The G8 Plan of Action and the Ammonia Sector

Dolf Gielen
G8 Industry Task Coordinator
International Energy Agency

IFA - IEA workshop, 13 March 2007

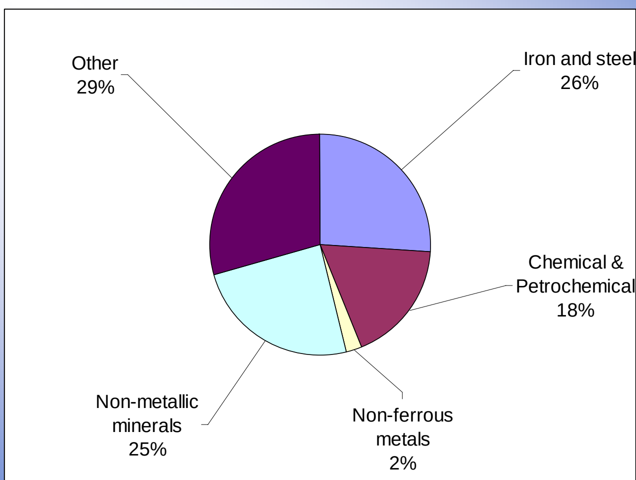
Industry Task

- Part of a package of 14 tasks, requested by the G8 and IEA countries
- Identify promising areas for industrial energy efficiency improvement and CO_2 reduction
- Advice regarding alternative scenarios
- Advice on policies and measures

Analysis Structure

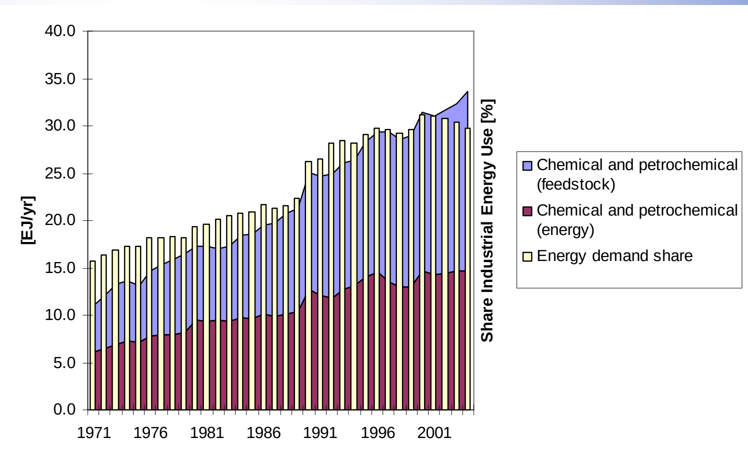
- *Energy Technology Perspectives 2006* contains a detailed industry chapter & scenario analysis
- *Indicators for Industrial Energy Efficiency and CO_2 Emissions* – May 2007
  - Ammonia section reviewed by IFA
- Efficiency potential analysis (new technologies) – End 2007
- *Energy Technology Perspectives 2008* will contain more detailed scenario analysis results
- Section in the IEA progress reports for German (2007) + Japanese (2008) G8 summit

Industrial Direct CO_2 Emissions



INTERNATIONAL ENERGY AGENCY AGENCE INTERNATIONALE DE L'ENERGIE

World Chemical & Petrochemical Industry Energy Use According to IEA statistics



INTERNATIONAL ENERGY AGENCY AGENCE INTERNATIONALE DE L'ENERGIE

Energy Use for Ammonia, 2005

Region	Production	Energy intensity	Fuel use use
	Mt NH_3	GJ/t NH_3	PJ/yr
Western Europe	12.2	35	427
North America	14.4	37.9	546
Former Soviet Union	20.9	39.9	834
Central Europe	6.2	43.6	270
China	43.7	48.8	2 133
India	12.2	40	488
Other Asia	13.3	37	492
Latin America	9	36	324
Africa	4	36	144
Middle East	8.5	36	306
Oceania	1.2	36	43
World	145.4	41.6	6007

Ammonia accounts for 5% of total manufacturing industry energy use

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Special Issues for Ammonia

- The industry is gas dependent and very energy intensive
- This affects the industry prospects (location choice, profitability)
- A lot of industry in developing countries
- A lot of CO_2 is captured and used for urea production
- Adequate ammonia fertilizer use can increase world bioenergy potentials substantially

Proposed Cooperation Themes

- Energy efficiency & CO_2 emission indicators on a country level
  - Data & analysis validation
- Explanation of differences on a country level
  - Feedstock mix
  - Technological characteristics of the capital stock
  - Process integration
- Advice on what can be done realistically
  - Cost & competitiveness
  - Time path
  - Technology & resource issues
- Advice on a transition path
  - Who should be involved
  - What is the role of various actors

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Dialogue Workshops with Industry

- Motor systems, 15-16 May 2006
- Cement, 4-5 September 2006
- Paper and Pulp:
  - Technical workshop, 9 October 2006, Paris
  - International Seminar, 30-31 October 2006, Rome
- Iron and Steel – 7 November 2006
- Petrochemicals- 12-13 December 2006
- Ammonia – 13 March 2007
- Aluminium – May 2007
- Cooperation with: CEPI, CEFIC, IAI, IETS, IFA, IISI, ICFPA, FAO, WBCSD,…

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Thank you

dolf.gielen@iea.org

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Challenges for the Ammonia Industry

Andrew Prince

British Sulphur Consultants

Ho Chi Minh City, Vietnam

March 2007

LONDON | RALEIGH | WASHINGTON | BEIJING

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31 Mount Pleasant, London WC1X 0AD UK
Tel +44 20 7903 2132 Fax +44 20 7833 4973
www.crugroup.com
www.britishsulphur.com

Presentation Overview

- Market Overview
  - Supply
  - Project outlook
  - Trade & geographic spread of industry
- Ammonia Production
  - Different feedstocks and costs
    - Environmental considerations
  - Project Costs
- Conclusions

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Outlook for Supply

- Ammonia capacity will grow from the current 177 million tonnes to 204 million tonnes by 2015.
- Major growth in East Asia, Middle East, North Africa, mainly due to advantageous production costs thanks to low-cost gas.
- North America capacity shrinking due to high gas costs; European plants vulnerable, particularly in Eastern Europe.
- New world-scale export-oriented plants due on-stream 2007-2010. Where new capacity exceeds demand requirements, uncompetitive plants are displaced.

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New Export Capacity ('000t/y)

Start-up	Plant	Country	Ammonia	Urea	Export Ammonia
EASTERN HEMISPHERE					
2006	Burrup Fertilizers	Australia	760		**760**
2006	Safco IV	Saudi Arabia	1,089	1,073	**470**
2006	EFC II	Egypt	396	635	**30**
2007	NPC - Assaluyeh I	Iran	677	1,073	**60**
2007	Razi	Iran	677		**677**
2007	SIUCI	Oman	660	1,155	**-**
2009?	NPC - Assaluyeh II	Iran	677	1,073	**60**
2009	Ma'aden	Saudi Arabia	1,089		**400***
2009	EBIC	Egypt	660		660
2010	NPC - Shiraz	Iran	677	1,075	**60**
2010	Qafco V	Qatar	1,089	1,155	**425**

*** - captive consumption for DAP**

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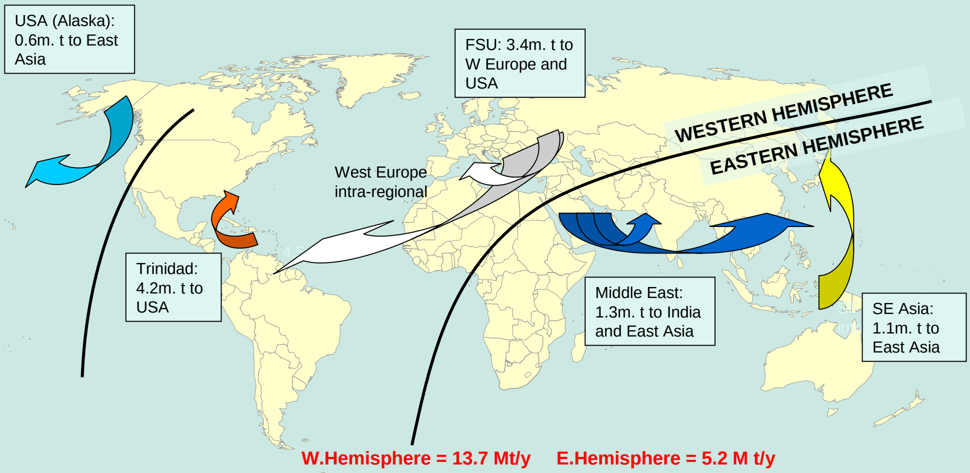
New Export Capacity ('000t/y)

Start-up	Plant	Country	Ammonia	Urea	Export Ammonia
WESTERN HEMISPHERE					
2006	Alexandria Fertilizers	Egypt	396	693	-
2009	MOPCO	Egypt	396	635	**30**
2009	Clico	Trinidad	610	1,056**	**200**
	Total		**9,853**	**9,100**	**3,832**

** - urea for UAN production

Key Deep-sea Merchant Ammonia Trade Routes



Source: IFA, British Sulphur

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Trade Outlook

- Ammonia trade grows from 18.9 million tonnes in 2005 at a CAGR* of 2.6% p.a. to reach 23 million tonnes ammonia in 2015.
- Trade represents ~13% of total ammonia production.
- Trade growth driven by closure of uncompetitive domestic capacity, displacement in the market by export plants of larger scale and advantaged feedstock costs and logistics.
- North America remains largest importer, with India close behind, East Asia grows towards end of forecast as marginal supplement to growing domestic capacity.
- Trinidad overtakes the FSU as largest exporter as FSU is declining due to production cost inflation, and the Middle East shows strong growth.

*** - Compound Annual Growth Rate**

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Why are more Ammonia plants not being built, despite...

- International ammonia prices have been very strong for past 4 years and remain high going into 2007.
- Demand outlook is positive, especially in Asia.
- Capacity is ageing in North America and Europe and appears vulnerable to displacement by modern, large-scale capacity.

BUT

- Feedstock costs have risen globally and impacted production costs negatively.
- Capital cost of new plants is high such that financing is tricky to justify.

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Two major challenges for the Ammonia sector

- Cost and availability of feedstock
- Capital Cost of Projects

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Ammonia Production Overview

Hydrogen + **Nitrogen** → **Ammonia** (+ CO_2)

Hydrogen

Source:
- Natural gas
- Naphtha
- Heavy Fuel Oil
- Vacuum Residue
- Coal

Nitrogen

Source: Air

The critical step of this process from a technical and cost perspective is the processing of the H-containing feedstock to yield Hydrogen.

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Ammonia Process Comparison

Feedstock	Process	Capital Cost Index	Energy / t NH_3	CO_2 emission / t NH_3
Natural gas	Steam reforming	1	28 GJ HHV	1.6 t
Naphtha	Partial oxidation	~1.3 - 1.5	35 GJ HHV	2.45 t
Heavy Fuel Oil / Vacuum Residue	Partial oxidation	~1.5	38 GJ HHV	2.2 t
Coal	Partial oxidation	~1.5 - 2.0	42 GJ HHV	3.3 t

Source: *Modern Production Technologies* (Appl, 1997), British Sulphur Nitrogen Cost Model

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Evolution of Feedstock preference

- **Gas** – historically gas was closely controlled by pipeline access and many gas deposits were regarded as stranded. Competition was relatively limited and prices were generally low. Low investment cost and high energy efficiency made it the feedstock of choice, where available.
- **Naphtha** – highly transportable, price linked to crude oil. Good compromise of price, energy efficiency and availability made it a popular option.
- **Fuel Oil & Residue** – relatively cheap but indexed to crude oil. Availability usually linked to nearby refinery. Modest efficiency and heavy metal contaminants made it less desirable unless cost was commensurately low.
- **Coal** – cheap and widely available but offset by high investment cost, inefficient process and by-product disposal issues.

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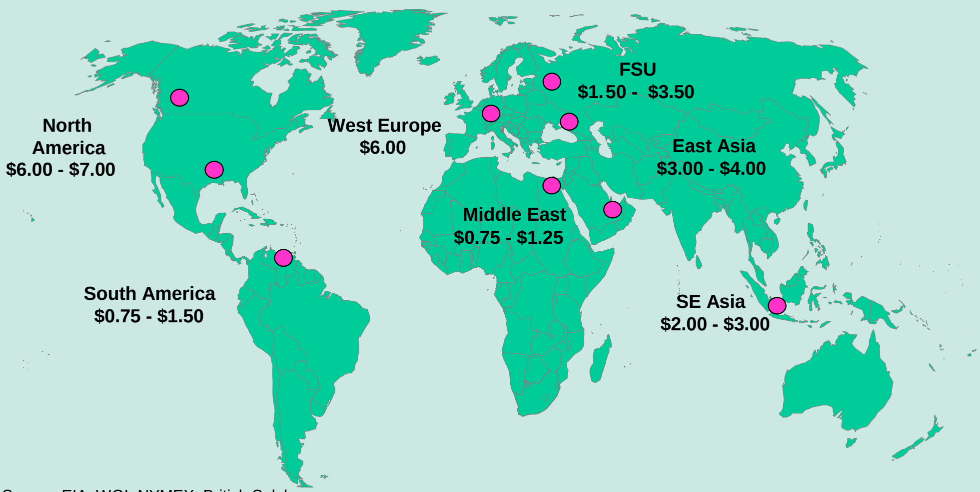
Typical 2007 Global Gas Prices ($/MMBtu)



Source: EIA, WGI, NYMEX, British Sulphur

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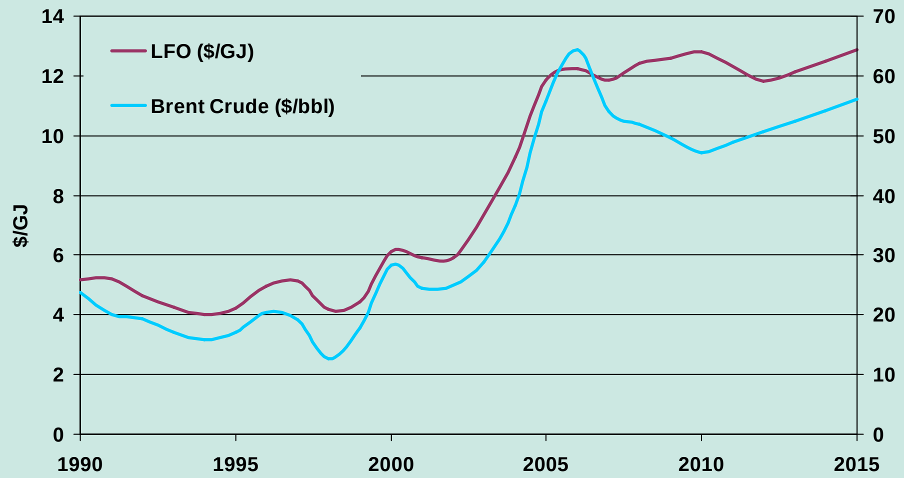
Crude Oil and Derivatives pricing



Source: OEF, CRU

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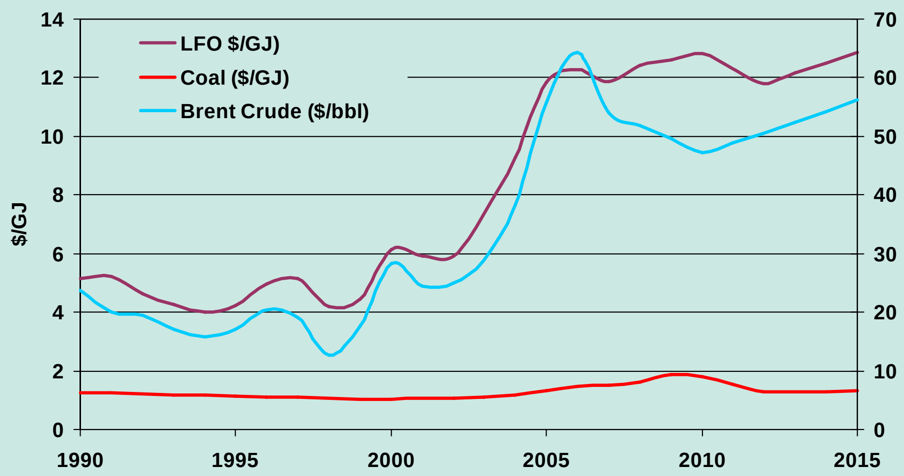
But Coal remains comparatively cheap!



Source: OEF, CRU

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Conclusions on Feedstock Selection

- **Natural gas** is not very cheap and not very stranded these days! Gas-based ammonia plants are only being built in locations where gas costs remain low. Distance to market is a minor consideration.
- **Naphtha** and other **crude oil derivatives** are mostly uneconomic as crude prices have skyrocketed since 2002. The full financial cost of production is too high to justify technology development.
- **Coal** is increasingly attractive as a feedstock because of low cost and gasification advances have improved efficiency substantially and lowered investment cost to some extent (by improving gas efficiency). Disposal of residual tars and higher CO_2 production remain a concern.

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Environmental Pressures to using Coal

- Carbon Dioxide
  - Greenhouse gas facing increasing regulation, especially in Developed Economies.
  - Volume produced directly linked to feedstock used.
  - Can be (partly) consumed by conversion into urea.
- NO_x gases
  - Low in ammonia plants, can be removed via SCR if necessary.
- Sulphur
  - Is easily removed as H_2S via scrubbing (Rectisol).
- Heavy metals, Ash & Tar
  - Heavy metals concentrate has a value and can be sold on specialist processors.
  - Incombustible material by-has a disposal cost associated with land-filling etc.
  - Increased water treatment duty.

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Is Coal the solution for the Ammonia Industry?

- For countries such as India and China, which have high cost gas costs, and a very large demand for Nitrogenous products, coal is attractive:
  - Emissions can be controlled.
  - New gasification technology allows efficient syn-gas generation.
  - Large-scale gasification is practical.

BUT

- How does the capital cost of modern coal-based ammonia plant compare to its gas-based equivalent?
  - 20 - 50% higher capex to include air separation unit, soot scrubbing and burner/reactor.
  - The capex does compare very favourably with the cost of coal gasifiers 10-15 years ago!

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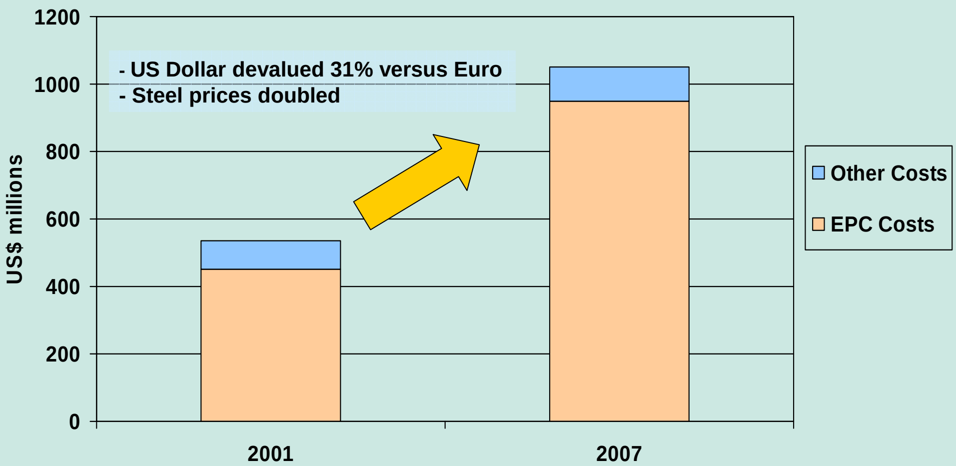
Capital Cost of New Projects



Basis: Natural gas–fired, steam-reforming 2,000t/d Ammonia & 3,250t/d urea (British Sulphur estimates)

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Summary

- There is a need for more Ammonia plants in future, especially in Asia...
- But the economics of initiating a new project are challenging because:
  - Rising feedstock costs are pushing up production costs,
  - And project costs have doubled in past 5 years.
- One solution is to pursue coal gasification in Asia. The low raw material cost reduces the cost of production and the resultant larger margin should offset the additional capex of the project.
  - Emissions can be managed cost-effectively.
  - But CO_2 output may be a concern if limits are imposed, as flue gases from reformers are more difficult to capture.

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Thank You!

Andrew Prince

British Sulphur Consultants

tel: +44 20 7903 2120

fax: +44 20 7833 4973

email: andrew.prince@crugroup.com

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Technology transfer and mitigation of climate change: The fertilizer industry perspective

IFA workshop on energy efficiency and CO_2 reduction
Ho Chi Minh, Vietnam 13 March 2007

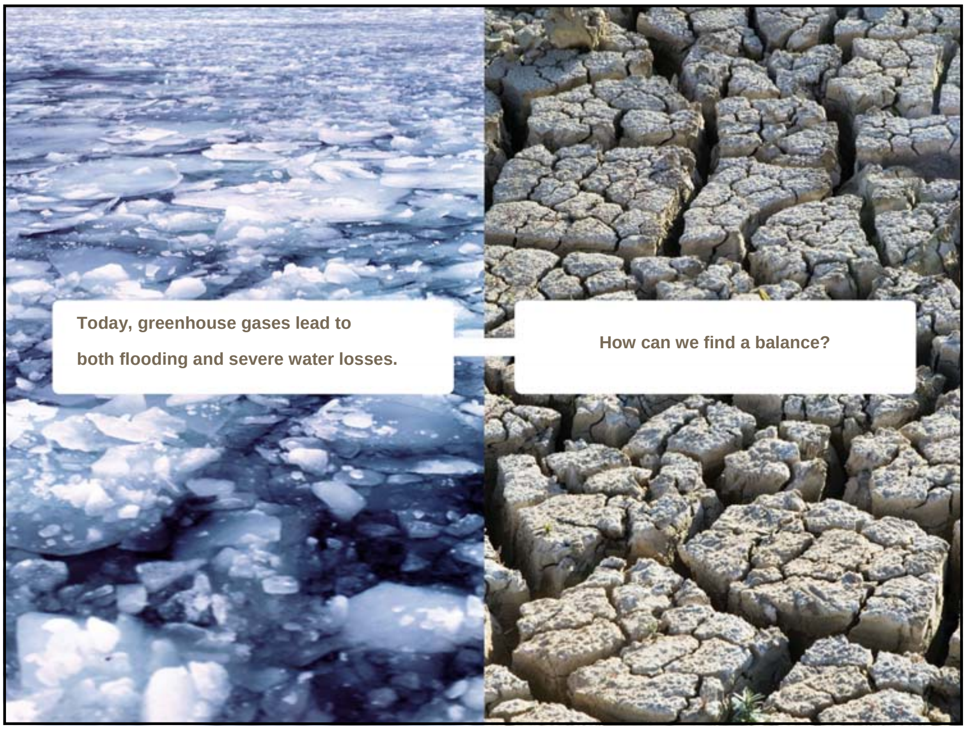
Tore K. Jenssen, Yara International

Thanks

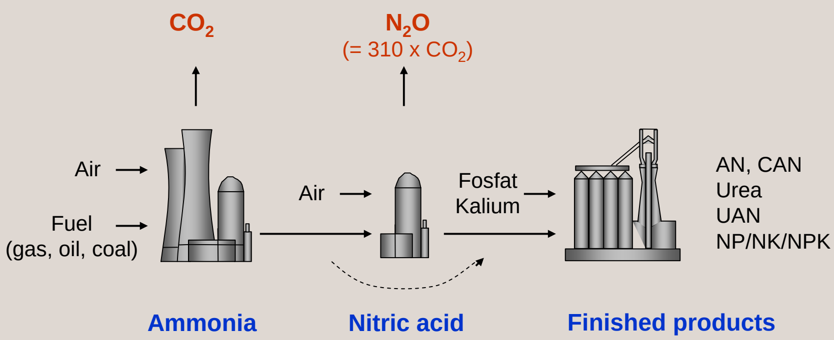
Many thanks to:

- Bhanu Swaminathan of the Fertilizer Association of India
- Kristen Sukalac of IFA

IPCC Expert Meeting Sept 2004:
"Technology Transfer and Mitigation of Climate Change"



Climate change is society's biggest challenge, also for us in the fertilizer industry



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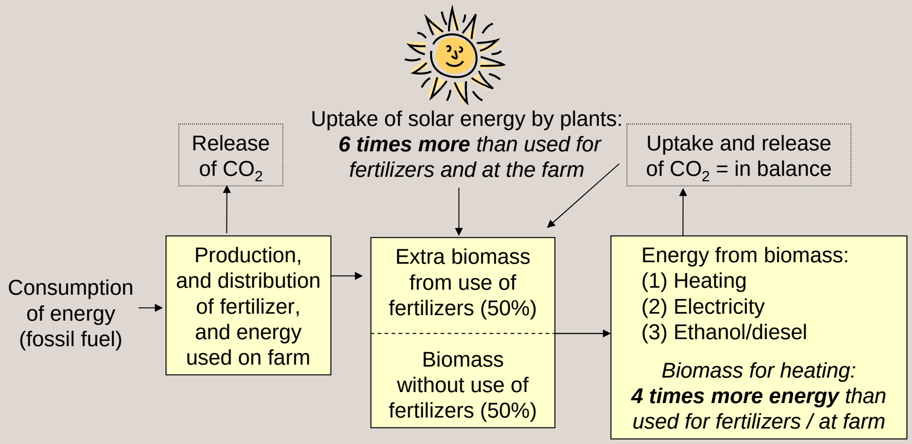
CO_2 emissions are related to energy consumption and type of feedstock

- The fertilizer industry consumes 1-2% of the world's energy
- 80% of the energy is used for ammonia production
- Different feedstock: Natural gas – Oil – Coal
- Driver for improvement: Energy cost and energy efficiency

N_2O emissions are process-related

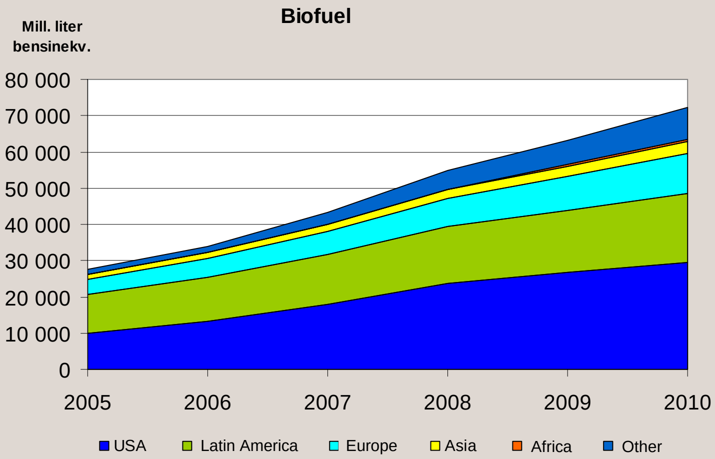
- Significant emissions from nitric acid producers – 100 plants in Europe with emission of 40 mill t CO_2-eqv, worldwide 75 million t CO_2-eqv
- Reduction technology is available, 70-90% reduction is possible, at low cost
- Driver for improvement: Permit regulations

The fertilizer industry in a wider perspective



Compared to use of fossil fuel:
4 times less CO_2 emission

Strong growth in biofuel for energy security



MMboe/day	2005	2006	2007	2008	2009	2010
Biofuel	*0,41*	*0,51*	*0,65*	*0,83*	*0,95*	*1,09*

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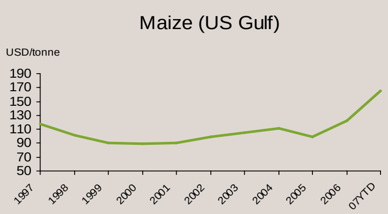
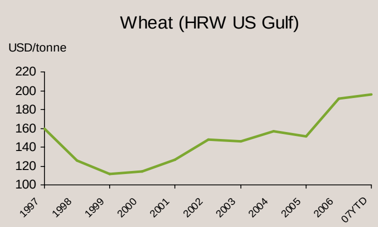
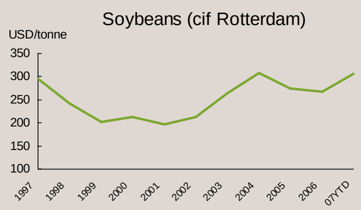
10-year grain/oilseed prices

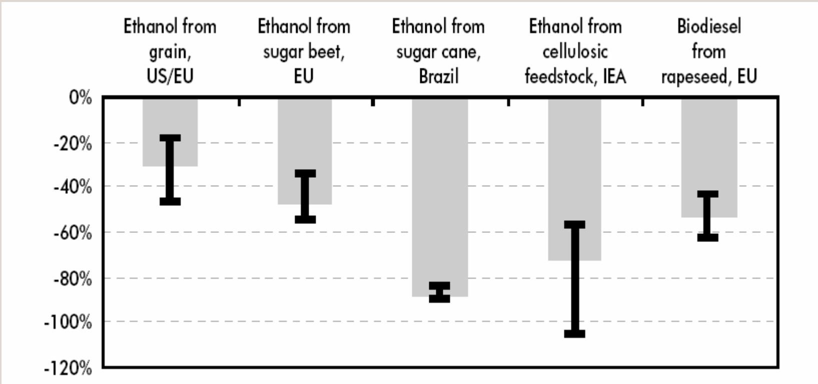






Source: World Bank

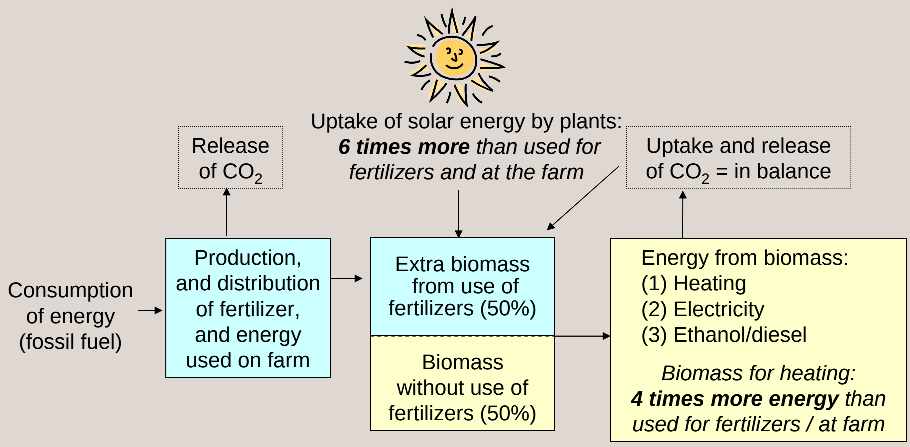
Reduction of CO_2 emission



From "well-to-wheels"

Source: IEA Biofuels for Transport

Our responsibility



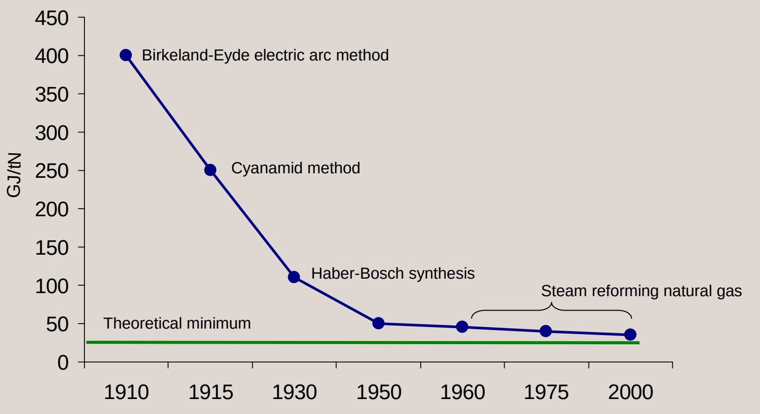
Compared to use of fossil fuel:
4 times less CO_2 emission

Our responsibility

- Energy efficient production
- Clean technology

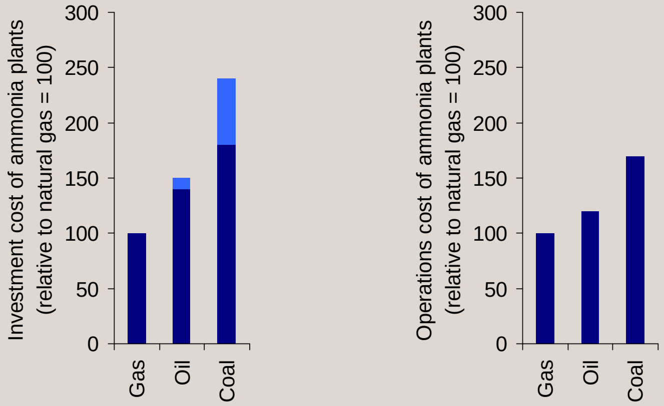
- Energy efficient distribution
- Crop specific fertilizers
- Efficient farming, with best use of fertilizers
  (high yield and environmental protection)

Close to minimum energy consumption / t NH_3



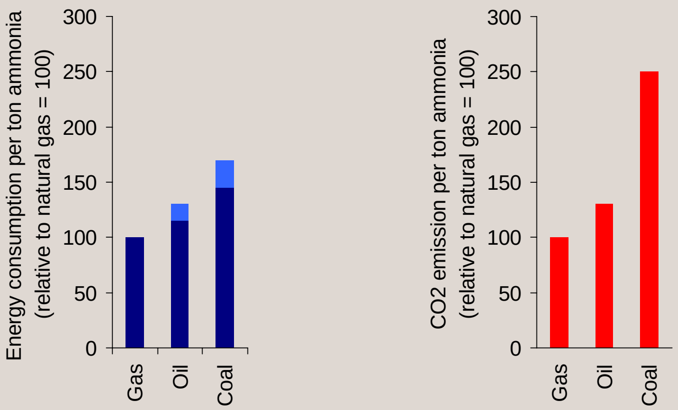
Investment and production cost comparisons (WE)

Steam reforming of natural gas is the preferred solution
Higher gas price makes coal more competitive



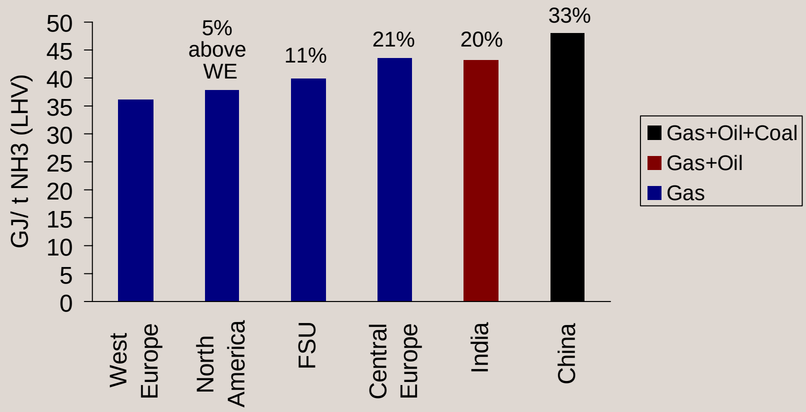
Energy consumption and CO_2 emissions

Most of the CO_2 can be captured and stored, but depends on cost



Regional variances (IEA 2003/04)

High gas cost → strong focus on efficiency (e.g. WE vs FSU)



Future

- Cost of feedstock
  → If high gas cost, shift to more coal → **more CO_2**
- Free and fair trade
  → Global price setting of feedstock?
  → If no, more production in low priced regions → **more CO_2**
- Cost of CO_2
  → Global or only European CO_2 emission trading?
  → If Europe only, more production in less regulated regions → **more CO_2**
- New developments
  → Will biomass become a feedstock?
  → Will electrolysis return?

Carbon capture and storage is discussed

Comment and analysis

Give carbon a decent burial

Most green groups are against it, but burying carbon dioxide under the sea is vital if we are to halt global warming, argue **Frederic Hauge** and **Marius Holm**

SWEEPING things under the carpet can be a bad idea. But what do you do when the floor is so thick with dust that any reduction would be an improvement? Swap dust on the floor for carbon dioxide in the air, and the carpet for the seabed, and that's a dilemma world governments now face.

In other words, as an interim measure until renewable energy replaces fossil fuels, should we start soaking up CO_2 from fossil-fuel power stations, the largest producers of CO_2, and bury it where it can't contribute to global warming? Given that the alternative means allowing climate

"If storage sites are selected carefully they could retain CO_2 over a geological timescale"

attention away from dealing with the root of the problem: our continuing dependence on fossil fuels. Green groups also worry that leaks from such burial sites could damage marine life.

Though these concerns are honourable, we are convinced they are misplaced. Tests to date indicate that there is little chance the gas would ever leak or escape. Natural hydrocarbons have stayed trapped in sedimentary basins for millions of years, and if storage sites are selected carefully they could reasonably be expected to retain CO_2 over a geological timescale. For example, in the Pisgah anticline north-east of Jackson Dome, Mississippi, 200 million tonnes of CO_2 is thought to have been trapped underground for over 65 million years.

In the North Sea, the Norwegian oil company Statoil is already burying CO_2. Natural gas from the Sleipner offshore field contains more CO_2 than is allowed in the gas distribution system, so Statoil has to separate out the excess. Instead of releasing it into the atmosphere, Statoil pumps it back offshore where it is injected into the saline Utsira aquifer 1000 metres below the seabed, under a layer of impermeable shale. Since the process began in 1996, about 1 million tonnes of CO_2 have been injected into the reservoir every year, equivalent to 3 per cent of Norway's CO_2 emissions. The alternative would also have cost Statoil dear in CO_2 emission taxes.

A seismic survey in 2002 by the British Geological Survey showed that the CO_2 was forming a bubble 1700

Technology transfer

- Industry responsibility:
  → Global standards based on BAT for new plants and revamps
- Drivers:
  → Reducing costs through greater efficiency
  → National food security strategies
  → National economic development strategies
  → Harmonisation of environmental regulations

  → **New**: Cost of CO_2 reductions
- Possible pitfalls:
  → Financing
  → Skills (content, project execution, operation and maintenance)
  → Compatibility of software and equipment

Does the regulatory framework promote efficient abatement of climate gases?

- Permitting = Old fashioned, slow and national differences
- Regulations based on economic drivers
  → Emission trading (positive)
  → Joint Implementation and Clean Development Mechanism (positive?)
  → Taxation (negative)
- Those that invest in the development and use of new technology for energy efficiency and emission reduction, should be credited. Those that are laggards, should be penalised.
- Absolutely necessary with global harmonisation of environmental regulations, especially for those emissions that have a global impact
- Emission allowances must be based on performance standards (emission per ton produced) - not slicing off a percentage on historic emissions

YARA

Conclusions

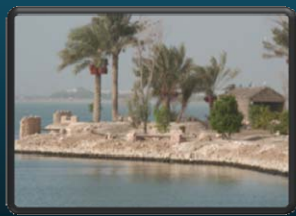
- Several factors influence the choice of technology
- Many points to a direction leading to increase in global CO_2 emissions
- Must have international (global) regulations for emissions of global impact
- Emission trading with performance standards is fair
  → Energy consumption (= CO_2) per ton of ammonia produced
  → kg N_2O per ton of nitric acid produced
- JI and CDM can be used for technology transfer, but fair?
- More R&D (carbon capture, bioenergy)
- Lobbying is necessary to get what the industry considers the best

YARA

شركة الخليج لصناعة البتروكيماويات

Gulf Petrochemical Industries Company

IFA Benchmarking of Global Energy Efficiency



Fadhel Al Ansari
Maintenance Manager
GPIC - Bahrain

March 2007

Prepared by GPIC in coordination with
PSI - **Plant Surveys International**

Agenda

- Introduction
- Importance of Benchmarks
- Energy & Emission Overview
- Key Finding
- Recommendations

IFA Technical Committee's Mission

- Actively promote the development of efficient, responsible production, storage and transportation of all plant nutrients in a sustainable manner.

"Our goal is to make energy efficient improvements a matter of course in everything we do."

Objective of Benchmarking Survey

- To assess the potential of IFA members to enhance their energy efficiency.
- To aid operators in assessment of their performance relative to others and in the identification of opportunities for improvement.
- To enable policy makers achieve energy and environmental policy objectives.

Why Benchmark Energy Efficiency

- Fertilizer production consumes 1.2% of the world's total energy annually.
- Ammonia production consumes 94% of the industry's total energy.
- For economic and environmental reasons – natural gas is the predominant hydrocarbon energy source for almost all nitrogen fertilizers.
- As a result, production processes that use less natural gas per unit of ammonia output reduces manufacturing cost and environmental impact.

IFA's First Energy Efficiency Benchmarking

- Energy Task Force established in 2003.
- PSI engaged to conduct the first benchmark survey.
- 2002-2003 operating period.
- Focused on energy efficiency and CO_2 emissions.
- 66 Ammonia plants participated.
- Benchmarking report issued Dec. 2004.

Benchmarking – Key Steps

1. Determine focus of benchmarking (for example – energy use).
2. Develop metrics.
3. Conduct comparisons.
4. Track performance over time.

Current IFA Benchmarking Status

- Step 1 & 2 completed – useful benchmark established.
- Now in a position to proceed with steps 3 & 4.
- Continuation will lead to reliable metrics so companies can use comparisons to assess their need for improvement.
- The next IFA ammonia plant benchmarking is planned to be conducted in 2008 based on 2006-2007 operating data.

Energy Efficiency

- Net energy efficiency includes all feedstocks, fuels, electricity, and "other energy" used by an ammonia plant.
- "Other energy" includes import steam and electricity as well as credits for energy exports such as steam and some off-gases.

$$\text{Net Energy Efficiency (GJ/mt } NH_3\text{)} = \frac{\text{Feed + Fuel + Other Energy (GJ)}}{NH_3 \text{ Production (mt)}}$$

Benchmarking Average Results

- Average energy efficiency for the 66 IFA ammonia plants is 36.9 GJ/mt NH_3.
- Average annual production is 395,900 tonnes/plant.

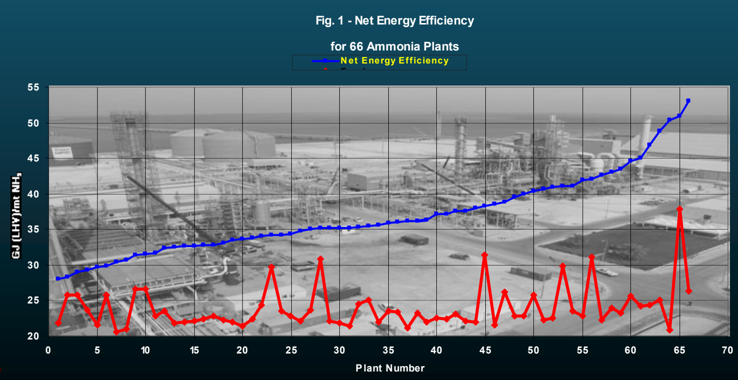
Table 1 – Net Energy Efficiency and Production Summary

66 Ammonia Plants	Average
NH_3 Production – mt as NH_3	395,900
Net Energy Efficiency - GJ/mt	36.9

Net Energy Efficiency

The gap between “net energy” and “feedstock” is “fuel” and “other energy” usage.

- Higher net energy is caused by increased “fuel” and “other energy usage”.



Plant Capacity and Energy Efficiency

- Plant capacity and energy efficiency are related.
- The largest plants are the most efficient.

Table 2 – Net Energy Efficiency and Plant Capacity

Basis: Current rated plant capacity
66 Ammonia Plants
Net Energy Efficiency - GJ/mt NH_3

Capacity mtpd	No. of Plants	Average
< 1,000	19	40.0
1,000 – 1,500	25	37.0
> 1,500	22	34.0

Plant Age and Energy Efficiency

- Older plants are generally less efficient than new ones.
- Some older plants have excellent energy efficiencies.
- These are a result of improvements through revamps and equipment upgrades.

Table 3 – Net Energy Efficiency and Plant Age

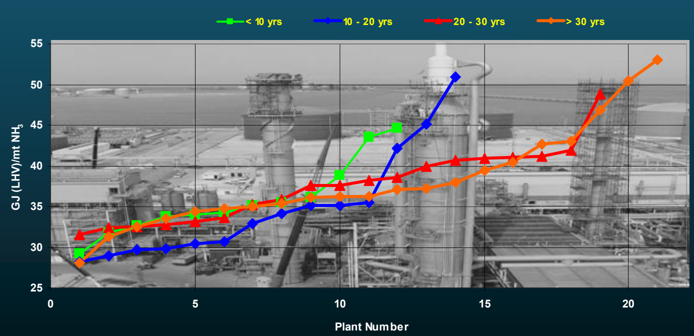
66 Ammonia Plants
Net Energy Efficiency - GJ/mt NH3

Age – Years	No. of Plants	Average
< 10	12	35.8
10-20	14	34.9
20-30	19	37.6
> 30	21	38.2

Plant Age and Energy Efficiency (Cont'd)

- Many of the older plants have good energy efficiencies due to revamps, equipment upgrades and operational improvements.

Fig. 3 - Net Energy Efficiency vs. Plant Age
66 Ammonia Plants



CO_2 Generation and Emissions

- **Ammonia plants have 2 CO_2 emissions sources.**
  1. Process CO_2 Emissions - from the CO_2 recovering system.
  2. Flue Gas CO_2 Emissions - from combustion.

Reducing CO_2 Emissions

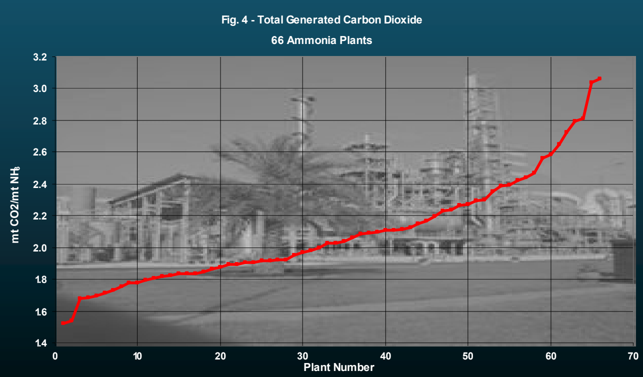
- Recover and use process generated CO_2 for other chemical products such as urea production.
  - This is the most utilized method.
- Recover CO_2 from combustion flue gas for use in other chemical products.
  - Technology exists to do this, implemented on a very small scale.
- Improve ammonia plant energy efficiency. Less CO_2 is generated and therefore emissions are reduced.
  - Many ammonia producers have done this.

Summary of CO_2 Emissions

- 33% of the total CO_2 generation is from combustion of fuels.
- 38% of the all CO_2 generation is recovered.
- 57% of process generated CO_2 is recovered.

Total CO_2 Generation

- Total generation varies widely.
- Net energy efficiency accounts for most of the variation. Processing heavier hydrocarbons also plays a role.



Key Findings

- Average net energy efficiency for the 66 IFA ammonia plants is 36.9 GJ/mt NH_3.
- The highest capacity plants are the most energy efficient.
  - Some of the best performing plants have a capacity less than 1,000 mtpd.

Key Findings (Cont'd)

- Newer plants have the best energy efficiencies.
  - Many older plant have improved their efficiencies through revamps and equipment upgrades.
- Ammonia plants built today use 30% less energy per tonne NH_3 than one built 30 years ago.
  - Current BAT for new plants is 28 GJ/mt NH_3 – just 30 years ago newly designed plants used 40 GJ/mt NH_3.
- Universal BAT application would reduce energy usage by 40% and reduce greenhouse gas emissions by 58%.

Key Findings (Cont'd)

- The least efficient ammonia plant uses about 90% more energy to produce a ton of ammonia. Most of this inefficiency is due to high fuel usage. This presents an opportunity for improvement through technology and equipment upgrades and other means.
- The 66 ammonia plants generate an average of 2.07 mt CO_2 for each mt of NH_3 produced. Of this ratio, 2/3 is process generated CO_2 and the remaining 1/3 is from fuel burning.

Key Findings (Cont'd)

- More than one-third (38%) of the generated CO_2 is not vented to the atmosphere because it is recovered for other uses (primarily urea production).
- Generated CO_2 in the 66 ammonia plants ranges from 1.5 to 3.1 mt CO_2/mt NH_3. Most of the variation is due to differences in energy efficiency where low energy usage ammonia plants generate less carbon dioxide per unit of ammonia production.

Recommendations

- Continue primary focus on energy and CO_2.
- Enact ways to enlarge participation - advertise IFA benchmarking in IFA newsletters and in other trade publications, involve IFA membership to solicit participation from their companies and other non-IFA organization, such as, AFA, EFMA, FAI, etc.

Recommendations (Cont'd)

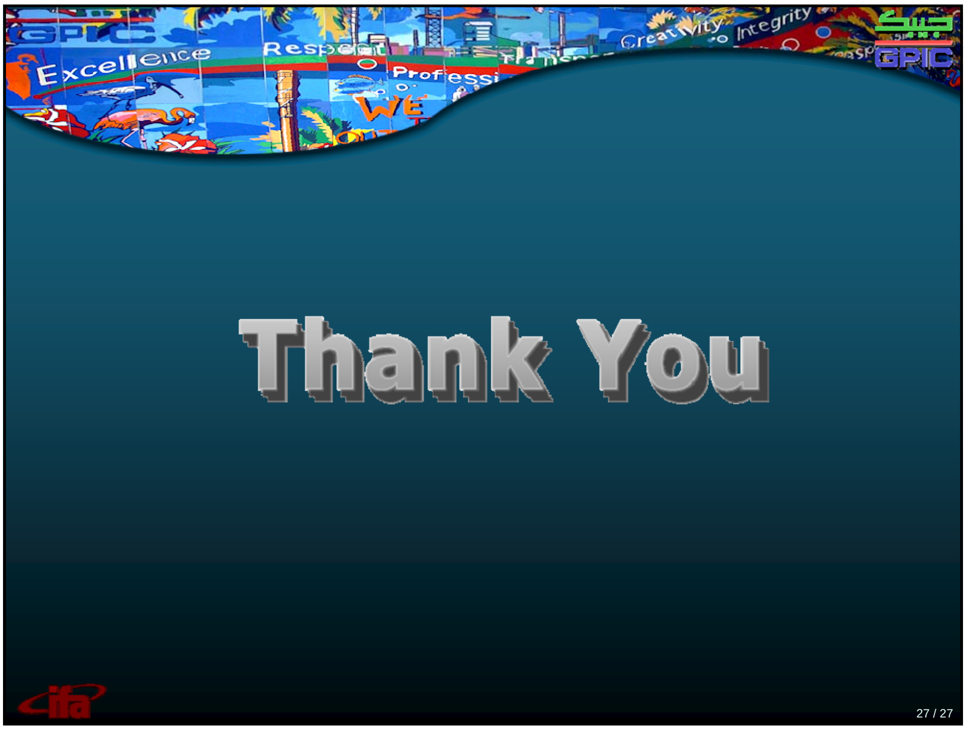
- Continue to track influence of plant capacity and plant age on energy efficiency.
- Begin tracking trends of "same" plants – those that have participated in past benchmarkings as well as the current benchmarking.
- As participation increases, the number of regional comparisons also increases.

Recommendations (Cont'd)

- Consider adding other metrics that may have an impact on energy efficiency or CO_2 emissions. Examples:
  - Process technology, improvement projects, best practices, etc.
- Governments should foster an enabling environment for investment in cleaner, more efficient technologies through financial incentives and stable, long term environmental policy.
- Governments and industry have an important role in facilitating the adoptions of BATs.
  - Parallel funding technology transfer.
  - New market mechanisms such as carbon financing.

Recommendations (Cont'd)

- The IFA Technical Committee should continue to encourage the development and adoption of technology improvements that can lead to greater production efficiencies, better health and safety standards and reduced emissions and discharges.


Excellence
Respect
Creativity
Integrity
GPIC
Thank You
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CARBON CREDITS—ORIGINATION TO COMMERCIALIZATION

ECO SECURITIES

Carbon trading and the Fertilizer Industry.

IFA Technical Meeting
Ho Chi Minh City
By: B.Thayananthan

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ECO SECURITIES

Content

- Climate Change
- The Clean Development Mechanism (CDM)
- Opportunities within the Fertilizer Industry
- EcoSecurities services

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Climate Change: The global community responded to climate changes via the Kyoto protocol

- **The issue at hand**: Anthropogenic (i.e., man-made) climate change is a fact. If and what the implications are and if and how to address them is under dispute.
- **The Kyoto protocol**: Aims to reduce GHG emissions by 2012 and distinguish two types of countries:
  - **Annex I** countries: With binding emission targets for industrialised countries:
    - West and Eastern Europe, Canada, Japan, New Zealand, Russia , Ukraine.
  - **Non-Annex I** countries: With voluntary participation of developing countries:
    - China India, South Africa, Philippines, Uruguay, Brazil, China, etc.

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Climate Change: The Kyoto protocol aims to curve the emissions of six GHG gasses

Carbon dioxide (CO_2)
GWP: 1

Methane (CH_4)
GWP: 21

Nitrous oxide (N_2O)
GWP: 310

Hydrofluorocarbons (HFC)
GWP: 11,700

Sulphur hexafluoride (SF_6)
GWP: 23,900

Perfluorocarbons (PFC)
GWP: 9,200

- The impact on Global Warming differs between the gasses. To accommodate for this the protocol includes a Global Warming Potential (GWP) per gas via which the impact can be expressed in CO_2 equivalent.

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Climate Change: The protocol includes three Flexible mechanisms (ET, JI, CDM)

- The flexible mechanisms allow countries to achieve their emission targets cost effectively:
  - **Emissions trading (ET)**: Trading of allowances between Annex I governments.
  - **Joint Implementation (JI)**: Projects between Annex I countries.
  - **Clean Development Mechanism (CDM)**: Projects in Non-Annex I countries with participation of Annex I countries.

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- Climate Change
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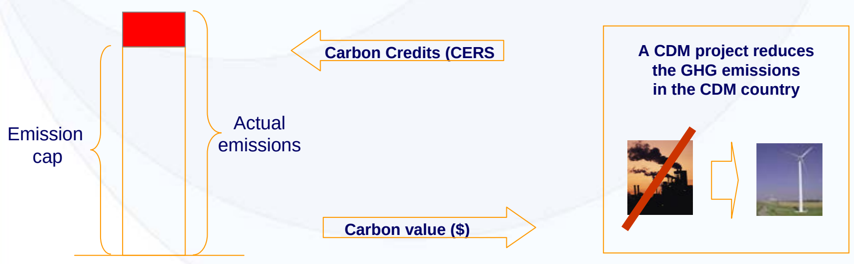
The CDM: The reduced GHGs in a non – Annex I can be sold to a Annex I country

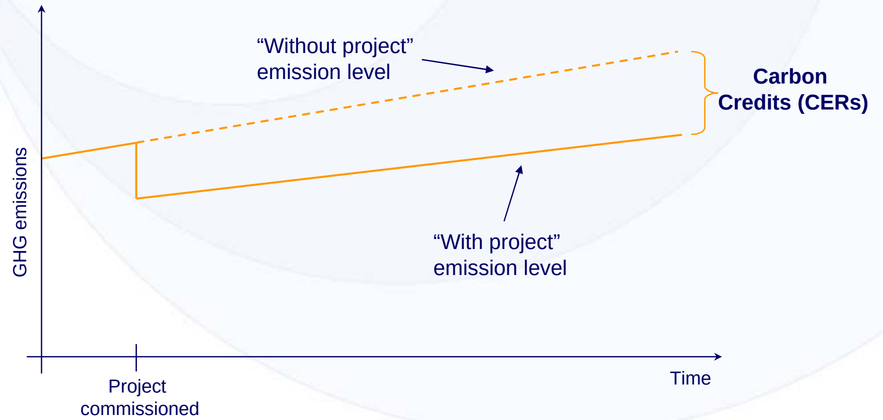
Annex I | **Non – Annex I**



Buyer | **Seller**

EcoSecurities

The CDM: The reduced GHGs in a non – Annex I can be sold to a Annex I country



EcoSecurities

CDM Requirement : Additionality Criteria

CDM projects has to satisfy the additionality criteria which means :

" ***The emission reductions of the proposed project must be additional to any that would occur in absence of the project."***

Tool for the demonstration and assessment of additionality (ver 03) available in the UNFCCC website and need to be used to demonstrate additionality of proposed project.

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The CDM: Alignment of the project development cycle with CDM activities

- The project development cycle

Concept → Feasibility analysis → Financial closure → Construction → Operation

- The CDM development cycle

Project Idea Note → Project Design Document → Project validation → Project registration → Project verification and CER issuance

- Carbon commercialisation cycle

Develop commercialisation strategy → Select buyer → Negotiate terms and conditions → Sign ERPA → Monitor contract compliance

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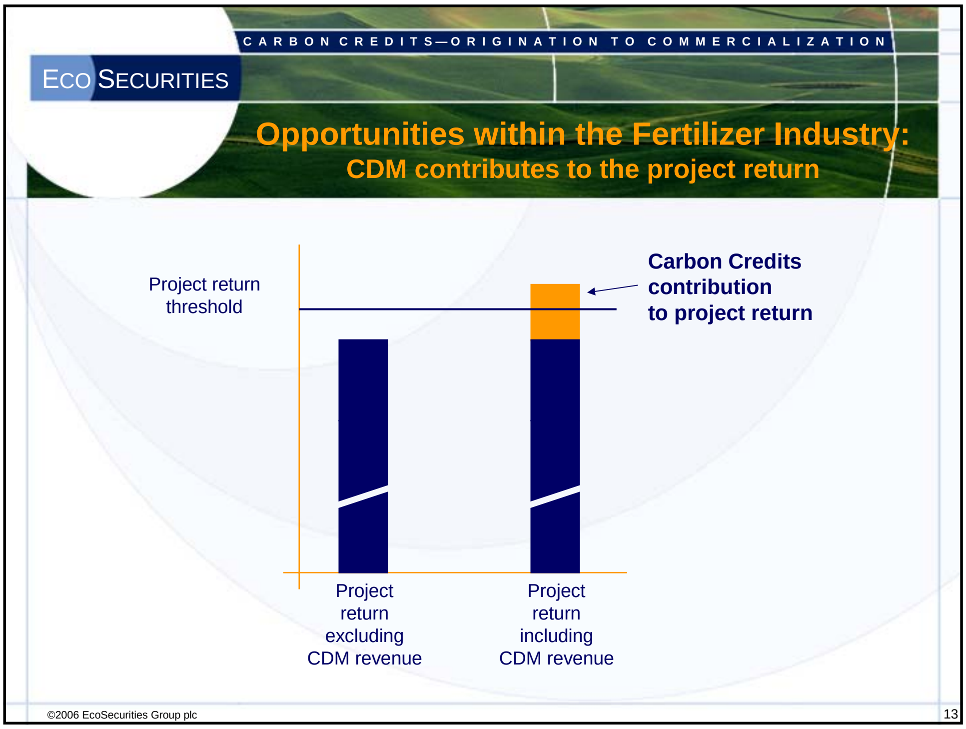
C A R B O N C R E D I T S — O R I G I N A T I O N T O C O M M E R C I A L I Z A T I O N
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Opportunities within the Fertilizer Industry:
CDM contributes to the project return
Project return threshold
Carbon Credits contribution to project return
Project return excluding CDM revenue
Project return including CDM revenue
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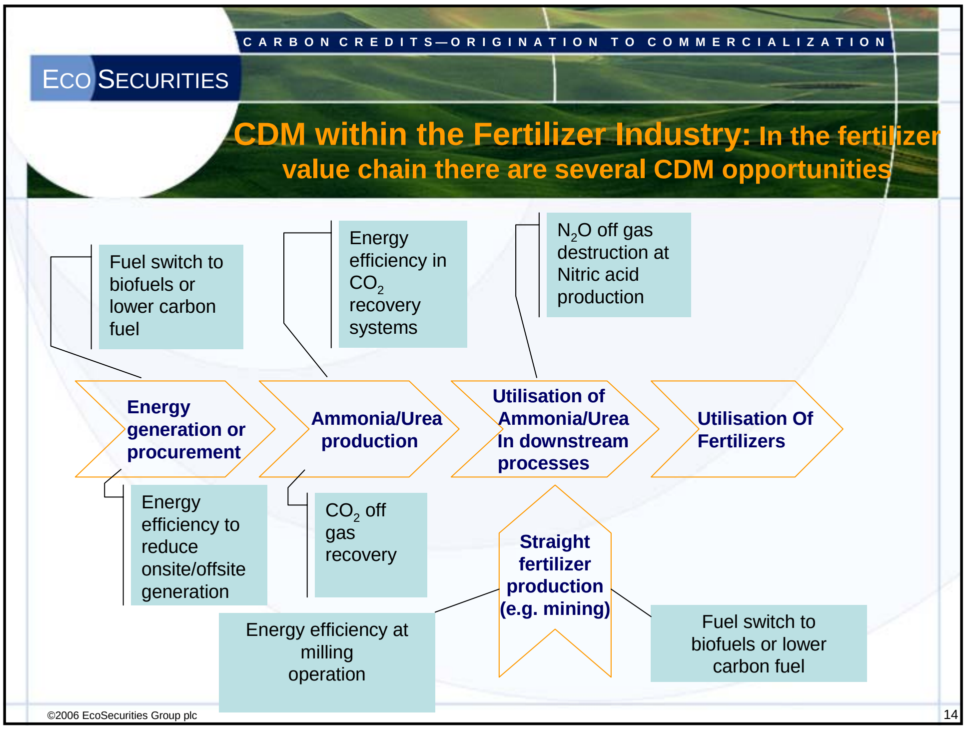
C A R B O N C R E D I T S — O R I G I N A T I O N T O C O M M E R C I A L I Z A T I O N
ECO SECURITIES
CDM within the Fertilizer Industry: In the fertilizer value chain there are several CDM opportunities
Fuel switch to biofuels or lower carbon fuel
Energy efficiency in CO_2 recovery systems
N_2O off gas destruction at Nitric acid production
Energy generation or procurement
Ammonia/Urea production
Utilisation of Ammonia/Urea In downstream processes
Utilisation Of Fertilizers
Energy efficiency to reduce onsite/offsite generation
CO_2 off gas recovery
Straight fertilizer production (e.g. mining)
Energy efficiency at milling operation
Fuel switch to biofuels or lower carbon fuel
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Related Available Methodologies in The Fertilizer Industry

Approved Methodologies

- ACM 0018 - Steam Optimization Projects in Production Processes (based on energy efficiency project by modification of CO_2 removal system of Ammonia plant to reduce steam consumption).
- AMS II.D - Energy efficiency and fuel switching measures for industrial facilities.
- AM 0028 - Catalytic N_2O destruction in the tail gas of Nitric Acid Plants.
- AM 0034 - Catalytic reduction of N_2O inside the Ammonia burner of Nitric Acid Plants.

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Related Available Methodologies in The Fertilizer Industry

Methodologies Under Consideration

- NM O170 - Nitrous Oxide Abatement Project Using Platinum Group Metals Secondary catalyst.
- NM 0176 - Carbon Dioxide Recovery From Flue Gas through installation of a CO_2 recovery plant (CDR).

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CDM within the Fertilizer Industry:
What's in it for the plant

- N_2O abatement project example:
  - **Current situation:**
    - 10.000 ton of N_2O vented to the atmosphere per year.
  - **Project implementation:**
    - Installation of N_2O abatement technology.
    - Construction time 3 - 12 months (operational July 2007).
    - CDM registration 4 – 5 months (in parallel).
  - **Value to plant:**
    - Emission reductions: 10.000 (tN_2O /y) * 310 (GWP) * 5,5 (credit period till 2012) = **17 million CERs**.

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CDM within the Fertilizer Industry:
N_2O projects under development

- Although a number of N_2O abatement technology available in the market, technical due diligence need to be carried out to access the suitability for each specific plant.
- EcoSecurities is at different stages of development with the following N_2O abatement projects:
  - Egypt (3)
  - Thailand (1)
  - Malaysia (1)
  - Tunisia (1)
  - South Africa (2)
  - India (2)
  - China (13)

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CDM within the Fertilizer Industry: Start of project implementation at Sichuan Golden Elephant Chemical Co., Ltd. China

Signing ceremony

N_2O Reactor

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Current Status of N_20 Projects

- ERPA's signed with 13 Chinese Nitric Acid Manufacturers to develop CDM for 25 plants (equivalent to 17.0 million CER's up to 2012)-EcoSecurities currently the largest N_2O CDM project developer in terms of CER portfolio.
- Technology selection process completed engaging various technology suppliers.
- Building up capacity in China to manage these projects (to have their own N_2O team-currently various expertise from UK, Malaysia and China pooled together to manage these projects).
- Monitoring management systems in place to monitor the performance of the data generated as per the monitoring methodology from the UK monitoring team's office.

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CDM within the Fertilizer Industry:
Urea/Ammonia projects under development

- Development of CDM in Qatar:
  - First CDM project on reduced flaring in the oil & gas industry.
  - Carrying out various CDM portfolio analysis in various industries in Qatar.
  - Currently identifying potential CDM projects for the Urea/Ammonia sector in Qatar.

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EcoSecurities services: Who we are

EcoSecurities is the world's leading originator, developer and trader of carbon credit projects

- NovaGerar Landfill Gas to Energy Project (Brazil) first registered CDM project in the history.
- "La Esperanza Hydroelectric Project" one of the first three projects with issued CERs in the world.
- A publicly-listed company since December 2005 on the London Stock Exchange.
- Voted as the best carbon advisory company six years in a row since 2001 by the readers of Environmental Financing Magazine.

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EcoSecurities services: Our portfolio & Experience


Wind farms


Landfills


Small scale hydro


N_2O abatement


Piggery AD


Biomass


Energy efficiency


Biodiesel

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EcoSecurities services: What we have to offer

- Example, EcoSecurities as N_2O abatement project developer:
  - To invest on an appropriate N_2O abatement system and assure a successful and fast registration of the project under CDM, increasing your revenues and reducing your risks.
  - EcoSecurities will:
    - Finance, install and maintain the N_2O Abatement System.
    - Develop CDM component.
    - Buy the all CERs from the Fertilizer Plant through a Emissions Reduction Purchase Agreement (ERPA).

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EcoSecurities services: the plants benefits

- No capital investment required.
- Constant and additional revenues from the carbon credits.
- Use the best and most suitable technology commercially available for your plant.
- Immediate start of project development (wider window of opportunity).
- Deal only with one partner (speed up process, more revenue).
- Low risks from project development to commercialisation.

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Contacts

B.Thayananthan
Business Development Consultant
Kuala Lumpur, Malaysia
Email: thaya@ecosecurities.com
Tel. +603 22820612

www.EcoSecurities.com

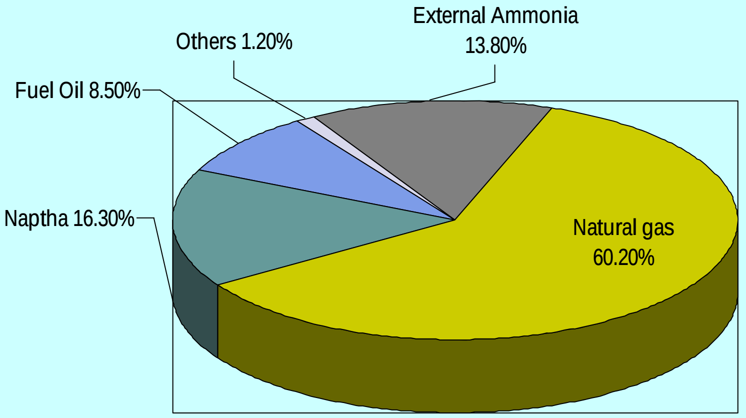
Energy Efficiency and CO_2 Emissions in the Indian Ammonia Sector

H. S. Karangle
Director (Technical)
Rashtriya Chemicals & Fertilizers Limited

Overview

- India ranks second in the world in production of nitrogenous fertilizer.
- Ammonia is the basic building block.
- India produced 12.8 million MT of ammonia in the year 2005-06.
- The average energy consumption is 9.1 Gcal/MT of ammonia.

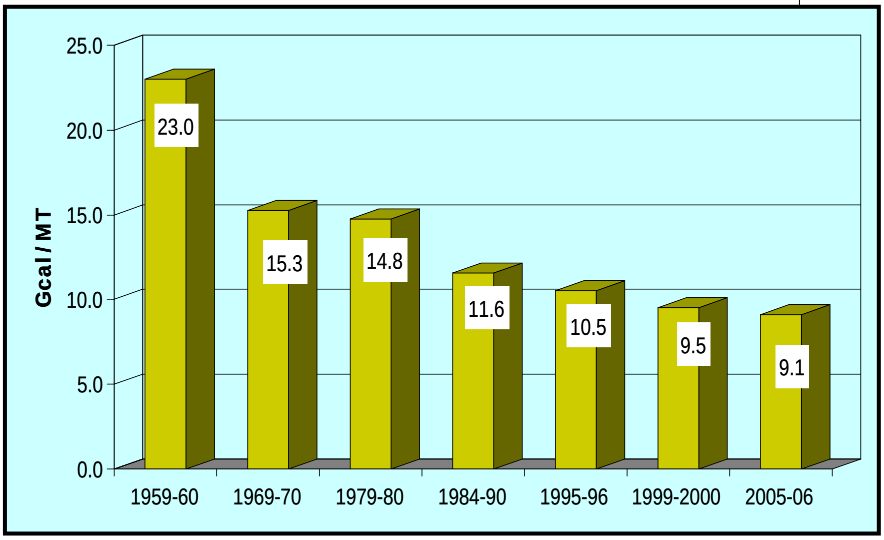
Feedstock wise capacity of Ammonia in India



Energy Trends

The average energy consumption per ton of ammonia has dropped from the highs of 23 Gcal that was prevailing in the 1960s to currently around 9.1 Gcal.

Ammonia energy consumption scenario in India



Energy Efficiency Measures

This has been achieved through:

- Switchover of feedstock;
- Advances in process technology;
- Improved catalysts;
- Better stream sizes;
- Increased capacity utilization and;
- Improved reliability.

Energy Consumption - Ammonia

PLANT TYPE	(Gcal/MT)
Gas based	7.56 to 9.90
Naphtha based	8.11 to 10.53
Fuel Oil based	11.45 to 20.81

Comparison of Energy Consumption of World Ammonia Plants

PLANT	AVERAGE ENERGY (Gcal/MT)
25% Most Energy Efficient Plants in India	8.41
25% Most Energy Efficient Plants in the World	8.49

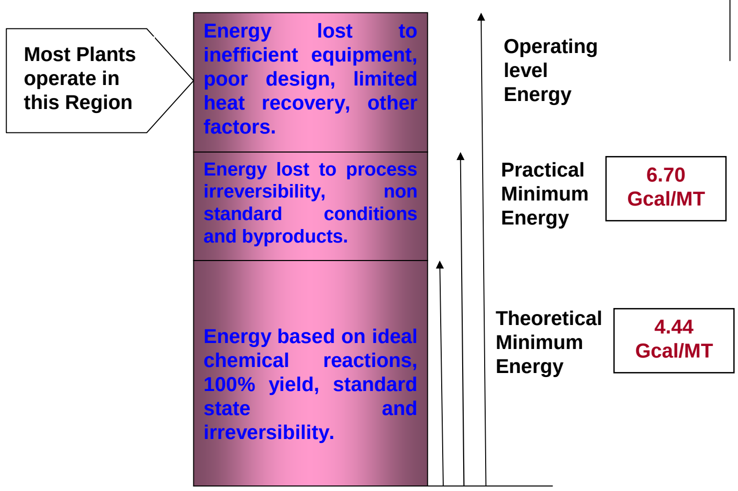
Source: Ammonia Plant safety, Vol 42, AICHE -2002 and FAI data for Indian Plants.

Energy Consumption - Ammonia

The most energy efficient Ammonia plants in the world produce ammonia at 6.7 Gcal per MT.

Typical Energy break-up	
Feed	64%
Fuel	28%
Power	5%
Steam	3%
TOTAL	100%

Categorization of Energy



Ammonia Manufacturing Process

Possible areas of improvement

- **More efficient compressors and their drives.**
- **Improvement in CO_2 removal system.**
- **Introducing combustion air preheat.**
- **Lowering steam carbon ratio.**
- **Lowering pressure drop in front end.**
- **Purge gas recovery.**
- **Fuel gas expander.**
- **Generating High Pressure steam from waste heat.**

A case study

A 900 MTPD ammonia plant employing technologies of eighties was revamped in 2006, with following objectives:

- Reduction in the specific energy consumption;
- Improvement in reliability;
- To enhance capacity;
- Minimizing the downtime to incorporate the changes.

A case study

The following major modifications were selected and implemented:

- Up-gradation of primary reformer;
- Improvement in CO_2 removal system;
- Replacement of synthesis gas compressor.

Implementation : 24 months.

The cost of the above modification is about US$ 55 million.

Primary Reformer Upgradation

- **Rearranging the staggered row of reformer tubes into Single row of catalyst tubes for better distribution of heat.**
- **Increasing the reformer tube diameter.**
- **Installation of triple decker catalyst.**
- **Replacement of reformer burners by force draught type.**
- **Installation of combustion air pre-heater in reformer convection.**
- **Replacement of inlet distributors, pigtails and outlet hot collector.**
- **Modification of roof, floor and its refractory.**

Primary Reformer

Modification in Steam Superheater

Feed gas and combustion air preheat was provided in the convection section:

- **To reduce the Stack temperature from 465 degree C to 159 degree C;**
- **To improve thermal efficiency.**

Steam Superheater

Process Air Compressor

Compressor internals were changed:

- **To cater to increased requirement of air for secondary reforming;**
- **To improve the compressor efficiency.**

Condensate Stripper

Conversion of Low Pressure process condensate stripper to Medium Pressure:

- **Steam used for stripping is recycled back to reformer as process steam;**
- **Improved condensate quality, can be fed directly to polishing unit.**

CO_2 Removal System

- Improved tower packing.
- Hydraulic turbine in rich solution.
- 5 stage flash vessel.
- Steam compressor.

Synthesis Section

- Installation of S-50 Converter.
- A loop boiler.
- Replacement of the synthesis gas compressor that was inefficient and prone to frequent downtime.

S 50 Converter

Loop Boiler downstream - S50 converter

Energy Saving

Scheme	Gcal/MT
Primary Reformer	0.63
Aux. Steam Superheater	0.08
MP condensate stripper	0.25
Carbon Dioxide removal system	0.54
Other schemes (Synthesis, turbines, compressors etc.)	0.76
Total	**2.26**

BENEFITS

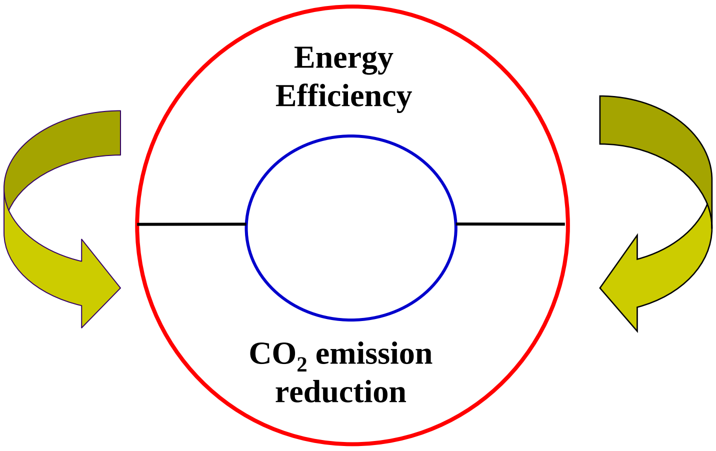
Before revamp ~ 11.0 - 11.2 Gcal/MT

After revamp ~ 8.7 - 8.8 Gcal/MT

Plus improved operability and reliability

Energy Efficiency and CO_2 emission

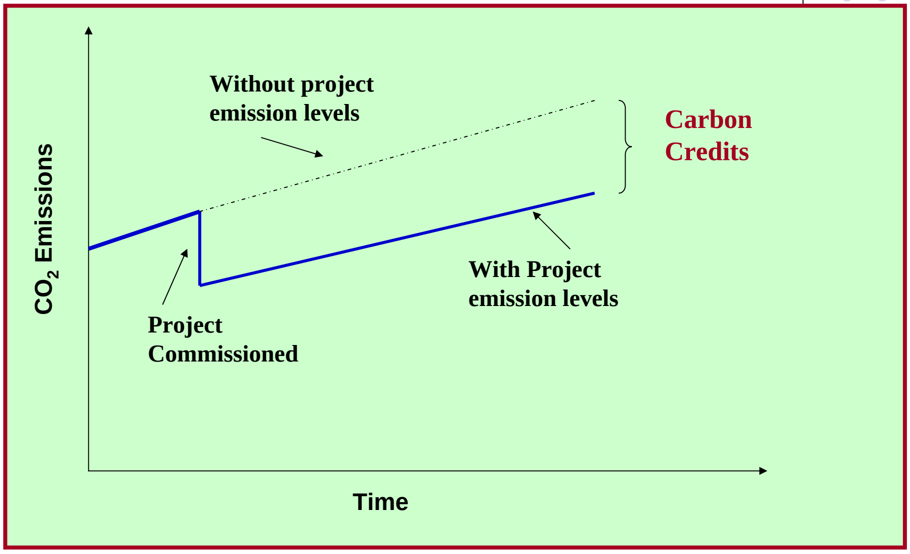
- Typically energy saving ultimately translates into reduction in fuel consumption.
- Reduced fuel consumption means burning of lesser quantity of fossil fuel and corresponding reduction in CO_2 emission.



Carbon Credits

- CO_2 is a greenhouse gas. Any project undertaken in a developing country causing reduction in greenhouse gas emission may qualify for Carbon Credits.
- An emission reduction of one MT of CO_2 qualifies for one carbon credit called Certified Emission Reduction (CER).
- These CER credits are tradable and can be used to contribute to the emission reduction commitment of industrialized countries under Clean Development Mechanism (CDM).

Generation of Carbon Credits



CDM - Additionality Criteria

All these projects should satisfy additionality criteria under Clean Development Mechanism (CDM).

Emission additionality:	**The project should lead to real, measurable and long term Green House Gas reduction.**
Financing additionality:	**The funding for CDM project activity should not lead to diversion of official development assistance.**
Technological additionality:	**Investments should be for newest and sound technologies.**

CDM Benefits

- As energy consumption pattern nears to its most efficient level it becomes increasingly capital intensive.
- Financial benefits from CDM improves the viability of a project.
- In many cases such benefits of CER credits under CDM is acting as a booster in pursuing a number of energy saving measures in ammonia plants.

Type of CDM projects

- **Energy Efficiency Improvement Projects.**
- **Feed Switch Projects.**
- **Carbon Dioxide Recovery (CDR) Projects.**
- **General Waste Recovery Projects connected with ammonia.**

Energy Efficiency Improvement Projects

- **The most common type applicable to ammonia Industry.**
- **Energy saving of 1 Gcal roughly translates into 0.2 CER.**
- **A 1000 MTPD ammonia plant with 2 GCal/MT reduction in energy is capable of generating approx. 132,000 CER per year.**
- **The methodology to be applied for such schemes under CDM is well established.**
- **Some ammonia plants in India have registered their project. Many other plants are on way.**

Feed Switch Projects

- Switching of feedstock from Naphtha to Gas leads to reduction in CO_2 emission and thus qualifies for CDM benefits.
- No approved methodology as yet. Some projects have progressed on this front and hopeful of getting registered under CDM soon.

Carbon Dioxide Recovery (CDR) Project

- Ammonia plants in India are linked with urea production. There is a need to maximize CO_2 generation so that ammonia produced is completely converted to urea.
- One of the way to overcome shortfall in CO_2 production is putting up a CDR unit to recover CO_2 from Flue gases exiting the reformer stack.
- It is highly capital intensive and benefits derived under CDM will help to improve the financial viability.
- A methodology is in advanced stages of approval.

General Waste Heat Recovery Projects connected with ammonia

General waste recovery projects associated with ammonia production facility is developed under this category. There are few approved methodologies, which can be adopted.

Basic Steps towards registration - under CDM

- Preparation of Project Design Document (PDD).
- Submission of PDD to UNFCCC through Designated National Authority.
- Use of approved methodologies for the project under consideration.
- Validation of CDM project Activity.
- Registration of the CDM project activity.

Conclusion

- Modern Indian Plants are at par with world class plants.
- The older plants have kept pace with the developments in technology and have put in serious efforts to bring energy efficiency to a comparable level.
- The way forward is to use clean feedstock and fuel like Gas and Liquefied Natural Gas, upgrade & modernize with respect to technology, equipment and machinery.
- While doing so avail the benefits under CDM for reducing green house gas emission.

THANK YOU

BEST AVAILABLE TECHNIQUES FOR THE PRODUCTION OF AMMONIA

2007 IFA Technical Committee Meeting
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J.A.M. van Balken
European Fertilizer Manufacturers Association

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Definition Best Available Techniques

"techniques" includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;

"available" techniques are those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;

"best" means most effective in achieving a high general level of protection of the environment as a whole.

33 BAT REF's covering Industrial Activities

Pulp and Paper manufacture	Refineries	Food, Drink and Milk processes
Iron and Steel production	Large Volume Organic Chemicals	Ceramics
Cement and Lime production	Smitheries and Foundries	Management of Tailings and Waste-Rock in Mining Activities
Cooling Systems	Intensive Livestock Farming	Surface treatment of metals
Chlor-Alkali manufacture	Emissions from storage of bulk or dangerous materials	Surface treatments using solvents
Ferrous Metal processing	Common waste water and waste gas treatment and management systems in the chemical sector	Waste Incineration
Non-Ferrous Metal processes	Economic and cross media issues under IPPC	Waste Treatments [Previously Waste Recovery/Disposal activities]
Glass manufacture	Large Combustion Plant	Speciality inorganic chemicals
Tanning of hides and skins	Large Volume Inorganic Chemicals - Ammonia, Acids & Fertilisers	Organic fine chemicals
Textile processing	Large Volume Inorganic Chemicals - Solid & Others	Polymers
Monitoring systems	Slaughterhouses and Animal By-products	Energy Efficiency

Executive Summary

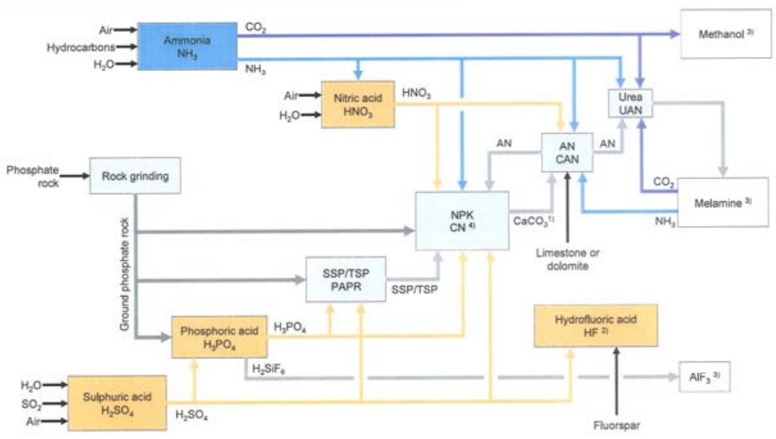

Figure 1: Overview of boundaries and links between the LVIC-AAF industries
[1] only with NPK production using the nitrophosphate route [2] not typically produced on fertiliser sites [3] not described in this document
[4] CN is $Ca(NO_3)_2$, and is alternatively produced by neutralisation of HNO_3 with lime (not described in this document)

ii December 2006 BS/EIPPCB/LVIC-AAF_BREF_FINAL

efma

Structure of the BATREF

- General information.
- Applied processes and techniques.
- Current emission and consumption levels.
- Techniques to consider in the determination of BAT.
- BAT for Ammonia.
- Emerging techniques.

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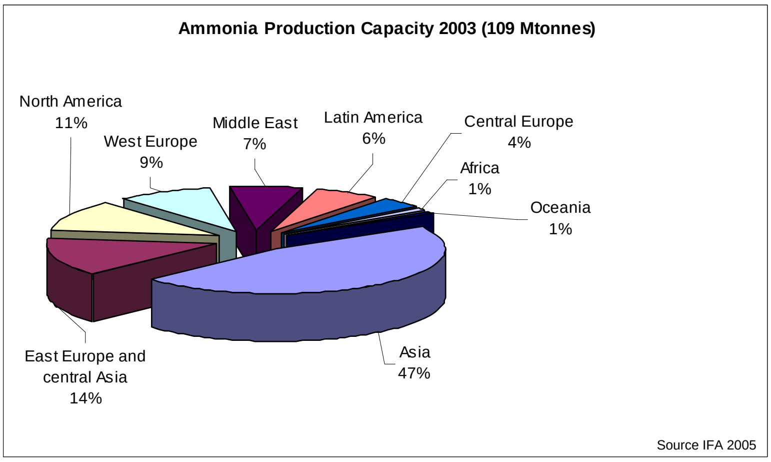
Ammonia Production Capacity (2003)



Applied Ammonia Processes

Feedstock	Process	% of world capacity
Natural gas	Steam reforming	77
Naphtha, LPG, refinery gas	Steam reforming	6
Heavy hydrocarbon fractions	Partial oxidation	3
Coke, coal	Partial oxidation	13,5
Water	Water electrolysis	0,5

Table 1. Applied processes and feed stocks in the production of ammonia [Ref. 4].

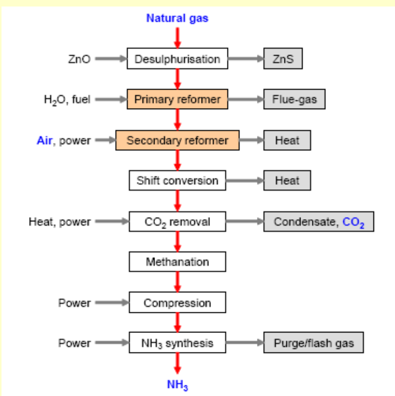
Applied Ammonia Processes

Feedstock	Process	Net primary energy consumption GJ/t NH3 (LHV)	Relative investment
Natural gas	Steam reforming	28*	1
Heavy hydrocarbons	Partial oxidation	38	1,5
Coal	Partial oxidation	48	2-3

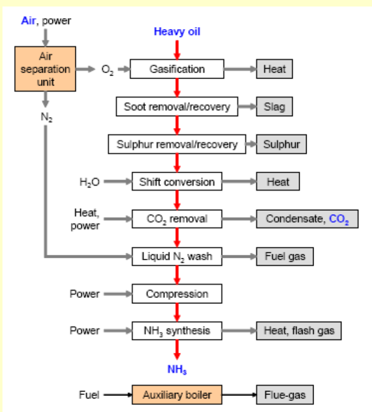
*Best achieved data

Table 2. Cost differences and total energy demands for ammonia production [Ref 4].

Conventional steam reforming



Partial Oxidation



Techniques to consider in BAT: Criteria

- Description of the technique.
- Achieved environmental benefits.
- Cross media effects.
- Operational data.
- Applicability.
- Economics.
- Driving force for implementation.
- Reference to literature and example plants.

26 techniques considered in the determination of BAT: a selection

- Heat exchange auto thermal reforming.
- Advanced process control.
- Use of gas turbine to drive the process air compressor.
- SNCR at the primary reformer.
- Improved CO_2 removal systems.
- Preheating of combustion air.
- Stripping and recycling of process condensates.
- etc.

BAT for Ammonia: NOx emissions

BATREF AAF

Plant concept	NO_x emissions as NO_2
	mg/Nm³
Advanced conventional reforming processes and processes with reduced primary reforming	90-230*
Heat exchange auto-thermal reforming	a)80 b)20
a)Process air heater b)Auxiliary boiler * Low end of the range best existing performers and new installations.	

Table 3. NO_x emission levels associated with BAT.

Comparison BAT levels NOx: EU versus EFMA 2000

	EIPPC definition	EFMA 2000			BATREF AAF 2006	
		ppmv	mg.Nm³	kg.t⁻¹ of product	mg/Nm³	kg.t⁻¹ of product
New Plants	Conventional reforming	75	150	0.45	90-230	0,29-0,32
	Reduced primary reforming				90-230	0,29-0,32
	Heat exchange auto-thermal reforming				20-80	0,175
	Partial oxidation				Not considered BAT	
Existing Plants	Conventional reforming	150	200-400	0,9	90-230	0,29-0,32
	Reduced primary reforming				90-230	0,29-0,32
	Heat exchange auto-thermal reforming				20-80	0,175
	Partial oxidation					

Table 4. Comparison of the BAT Emission levels for NO_x (EFMA 2000 versus EU BATREF AAF).

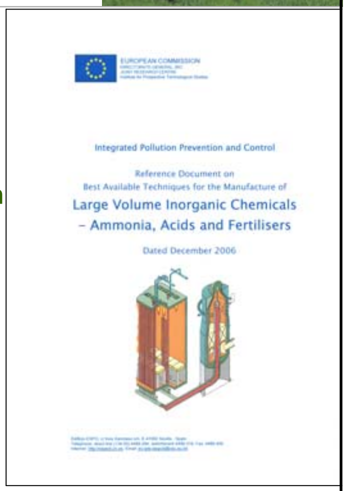
Comparison BAT Energy consumption levels: EU versus EFMA 2000

	EFMA 2000			EU 2006
	Feed	Fuel	Total	Net
Plant concept	GJ(LHV).t^{-1} NH_3			
Conventional reforming	22.1*	7.2-9.0**	29.3-31.1***	27,6-31,8
Excess air reforming	23.4*	5.4-7.2**	28.9-31.6	27,6-31,8
Auto-thermal reforming	24.8*	3.6-7.2**	28.4-32	27,6-31,8
Partial oxidation	28.8*	5.4-9.0**	34.2-37.8	

*Modern plant
**Efficient stand-alone plant with no energy export and no other import than feed-stock and fuel
***In new reforming plants the total energy consumption should not exceed 29.3 GJ(LHV).t^{-1} NH_3

Concluding remarks

- **Limited number of Fertilizers**
- **Main focus on NOx and Energy consumption**
- **Partial oxidation not BAT for new plants**
- **Emerging techniques not considered**



Future Energy Efficiency and CO_2 Reduction Potential

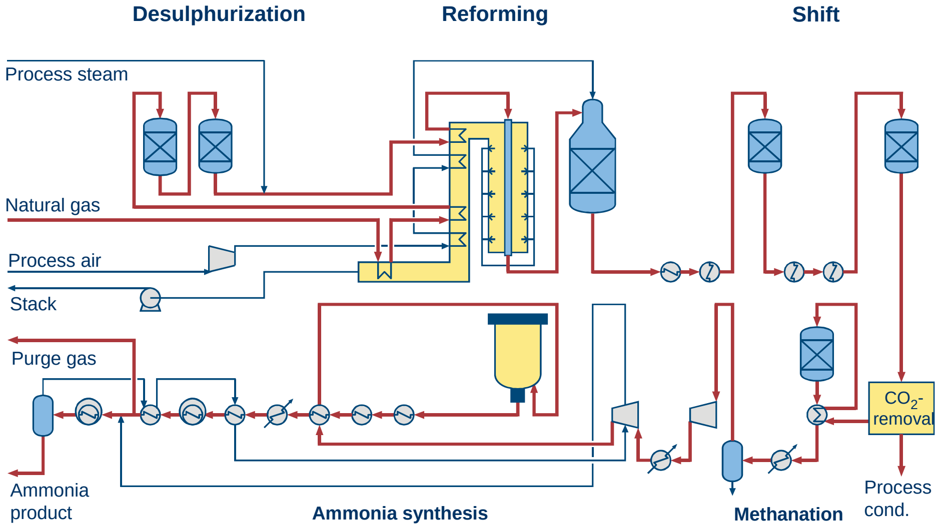
Svend Erik Nielsen

Haldor Topsøe A/S

Outline

- Energy efficiency in ammonia plants
  - Current design
  - Historical development
  - Technology development
- Highlights of specific process features
  - Reforming section
  - Ammonia synthesis converter
- CO_2 reduction potential
- Integration with steam and power system
- Conclusion

Current scheme



Historical development - ammonia plants

- Plant energy consumption in the early 1980'ies was around 10.5 Gcal/MT NH_3
- In the late 1980'ies, this figure was around 7.75 Gcal/MT NH_3
- Many plants have been revamped, and best current plant is today around 7.1 Gcal/MT NH_3 after revamp
- For new plants, the current state-of-the-art consumption is around 6.6 Gcal/MT NH_3

Energy efficiency - ammonia plants

- A typical energy consumption figure based on the current scheme is today 6.8 Gcal/MT NH_3
- Two scenarios:
  - Stand-alone ammonia plant with no requirement for CO_2 production
  - Ammonia/urea complex
- Difference in climatic conditions (cooling water temperature and other site specific conditions)
- How much can the energy consumption figure be reduced in the (near) future ?

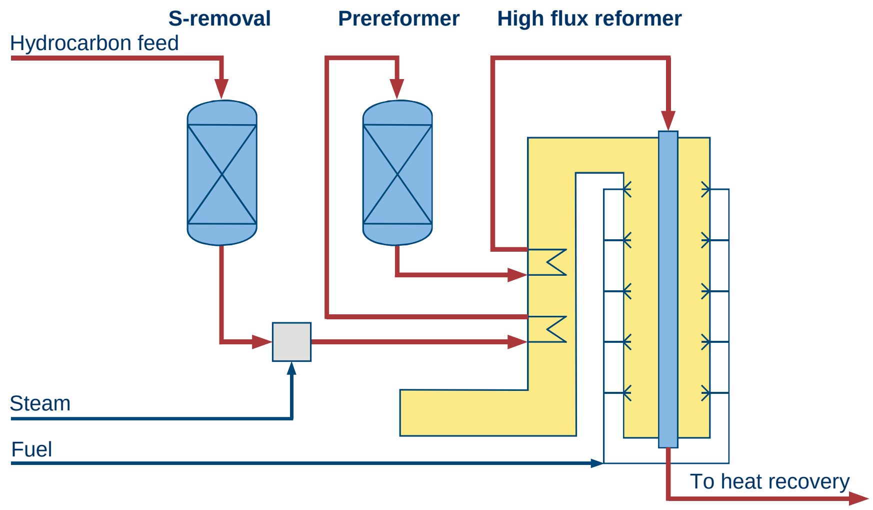
Energy reducing features

- High pressure in the front-end
- Low pressure in the ammonia synthesis loop (saving of power for synthesis gas compressor)
- aMDEA CO_2-removal
- Improved ammonia conversion in the loop
- Cryogenic purge gas recovery unit, returning the recovered hydrogen at high pressure compared to the membrane purge gas recovery unit
- Only major compressors on turbine drive (avoiding small inefficient steam turbines)
- Latest generation of rotating machinery

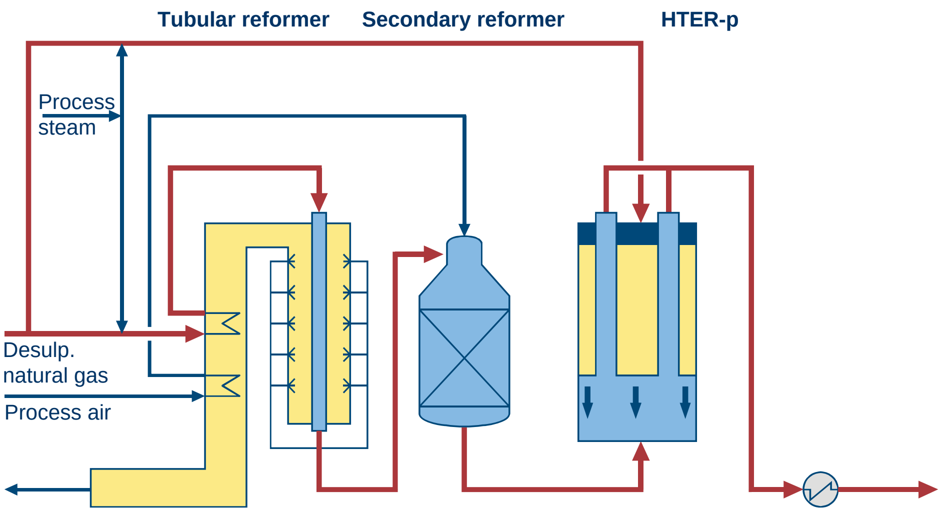
Technology development

- High flux primary reformer with prereformer
- HTER-p (Haldor Topsøe Exchange Reformer)
- S-300 converter
- Improved catalysts

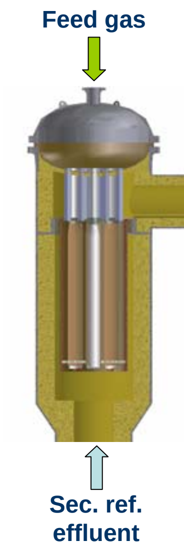
Prereforming



HTER-p flowsheet

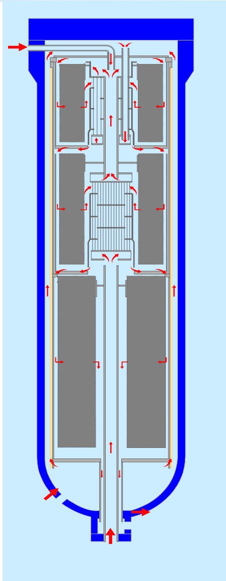


The HTER-p

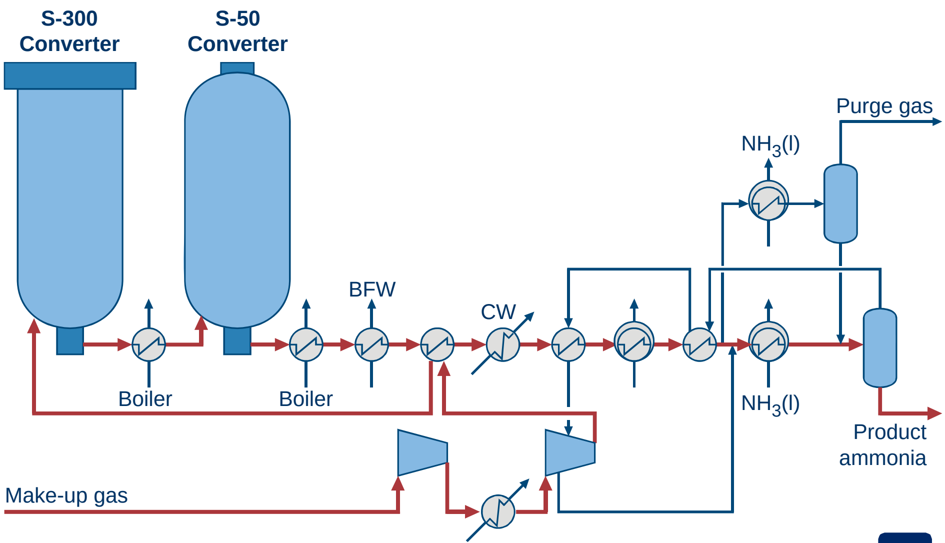


- Compact
- Optimised utilisation of pressure vessel volume
- Allows for removal of internals
- No restriction of thermal movement

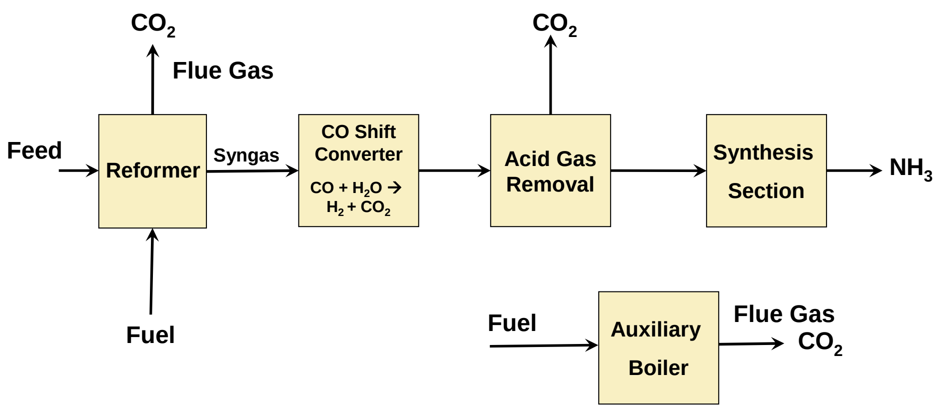
S-300 ammonia synthesis converter



S-350 ammonia synthesis loop



CO_2 emissions from ammonia plants



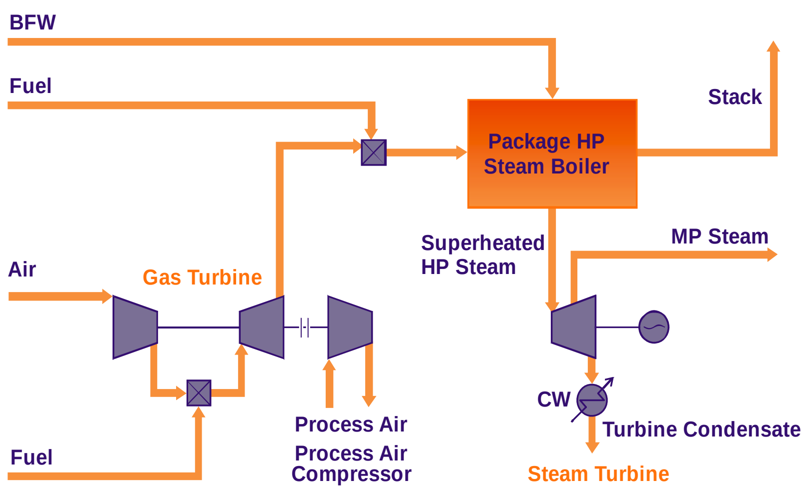
CO_2 reduction potential (1)

- About 75 % of the hydrocarbon is used as feed and 25 % as fuel in a steam reformer based ammonia plant
- In most plants, all the CO_2 generated from the feed is used in downstream plants (f. ex. urea)
- How much can the CO_2 emission be reduced in the (near) future in an ammonia plant ?

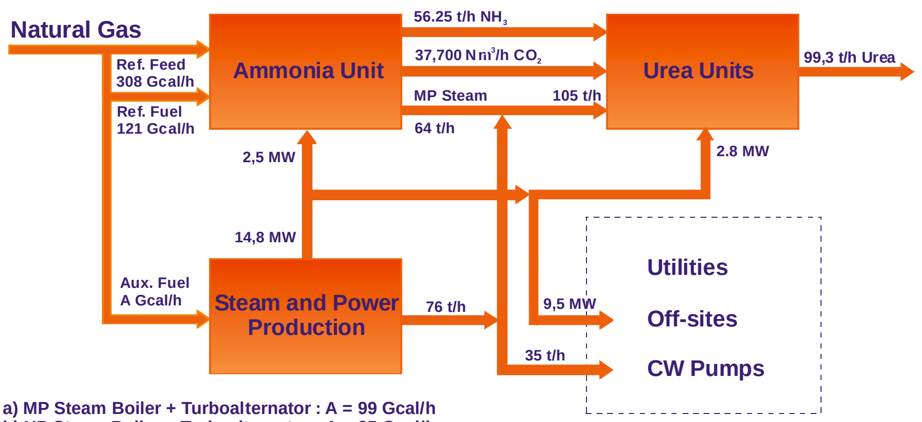
CO_2 reduction potential (2)

- Reduce fuel firing in plant (prereformer and HTER) – up to 20-25% reduction
- Remove CO_2 from flue gases (reformer and auxiliary boiler) – up to 90% can be removed
- Use combustion air preheat to reduce fuel firing
- Improve efficiency of steam and power generation unit in the complex

Integration of gas turbine driver in the ammonia process

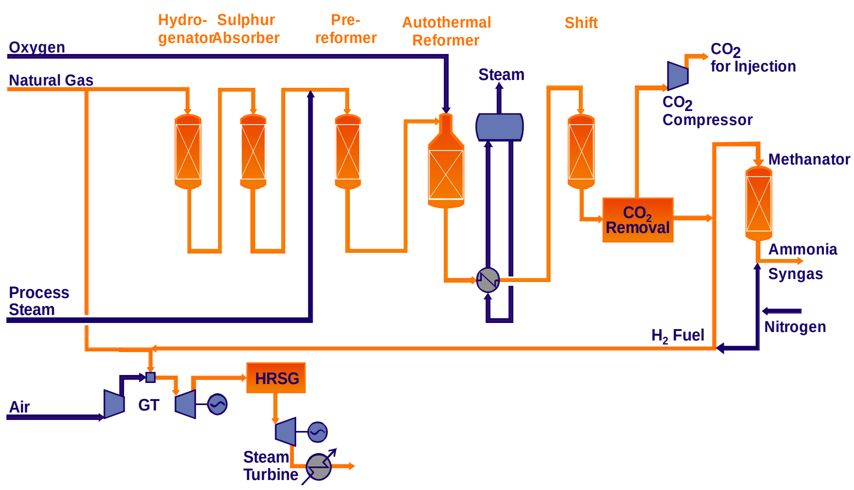


Integration with urea plant (1350 MTPD ammonia / 2385 MTPD urea)

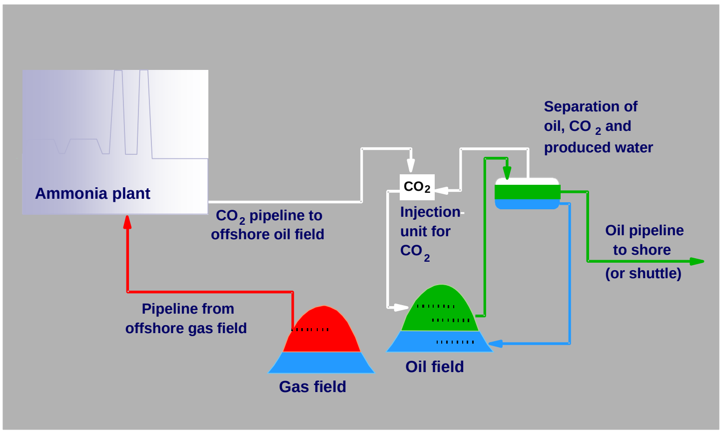


a) MP Steam Boiler + Turboalternator : A = 99 Gcal/h
b) HP Steam Boiler + Turboalternator : A = 85 Gcal/h
c) Gas Turbine + MP Steam Boiler : A = 73 Gcal/h
d) Gas Turbine + HP Steam Boiler : A = 67 Gcal/h

Integrated reforming and power cycle



Carbon effective ammonia production CO_2 for EOR



Conclusion

- Ammonia technology is continuously developed by introduction of new equipment designs and improved catalysts to suit the marked needs
- When the ammonia process is designed for low energy consumption it automatically results in low CO_2 emission as well
- Especially from ammonia/urea complexes the emissions are minimal
- Technology exists to integrate the plant with the off-sites to reduce the CO_2 emission to zero

"Energy Reduction, Environment Protection by CO_2 Reduction & Feed Stock Change-over at IFFCO Phulpur "

Yogesh Narula
Chief Manager (Process)

Indian Farmers Fertiliser Coop. Ltd.
Phulpur Unit

INTRODUCTION

1st. Plant of Chem. Fertiliser for Super Phosphate at Ranipet (T.N.) : 1906.

Indian Fertiliser Industry is more than 100 years old.

Initial 50 years , usage of Fertiliser's almost NIL.

During '50's traditional agriculture practices with limited use of Fertilisers.

During early 60's marked jump in Fertliser's consumption, mainly thru' Imports.

Introduction of RPS in 1977 , leading to rapid growth of Fertiliser Industries in 80's and 90's.

India emerges as the Third Largest Global Producer and User of Chemical Fertilisers.

India becomes Self Sufficient in Food-Grain Production.

About IFFCO

- Indian Farmers Fertiliser Co-operative Limited (IFFCO) was registered on November 3, 1967 as a Multi-unit Co-operative Society.
- Initially commissioned Ammonia/Urea complex at Kalol and DAP/NPK complex at Kandla in 1975.
- Subsequently commissioned Ammonia / Urea complex at Phulpur and Aonla in 1981 and 1988 respectively.
- In 1993, IFFCO had drawn up a major expansion programme of all the four plants under overall aegis of IFFCO VISION 2000.
- Last year acquired DAP/NPK unit at Paradeep.
- Marketing of IFFCO products – channelised through 37,500 member co-operative societies and 158 Farmers Service Centers in over 28 States / Union Territories in India.
- Set up Oman India Fertiliser Company (OMIFCO) at Sur in Oman with annual capacity of producing 16.52 lakh tonne Urea other joint venture partner, Oman Oil India Company (OOC).
- Launched another company Indo-Egyptian Fertiliser Company (IEFC), a joint venture with El Nasr Mining Company (ENMC), for setting up a Phosphoric Acid Plant in Egypt.

IFFCO-PHULPUR UNIT
A Profile

Phulpur-I	Process Licensor	Annual Capacity
•Ammonia Plant	MW Kellog, U.S.A	322400 MT
•Urea Plant	Snamprogetti, Italy	551100 MT

FM 55252
(ISO 9001:2000 certified)

Phulpur-II	Process Licensor	Annual Capacity
•Ammonia Plant	HTAS, Denmark	501600 MT
•Urea Plant	Snamprogetti, Italy	864600 MT

EMS 57450
(ISO 14001 certified)

•Commercial Production

•Phulpur-I	Urea	Mar. 28, 1981
•Phulpur-II	Urea	Dec. 22, 1997

CHALLENGES FACED by FERTILISER INDUSTRY

- Steep rise in Cost of Inputs mainly Gas, Naphtha, FO/LSHS etc.
- Subsidy Burden.
- Late disbursement of Subsidy due to Insufficient Allocation in Budget.

IFFCO

STRATEGIES

- Consolidation of Operations to Compete.
- Reduction in Cost of Production by reducing Energy Consumption .
- Optimization in usage of Resources.
- Pooling of Catalyst and Spares.
- Use of Cheaper and Better Feed-Stock.
- Improving Reliability and Productivity of Ammonia and Urea Plants.

IFFCO

STRATEGIES (Cont.)

Use of Modern Process Technologies: Ammonia

- Addition of S-50 Converter.
- Better Catalyst in Reformer / Shift Reactors.
- Improving Performance of CO_2 Removal Section.
- Installation of Molecular Sieves of Ammonia Wash Unit for Purification of PG.
- Use of Installation of PGR Unit to recover H2 & NH_3 from Purge Gas .
- Change of MoC from CS to SS for critical Exchangers.
- Recovery of Waste Heat from flue gases of Reformer.

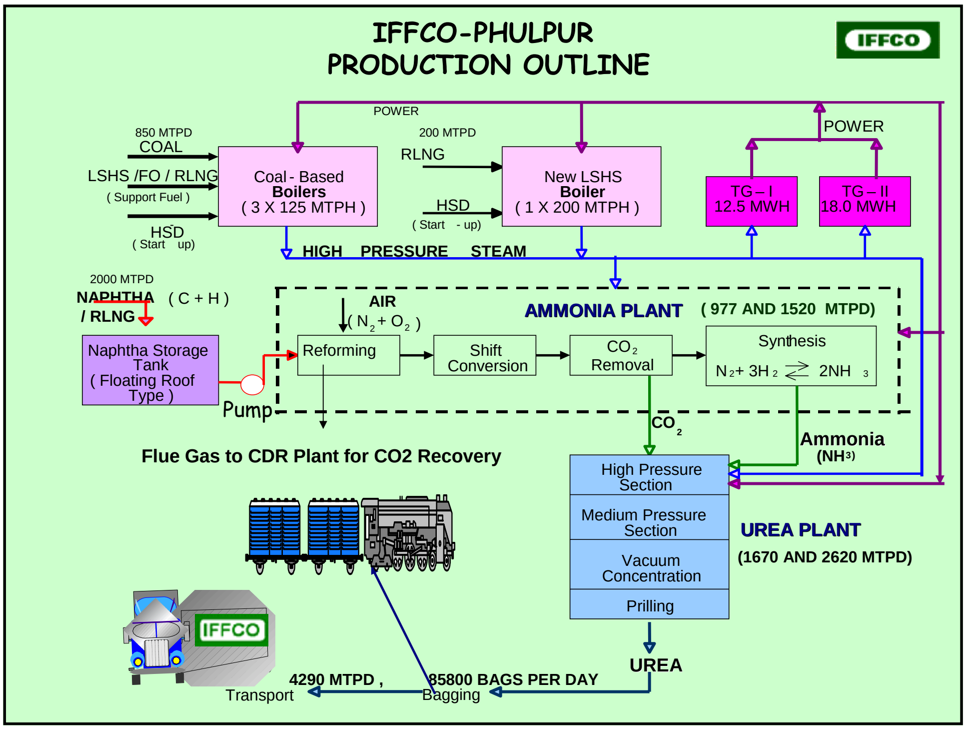
STRATEGIES (Cont.)

Use of Modern Process Technologies: Urea

- Increase CO_2 Feed temperature by recovering Heat from 3rd Stage discharge of Compressor.
- Replacement of old HP Stripper by New Bi-Metallic Stripper.
- Installation of Pre-Concentrator and MP Pre Decomposer.

Use of Modern Process Technologies: Others

- Installation of VSD in Electric Motors for Power Optimization.
- Installation of Energy Efficient Moving Machines mainly Compressors.
- Upgrading Instrumentation System by switching over to DCS.
- Capacity Enhancement through Modifications & Retrofit.



Energy Saving Project - Background

1. GOI implemented the New Group Pricing Schemes for Urea Fertilizer Industry w.e.f. April 2003.
2. Energy Norms were made more stringent.
3. Incentive were provided for Energy Efficient Plants.
4. No mopping of Energy Efficiency and no recognition of Capital Invested.

- In order to lower the Energy Consumption below the prescribed Norms Energy Saving Project was envisaged for all the five Ammonia Plants at Kalol, Phulpur-I, Phulpur-II, Aonla-I and Aonla-II Units.
- Project was bifurcated in two Phases viz. Phase-I and Phase-II Project for ease of implementation and to accrue the early benefits.

Energy Saving Project - Milestones

- Feasibility Study & Basic Engineering: HTAS Denmark
- Detailed Engineering : PDIL Noida

Project Zero Date

- Phase-I : September 2003
- Phase-II : October 2003

Project Completion Date

- Phase-I : Annual Turn Around in 2005
- Phase-II : Annual Turn Around in 2006

Project Cost

- Rs. 1500 million

Energy Saving Project

Various Energy Saving Schemes Implemented

Energy Saving Project at Phulpur-I

PHASE–I

- LTS Guard Bed System.
- Revamp of CO_2 Removal System to 2 stage GV System.
- Improvement in Shift Outlet System.

PHASE–II

- S-50 Synthesis Converter & MP boiler.
- Drying of Make-up Gas and Synthesis Loop Re-piping.
- Revamp of Synthesis Gas Compressor.
- Final Gas Chiller.

Energy Saving Project at Phulpur-I

IFFCO

L.T. Guard Bed System

CO Slip:

Before : 0.32 %

After : 0.14 %

Energy Saving Project at Phulpur-I

IFFCO

CO_2 Removal Section Revamp from 1-Stage to 2-Stage GV Process

Regeneration Energy

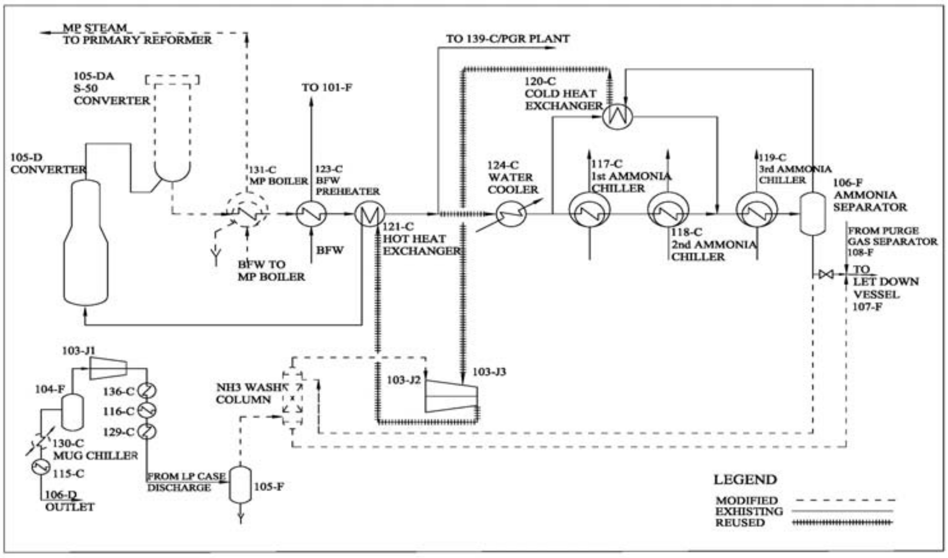
Before : 1049 kcal/NM3 CO_2

After : 760 kcal/NM3 CO_2

Savings : 289 Kcal/NM3 CO_2

Energy Saving Project at Phulpur-I

IFFCO



Schematic Diagram of Modified Back-end of Ammonia Plant: **Phulpur-I**

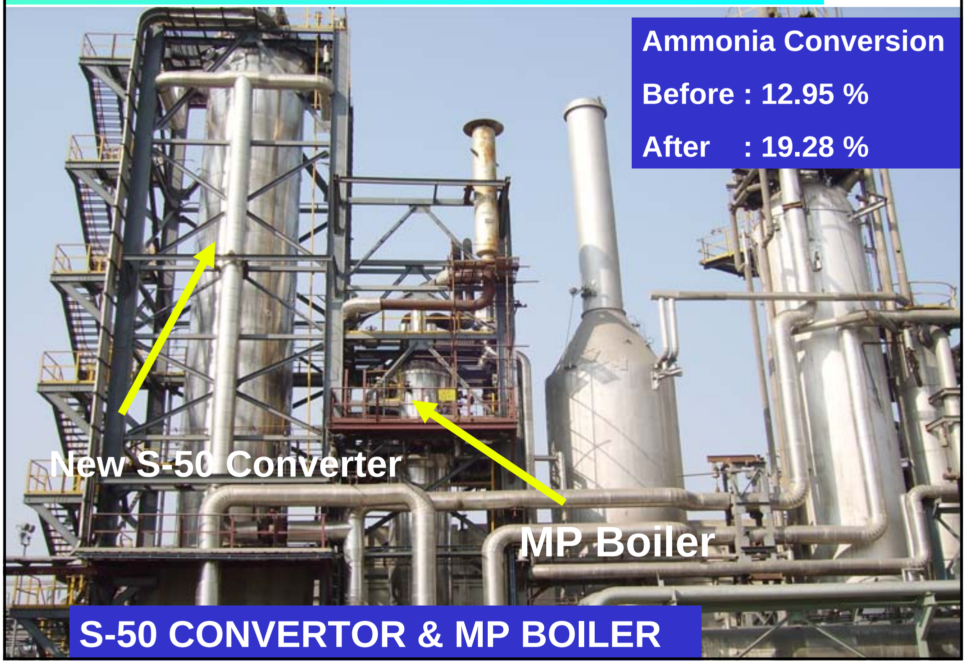
Energy Saving Project at Phulpur-I

IFFCO

Ammonia Conversion

Before : 12.95 %

After : 19.28 %



S-50 CONVERTOR & MP BOILER

Energy Saving Project at Phulpur-I

Ammonia Wash Unit

- To Remove the Oxides present in the Make-up Gas.
- This avoids Compression of Ammonia in the Synthesis Gas thus saves Compression Energy.

Energy Saving Project at Phulpur-II

PHASE–I

- LTS Guard Bed System.

PHASE–II

- S-50 Synthesis Converter & HP boiler.
- Final Gas Chiller.

Energy Saving Project at Phulpur-II

IFFCO

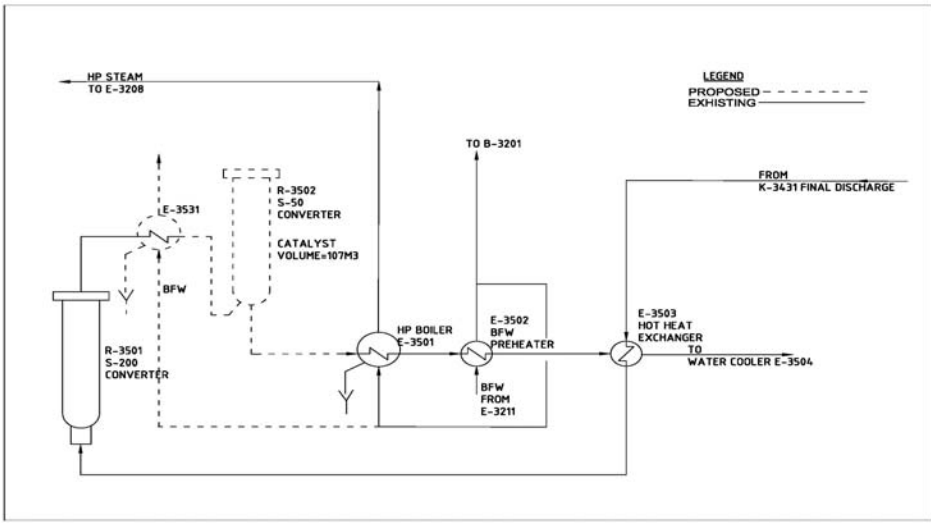
CO Slip:

Before : 0.27 %

After : 0.13 %

Energy Saving Project at Phulpur-II

IFFCO



S-50 radial flow Synthesis Converter and HP Boiler

Energy Saving Project at Phulpur-II

IFFCO

Ammonia Conversion
Before : 19.30 %
After : 24.33 %

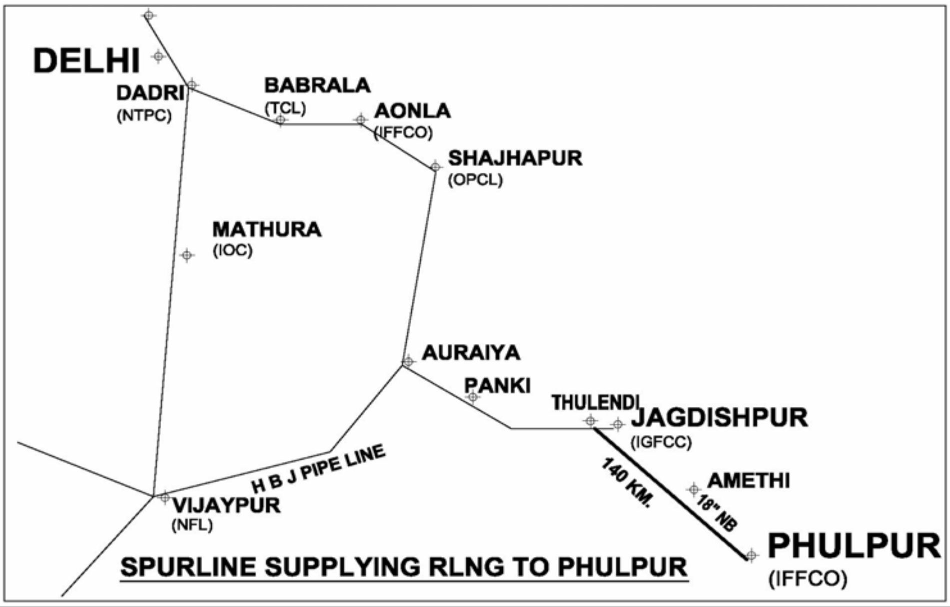
HP Boiler

IFFCO

RLNG CONVERSION PROJECT

IFFCO: PHULPUR UNIT

RLNG CONVERSION PROJECT



Total Naphtha / LNG Requirement

Base Case

	Phulpur –I	Phulpur -II	Total
Naphtha Yearly (Lakh MT/ Year)	2.4	4.3	6.7

After Conversion to LNG (Million SM3/day):

	Phulpur –I	Phulpur -II	Total
At Reassessed Capacity	0.95	1.55	2.50
LNG in Boiler -4	-	0.35	0.35
Total LNG	**0.95**	**1.90**	**2.85**
With Enhanced capacities	1.10	1.73	2.83
LNG in Boiler -4	-	0.17	0.17
Total LNG	**1.10**	**1.90**	**3.00**

Major Activities – RLNG Conversion (Amm.-I) IFFCO

- Complete Changeover to RLNG from Naphtha in both Feed Stock & Fuel.
- All liquid fuel burners in top arch (162 Nos.), tunnel (09 Nos.), hydrocarbon feed pre heater (04 Nos.) and auxiliary (05 Nos.) boiler, were replaced with new RLNG burners.
- RLNG pre heater coil was installed in between LT super heater and combustion air pre heater.
- New gas reforming catalyst, was loaded in primary reformer tubes.

LNG Control Station in Amm.- I Plant

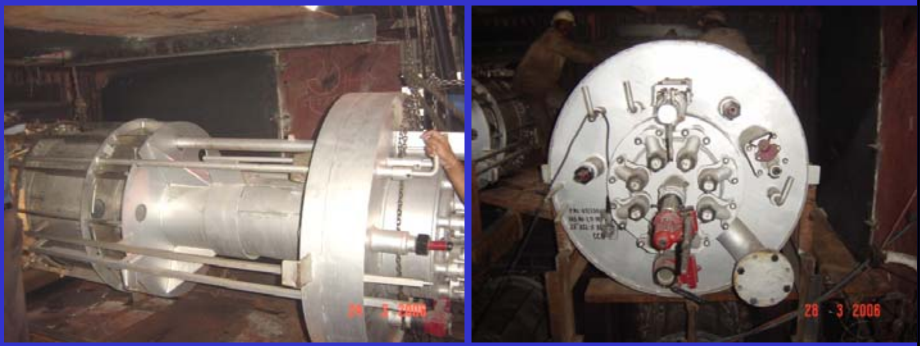
Major Activities – RLNG Conversion (Amm.-II) IFFCO

- Complete provision for online switching of feedstock from Naphtha to RLNG.
- Fit-up for converting Fuel of GT from Naphtha to RLNG.
- Existing Burners replaced with modified burners; Primary Reformer (H-3501). Total 288 burners replaced.
- Two RLNG heating coils were installed in waste heat section of Primary Reformer.
- Modification in HRU Burners and its Control system: Naphtha burners were modified to dual firing burners with facilities of on line change over.

RLNG Fuel Skid for HRU / GT in Ammonia-II

RLNG Conversion Activities : Yard Piping and SG Plant

- RLNG Yard Piping blowing with air from GT was done.
- In Boiler # 4 , Dual firing (RLNG & FO) burners installed successfully.
- In Coal based boiler provision made to use RLNG as support fuel in place of Fuel Oil.



View of Dual Firing Burners in Boiler # 4

CARBON-DIOXIDE RECOVERY PLANT

IFFCO: PHULPUR UNIT

C.D.R. PROJECT

IFFCO

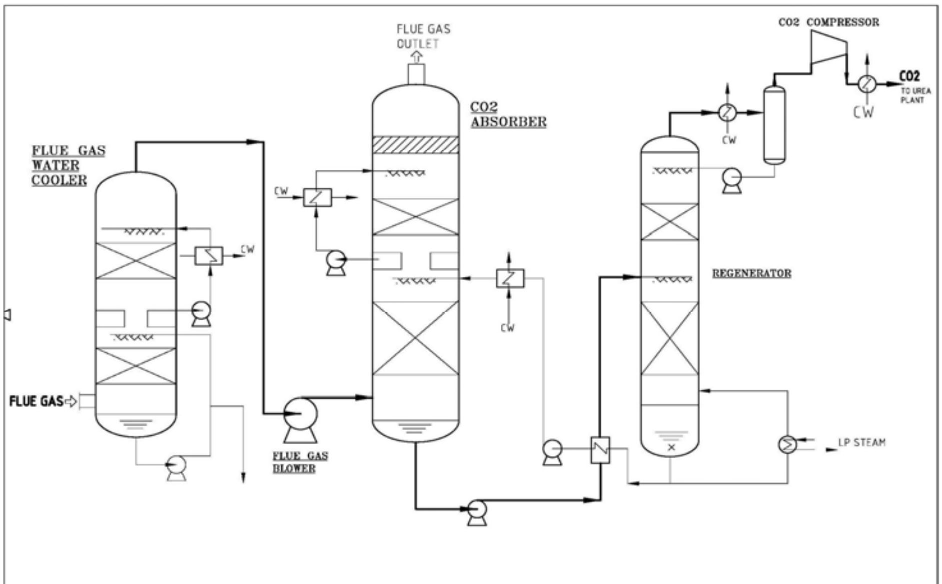
• Capacity	:	450 MT of CO_2 per day
• CO_2 Recovery from	:	Primary Reformer flue gas of Ammonia-II
• Turnkey Project by	:	M/s Tecnimont ICB, Mumbai
• Process Consultant	:	M/s MHI, Japan
• Detailed Engg. & Execution	:	M/s Tecnimont ICB, Mumbai

Milestones

➢ Zero Date of project	:	March 25 , 2005
➢ Contractual date of completion	:	December 23 , 2006
➢ Actual Completion date	:	December 16 , 2006

C.D.R. PROJECT

IFFCO



PROCESS FLOW DIAGRAM OF CDR PLANT

C.D.R. PROJECT



Different Views of CDR Plant

Reduction in CO_2 Emission

- **Reduction Due to Energy Saving Project**
  - Reduction in Steam Consumption to a tune of 35 MT/hr.
  - Reduction in Coal/FO firing in Steam Generation facilities.
- **Reduction Due to LNG Change Over**
  - Gas being lean in Carbon lesser CO_2 is generated than Naphtha in Feed. Earlier CO_2 was vented to atmosphere.
  - Firing of gas in furnaces in Amm. Plant & SGP Plant in place of Naphtha & Fuel Oil.
- **Reduction Due to CDR Project**
  - CDR Plant recover CO_2 from Amm.-II plant Primary reformer stack.
  - Out of total flue gas flow of 182086 Nm3/hr, 128790 Nm3/hr routed to CDR Plant.

Estimated annual reduction in Emission: more than 0.6 million tonnes.

Future Action Plan

Capacity Enhancement Project

PLANT	EXISTING CAPACITY (MTPD)	REVISED CAPACITY (MTPD)
PHULPUR-I		
AMMONIA	977	1215
UREA	1670	2115
PHULPUR-II		
AMMONIA	1520	1740
UREA	2620	3030
TOTAL ANNUAL UREA CAPACITY (MT)	14,15,700	16,97,850
ANNUAL INCREASE IN UREA PRODUCTION (MT)		2,82,150
PERCENTAGE INCREASE		19.9

Targeted Completion of Schemes: Year 2007

Future Action Plan

Major Schemes : Capacity Enhancement Project

- Ammonia Plants:
  - Revamp of Process Air Compressor and Syn. Gas Compressor
  - Replacement of Few Exchangers
  - Modification in Primary & Secondary Reformer Burners
- Urea Plants:
  - Installation of Pre-Concentrator along with MP Pre-Decomposer
  - Installation of additional HP Ammonia Pump and Carbamate Pump
  - Additional Cooling Water Cell
  - Modification in Various Pumps
  - Replacement of Few Exchangers
  - Prill Cooling System

Recognition Received from Ministry of Power Govt. of India for Energy Efficiency initiatives

IFFCO

2005

2006

National Energy Conservation Award

IEA Industrial Energy-Related Technologies and Systems

Weel & Sandvig ENERGY AND PROCESS INNOVATION

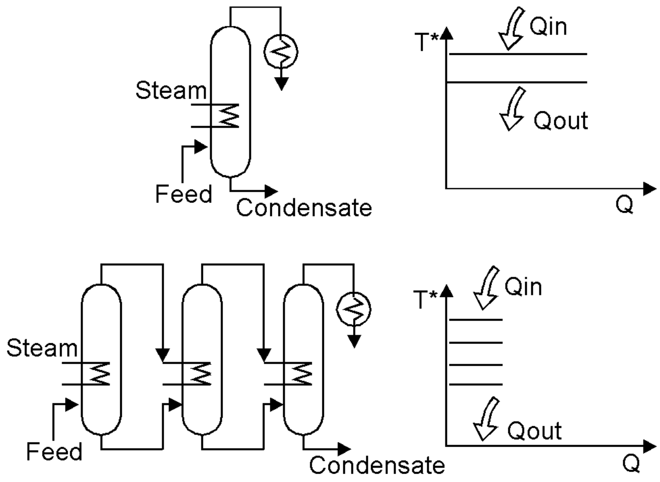
Energy efficiency measures in fertiliser sites

Jan Sandvig Nielsen
Weel & Sandvig
IEA - IETS

Outline

- Process integration in the fertiliser industry
  - Introduction to process integration
  - Site wise energy optimisation at Acron, Russia
    - Plant optimisation (Nitric acid)
    - Cogeneration (ammonia)
    - Heat export (ammonia, methanol, nitric acid, AN etc)
- International cooperation under IEA
  - Presentation of IETS
  - Opportunities for the fertiliser industry
    - Credibility

BAT
Evaporator thermal design



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3

Evaporator design for optimal energy efficiency

- "Golden rule for optimal energy use"
  - Use as many stages as possible
    - Reduced driving forces
    - Larger heat exchange area
  - Product properties may constraint number of stages
  - Trade off: Energy efficiency / capital costs
    - **1 stage** Energy: 100 Heat Exchange Area: 100
    - **2 stages** Energy: 50 Heat Exchange Area: 400
    - **3 stages** Energy: 33 Heat Exchange Area: 900
    - **Etc**
  - BAT technology for evaporators?
    - 3 stages?

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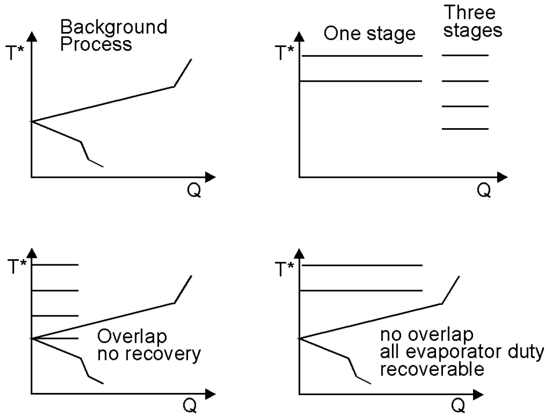
4

Integration of evaporator plants

- Evaporators in site context

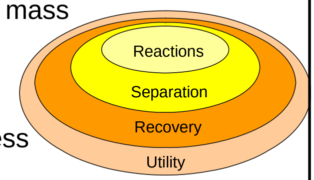


- BAT is context dependent

5

Process integration analysis (System analysis)

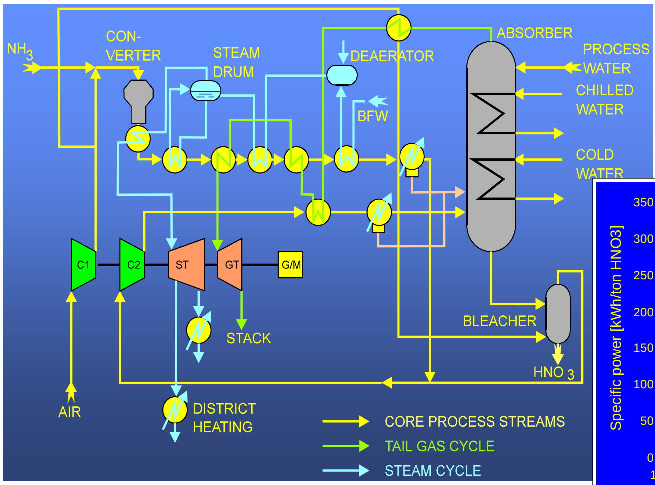
- Aim
  - To optimise process interaction in order to reduce total energy consumption
- Method
  - Setting up initial balances (energy- and mass balances, process modelling)
  - Screening of potential savings by heat recovery
  - Screening of potential savings by process changes and heat recovery
  - Realisation of targets

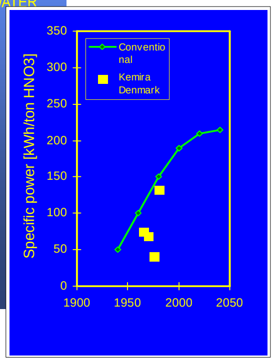


- Results
  - Improved insight in process interactions
  - An overall view of potential energy savings

6

Nitric acid process





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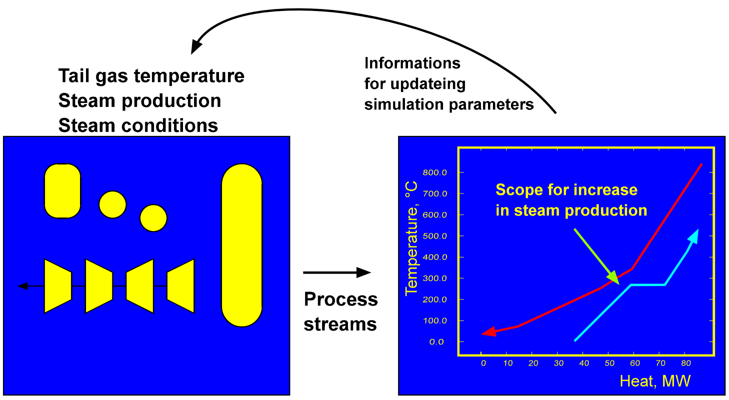
Process integration approach



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Nitric acid plant example
Process modifications

- Process integration analysis provided insight
  - Bottleneck – tail gas flow rate
- Tail gas flow rate enhancement
  - Integrated tail gas humidification
- Consequences
  - Increased heat recovery to gas turbine cycle
  - Steam cycle can be omitted
  - Simplification of process lay-out

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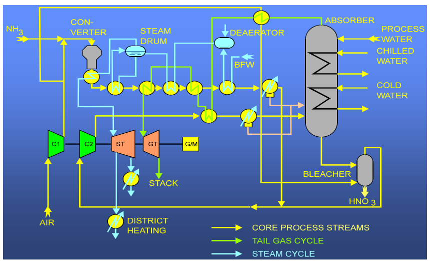
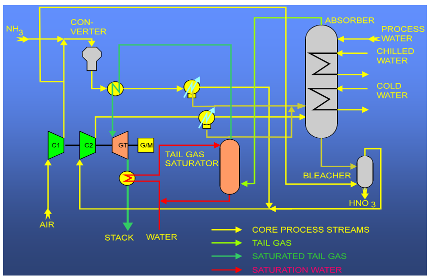
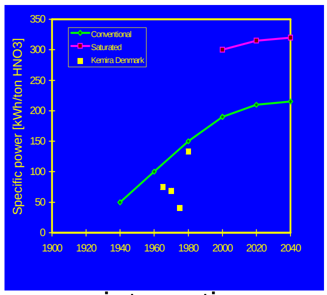
Nitric acid plant
Process comparison





- FIXED CAPITAL COST
- CONVENTIONAL
  - 225 kWh/ton HNO3
  - COMPLEX DESIGN
  - PROVEN CONCEPT
- SATURATED DESIGN
  - 312 kWh/ton HNO3
  - SIMPLE DESIGN
  - NEW CONCEPT
  - BUT STANDARD EQUIPMENT



Process integration can help out of the box thinking!

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Site optimisation at Acron, Russia

- Aim of analyses
  - Introduce process integration methods
  - Discover process improvement areas
    - Direct applicable solutions (pay back < 2 years)
    - Long term solutions (pay back > 2 years)
  - Combine expert knowledge of Acron and consultants
    - Exploit new opportunities

Weel & Sandvig ENERGY AND PROCESS INNOVATION

Overview of primary analyses

- Nitric acid process
  - Gas reduction, power production
  - N_2O reduction
- Gas system
  - Gas expander
- Ammonia plant
  - Gas turbine system for power and steam production
- Methanol plant
  - Increased preheat (Reduced oxygen consumption)
- AN plant
  - Send condensate to the nitric acid processes (reduces steam consumption in the neutralisers)
- All processes
  - Recover waste heat for building heating purposes and/or heat export to Novgorod

Nitric acid UKL

Weel & Sandvig ENERGY AND PROCESS INNOVATION

- Base case simulation
  - Energy and mass balances
  - Identification of process equipment characteristics
  - Identification of inconsistencies
- Identification of potential improvements
  - Screening for improvements
  - Conceptual process simulation model
  - Identification of principal optimisation parameters
  - Evaluation of potential savings
- Actual design proposals

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Nitric acid
Short terms improvements

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- Solution carried out by Acron during the project
  - Improved preheat of process gas before NO_x reduction unit
  - Achieved improvement (per plant)
    - Natural gas reduction: 320 – 360 nm3/h (2.5-2.9 mills nm3/yr)
    - CO_2 emission reduction: ca. 5 000 tons/yr.
  - Pay back: Less than 2 years.
  - Detailed engineering carried out by Acron

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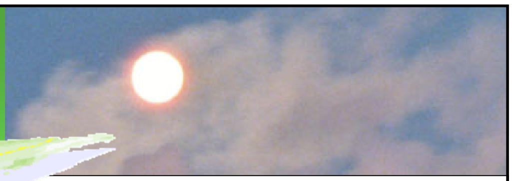
Nitric acid
Long term opportunities

- Significant potential for energy savings
  - Improved heat recovery
  - Power production
- Energy saving potential
  - Natural gas savings up to 11 mills. Nm3/yr. (per plant)
  - Possible CO_2 reduction (21 000 tons/yr. per plant)
- Currently too long pay-back period
  - 4 – 10 years pay back at current energy costs
- Strategic planning
  - Change in energy costs
  - Plant upgrade
  - Integration of environmental protection systems

Selected other saving potentials

- Gas expander
  - Produce power by expanding high pressure n-gas
    - 3 MW electricity
    - Pay back period 2-4 years
- Methanol plant
  - Improved process integration
    - Reduced power – oxygen generation (5 100 MWh/yr)
    - Decreased steam demand (up to 49 000 MWh/yr)
- Ammonia plant
  - Power production
  - Reduction of steam consumption
- Heat export potential (80 - 140 C)
  - Significant potential for heat export from Acron
  - 150 MW waste heat



iets

IEA Industrial Energy-Related Technologies and Systems
An Implementing Agreement under the auspices of the OECD International Energy Agency

Jan Sandvig Nielsen
Denmark

Presentation

Ho Chi Minh City

March 2007

What is the IEA?

The International Energy Agency (IEA) was founded by the OECD countries in 1974 to reduce dependence on imported oil.

The shared goals of IEA members today are **energy security, economic growth and environmental protection**.

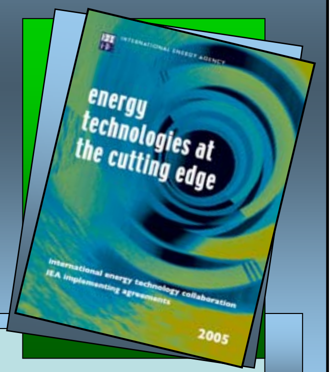
Energy technology innovation and widespread deployment of more economical and environmentally benign technologies are central parts of the IEA's work.

For more information about the IEA:
http://www.iea.org/Textbase/about/docs/Overview.pdf

What is an IEA Implementing Agreement?

IEA Implementing Agreements offer the **framework** for collaborative projects.

Interested countries join together to study applications of existing technologies, research new technologies, co-ordinate national research programmes or share information.



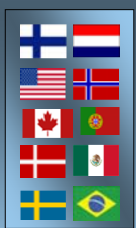
Today there are 40 collaborative projects in the following areas:
End-Use; Fossil Fuels; Renewable Energies and Hydrogen; Fusion Power; Cross-sectional Activities.

For more information about the Implementing Agreements:
http://www.iea.org/textbase/nppdf/free/2005/IAH2005mep_Full_Final_WEB.pdf

The IETS Implementing Agreement

The IETS is an Implementing Agreement under the IEA, focusing on **energy efficient industrial technologies and systems**.

The Programme was established in 2005 as the result of merging, revamping and extending activities formerly carried out by separate industrial IEA Programmes.

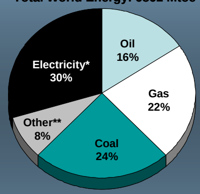


The IETS currently has ten member countries: Finland, USA, Canada, Denmark, Sweden, the Netherlands, Norway, Portugal, Mexico and Brazil.

For more information about IETS:
http://www.iea-iets.org/ Information Brochure “About IETS”

Energy use in industry

Figure 1. Industry Energy Worldwide: 2059 Mtoe:
Total World Energy: 6861 Mtoe



*includes power from renewables
**combustible renewables & waste

Today, industry accounts for about **one-third of total global energy use**.

The sector is responsible for about **22% of worldwide CO_2 missions**, of which:
26% are from the iron and steel industry,
25% from non-metallic minerals and
18% from petrochemicals.

Source: IEA

Energy efficiency potential

Overall, industry offers a **significant savings potential** at low or even negative cost.

As a result, there is a greater potential for reducing greenhouse gas emissions at a lower cost than could be achieved in other sectors. A long-term potential for CO_2 emission reductions in this sector is 25-30%.

This potential deserves more attention than it has received so far.

Source: IEA

Energy efficiency opportunities

Some examples:

• In primary steel production, efficiency improvements on the order of 20 to 30% are available based on existing technology;

• Improvements to steam supply systems and motor systems offer efficiency potentials on the order of 15 to 30%;

• Combined heat and power generation can bring 10 to 30% fuel savings over separate heat and power generation;

• CO_2 capture and storage (CCS) could be applied to several industries on a gigatonne-scale, especially in the production of chemicals, iron and steel, cement and paper pulp.

Source: IEA

Identifying opportunities in industry

Identifying opportunities in industry is complex due to the great diversity of processes and products.

Moreover, evaluating the techno-economic aspects and reliability of those opportunities can be time-consuming and difficult.

Much more research, development and demonstration (RD&D) and international co-operation will be needed to successfully identify and capture the world-wide opportunities for industrial energy efficiency improvement.

Mission of IETS

To foster international co-operation among OECD and non-OECD countries for accelerated research and technology development of industrial energy-related technologies and systems.

Strategic Objectives of IETS

- To strengthen international cooperation on energy saving and GHG mitigation in industry;
- To facilitate cooperation between different industrial R&D disciplines;
- To improve knowledge transfer and information between countries, researchers and industries;
- To provide IEA and the G8 countries with energy consumption data and energy efficiency opportunities.

IFA aspects

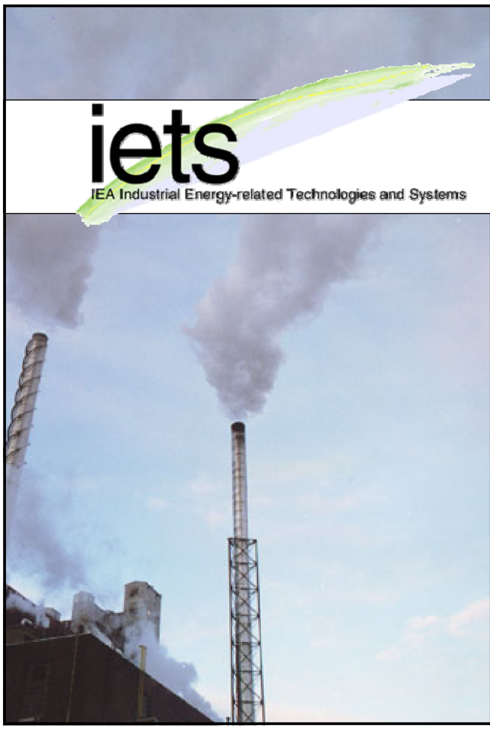
- Benefits
  - Cooperation with energy technology experts
    - Share knowledge with other industries
  - Added credibility by working with IEA
- Potential working packages
  - Energy management guidelines
  - KPI's
  - Best practice
  - Benchmarking

More information about the IETS

Visit our homepage

www.iea-iets.org

IETS Newsletter: please go to www.iea-iets.org for free subscribtion and downloads



Contacts:

Jan Sandvig Nielsen
jsn@weel-sandvig.dk

IETS Chair
Mr. Thore Berntsson, Sweden
thore@chemeng.chalmers.se

IETS Secretariat
Ms. Lena Nordland Berg, Norway
LNB@kanenergi.no

Contact information, all delegates:

www.iea-iets.org

IEA Greenhouse Gas R&D Programme

Carbon dioxide Capture & Storage (CCS)

Harry Audus
IEA Greenhouse Gas R&D Programme

IFA Technical Committee Meeting
12-14th March 2007, Ho Chi Minh City, Vietnam

www.ieagreen.org.uk

IEA Greenhouse Gas R&D Programme

Overview of Presentation

- Introduction
- CCS Projects
- CCS Options and Economics
- Is NH_3 an 'early CCS opportunity' ?
- Summary & Conclusions

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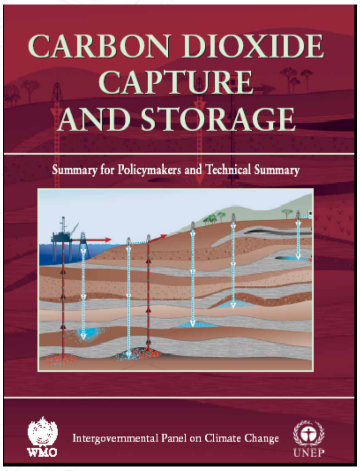
IEA Greenhouse Gas R&D Programme

CCS now an option

- Significant progress in this area
- IPCC Special Report on CO_2 capture and storage
  - CCS recognised as a mitigation option
    - National emissions accounting
    - Emissions trading



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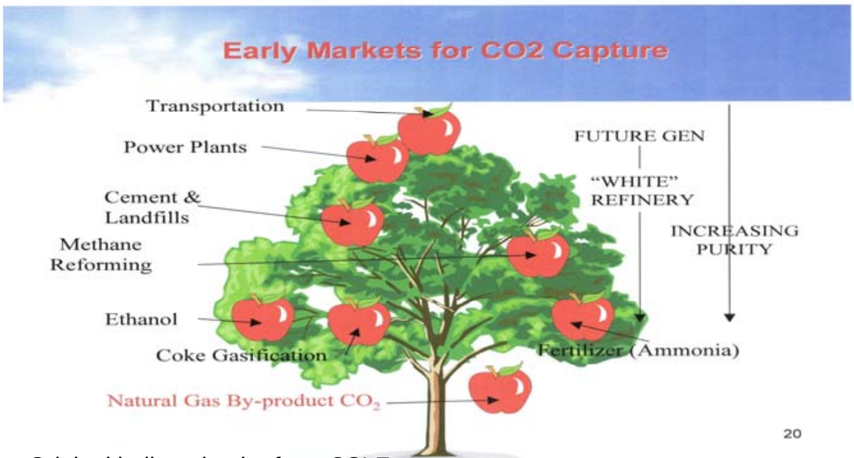
NH_3 quoted as an 'Early-Opportunity'



Original believed to be from CSLF

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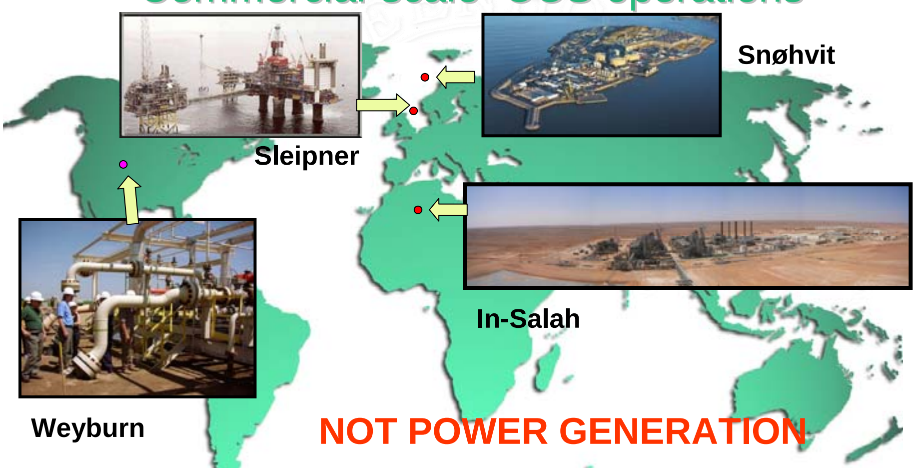
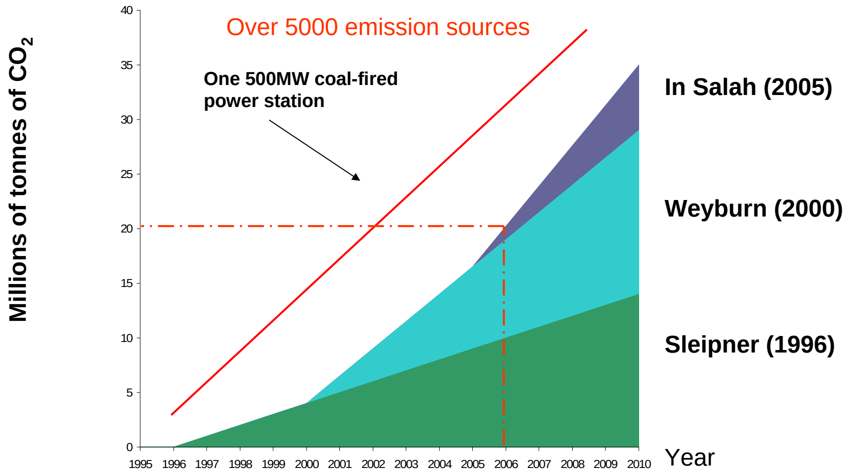
CCS Projects
&
Technology Status

Commercial-scale CCS operations



Images Courtesy of BP, Statoil, and PTRC

Monitored CO_2 Storage



Existing activities

- Most actual activity is in the oil and gas sector
  - CO_2 Capture
    - Amine scrubbing demonstrated at 1Mt/y scale in oil and gas field operations
      - Sleipner and In-Salah
    - Not power generation
  - 3100km pipelines mostly in North America transporting CO_2 for EOR operations
  - Several large projects injecting CO_2 at 1Mt/y scale
    - Sleipner and In-Salah – deep saline aquifers
    - Weyburn – oil field

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International Acceptance

- Kyoto Protocol route:
  - The Clean Development Mechanism (CDM)
  - CDM option was raised at COP11/MOP1 but a decision was deferred – for 2 years!
  - Outstanding issues from COP/MOP:
    - Permanence
    - Additionally
    - Project boundaries
    - Project leakage
- Storage under the sea bed
  - Important breakthrough in 2006 – sets precedent
  - Storage under seabed will be legal under terms of London Convention 1996 Protocol

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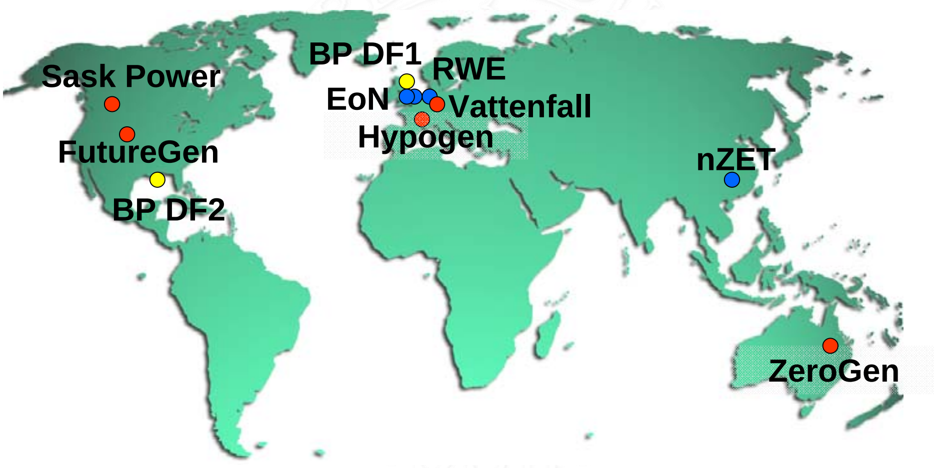
Power Sector CCS Projects



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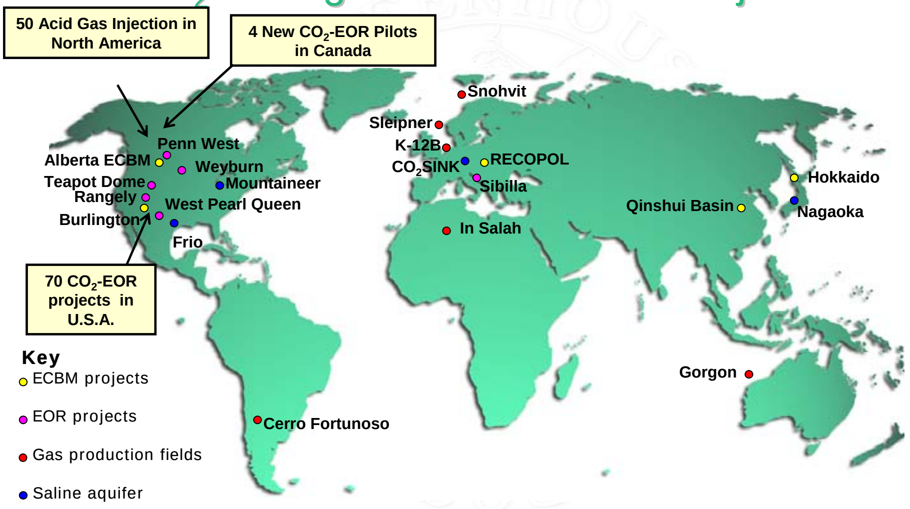
CO_2 Storage Demonstration Projects



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Near-term Implementation

- Currently we are seeing developments in the gas sector
  - CO_2 removal required to meet gas pipeline standards
  - Low incremental cost for CCS
- CO_2-EOR projects not developing as could have been expected worldwide
  - High oil prices could be expected to stimulate development of EOR projects

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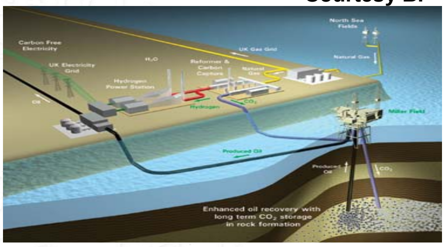
CO_2-EOR opportunities

- North Sea seen as an opportunity for CO_2-EOR
- Studies by NPD and UK DTI said that it is uneconomic
  - CO_2 supply and infrastructure requirements
- New commercial projects now being planned
  - BP DF1 development at the Miller field
  - Statoil/Shell 'Halten' development

Courtesy BP



Courtesy Shell/Statoil

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CCS Options

&

Economics

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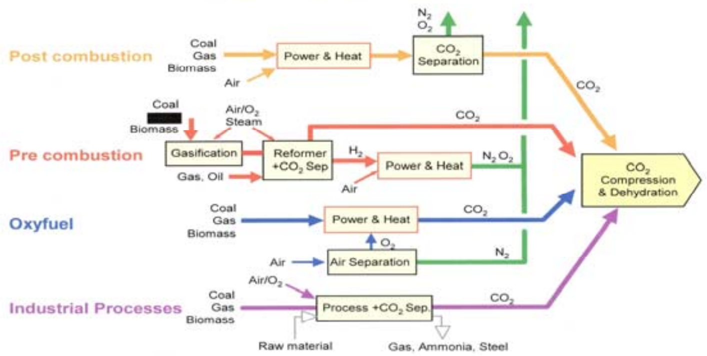
IPCC view of CO_2 Capture Opportunities

CO2 Capture



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

WMO UNEP

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IPCC view of CCS costs

CCS component costs

CCS component	*Cost range*
Capture from a power plant	15 - 75 US$/t$CO_2$ net captured
Capture from gas processing or ammonia production	5 - 55 US$/t$CO_2$ net captured
Capture from other industrial sources	25 - 115 US$/t$CO_2$ net captured
Transportation	1 - 8 US$/t$CO_2$ transported per 250km
Geological storage	0.5 - 8 US$/t$CO_2$ injected
Ocean storage	5 - 30 US$/t$CO_2$ injected
Mineral carbonation	50 - 100 US$/t$CO_2$ net mineralized

20-30% cost reduction over next 10 yrs

Monitoring/ verification: 0.1-0.3 US$/t CO2

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

WMO UNEP

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COST OF CO_2 SUPPLY

	US$/tonne CO_2
Capture	25-35
Transmission	5-10
Storage	5-10

Overall Cost of CO_2 from CCS is about 35 - 55 US$/tonne CO_2. Cost of 'early opportunity' CO_2 could be about 10-20 US$/tonne

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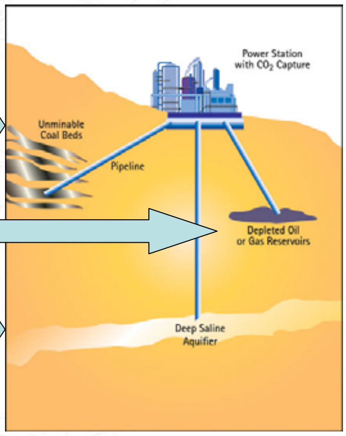
Geological storage: Options

Unminable Coal Seams
30 Gt CO_2
Able to store <2 Years of 2030 Emissions

Depleted Oil & Gas Fields
930 Gt CO_2
Able to Store 50 Years of 2030 Emissions

Deep Saline Aquifers
400-10 000 Gt CO_2
Able to store 20 - 530 Years of 2030 Emissions



Note: CO_2 Storage capacity at cost of 20 US $ per tonne of CO_2

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Is Ammonia Production an Early Opportunity ?

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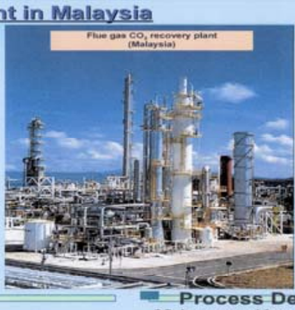
CO_2 Capture an integral part of NH_3 production

MITSUBISHI CO_2 Recovery Technology from Flue Gas

Commercial Scale Plants

1. CO2 Recovery Plant in Malaysia

Flue gas CO_2 recovery plant (Malaysia)



Plant Outline

CO2 recovery capacity	200 ton/day
Solvent	KS-1
Use of CO2	Urea production
Start of operation	October, 1999
Client	Petoronas Fertilizer (Kedah) Sdn Bhd
Location	Kedah Darul Aman, Malaysia
Flue gas source	Stream reformer flue gas

Process Description

CO_2 is recovered from flue gas of steam reformer of ammonia plant and delivered to CO_2 compressor for urea synthesis. Recovered CO_2 is used to increase urea production. The first commercial plant for flue gas CO_2 recovery using this advance technology has been operating in Malaysia since October 1999 for Urea production. Performance of process is excellent in terms of low steam consumption, very low solvent degradation and low solvent loss.

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IPCC emission factors

- tCO_2/tNH_3
  - 1.7 for modern plant - natural gas feedstock
    - 1.2 process & 0.5 heat & power
  - 2.8 for modern partial oxidation
  - 2.1 average for existing plant – natural gas
  - 3.3 average for existing plant – partial oxidation
- tCO_2/t urea
  - 0.73

IEA Greenhouse Gas R&D Programme

CO_2 balance on ammonia/urea complex

- Global figures (year 2000)
  - 155 million tonnes CO_2 surplus to urea requirements
- Modern complex (private communication)
  - 2000mtpd NH_3 and 3200mtpd urea
  - Excess CO_2 1064mtpd
  - Most of excess is flue gas not process gas

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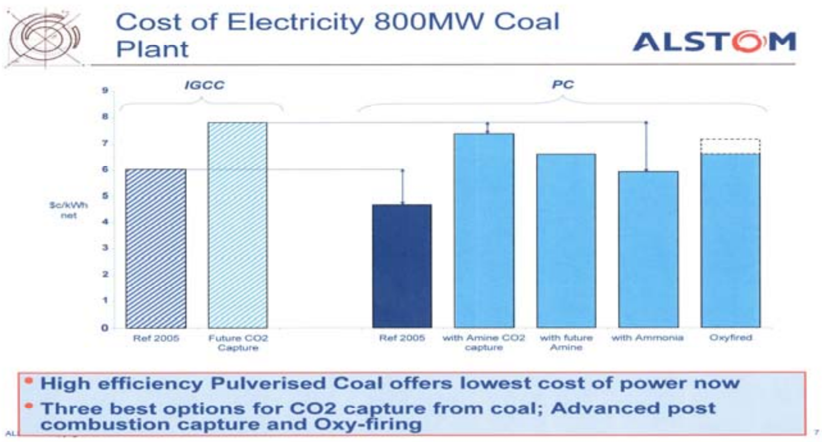
Ammonia is potentially a capture solvent



Summary and Conclusions

- CCS is now a firm policy option for CO_2 emission reduction
- Commercial-scale activities are in progress and CCS is gaining credibility
- The financial incentives are not in place
- Early opportunities could help establish CCS
- Further work would be useful to examine ways & means by which NH_3 production could be established as an early opportunity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Chevron
EniTecnologie
e-on
EPRI
ExxonMobil
REPSOL YPF
RWE
Schlumberger
STATOIL
TOTAL
VATTENFALL
* Formalities pending
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