using AM0034 or AM0028.)



(Data source: N.serve, personal communication, based on CDM monitoring reports)

Table 3 compares the impact of the CDM on revenues for nitric and adipic acid projects. Nitric acid is usually not sold directly but used in the production of ammonium nitrate (primarily for use as fertilizer). Prices for ammonium nitrate, which contains approximately 75% nitric acid, vary by region and fluctuate according to market conditions. According to industry sources, current prices range between EUR 100-225 per tonne of ammonium nitrate. Nitric acid production costs are highly influenced by gas and electricity prices and by labor costs and therefore tend to be lower in countries with low energy prices (and/or high subsidies) and low labor costs. For our analysis we use an estimated average production cost of EUR 125.[9] As product profits are typically considerably lower than the costs for production, it becomes clear that profits from the CDM are significant for both project types, yet they are much lower for nitric acid than for adipic acid production. In the case of nitric acid, we estimate the profits from CERs to be about in the same order of magnitude as the profits from the primary product. In the case of adipic acid, CER profits exceed the profits from the primary product by as much as an order of magnitude.[10]

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[9] Based on N.serve, personal communication.[10] We cannot provide precise estimates comparing profits from CERs with profits from the sale of the primary product as we lack data on the current profit margins of nitric and adipic acid production. Also production costs are based on best-guess estimates from industry experts and are not based on any data analysis. Only the sales prices for ammonium nitrate where available. For our estimates, we assumed a 15-20% profit margin on sales.

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Table 3 Estimated Impact of CDM on Revenues For Nitric and Adipic Acid

	Nitric Acid	**Adipic Acid**[11]
CERs produced per tonne of product	2 (range 0.5-3.8)	82.4
Abatement and CDM transaction costs per CER (t of CO_2e)	EUR 3-4	EUR 0.75
Price per secondary CER	EUR 13	EUR 13
Net Profit from CDM per t of product	average EUR 18-20[12] (range EUR 4.5-38.1)	EUR 1009
Production cost per t of product	N/A	EUR 900-1300
Sales price per tonne of product	EUR 100-225 t of ammonium nitrate	N/A
Extent of estimated leakage	N/A	About 20% of the CERs issued from this project type for 2008 and 2009

If CER profits are high, leakage may occur: production may shift from non-CDM plants to CDM plants. Leakage can undermine mitigation goals and pose economic risks for industries in countries that are ineligible under the CDM. In the case of nitric acid, leakage away from non-CDM plants that do not mitigate and are located in countries with no emissions cap (this applies to most plants in developing countries and the US) would lead to no overall increase in greenhouse gas emissions. Leakage away from plants in countries with an emissions cap would undermine mitigation goals and increase emissions, irrespective of the abatement practices of those plants. If a CDM project displaces production in these countries, the decrease in N_2O emissions associated with lower nitric acid production levels will enable the country to increase other GHG emissions covered by the cap (Figure 3). We were unable to obtain trade data for nitric acid. Nonetheless, according to industry experts, nitric acid plants are often locally operated and much of the product is sold locally. If indeed, the amount of international trade in nitric acid is currently quite limited, then it reduces the risk of leakage.

However, lacking detailed data on nitric acid trade and profit margins, we are unable to conclude definitively that the CDM could not induce leakage. It is conceivable that if profits from CER sales could double the profits of nitric acid production – consistent with the estimates in Table 3, assuming profit margins of 10-20% – international trade in nitric acid, though confined to date, could expand. Yet the authors judge the current risk of carbon leakage, i.e. at current CER prices, for this project type as limited. Nevertheless, it is worth considering approaches that could minimize such leakage risk, which would increase if CER prices were to rise significantly. As we discuss further below, one approach could be to use crediting baseline based on an emissions benchmark low enough to reduce the risk of leakage while still providing sufficient profit to project developers.

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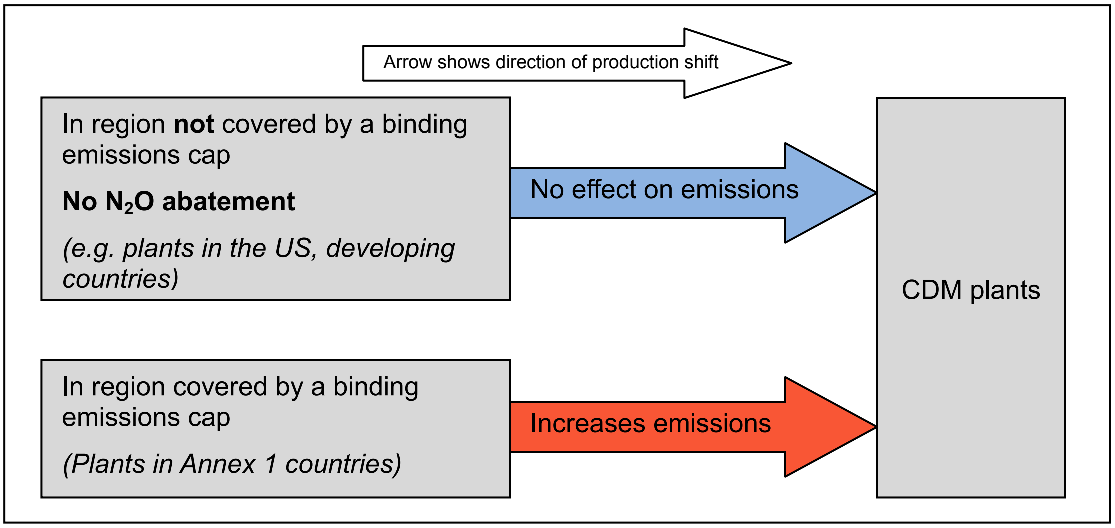
[11] All figures for adipic acid are taken from Schneider et al, 2010, table 6.

[12] Wara 2006 estimates net CDM profit to be EUR 21.09 per t nitric acid.

Figure 3: Illustration of the Effect on Global Emissions of a Shift in Production of Nitric Acid from Non-CDM to CDM Plants



How to establish emissions baselines under the two different abatement technologies

In the following sections we briefly explain the nitric acid production process and the currently available abatement technologies. We then compare N_2O emission rates before abatement (baseline emissions) and after abatement (project emissions) and try to answer the following questions:

- Is it possible and likely that operating conditions are manipulated to maximize emission reductions?
- Is the baseline emissions factor, established ex-ante for projects with secondary abatement (AM0034), representative of the baseline emissions that are actually occurring (but cannot be measured when using a secondary catalyst)?
- What are potentially more suitable alternatives to establishing baseline emissions factors?

Nitric acid production process

In the industrial production of nitric acid, ammonia (NH_3) is oxidized over precious metal gauzes containing platinum, rhodium and often palladium (primary catalyst) to produce nitrogen monoxide (NO) which then reacts with oxygen and water to form nitric acid.[13] Nitric acid is produced during so called production “campaigns.” The duration of the campaign is expressed in tons of pure nitric acid produced until the primary catalyst has reached the end of its design life. At the beginning of each campaign a new primary catalyst is installed. A campaign usually lasts 3–12 months, depending on the type of plant. The better a primary catalyst functions the fewer the unwanted by-products. One of the unwanted by-products of this process is N_2O. As the primary catalyst ages, it becomes less efficient,

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[13] The basic Ostwald process which is used in most Nitric acid plants involves 3 chemical steps:
Catalytic oxidation of ammonia with atmospheric oxygen, to yield Nitrogen Monoxide: $4 NH3 + 5 O2 \rightarrow 4 NO + 6 H2O$
Oxidation of the Nitrogen Monoxide to Nitrogen Dioxide or Dinitrogen Tetroxide: $2 NO + O2 \rightarrow 2 NO2 \leftrightarrow N2O4$
Absorption of the Nitrogen Oxides with water to yield Nitric Acid: $3 NO2 + H2O \rightarrow 2 HNO3 + NO$

and, therefore, N_2O emissions tend to increase toward the end of a campaign. If not destroyed through an additional treatment process, the N_2O is released into the atmosphere (Perez-Ramirez et al 2003).

Abatement technologies

The technologies to destroy N_2O emissions at nitric acid plants can be classified based on the process location of the treatment device:

Primary abatement: prevents N_2O being formed in the ammonia burner.
This abatement method requires modifications of the oxidation gauzes so that the oxidation process is optimized and production of N_2O and other unwanted by-products is minimized. According to gauze suppliers, such gauze improvement could potentially lead to a 30-40% reduction of N_2O formation (EC, 2009). No CDM methodology exists for this abatement method, and emission reductions achieved through primary abatement do not result in CERs or ERUs. Yet a change in type of gauze does affect how baseline emissions are established in AM0034 and will be discussed further below.

Secondary abatement: removes N_2O in the burner after the ammonia oxidation catalyst.
This abatement method requires installing a secondary N_2O destruction catalyst[14] below the primary catalyst inside the oxidation reactor. The CDM methodology AM0034 is specifically for nitric acid plants that install such a secondary catalyst[15]. The abatement efficiency of the secondary catalyst varies from about 50% to over 90% and depends on the design and operating conditions of the nitric acid plant and how the secondary catalyst is installed. As of September 2010, there were 49 registered CDM projects using AM0034. Based on the CDM project monitoring reports, they achieved an average abatement efficiency of 70% (UNEP Risoe, UNFCCC, N.Serve 2010a).

Tertiary abatement: removes N_2O from the tail gas.
This abatement technology is installed downstream of the absorption tower and based on either thermal or catalytic decomposition[16]. Tertiary abatement methods are highly effective at minimizing N_2O emissions (over 90%) and are attractive because they do not interfere with the nitric acid production process. However, they usually require a high tail gas temperature which in some cases requires additional fuel use to bring up the tail gas temperatures. CDM methodology AM0028 is aimed at nitric acid (and caprolactam) plants that install tertiary treatment. Because of its higher investment costs and more demanding technical requirements than secondary treatment, tertiary abatement is used less frequently and is usually installed in larger plants. As of September 2010, there were 8 registered CDM projects using AM0028. Based on the CDM project monitoring reports, they achieved an average abatement efficiency of 86% (UNEP Risoe, UNFCCC, N.Serve 2010a).

The different abatement technologies, secondary under AM0034 and tertiary under AM0028, establish the project's baseline emissions in different ways: In AM0028, the abatement technology is installed after the absorption tower. It is therefore possible to measure the emission reductions after project

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[14] This secondary catalyst has to be replaced regularly but less often than the primary catalyst.

[15] Secondary catalysts are produced by several industrial suppliers such as BASF, Heraeus, Johnson Matthew, Umicore, Yara (EC 2006, 2009).

[16] See footnote 3.

implementation by measuring N_2O content in the waste gas which goes into the destruction device (baseline emissions) and in the exhaust gas leaving the destruction device (project emissions). Baseline emissions and destruction efficiencies can therefore be calculated for each project campaign. Under AM0034, on the other hand, the destruction device is located in the oxidation chamber below the primary catalyst in a high temperature, high pressure and high acidity environment. It is currently technically impossible to measure N_2O concentrations in such an environment[17]. The baseline emissions therefore have to be established beforehand during the so called baseline campaign. The baseline campaign is run before the CDM project is implemented (i.e. before the secondary catalyst is installed) and N_2O emissions are measured in order to establish the baseline emissions factor ($EF_{baseline}$).

Comparison of baseline emissions

N_2O emissions from nitric acid production are highly variable. Emission rates depend on the operating conditions, such as operating pressures[18], catalyst type and age, concentration of nitric acid, and abatement processes (Perez-Ramirez et al 2003, EC 2009). The IPCC default emission factors[19] range from 5 to 9 kg of N_2O per tonne of nitric acid produced, but emissions of 19 kg and higher have been reported in some instances (N.serve 2010, IPCC 2000). The average European plant emits an estimated 6 kg of N_2O per tonne of nitric acid (EC 2006). Table 4 shows the IPCC default emission ranges and the average baseline emissions reported by CDM projects.

Table 4: Comparison of IPCC and CDM Baseline Emission Figures[20]:

Type of Plant	**Kg of N_2O emissions per t of nitric acid produced**					
	IPCC default emissions factors	**IPCC uncertainty ranges**	**Average BL emissions factor of AM0034 projects**	**Range of BL emissions factors of AM0034 projects**	**Average BL emissions factors of AM0028 projects**	**Range of BL emissions factors of AM0028 projects**
Low pressure plants	5 (+/- 10%)	4.5-5.5	4.84	4.84 (SS=1)	8.24	5.72-10.77 (SS=2)
Medium pressure plants (3-7 bar)	7 (+/- 20%)	5.6-8.4	8.82	4.55-20.74 (SS=19)	8.05	5.19-10.38 (SS=7)
High pressure plants (>8 bar)	9 (+/- 40%)	5.4-12.6	9.56	5.57-14.25 (SS=8)	10.56	8.46-12.72 (SS=5)
Average of all plant types	N/A	N/A	8.92	N/A	8.98	N/A

N/A = not available, not applicable; SS = sample size; BL = baseline
(Source: IPCC 2006, table 3.3; CDM data: N.serve, 2010a and personal communication Oct-8-10)

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[17] AM0051 suggests a technology to measure baseline emissions in the ammonia oxidation reactor. Yet no projects have been implemented under this methodology and technical experts agree that it is currently technically not feasible to install such a measuring device.

[18] Older dual plants tend to operate with low pressure/medium pressure, while more modern dual plants operate with medium pressure/high pressure (EC 2006).

[19] Excluding emissions factors from plants that have installed NSCR technology, see footnote 3.

[20] Baseline emissions averages for AM0028 and AM0034 projects are not weight by production or capacity.

The comparison shows that the baseline emission factors applied in CDM projects are on average within the range of the IPCC default emission factors for plants without N_2O abatement technologies. The comparison also shows that the average emissions factors for AM0028 and AM0034 projects are very similar (just slightly under 9 kg / t nitric acid).[21] In theory, there is a larger incentive to manipulate baseline emissions under AM0034, since the baseline campaign is run only once before implementation of the CDM project and the resulting baseline emission rates are then used for all following project campaigns. If a plant operator who uses AM0028 was to manipulate operating conditions in order to maximize N_2O baseline emissions, he would have to do so during every single project campaign, since baseline emissions are not established ex-ante. Analyzing monitoring reports from Am0028 projects, we found no indication of such ongoing manipulation, as baseline emissions often vary between monitoring periods and do not seem to follow any clear trend. To create more by-products such as N_2O, operations have to run sub-optimally, yet this would also decrease the level of nitric acid production and hence likely have a negative effect on the profitability of nitric acid production.

As explained, to maximize emissions reductions AM0028 projects would have to manipulate every single project campaign. AM0034 projects, on the other hand, would only have to manipulate their baseline campaign. But if manipulation of operating conditions were widespread for AM0034, we might expect to see a difference between the baseline emission rates for AM0028 and AM0034 projects. The fact that the average emissions factors are very similar may indicate that there is no systematic manipulation of baseline campaigns in AM0034, assuming all other factors (e.g. plant types and pressures) are similar. It is also possible that, a few AM0034 plants have manipulated their baseline emission factors. There are at least 4 projects that have baseline emissions outside the IPCC range at over 12kg, one with baseline emission rate of over 20kg. To further examine the likelihood of manipulation for AM0034 projects, we explore under which conditions such manipulation would have to occur in order to be successful.

Is it possible to manipulate operating conditions to maximize N_2O baseline emissions?

In the following section we examine if it is likely that the baseline campaign could be manipulated in such a way as to maximize the baseline emissions factor ($EF_{baseline}$) which could lead to an over-estimation of CERs. To maximize CERs the project developers could try to prolong the baseline campaign, as this would potentially increase the baseline emission factor. Figure 4 and Figure 5 help illustrate the process and the argument.

Effect of the campaign length on N_2O formation

According to AM0034, the baseline campaign has to be operating within a range of accepted operating parameters. These operating parameters are established prior to the baseline campaign during five so called “historic campaigns”. [22] The historic campaigns have usually taken place well in advance of the

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[21] If the average for AM0034 projects is weighted by output, the average drops to 8.44.

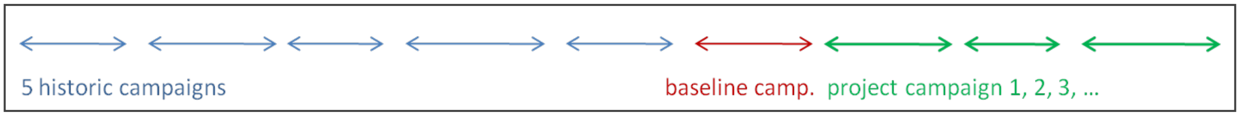
[22] From AM0034 version 4, p. 5:
The “permitted range” for oxidation temperature and pressure is to be determined using one of the following sources:
(a) Historical data for the operating range of temperature and pressure from the immediately previous five campaigns. (or fewer, if the plant has not been operating for five campaigns). In case there are abnormal campaigns1 identified by the project participants among these five campaigns, a request for deviation from this methodology; should be submitted; or,
(b) If no data on historical temperatures and pressures is available, the range of temperature and pressure stipulated in the operating manual for the existing equipment; or

implementation of the CDM project (Figure 4). It is therefore less likely that operating parameters of the historic campaigns are manipulated since most plant operators will likely not have planned to implement a CDM project during the years those campaigns were run. The average length of the five historic campaigns is expressed as CL_{normal} and measured in tonnes of nitric acid produced. CL_{normal} determines the maximum acceptable operating length of the baseline campaign. If one of the five historic campaigns is deemed 'abnormal' it can be excluded from the calculation of CL_{normal}.

Maximizing the baseline campaign length could potentially be useful for maximizing emissions reductions because N_2O emissions tend to rise toward the end of a campaign because the primary catalyst becomes less efficient.[23] It is therefore likely that the baseline emissions factor ($EF_{baseline}$) will be higher for longer baseline campaigns than for shorter ones. Because the historic campaigns determine the maximum acceptable operating length of the baseline campaign (CL_{normal}) changes in the lenth of CL_{normal} can potentially influence the baseline emissions factor: If the baseline campaign is longer than CL_{normal} the methodology requires that values for N_2O measured beyond CL_{normal} have to be eliminated (Figure 5, baseline determination). If the maximal allowable length based on historical data (CL_{normal}) has been maximized, it is less likely that tail end N_2O values from the baseline campaign have to be eliminated. This could be achieved by eliminating shorter historic campaigns by labeling them as 'abnormal.' Yet whether maximizing the permissible baseline campaign length would help maximize CER generation depends also on the project campaign length:

> **Project Campaign Length (CL_n) is longer than CL_{normal}**: In this case having maximized the permissible baseline campaign length would potentially help increase eligible emissions reductions (Figure 5, example A).
>
> **Project Campaign Length (CL_n) is shorter than CL_{normal}**: In this case the methodology requires that the baseline emission factor ($EF_{baseline}$) *has to be recalculated*, eliminating the N_2O concentration values from the baseline campaign that occurred beyond CL_n. In this case, having maximized the permissible baseline campaign length would be less likely to help maximize emission reductions, since the tail end values for $EF_{baseline}$ would have to be eliminated (Figure 5, example B). The effect on maximizing emissions reductions will depend on how much shorter CL_n was compared to what CL_{normal} would have been if it had not been maximized. The net effect is difficult to establish because the value for the non-manipulated CL_{normal} is not known.

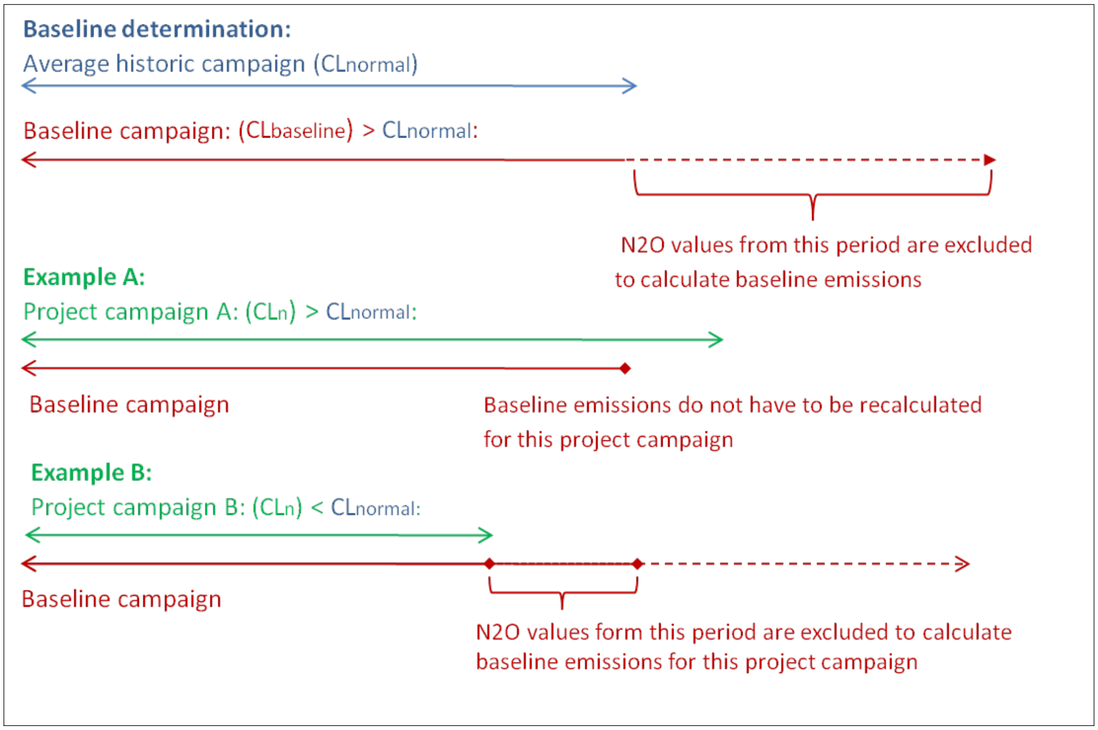
Figure 4: Chronological Sequence of Campaigns in AM0034



(c) If no operating manual is available or the operating manual gives insufficient information, from an appropriate technical literature source.

[23] EC (2007) notes: *For a medium pressure burner, a fresh gauze yields <1.5 % N_2O resulting in a tail gas concentration <1000 ppm. This can rise to 1500 ppm at the end of a campaign, corresponding to a 2.5 % of ammonia being converted to N_2O.*

Figure 5: Impact of Campaign Lengths on N_2O Emissions Factor



Hypothetical example to illustrate effect of campaign length on baseline emissions: Only in Example A would maximizing CL_{normal} potentially yield more emissions reductions. In Example B, maximizing CL_{normal} would likely not be useful for maximizing emissions reductions.

The discussion shows that the project campaign length determines if manipulating the average length of the five historic campaigns (CL_{normal}) could potentially help to maximize baseline emissions ($EF_{baseline}$) and lead to an increase in emissions reductions.[24]

To summarize, nitric acid project developers determine baseline emission rates *after* establishing intent to develop a CDM activity. In principle, such a situation could create moral hazard, where project developers might manipulate the baseline in order to maximize N_2O production and thus generate greater emission reductions and resulting CERs during the crediting period. However, based on the information available to us, we find no evidence that manipulation has occurred, and furthermore that the incentives for such manipulation are limited.

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[24] To further test if longer baseline campaigns tend to lead to higher emissions factors we conducted a statistical analysis of the correlation between campaign length and emissions factors of all AM0028 projects. The result shows that there is only a very weak correlation (Median of $R^2 = 0.26$) further strengthening the argument that manipulations of campaign length is probably of limited use for maximizing emissions reductions. Please note that because of the limited data size and data quality issues the results can only indicate a trend. The sample size for this analysis was small (14 plants with 2-14 data points each) and the reliability of the data is limited, as almost half the values come from monitoring periods for which no credits have been issued yet. Also, monitoring periods do not necessarily coincide with one single project campaign.

How representative are baseline campaigns?

Once the baseline emissions factor is established under AM0034, it is set for all subsequent project campaigns (with the above explained adjustments in cases where the project campaign length is shorter than CL_{normal}). It is therefore important that the baseline emissions factor is representative, i.e. that the baseline values used are close enough to the baseline emissions that occur during project campaigns (but cannot be measured). We again used the data from AM0028 projects to test the variability of baseline emissions from campaign to campaign and project by project[25].

Figure 6 shows that the variability in baseline emissions is considerable both between plants and between different monitoring periods at a single plant.[26] For example, the baseline emissions for the three available monitoring periods for plant 5 of project1481 (the sixth project in Figure 6) were 4.5kg, 7.8kg and 10kg. If this project would have applied the methodology AM0034, the baseline emissions might have been fixed at any value within this range for all crediting period (up to 21 years), depending on which campaign was used to establish baseline emissions. The considerable variability in the baseline emissions from different campaigns puts in question whether the approach pursued in AM0034 – the use of a single campaign to establish baseline emissions for all crediting periods – is appropriate. If baseline emissions are highly variable over time and differ significantly between campaigns, the use of a single campaign may not result in reasonably representative baseline emissions: depending on when the baseline campaign was conducted, emission reductions may be significantly under- or overestimated.

In addition, the current approach in AM0034 is quite cumbersome and involves considerable transaction costs and delays in the implementation of CDM projects. This project type is faced with serious credit issuance delays: Only 18 of the 78 monitoring reports that have been submitted for AM0034 projects have resulted in credit issuance: For 77% of all monitoring reports, project developers are still awaiting issuance. Only 10 of the 35 projects that have submitted monitoring reports have received credits at all. For projects that use a tertiary treatment method (AM0028), the numbers are less pronounced: only 4 out of 15 projects with monitoring reports have not yet received credits (44% of the 83 monitoring reports have not yet resulted in credit issuance). This may partly be due to the fact that baseline emissions under AM0028 are actually measured with each project campaign and may therefore face less scrutiny from DOEs and the UNFCCC than the monitoring reports for AM0034 projects.

Figure 6 shows that there is even more significant variation between plants. Under the current system, plants that have very high baseline emissions are rewarded by receiving more credits than plants with lower baseline emissions (assuming similar destruction efficiencies). It could be argued that rewarding plants with high baseline emissions is counter-productive – since it may encourage keeping baseline emission high – and unfair since well-managed plants with lower baseline emissions receive fewer credits. In the conclusions below, we therefore recommend to use an emission benchmarks to determine baseline emissions for both methodologies that is set at a level that would preserve the environmental integrity of the project type and still provide sufficient profit to project developers.

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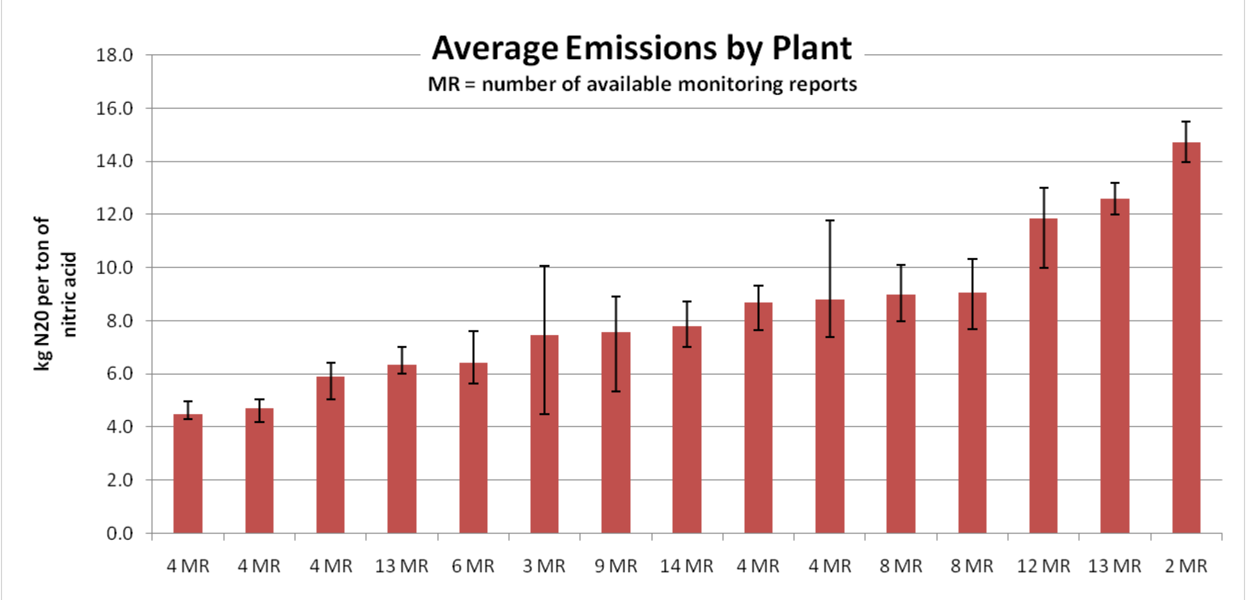
[25] Again, it is important to keep in mind the limitation of the available data set (see preceding footnote).

[26] It is important to note that monitoring periods in AM 0028 project do not necessarily correspond to complete project campaigns.

Figure 6: Average Measured Baseline Emissions for AM0028 Plants, Showing Highest and Lowest Measured Baseline Emissions Factors.



(Data taken from AM0028 monitoring reports)

Business-as-usual improvement in primary gauze efficiency

AM0034 currently requires that if a new type of primary gauze is installed for a project campaign either the baseline campaign has to be repeated to establish a new baseline emissions factor or the IPCC default emissions factor of 4.5 kg per tonne of nitric acid (lowest end of the uncertainty range, see Table 4) has to be used. While this provision aims to ensure that emission reductions are not over-estimated if a new type of primary gauze is used it may not be fully effective, for the following reasons:

- It could potentially create perverse incentives for the plant operators to continue using outdated gauzes because the introduction of a new gauze would require a new baseline campaign and thus for a certain period a loss of CERs.
- It does not take into account BAU improvements of primary gauze performance (or other technological improvements that lead to a decrease in N_2O emissions) over time.

Primary gauze improvements are highly attractive even without increased CER revenue, since they lead to an optimization of nitric acid production. Perez-Ramirez (2003) estimates that an increased NO yield of 1% in a medium nitric acid plant would lead to a profit of about EUR 500,000 annually. One possibility to address BAU improvements in the methodology would be to introduce a factor to account for technological improvement in gauze technology, which is applied independently of whether new gauzes are actually used or not. The effect of such a factor would be that the baseline emissions would slightly decrease each year, reflecting the improvements commonly observed over time. Such an approach could also eliminate the requirement to run a new baseline campaign if a new type of gauze is installed, which is currently a disincentive for project developers because they cannot generate CERs during that new baseline campaign. However, to propose a meaningful BAU improvement factor would require information about the expected improvement rates which could prove difficult to obtain.

Conclusions and Recommendations

The evaluation of CDM projects for N_2O abatement from nitric acid production reveals a number of interesting results.

1. **The carbon market was very effective in fostering abatement in an industry that had not been abating N_2O emissions previously.**
   N_2O abatement in nitric acid plants was not practiced, except for a few pilot projects in Europe, before the implementation of CDM, JI and the EU-ETS. With CDM support, new secondary and tertiary N_2O abatement technologies and monitoring standards[27] were introduced in 63 plants in 11 Non-Annex-1 countries.

2. **No evidence of systematic baseline manipulation was found**
   Nitric acid project developers determine baseline emission rates *after* establishing intent to develop a CDM activity. In principle, such a situation could create moral hazard, where project developers might manipulate the baseline in order to maximize N_2O production and thus generate more CERs during the crediting period. However, based on the information available to us, we find no evidence that manipulation has occurred, and furthermore that the incentives for such manipulation are limited. In particular, we find that:

   - Many actions that would tend to increase N_2O emissions also tend to decrease the efficiency of nitric acid production, and are thus generally not in the interest of project proponents.
   - Under AM0028, baseline emissions often vary considerably between monitoring periods and do not seem to follow any clear trend that would be a sign of manipulation.
   - Because N_2O emissions tend to rise towards the end of a campaign it is, in theory, possible that baseline emissions could be increased by maximizing the length of the baseline campaign. There is a larger incentive to manipulate baseline emissions under AM0034, since the baseline campaign is run only once before implementation of the CDM project and the resulting baseline emission rates are then used for all following project campaigns. Yet emissions factors from AM0028 projects are very similar to those from AM0034 projects. This indicates that at least on aggregate, the AM0034 methodology does not seem to lead to manipulation of baseline emissions in order to maximize CER generation.

3. **Baseline emissions vary significantly between plants and between monitoring periods**
   The variability in baseline emissions is considerable both between plants and between different monitoring periods at a single plant (*Figure 6*). The considerable variability in the baseline emissions from different monitoring periods puts in question whether the approach pursued in AM0034 – the use of a single campaign to establish baseline emissions for all crediting periods – is appropriate. If baseline emissions are highly variable over time and differ significantly between campaigns, the use of a single campaign may not result in reasonably representative baseline emissions: depending on when the baseline campaign was conducted, emission reductions may be significantly under- or overestimated.

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[27] Both nitric acid methodologies require the use of EN14181, a European monitoring standard that ensures high reliability and accuracy in data monitoring.

Baseline emissions vary even more significantly between plants: they can vary by up to a factor of four (Figure 6 and N.serve 2010a). This variability is due to the plants' age, type and operating conditions. Under the current system, plants that have very high baseline emissions receive more credits than plants with lower baseline emissions (assuming similar destruction efficiencies). It could be argued that rewarding plants with high baseline emissions is counter-productive – since it may encourage keeping baseline emission high – and unfair since well-managed plants with lower baseline emissions receive fewer credits. This problem is not unique to this project type.

4. **Both methodologies, but especially AM0034, are complex and projects are experiencing significant delays in credit issuance**

The current approach in AM0034 is complex and involves considerable transaction costs and delays in the implementation of CDM projects. For example, the issue of how to define an 'abnormal' historic campaign which then can be excluded from the calculations (see discussion on p.11) has been a contentious topic between project developers and the UNFCC. The definition of what constitutes an abnormal historic campaign has recently been changed in an effort to clarify the rules and minimize risk of manipulation. Yet the current definition had been deemed unworkable by many project developers[28].

Nitric acid projects are faced with serious credit issuance delays: Project developers are still awaiting issuance for 77% of all monitoring reports from AM0034 projects. Only 10 of the 35 projects that have submitted monitoring reports have received credits at all. For projects that use a tertiary treatment method (AM0028), the numbers are less pronounced: 44% of the 83 monitoring reports have not yet resulted in credit issuance. This may partly be due to the fact that baseline emissions under AM0028 are actually measured with each project campaign and may therefore face less scrutiny from DOEs and the UNFCCC than the monitoring reports for AM0034 projects.

Given these findings, we recommend introducing a benchmark factor for baseline emissions. Such a common benchmarking approach for both AM0028 and AM0034 projects could:

- Preserve the environmental integrity of the project type and still provide sufficient incentives to project developers.
- Greatly simplify the methodology and the requirements for project developers.
- Help reduce issuance delays and transaction costs.
- Safe-guard against any potential risks of carbon leakage.
- Be expanded to enable inclusion of new plants.

A benchmark would have to be carefully chosen, evaluating conditions in developing countries as well as the experience from JI projects. Some European countries are already requiring the use of baseline emission benchmarks: For example, France and Finland require a benchmark of 2.5kg of N_2O per

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[28] For the current definition see: http://cdm.unfccc.int/Panels/meth/meeting/10/045/mp45_rep.pdf
For a response by the Project Developer Forum, see
http://www.pd-forum.net/files/80f1a415c0584b3a03fdc51dabd001bc.pdf

tonne of nitric acid for 2009-2011 and 1.85 kg starting in 2012. Spain and Germany require a benchmark of 2.5 kg. This means that a project can only earn up to 0.8 CERs (at 100% destruction efficiency) per tonne of nitric acid. This reduces profitability by approximately two-thirds compared to the average CDM project (which generates 2 CERs per tonne of nitric acid) The fact that JI projects that have to use a stringent baseline factor are still being implemented, indicates that projects can be profitable even when a stringent baseline is used.

We recommend that the CDM Methodology Panel, with input from stakeholders and industry experts, work to come up with a precise benchmark level. Taking into account IPCC emissions factors, the benchmark figures used for the EU, and the baseline emissions that have been reported for CDM nitric acid projects, an initial baseline emission rate in the range of 4 to 5 kg N_2O per tonne of nitric acid might be suitable, declining over time to reflect autonomous and spur additional technology improvements (such as the primary gauze improvements that lead both to greater efficiency in nitric acid production and a reduction in N_2O emissions.) It is important to note, that a revised version of the methodology would only apply at the renewal of the crediting period of each of the nitric acid CDM projects.

New nitric acid plants in Non-Annex 1 countries are currently ineligible for the CDM. It might make sense to include such projects in the CDM to increase CDM project opportunities while ensuring N_2O abatement technology is adopted at new facilities[29]. However, provisions should be put in place in a methodology for new nitric acid plants to ensure that plants are not intentionally constructed or operated in a manner that increases N_2O emissions and that production is not shifted from existing plants to new plants due to the CDM. Such a methodology should include a stringent baseline emissions factor.

Over the past years, industrial gas CDM projects have come under increased scrutiny. Our study suggests that although there are important areas where the nitric acid methodologies could be improved and strengthened, on the whole this project type does not appear to have the unintended negative consequences (e.g. manipulation or carbon leakage) as have been suggested for HFC-23 and adipic acid projects. Indeed, as noted above, application of carbon market mechanisms to the nitric acid sector has spurred important innovations in technology and practice.

Policy makers are currently debating how to address the shortcomings of industrial gas projects. We would like to stress the importance of distinguishing among different industrial gas project types when designing possible policy remedies. Only separate and well-designed measures that target the specific nature of each project type can ensure that risks are minimized for each individual project type, that overall mitigation benefits maximized, and the positive elements of market mechanisms are reinforced.

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[29] There have been several new methodology submissions to include new facilities (e.g. NM319 and NM284). None of these methodologies have been approved so far. (http://cdm.unfccc.int/methodologies/PAmethodologies/pnm/byref/NM0319 and http://cdm.unfccc.int/methodologies/PAmethodologies/pnm/byref/NM0284)

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