



NOTE

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To
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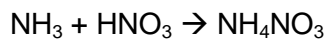
Calculation of Carbon Footprint of Fertilizer Production

1 Introduction

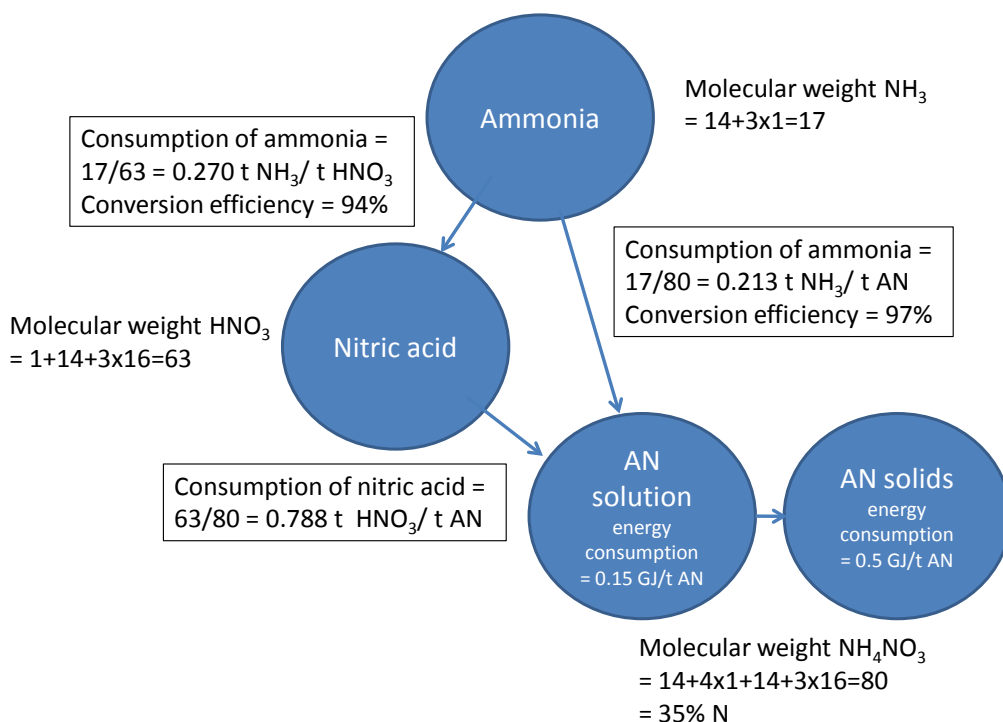
This note documents the calculation methodology for establishing the carbon footprint (greenhouse gas emissions) of fertilizers based on ammonium nitrate (AN). It is limited to the emissions arising from the production of the nitrogen content of the fertilizer. The methodology is documented in response to the requirements of the emission standard set by the Swedish food industry for climate branding (ref 1).

2 Basic Principles

Ammonium nitrate is produced by the reaction of ammonia with nitric acid:



Schematically, for a modern plant, this can be shown as follows:





Thus, the carbon footprint for AN (t CO₂-eqv / t AN) is calculated as follows:

- Energy consumption for ammonia production (GJ/t NH₃)
 - x Carbon factor of energy source (t CO₂/GJ)
 - x Amount of ammonia used for producing AN (0.213 t NH₃/t AN + 3% for efficiency loss)
- + Energy consumption for ammonia production (GJ/t NH₃)
 - x Carbon factor of energy source (t CO₂/GJ)
 - x Amount of ammonia used for producing nitric acid (0.213 NH₃/t AN + 6% efficiency loss)
- + Emission from nitric acid production (t N₂O per t HNO₃)
 - x Global Warming Factor for N₂O (t CO₂-eqv/ t N₂O)
 - x Amount of nitric acid used for producing AN (0.788 t HNO₃/t AN + 3% efficiency loss)
- + Energy consumption for AN solution and solidification processes (GJ/ t AN)
 - x Carbon factor of energy source (t CO₂/GJ)
- Heat export from nitric acid production (GJ/t AN)
 - x Carbon factor of replaced energy (t CO₂/GJ)

3 Data

The following data are used as reference values:

Global Warming Factor for N₂O = 296 (ref 2)

Carbon factor for energy source (kg CO₂/ GJ) (ref 3):

| | |
|-------------------------|--------|
| Natural gas | = 56.1 |
| Liquefied petroleum gas | = 63.0 |
| Residue fuel oil | = 77.3 |

Ammonia plant energy efficiency (GJ/ t NH₃ low heat value):

| | |
|------------|----------------|
| EU BAT | = 31.8 (ref 4) |
| EU average | = 35.2 (ref 5) |
| Russia | = 40.3 (ref 6) |

Nitric acid plant N₂O emission (kg N₂O/ t HNO₃):

| | |
|--|-----------------------------------|
| EU BAT (with catalytic abatement technology) | = 1.85 (ref 4) |
| Average without catalytic abatement technology | = 7.5 (4-15 depending on process) |

Heat export from nitric acid production (GJ/t HNO₃):

| | |
|-----------------|---------------|
| Average plant | = 0 (ref 7) |
| 25% best plants | = 0.6 (ref 7) |

Energy consumption for AN solution plant = 0.15 GJ/ t AN (ref 8)

Energy consumption for AN solidification = 0.5 GJ/t AN (ref 8)



4 Carbon Footprint for AN production

Using the data above data the carbon footprint of AN-based fertilizers becomes (for the production of the nitrogen-content of the fertilizer):

| Production technology | t CO ₂ -eqv per t N |
|---|--------------------------------|
| EU BAT, with natural gas as energy source | 3.6 |
| EU average NH ₃ -plants and without de-N ₂ O catalyst technology, with natural gas as energy source | 7.8 |
| AN-based fertilizers delivered by plants with average Russian NH ₃ energy efficiency and without de-N ₂ O catalyst technology | 8.1 |

In comparison, the emission standard set by the Swedish food industry for climate branding (ref 1) requires the carbon footprint for fertilizers to be below 4 kg CO₂-eqv per kg nitrogen (4 t CO₂-eqv per t N).

The carbon footprint for fertilizers produced by Yara and delivered to the Nordic countries are shown below (for the production of the nitrogen-content of the fertilizer). This takes account of the latest performance data for the Yara production sites as well as the emission related to sourced ammonia from non-Yara producers (used by Yara for making fertilizers).

| Production of AN-based fertilizers at Yara production sites, for deliveries to Denmark, Finland, Norway and Sweden | t CO ₂ -eqv per t N |
|--|--------------------------------|
| Glomfjord | 3.3 |
| Porsgrunn | 2.9 |
| Siilinjärvi | 3.1 |
| Uusikaupunki | 3.6 |
| Rostock | 3.1 |
| Sluiskil | 2.6 |

Yara fertilizers to the Nordic countries are supplied from different production sites. Taking account of the supply pattern, the carbon footprint per country becomes:

| Average carbon footprint for AN-based fertilizers delivered to: | t CO ₂ -eqv per t N |
|---|--------------------------------|
| Denmark | 3.3 |
| Finland | 3.2 |
| Norway | 3.1 |
| Sweden | 3.1 |

5 Discussion

The difference in carbon footprints for Yara production sites is due to (1) differences in energy efficiency and energy source of ammonia production and (2) differences in the efficiency of N₂O abatement (due to differences in nitric acid process design and operating parameters).

For evaluating the sensitivity of the results for the Yara plants, the following parameters are varied:

- *If all ammonia was supplied by Russian producers:*
The highest carbon footprint for the production sites becomes 3.6 kg CO₂-eqv per kg N.
The highest carbon footprint for a country becomes 3.4 kg CO₂-eqv per kg N.
- *If the enthalpy of Russian natural gas was increased from 7900 kcal/m³ (ref 6) to 8200 kcal/m³:*
The highest carbon footprint for the production sites becomes 3.7 kg CO₂-eqv per kg N.
There is basically no change in the carbon footprints per country.
- *If the de-N₂O catalyst loose efficiency by 20%:*
The highest carbon footprint for the production sites becomes 3.8 kg CO₂-eqv per kg N.
The highest carbon footprint for a country becomes 3.5 CO₂-eqv per kg N.
- *For AN-based fertilizers with fillers like dolomite or gypsum (CAN 27 and AXAN 27-S), what will the additional energy requirement associated with processing of the fillers mean for the carbon footprint, and will CN satisfy the Swedish emission standard:*
Mining and grinding of solid additives for the solidification process are assumed to consume 1.2 GJ per t product (ref 8), i.e. approximately 0.3 GJ per t of fertilizer. The carbon footprint of such products per kg N is insignificantly higher than the carbon footprint for straight AN, and well below the emission standard of the Swedish food industry.
For calcium nitrate (CN 15.5% N made as a by-product in the nitrophosphate process), the additional energy consumption is assumed 5.2 GJ per t N (ref 8). The carbon footprint for CN from Glomfjord and Porsgrunn (only producers of CN) is below the emission standard of the Swedish food industry.
- *For AN-based NPK fertilizers, what is the effect of the carbon footprint of P and K if all emissions are related to N:*
In composite AN-based fertilizers containing other nutrients like phosphorous and potassium, the nitrogen production is by far the predominant source of greenhouse gas emissions. The carbon footprint per kg N remains basically the same for different AN-based NPK fertilizers as for straight AN. If other nitrogen sources are used to replace AN, the carbon footprint for NPK will be lower. For detailed calculation of the carbon footprint for different types of fertilizers, see ref 8.

In order to understand the full carbon footprint of different fertilizers, the emissions occurring before and after production should also be accounted for, i.e. the full lifecycle of fertilizers should be considered. In addition to emissions from production, this includes emissions from the extraction and supply of raw materials and energy, from transportation, from application of the fertilizer and from growth of biomass (including the release of greenhouse gases from the soil due to fertilizer use). Such a full life cycle is not the aim of this note, but it is evident from life cycle analysis carried out at Yara Hanninghof Research Centre (ref 9) that the production and the emissions from the soil due to fertilizer use, are the two principal greenhouse gas emission sources. The lifecycle approach is particularly important when comparing ammonium



nitrate with urea as a nitrogen source. At the production stage, urea will have lower emissions, but higher emissions from the field when used. In total, the carbon footprint from the production and use of urea will be approximately 20% higher compared to AN-based fertilizers (ref 10). Urea also emits much more ammonia to the atmosphere during farming than AN, thus increasing the risk of not meeting the national limits on emissions of acidifying substances defined by the Gothenburg Protocol. To compensate for this loss, the farmer has to apply a higher dosage of nitrogen from urea, in order to obtain the same yield as with AN-based fertilizers.

6 Conclusion

In conclusion, fertilizers produced by Yara and supplied to the Nordic countries satisfies the criteria established by the Swedish food industry for climate branding, i.e. below 4 kg CO₂-eqv per kg nitrogen.

7 References

- 1 Standards Document: Climate Certification for Food 2009-1, www.klimatmarkningen.se
- 2 IPCC Third Assessment Report - Climate Change 2001
- 3 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 2 Stationary Combustion
- 4 IPCC Reference Document on Best Available Techniques for the Manufacture of Large Volume Inorganic Chemicals - Ammonia, Acids and Fertilizers, EU Commission, August 2007
- 5 Energy Efficiency and CO₂ Benchmarking of European Ammonia Plants - Operating Period 2007-08, Plant Surveys International Inc, December 2009
- 6 Russian Nitrogen, No 2, 2010 (energy consumption for feed and fuel = 39.6 GJ/t NH₃) + data from ref 4 (average net steam/electricity consumption from European plants = 0.7 GJ/t NH₃)
- 7 Benchmarking of Energy Efficiency of Nitric Acid Plants, Process Design Center, The Netherlands, June 2008
- 8 Energy Consumption and Greenhouse Gas Emissions in Fertilizer Production, by Gunnar Kongshaug, Hydro Agri (Yara), presented at IFA Technical Conference, Marrakesh, Morocco 1998
- 9 GHG Emission and Energy Efficiency in European Nitrogen Fertiliser Production and Use, by Frank Brentrup (Yara) and Christian Pallière (Fertilizers Europe), Proceedings 639 presented at the International Fertiliser Society 2008
- 10 Fertilisers Europe Annual Report 2009, www.efma.org