Yara's de-N_2O technology

A well-proven, cost efficient choice for reducing nitrous oxide emissions

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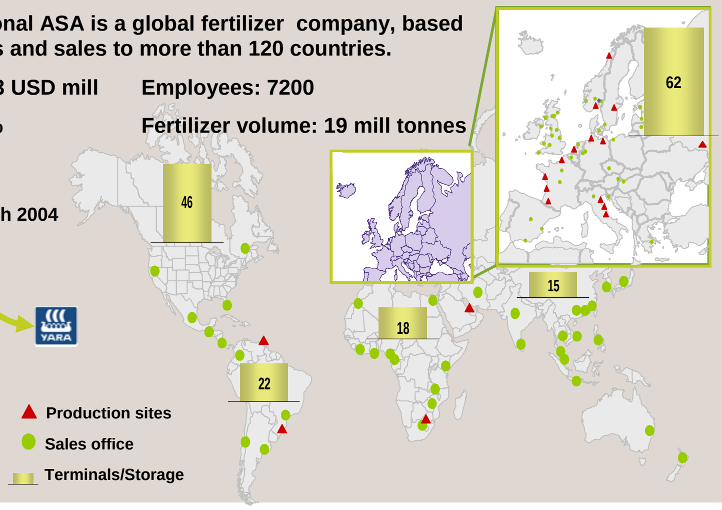
Yara – A global fertilizer company

Yara International ASA is a global fertilizer company, based in 50 countries and sales to more than 120 countries.

EBIDTA: 1,033 USD mill | **Employees: 7200**

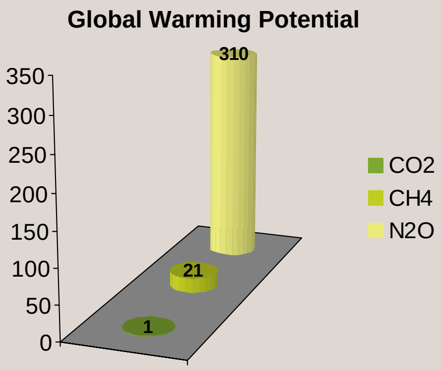
CROGI: 14,4 % | **Fertilizer volume: 19 mill tonnes**

25. March 2004



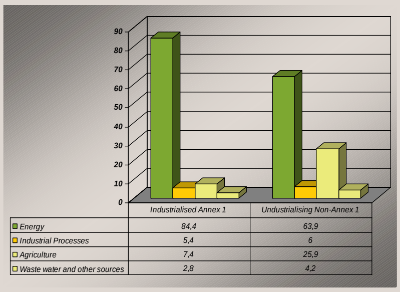
The global warming is a challenge for the international community

- Climate models predict the global temperature will rise by 1,4-5,8 ºC by the year 2100
- This change would be much larger than any climate change in the last 10,000 years
- Nitrous oxide is a major Green House Gas (GHG)



GWP= Global warming Potential, the ratio of the heating effect of the release of 1 t of greenhouse gas into the atmosphere compared with that due to the release of 1 t of CO_2

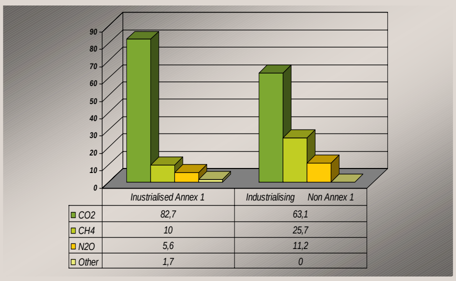
Nitrous oxide (N_2O) emissions seen in a perspective



	Industrialised Annex 1	Undustrialising Non-Annex 1
Energy	84,4	63,9
Industrial Processes	5,4	6
Agriculture	7,4	25,9
Waste water and other sources	2,8	4,2

Global Industrial Processes contribute with 5-6 %

N_2O contributes to global warming by 6-11%

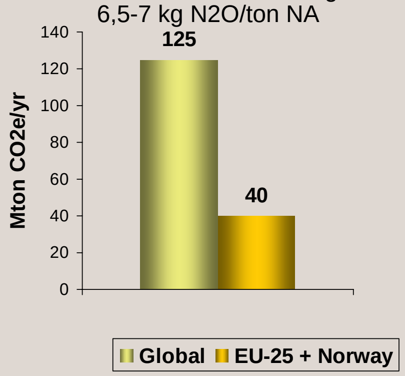


	Inustrialised Annex 1	Industrialising Non Annex 1
CO2	82,7	63,1
CH4	10	25,7
N2O	5,6	11,2
Other	1,7	0

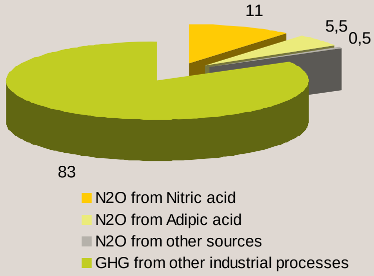
Greenhouse Gas Emissions data for 1990-2003 submitted to the United Nations Framework Convection on Climate Change: “Key GHG Data”.

N_2O emissions from Nitric acid (NA) producers

Globally 125 Mton CO2e/yr
Estimated from average emission
6,5-7 kg N2O/ton NA



Europe: EU-25 + Norway
11% of industrial emissions



Yara – One of the pioneers of fertiliser companies to develop technologies for N_2O abatement

Already in the 1992 abatement technology was installed in our new nitric acid plant in Norway, which cut the N_2O emission by 70%.

This technology development for new plants is now complemented by a technology for N_2O abatement for existing plants

Yara total Nitric acid capacity:
19 plants and 5,5 mill t/a

Nitrous oxide formation in nitric acid production

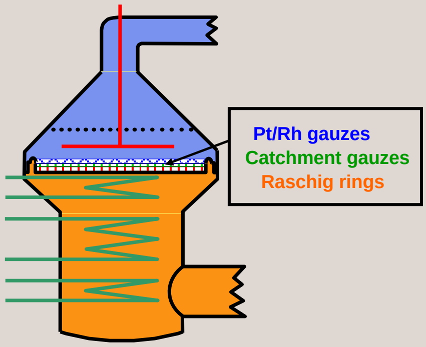
- N_2O is formed during oxidation of ammonia
- A mixture of ammonia and air reacts over precious metal gauzes in the ammonia burner forming the desired gas nitric oxide (NO):

$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$

Undesired reactions:

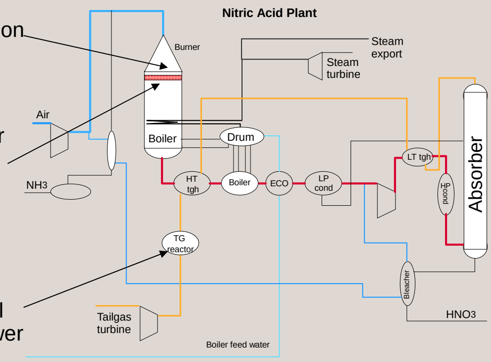
$4\ NH_3 + 3\ O_2 \rightarrow 2\ N2 + 6\ H_2O$

$4\ NH_3 + 4\ O_2 \rightarrow 2\ N_2O + 6\ H_2O$



3 main “ways” for N_2O abatement

- **Primary:** N_2O formation is partially prevented during the ammonia oxidation by modifying the ammonia oxidation gauzes.
- **Secondary:** N_2O is removed just after being formed, in the catalyst basket located under the metal ammonia oxidation gauzes or N_2O by enlarging the space between the catalyst gauze and the process gas cooler.
- **Tertiary:** N_2O is removed from the tail gas downstream of the absorption tower in a new separate reactor.



Yara's technologies for secondary N_2O abatement

Yara has patented two technologies:

- **Homogeneous** N_2O decomposition: Increased residence time (1-3 sec) in extended chamber in ammonia burner
- **Catalytic** high temperature decomposition in the burner basket located beneath the ammonia oxidation gauzes The de-N_2O catalyst is selective and promotes the reaction: $N_2O \rightarrow N_2 + ½ O_2$

Why catalytic secondary?

- **High efficiency location**
  - N_2O decompose more quickly
  - High efficiency can be achieved with a small amount of catalyst.
- **Low investment costs**
  - Re-use of existing basket in the burner
  - No need to install an additional catalytic reactor
  - No downtime period
  - Quick and easy to install

Yara De-N_2O catalyst – a result of extensive research

Yara catalyst is based on 17 years research in laboratory and integrated pilot plant aiming to achieve the following:

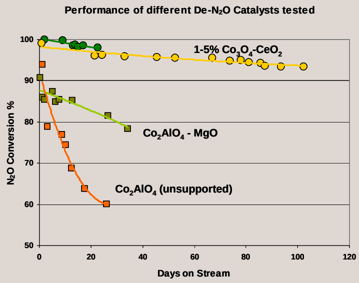
- An optimal reactive component – thermally stable at 800-1000°C
- High efficiency & selectivity of de-N_2O decomposition – no decomposition of NO
- A form of the reactive component to achieve a stable activity and to avoid any losses
- An optimal support material
  - Resisting sintering and keeping a high surface area
  - Improving the mechanical properties
  - No material evaporation
  - Thermal expansion close to burner construction material to avoid catalyst mal-distribution in the basket.
- Models of the kinetic properties to be applied for different pressures and temperatures
- An optimal pellet shape to maximise surface/volume ratio and to minimize pressure drop

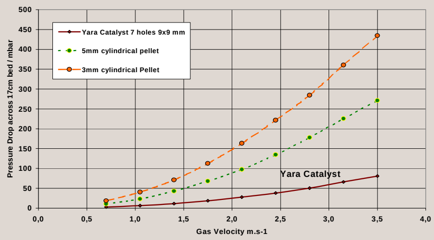
A specific focus on catalyst composition

Many tests have been performed on the active composition with extensive tests among different cobolt-aluminium and cobalt-iron spinels:

$Co_{3-x}M_xO_4$ with x=0 to 2 & M= Al, Fe

Different support materials: Magnesia, alumina and alumino-silicates failed. Ceria was the best candidate





..and catalyst shape

Pressure drop comparison for different catalyst shapes

Measured in Nitrogen at room temperature

The Pilot Plant Facility – a key component of our development

- Different generation of catalyst with various substances and compositions have been manufactured and tested in Yara's own research facilities. All these tests have been performed in a fully integrated pilot plant.

- Operating range
  - Pressure: 1.5-13 bar
  - Temperature up to 940 ºC
  - Load: Up to 40 tN/m^2d
- Pilot plant start up in 1993
- 2 independent reactors. 3,5 liters of de-N2O catalyst each.
- Control of the pressure, NH3 flow, compressed air for each reactor.

Yara de-N_2O catalyst is now produced in full scale production facilities

- After extensive testing, preliminary industrial scale plant application was scheduled
- Production techniques was developed and improved. The resulting patented production method yields a robust and high porosity catalyst
- The catalyst was installed in Yara's French plants to gain long-term experience
- An industrial scale catalyst production facility started up in 2005

The catalyst is a multi cored cylindrical pellet 9x9 mm.
The catalyst is available in 50 litres drums, Net weight 40 kg, packed in plastic bags of 10 kg for easy handling.

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Yara de-N_2O catalyst: Easy to install

- The De-N_2O catalyst is installed in the basket. If the basket is too deep the catalyst is installed on top of remaining raschig rings
- The catalyst is carefully levelled to get an homogeneous & flat surface without breakage the pellets
- The gauze pack is installed as normal on the top of De-N_2O catalyst.

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Yara's experience in full scale operation

Yara de-N_2O catalyst has been installed in Yara's nitric acid plants in France

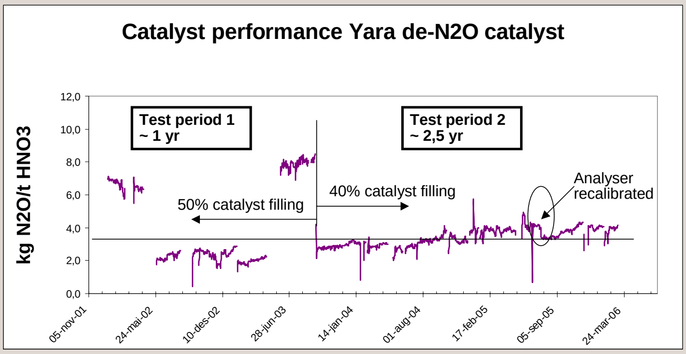
Plant	HNO_3 plant capacity (mtpd)	Burner diameter (m)	Burner Pressure (bar abs.)	Burner temperature (°C)	Burner load (tN/m2	Operating time (yrs)
1	1380	4,6	4,7	885	19,5	> 3
2	240	3	3,7	870	9,7	> 3
3	980	4	3,4	890	7,5	2*)

*) Increased catalyst filling from industrial scale catalyst production facility in Aug. 2005

Abatement efficiency:

- **60% in test installations with partially filled baskets**
- **90% abatement achieved with increased catalyst filling**

Observed performance in Yara plant in France



The catalyst was first time installed in May 2002 with a 50% catalyst filling.
The catalyst was reinstalled after a test period of about 1 year; the catalyst layer was then a 40% filling of the basket. The catalyst is still on stream after 3,5 yrs.

The experience from installations is positive

Main advantages:

- High level of N_2O abatement; using in house developed kinetic models show abatement levels up to more than 90% can be achieved in most plants
- No modifications in operating procedures and parameters
- No risk of downstream pollution
- Low investment costs
  - Easy & cost effective to install in burner basket below the Pt/Rh gauze: re-use of the existing basket without any modifications
- Catalyst is robust and abatement efficiency is retained after operational start/stop including change of ammonia oxidation catalyst (for one of the plants 9 gauze changes)
- Catalyst mechanical behaviour is not affected by the pressure variation

The Kyoto protocol set the agenda for N_2O reductions

- Most members of the Organisation for Economic Co-operation and Development (OECD) plus the states of central an Eastern Europe known as Annex 1 countries (“industrialized countries”) have committed themselves to adopting policies and measures aimed at returning their GHG emissions to 1990 levels
- The Kyoto Protocol to the UNFCCC strengthens the international response to climate change by consensus at the Conference of the Parties (COP-3) in Dec. 1997. It contains legally binding emission targets for Annex 1 countries
- Each countries emission targets must be achieved in the period 2008-2012

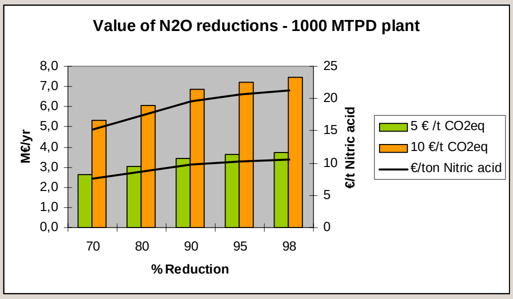
United Nations Framework Convection on Climate Convection (UNFCCC)

Mechanisms are in place for reduction of N_2O emissions

- Clean Development Mechanism (CDM) and the Joint implementation (JI) mechanism allow Nitric acid producers to define projects for abatement
- The CDM mechanism allows Annex 1 Parties to implement sustainable development project activities that reduce N_2O emissions in non-Annex 1 Parties, the certified emission reductions (CER's) generated can be used by Annex 1 Parties to help meet their own emission targets
- N_2O abatement project can be selected today as a CDM project, which allows trading CER's worldwide under CDM conditions. Such CER's trading makes the N_2O abatement project very attractive for nitric acid plant owners.

Potential value of N_2O reductions

The potential global value of all N_2O emissions from nitric acid production is in the range of 1000 M € per year at 10 €/ CO_2eq and 80% abatement and inlet concentration of 7 kg N_2O /ton nitric acid
The value will depend on trading regimes in specific countries.



Value generation from N_2O reductions for a 1000 MTPD plant in a CDM country

Assumption: All achieved reduction will be credited

Yara cuts climate gas emissions in Norway

- **Press release - October 2005:**

  YARA will install its own new technology for the reduction of emissions of the climate gas N2O (nitrous oxide) at the Company's fertilizer plants in Norway. This will lead to reductions of approximately 0,5 millions tonnes of CO2 equivalents per year, representing close to 20% reduction of the total climate gas emissions from YARA in Norway today.

  ⇒ **3 new catalyst installations are scheduled in 2006**

2006 – A new step for Yara's De-N_2O catalyst

- Yara has developed a robust catalyst with high efficiency and stable performance. The abatement system can be tailored to reduce N_2O emissions to fit the client's requirements and reduce N_2O emission levels in nitric acid plants up to more than 90%
- Based on more than 3 years experience in large capacity production facilities Yara has decided to make the proven technology commercially available to the industry to meet their obligations of N_2O reduction
- **Press release - March 2006:**

  "A sales and marketing agreement has been signed with Johnson Matthey Plc Noble Metals for marketing the catalyst globally to Clean Development Mechanism (CDM) and joint implementation (JI) countries as established and defined by the Kyoto protocol"


THANK YOU
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Back-up

Operating parameters Ambes plant

- **Operating conditions**
  - Pressure: 4.7 bar
  - Temperature 890°C
  - Capacity 1300 MTPD
  - Load 19 tN/m^2
  - Inlet N_2O conc.   8.14 kg N_2O/t HNO_3
  - 60 mm catalyst layer
  - Pressure drop is approx 3 times the same filling height of Raschig rings
- **Results**
  - Outlet N_2O conc. 2.9 N_2O/t HNO_3 (64% reduction with 40% filling)
- **Potential**
  - The catalyst layer may be increased to 150 mm
  - Outlet N2O conc. 0.6 N2O/t HNO3 (92% reduction)

The Pilot Plant Facility

- Control and automatic measures and records
- Several gas analyzers and sampling points.
- Possibilities to operate the pilot plant at different pressure & loads and to analyze the N2O concentration before and after the catalyst for each conditions and temperature.