FEEDING THE EARTH

ENERGY EFFICIENCY AND CO_2 EMISSIONS IN AMMONIA PRODUCTION

Farmers use nitrogen fertilizers to manage the fertility of their soils and provide nutrients for their crops to grow. Nitrogen fertilizers contribute to producing close to 50% of the food grown worldwide. However, their production is energy-intensive due to the ammonia synthesis from which 99 per cent of all nitrogen fertilizers are derived. Some 94% of the energy consumed by the fertilizer industry is used for ammonia synthesis and fertilizer production consumes 1.2% of the world's total energy on an annual basis. It is also one of the industry's main sources of GHG emissions. Fertilizer manufacturers are, therefore, encouraged to adopt Best Practice Technologies (BPTs), which can allow gains of up to 30% in energy efficiency. IFA conducts energy efficiency surveys and benchmarkings to monitor such progress and promote best practices.

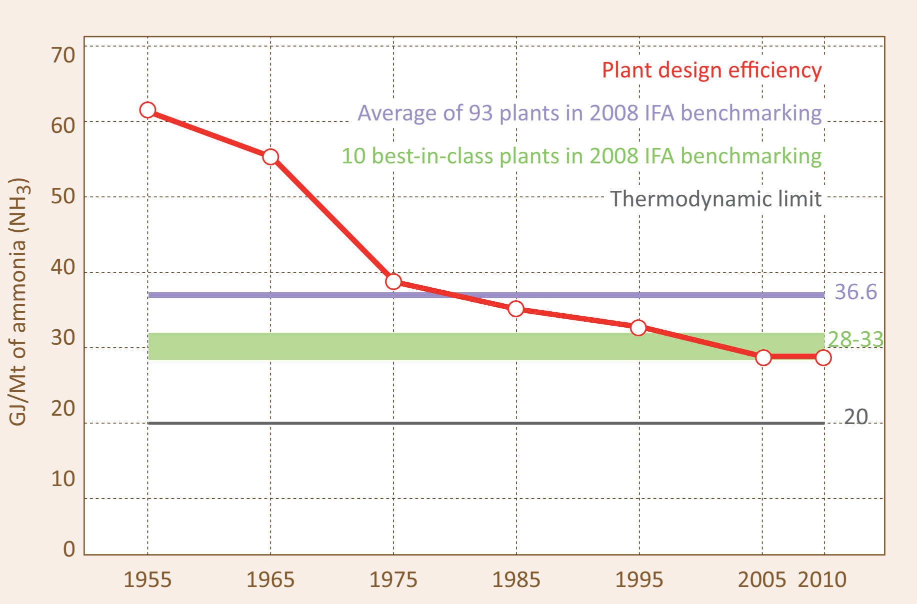
The fertilizer industry can achieve continuous improvement in the efficient use of global energy resources

Fertilizer production consumes approximately 1.2% of the world's total energy on an annual basis. Since ammonia production accounts for some 87% of the industry's total energy consumption, the fuel and feedstock used to produce ammonia are by far the main energy requirements.

For both economic and environmental reasons, natural gas is the primary hydrocarbon feedstock used in ammonia synthesis (from which almost all nitrogen fertilizers are derived). Therefore, production processes that use less natural gas per unit of ammonia output reduce manufacturing costs.

Energy efficiency in the manufacture of nitrogen-based fertilizers has significantly improved since the early 20th century. **Modern plants are rapidly approaching the theoretical minimum energy consumption for ammonia production.** Energy

Improved energy performance



consumption per unit of product is 30% less than it was four decades ago, and **the best performers are approaching the thermodynamic limit of minimum energy use**. Nevertheless, a number of plants are not yet equipped with the most advanced technologies, suggesting that global energy consumption in the industry could be significantly reduced through the adoption of new technology in the coming decades.

IFA conducts energy benchmarking surveys

To assess this potential, the International Fertilizer Industry Association (IFA) periodically conducts an industry-wide benchmarking survey which is used to estimate energy efficiency in the ammonia sector. This survey is designed to improve IFA producers' knowledge of plant performance; to assist operators in assessing plant efficiency relative to industry averages; and to help identify opportunities for continual improvement. The results are also valuable to policy makers, as they can serve as a basis for well-adapted policy analysis and implementation.

The survey gathers information on participating plants' average net energy efficiency during the year, based on the following calculation:

Net Energy Efficiency = Feed + Fuel + Other Energy / NH_3 Production

Energy includes that required to produce ammonia, as well as that used in operations, e.g. startups, shutdowns and catalyst reductions. Offsite emissions related to energy imports were also calculated in order to reflect operations' overall energy and environmental footprint more accurately.

On an annual basis, plants generally do not operate at their design energy efficiencies, which are based on continuous operation with equipment and catalysts in good condition. During certain years, they may operate at energy efficiencies approaching this level. However, energy use in plants with frequent outages, inefficient equipment or poor catalyst activity is much higher. Along with inherent differences in plant design energy efficiencies, this accounts for the wide variations in the efficiency of energy use in different plants.

Due to the variety of manufacturing methods and raw materials, no single process can be identified as a Best Practice Technology (BPT) for ammonia production. Except in China (which uses coal for almost all ammonia production), natural gas is a raw material for the vast majority of the ammonia produced worldwide.

Summary of the findings of the 2008 benchmarking survey

The 2008 IFA benchmarking survey included participation by 93 plants located in 33 countries, representing approximately one quarter (40 million tonnes) of total world ammonia production.

Average net energy efficiency in the 93 ammonia plants surveyed in 2008 was 36.6 GJ/mt NH_3 (ranging from 27.0 to 58.2 GJ/mt NH_3). The top quartile performed in the range of 28 to 33 GJ/mt NH_3. These figures are comparable to theoretical design efficiencies and are near the optimum efficiency level, for a new plant, of approximately 28-29 GJ/mt.

Overall, a plant built today uses some 30% less energy per tonne of ammonia produced than one constructed 40 years ago. Technological advances have accompanied economic changes, and restructuring has rewarded more efficient producers. In Europe and North America, where energy costs are high, average energy consumption has been drastically reduced through the revamping or closing of inefficient plants. Energy costs have also led to the construction of new state-of-the-art units in regions including North Africa and the Middle East, where there are abundant supplies of affordable natural gas.

The move towards higher capacity plants has helped to implement more efficient technologies. Capacity upgrades offer a cost-effective opportunity to install better performing technology. Comparisons of current performance against Best Practice Technologies (BPTs) indicate that there is still room for improvement. **The BPT energy requirement for the top ten percentile natural gas-based ammonia production facilities operating today is 32 GJ per tonne of ammonia (net energy consumption).** This suggests that revamping less efficient existing plants would increase energy efficiency and decrease CO_2 emissions by some 10%. The cost would be significant, sometimes exceeding USD 20 million per site.

Shifting production from poorly performing plants to new production sites with Best Available Technologies (BATs) would improve overall energy efficiency by up to 25%, with a corresponding decrease in GHG emissions of about 30%. But this is a long-term scenario, stretching over decades.

Finally, per tonne of ammonia the energy requirement for coal-based plants is significantly higher than that for natural gas-fired facilities. A coal-based unit also produces roughly 2.4 times more CO_2 per tonne of ammonia than a natural gas-based unit.

In view of the availability and relative costs of energy sources in different regions, and the policy imperative in China to achieve food security through ensuring domestic fertilizer supply, coal-based ammonia synthesis is expected to increase in coming years. Carbon Capture and Storage (CCS) could be an important means of minimizing emissions from coal-based production.

A historical perspective on ammonia synthesis

Unlike other nutrients, mineral sources of nitrogen for fertilization have been rare and largely unavailable on a global scale. For this reason, nitrogen remained the single most important limiting factor for crop production and stable food supplies until well into the 20th century. In Germany, Fritz Haber began investigating how to combine nitrogen from the atmosphere with hydrogen to form ammonia. In 1909, he discovered how to synthesize ammonia from air under high pressure and temperatures, which led him to receive the 1918 Nobel Prize in Chemistry. Carl Bosch subsequently made the breakthroughs necessary to bring the process to an industrial scale, thus ushering in the modern nitrogen fertilizer industry. In 1931, Bosch was the Nobel Chemistry Laureate for this accomplishment. Industrial nitrogen fixation is the only achievement to date to be recognized by two separate Nobel Prizes.

Responsibility of the fertilizer industry

- Enable and promote further technological advancements that will reduce energy consumption.
- Disseminate these technologies worldwide.

Recommendations to governments and multi-lateral organizations:

- Foster an enabling environment for investment in cleaner, more efficient production technologies through financial incentives and stable, long-term environmental policy.
- Facilitate the adoption of BATs through such initiatives as the creation of parallel funding for technology transfer to the developing world, capacity building, and the use of new market mechanisms such as carbon financing (i.e. Clean Development Mechanism, Joint Implementation).

What are Best Available Technologies or Techniques (BATs)?

The term "Best Available Techniques" is defined in the European Directive on Integrated Pollution Prevention and Control (IPPC) as "the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole." (96/61/EC).

The overall aim of such an integrated approach is to improve the management and control of industrial processes so as to ensure a high level of protection for the environment. Central to this approach is the general principle that operators should take all appropriate preventative measures against pollution, specifically through the application of best available techniques (BAT) enabling them to improve their environmental performance.

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

"**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 as long as they are reasonably accessible to the operator.

Table. Comparison of Best Available Technology processes for ammonia production

Energy source	Process	Energy GJ/t ammonia	CO_2 emissions t/t ammonia	GHG index*
Natural gas	Steam reforming	28	1.6	100
Naphtha	Steam reforming	35	2.5	153
Heavy fuel oil	Partial oxidation	38	3.0	188
Coal	Partial oxidation	42	3.8	238

* Using natural gas as the reference, this index shows the relative carbon intensity of different energy sources.

Source: Prince, A. (2007) "Initiating New Projects in the Ammonia Sector." Presented at the IFA Technical Committee Meeting, Workshop on Energy Efficiency and CO_2 Reduction Prospects in Ammonia Production, 12-14 March 2007, Ho Chi Minh City, Vietnam. Published online at www.fertilizer.org.

IFA Technical Committee

The IFA Technical Committee encourages the development and adoption of technology improvements that lead to greater production efficiencies and reduced emissions and discharges, as well as better health and safety standards throughout the fertilizer industry. The Committee's mission is to actively promote the development of efficient, responsible production, storage and transportation of all plant nutrients in a sustainable manner.

For more information: www.fertilizer.org/ifa/Home-Page/ABOUT-IFA/IFA-s-structure/IFA-s-committees#Tech

Feeding the Earth represents a series of issue briefs produced by the International Fertilizer Industry Association to provide current information on the role of fertilizers in sustainable agriculture and food production.

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