Technology Transfer to Reduce Climate Change Impacts from the Fertilizer Industry

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Knowledge transfer to reduce GHG emissions: lessons from the fertilizer industry

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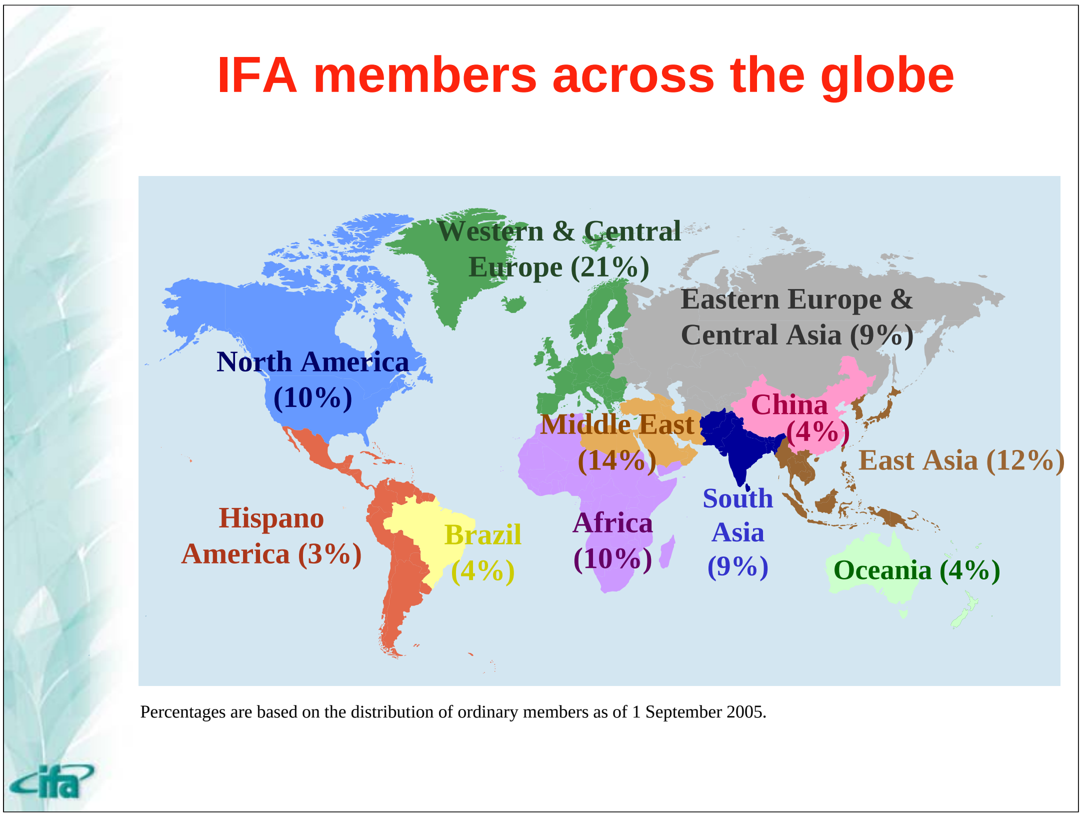
This paper was initially presented to the IPCC Expert Meeting on Industrial Technology Development, Transfer and Diffusion in Tokyo in September 2004.

As well as relying on published literature, this report benefitted from the input of the following fertilizer production technology engineering firms:
Ammonia Casale
Davy Process Technology
Jacobs Engineering Ltd
Kaltenbach Thuring

Based in Paris, France, the International Fertilizer Industry Association (IFA) is a not-for-profit organization representing the global fertilizer industry. IFA has more than 450 members in some 80 countries. About half of the membership is based in developing countries. IFA member companies represent all the activities related to the production and distribution of every type of fertilizer, their raw materials and intermediates. This includes support activities such as plant construction, technology licensing and shipping, among others. IFA's membership also includes organizations involved in agronomic research and training with regard to fertilizers.



This slide, which shows the distribution of IFA's producer members, gives a picture of how completely the fertilizer industry is scattered across the globe. The bulk of the industry is now based in developing countries. (And more Chinese members have joined since this analysis was done).

One important aspect of the fertilizer industry that should be noted is that in a number of, mostly developing, countries this industry remains partially or fully nationalized. Therefore, depending on where in the world you are, the business logic is not the same. In some places, market imperatives are dominant, whereas as policy objectives such as food security, agricultural development or economic diversification, may be the primary preoccupation elsewhere.

IFA's mission

- To improve the operating environment of the fertilizer industry in the spirit of free enterprise and fair trade.
- To collect, compile and disseminate information, and to provide a discussion forum on all aspects of the production, distribution and consumption of fertilizers, their intermediates and raw materials.
- To actively promote efficient and responsible production and use of plant nutrients to maintain and increase agricultural production worldwide in a sustainable manner.

IFA's mission is threefold. For the purposes of today's presentation, the most relevant aspects are the collection and dissemination of information about the industry and the promotion of efficient and responsible production.

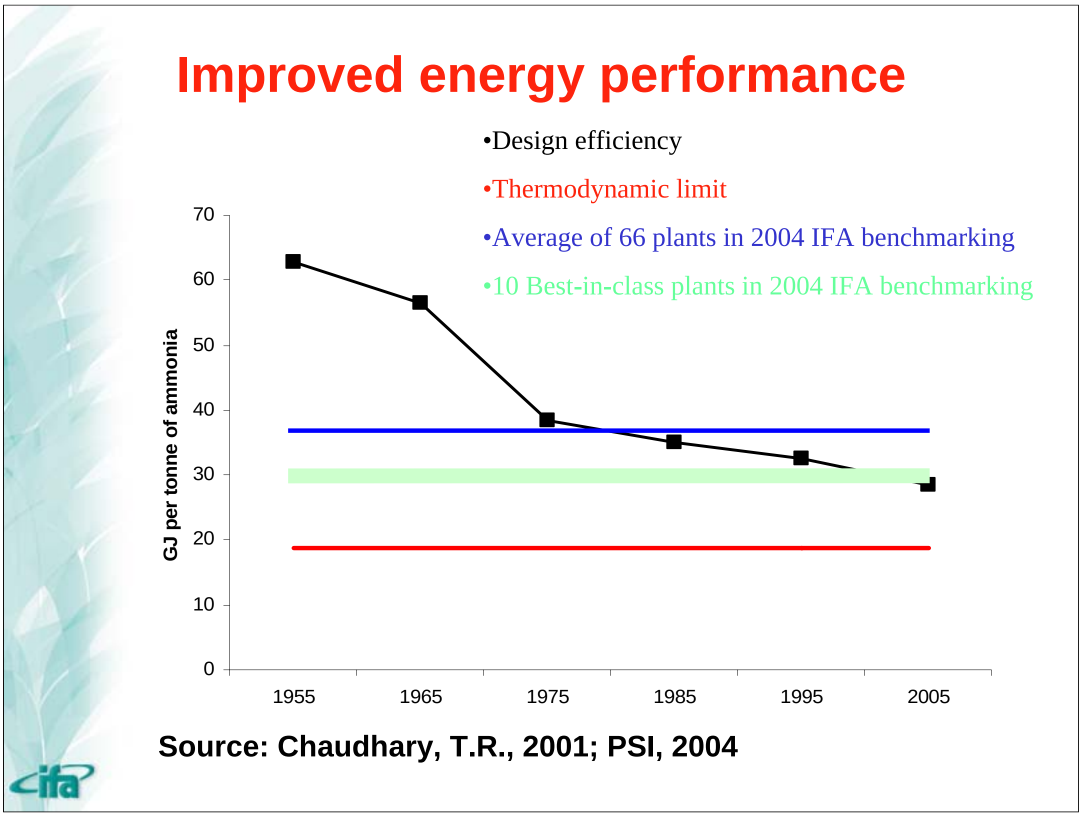
Some useful background info

- Industrial processes for capturing atmospheric nitrogen developed in early 20^{th} century
- Supplies some 40% of protein consumed by humans today
- Ammonia production = 94% energy use of entire industry
- Fertilizer production accounts for 1.2% of global energy use and GHG emissions

The simplest description of a fertilizer is a source of one of 16 or so nutrients that plants require to grow. There are several sources of these nutrients, the most common being manufactured fertilizers, animal manures, biological nitrogen fixation, green manures and recycled wastes. Until the early 20th century, the most limiting nutrient was nitrogen, which is abundant in nature (comprising some 78% of the atmosphere), but in a form that cannot be used by plants. Industrial synthesis of ammonia, was therefore a major breakthrough for reducing hunger, and was considered such a major advance for humanity that it was rewarded with not one but two Nobel prizes.

However, considerable energy is required to break the strong bond in dinitrogen. This energy intensity is related to the production of significant quantities of greenhouse gas emissions.

Because ammonia production accounts for some 94% of the fertilizer industry's energy consumption, we can use this sector as a proxy for the industry's overall performance when it comes to energy efficiency and greenhouse gas emissions.



The process flow sheet for ammonia production has changed little in more than four decades. Nonetheless, there have been dramatic improvements in fertilizer production over the years, resulting in phenomenal reductions in energy consumption per unit of ammonia.

This graphic shows that the nameplate efficiency of modern ammonia plants approaches the thermodynamic limit. In our best performing plants, there is little margin for further improvement unless there is a major technical breakthrough in how to synthesize ammonia.

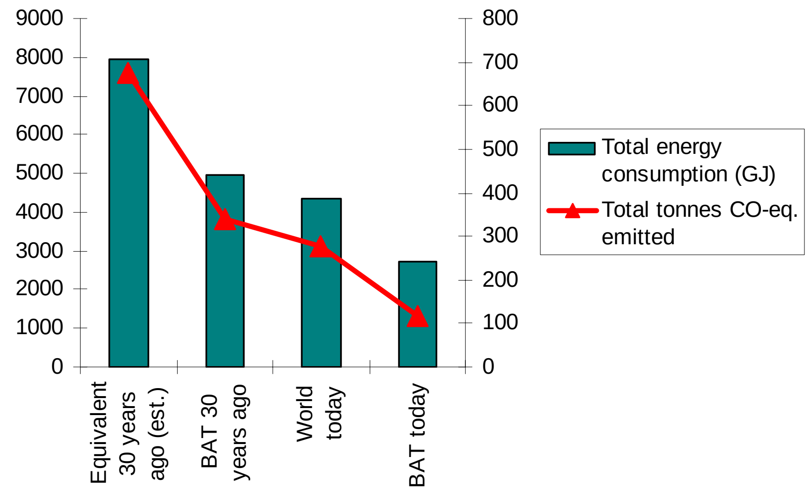
An ammonia plant built today uses some 30% less energy per tonne of ammonia than was the case thirty years ago. Technical advances have gone hand-in-hand with economic changes. Not surprisingly, restructuring has rewarded more efficient producers. Therefore, in Europe, where restructuring is virtually complete, the average energy consumption per tonne of ammonia is a further 15% below the global average because inefficient producers were those driven out of that market. The move towards higher capacity plants has also helped implement more efficient technologies. Capacity upgrades offer a cost-effective opportunity to install better performing technology.

Improved energy performance

- **An ammonia plant built in 2000 uses some 30% less energy per tonne of ammonia produced than those designed around 1970**
- **Restructuring has rewarded more efficient producers**
- **Capacity upgrades provide opportunities for revamping**

As a result, an ammonia plant built today uses some 30% less energy per tonne of ammonia than was the case thirty years ago. Technical advances have gone hand-in-hand with economic changes. Not surprisingly, restructuring has rewarded more efficient producers. Therefore, in Europe, where restructuring is virtually complete, the average energy consumption per tonne of ammonia is a further 15% below the global average because inefficient producers were those driven out of the market. The move towards higher capacity plants has also helped implement more efficient technologies. Capacity upgrades offer a cost-effective opportunity to install better performing technology.

Global energy consumption of the fertilizer industry and related CO_2 emissions



Source: Jenssen and Kongshaug, IFADATA

The bars in this graphic indicate the global energy consumption for today's ammonia production (based on 2003 figures). Were the same quantities produced using the Best Available Techniques (BAT) from 30 years ago, total energy consumption would be some 14% higher. Since most production sites were not performing to this ideal three decades ago, the energy requirements might have been as much as 83% higher using old technology and management techniques.

In contrast, a universal application of today's BATs would allow the fertilizer industry to further reduce its energy consumption by nearly 40%.

We can also estimate that the fertilizer industry today would emit at least an additional 59 Mt CO_2-equivalent per year were it not for the advanced technology that has been installed to date. The actual reduction is probably much greater: if we assume that actual industry emissions per tonne NH3 were twice as high three decades ago as under old BAT conditions, emissions from producing today's quantities of ammonia using the obsolete technology and management mix would equal more than 676 tonnes of CO_{2-}equivalent per year. The overall reduction has therefore already been about 400 tonnes of CO_2-equivalent per year, or a 57% reduction. Universal uptake of today's BATs would reduce the industry's greenhouse gas emissions by a further 161 Mt CO_2-equivalent per year or 58%.

It is therefore in the interest of producers, who would like to reduce their energy costs, as well as of society at large, which seeks to reduce greenhouse gas emissions, to foster a rapid uptake of better performing fertilizer production technology across the globe. However, this process will not be without a cost, the first of which being the significant financial investment required. As technology upgrades are often accompanied by capacity upgrades, we cold very well see massive structural readjustments in some countries, where large, efficient production facilities would displace less efficient and more labour-intensive producers. This could have painful consequences for local economies and would require social policy responses. It could also influence other policy objectives; for example, a relatively poor country that became dependent on fertilizer imports might find it more difficult to ensure food security.

Global energy consumption of the fertilizer industry

	GJ / yr	% of today
Est. 30 years ago	7925	183
BAT 30 years ago	4953	114
World today	4342	100
BAT today	2714	63

Source: Jenssen and Kongshaug, IFADATA

This table indicates the global energy consumption for today's ammonia production. Were the same quantities produced using the Best Available Techniques (BAT) from 30 years ago, energy consumption would be some 14% higher. In contrast, the bottom line shows that a universal application of today's BATs would allow the fertilizer industry to reduce its energy consumption by nearly 40%. This would, in turn, reduce the industry's greenhouse gas emissions by 161 Mt CO_2-equivalent per year or 58%. All this without further technical innovation.

Global CO_2 Savings of the fertilizer industry

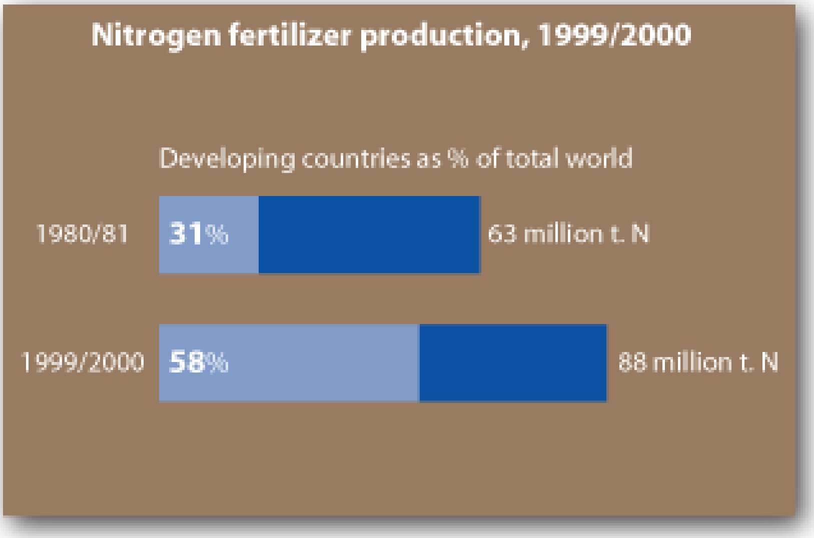
	CO_2-eq. / yr	Emissions as % of today
Est. 30 years ago	*676*	183
BAT 30 years ago	*338*	121
World today	279	100
BAT today	118	42

Source: Jenssen and Kongshaug

Using these same ratios, we can also estimate that the fertilizer industry today would emit at least an additional 59 Mt CO_2-equivalent per year were it not for the advanced technology that has been installed to date. The actual reduction is probably much greater: as today's industry averages well above the BAT level, it is likely that the same was true three decades ago. If we assume that the industry was performing twice as high as the BAT, emissions at that time would have equalled more than 676 tonnes of CO_{2}-equivalent per year. The overall reduction would therefore already be about 400 tonnes of CO_2-equivalent per year, or a 57% reduction.

It is in the interest of producers, who would like to reduce their energy costs, as well as society at large, which seeks to reduce greenhouse gas emissions, to foster a rapid uptake of better performing fertilizer production technology across the globe. However, this process will not be without a cost. As technology upgrades are often accompanied by capacity upgrades, we may very well see massive structural readjustments, where large, efficient production facilities would displace less efficient producers. This could have painful consequences for local economies and would require social policy responses. It could also influence other policy objectives; for example, a relatively poor country that became dependent on fertilizer imports might find it more difficult to ensure food security.

New geographical structure



The improvements that have been made by our industry are all the more impressive when put in the context of the geographical shift in the global fertilizer industry during recent decades. A number of factors have driven this sector's shift from Europe and North America towards developing countries:

•Identification of fertilizer as a strategic product to support national food security strategies

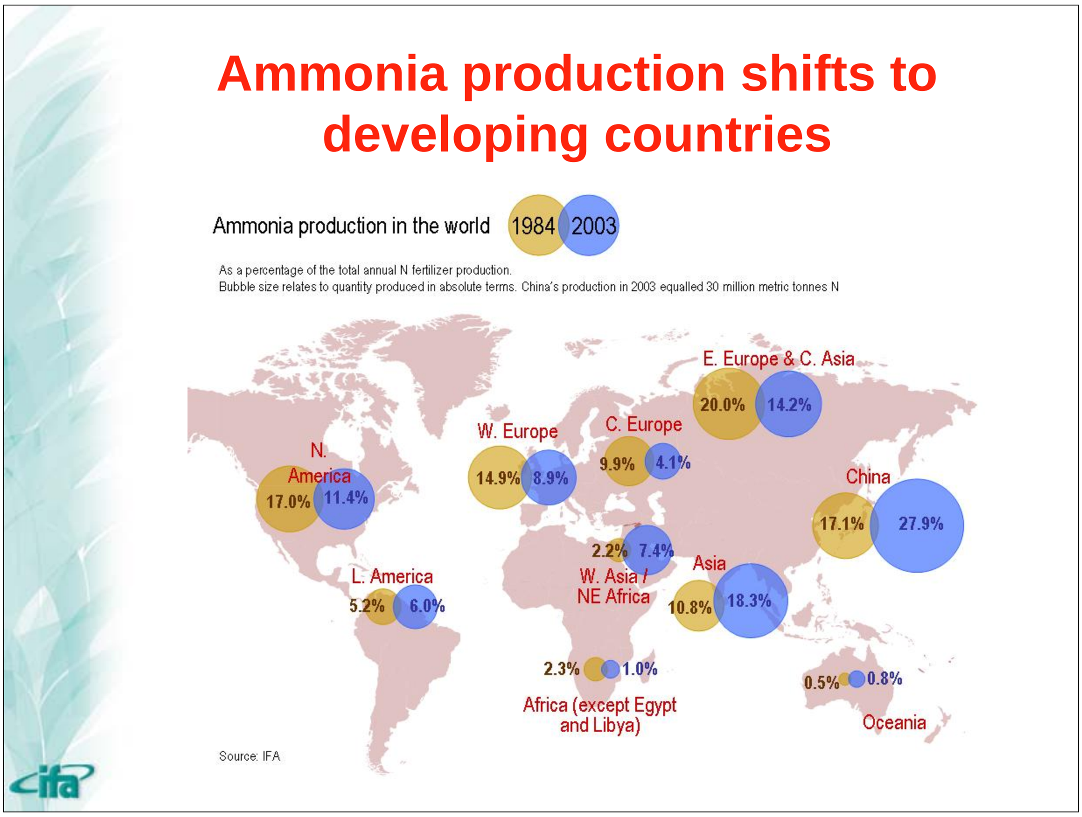
•Desire of developing countries to diversify economic production by selling value-added products as opposed to raw materials

•Relative abundance of affordable supplies of raw materials in developing countries

•Proximity of rapid agricultural development (growing markets) to fertilizer raw materials

•The double impact in the 1970s of the oil crises and more stringent environmental regulations, which together squeezed inefficient producers in industrialized countries.

Developing countries and countries in transition now account for more than two-thirds of global nitrogen fertilizer production. Annex 1 countries only account for 31% of global ammonia production.



This image shows the shift, with a focus on ammonia.

Given this shift towards less experienced producers, the question can be asked how the improvements in technology have occurred, defying received wisdom that shifting production to less developed countries automatically means compromising environmental protection.

The short answer is that new facilities in developing countries often use technology that is among the best, if not absolutely state-of-the-art, whereas existing facilities in the mature markets can at best retrofit existing sites.

Implementing new technology

- **Analysis and decision-making**
- **Execution**
- **Follow-up**

To begin this discussion, it is useful to review HOW fertilizer companies put new technology in place.

Regardless of whether the project is a greenfield plant or a revamp, every project can be broken down into three principal stages: analysis and decision-making; execution and follow-up.

It should be noted that the nitrogen fertilizer industry suffers from an endemic excess of capacity globally. This means that profit margins are very low and competition for markets is fierce. This would normally slow down the development of new facilities, thus reducing the opportunities for putting improved technologies into production.

However, many producers still make the decision to construct new facilities or expand existing ones, in part because there is little danger that the basic chemical processes or products will become obsolete. This renewal process creates natural opportunities for driving the energy efficiency of the industry ever upwards as more recent, better-performing technology is generally more cost-effective over the facility's lifespan.

Analysis and decision-making

- **Conceptual study**
- **Feasibility study**

The conceptual study will give an overview of the project's potential. This includes reviewing the company's existing product line to look for synergies. For example, urea facilities are always located together with ammonia plants because waste CO_2 from ammonia production serves as an input for urea. Incidentally, this means that the life-cycle production of greenhouse gases may vary significantly from what can be assumed at any one stage of production. As a matter of fact, life-cycle analyses carried out at the research centre of what was then Norsk Hydro (now Yara) indicates that the capture of energy and carbon through enhanced crop output more than compensates (by several factors) for the energy used and CO_2 emitted during the production, transport and application of nitrogen fertilizers.

The appropriate capacity will also be determined at this stage. This depends on the limits of the technology considered and market conditions.

The feasibility study also looks at other details, including potential suppliers and contractors, possible environmental impacts and alleviation measures. The latter will be relevant for regulatory and bureaucratic formalities as well as affecting the economic assessment.

Factors enabling technology transfer and implementation

- **A predictable regulatory framework**
- **Accessible documentation on the real-life performance of new technologies that may be considered risky until proven**
- **Ability to secure financing**

A number of factors will smoothen this process and increase the chances of technology transfer taking place. These include a predictable regulatory framework, documentation on the performance of newer technologies and available financing.

Execution

- Bidding process
- Project management
- Basic engineering
- Detail engineering
- Procurement
- Construction
- Commissioning

Of the stages of execution shown here, the two phases of engineering are the most relevant for our discussion today. Basic engineering is effectively the technology transfer package, put into a form that can be implemented by the detail engineering contractor. There is a growing trend for project engineering to be carried out at multiple sites, a practice greatly facilitated by the evolution of information and communication technologies.

Multi-site engineering

BENEFITS

- **Reduced costs**
- **Longer project days (multiple time zones)**

DRAWBACKS

- **Looser hierarchical structure may reduce control**
- **Increased possibility of misunderstanding**
- **Technical conversion errors (e.g. software)**

Multi-site engineering can reduce the overall duration of the project by lengthening working days. For example, a technology provider in the Netherlands can send instructions at the end of Day 1, which are considered by the detail team in China on Day 2. At the end of Day 2, the Chinese team sends its questions back to the Netherlands. The answers may then be examined during Day 2 in the Netherlands, which starts when the Chinese team goes off duty. At least one full calendar day has been saved.

Salary differentials between countries may also help reduce costs. It is increasingly preferred to use qualified detail engineers from the receiving country than to import expensive expatriate engineers. This also fosters the development of a skilled workforce in the receiving countries and could eventually lead to the transfer of most basic engineering capacity to developing countries. This is positive for the overall development level of the receiving country, but may eventually eliminate the salary differential and thus cost savings.

Although there are benefits to multi-site engineering, this practice is not without risks. Chains of command are looser in multi-site projects, which can slow down responsiveness. Furthermore, distance, language and cultures (both national and working cultures) can all lead to misunderstandings. Finally, the use of different equipment or software can induce conversion errors.

Follow-up

- **Operation**
- **Upkeep**
- **Feedback loops**

One of the most overlooked aspects of whether technology transfer is successful or not is follow-up. Building the technology is one thing, but operating it properly is another. Optimal operation necessitates that the local workforce be adequately trained and understand the consequences of poor management.

Upkeep determines whether the technology CAN continue to operate optimally, assuming good management. As opposed to technology transfer, which is a one-off investment, knowledge transfer to ensure optimal operation is a continuous process and requires resources on an ongoing basis, if for no other reason than the fact that there is turnover in the workforce.

Finally feedback from tests and operations allows the technology and installation to be improved and helps to avoid delays and costly maintenance shutdowns. It also fosters better implementation of similar technology packages in the future.

The follow-up stage depends heavily on the human element. Technology is important, but people are even more so as technology only provides potential that must be realized by operation and management.

Drivers for Technology Transfer

- **Reducing costs through greater energy efficiency**
- **National food security strategies**
- **National economic development strategies**
- **Corporate-level business plans**
- **Environmental legislation license to operate**

At this point, we can extract out some of the basic elements that have driven technology transfer in the fertilizer industry. The relative weight of each factor depends on a number of things, not least of which is whether the company operates in the private or public sector.

Reducing costs through greater energy efficiency is a universal motivation for technology transfer, particularly in the case of revamps.

Policy goals such as food security and economic diversification may also play a role.

Corporate business plans can influence technology transfer, especially where a capacity upgrade provides a window of opportunity for a technical refitting at reduced cost.

Finally, in some countries, environmental legislation and concerns over maintaining a societal license to operate have created an imperative for installing better performing technology.

Factors Influencing the Success of Technology and Knowledge Transfer

- **Good match of technology to local conditions**
- **Economic considerations**
- **Synergy with other modifications**
- **Qualifications of project team and operators**
- **Number and integration of engineering teams**
- **Compatibility of software and equipment**

Once technology transfer is undertaken, there are a number of factors that influence its success rate. In the case of technology put in place to improve energy efficiency, success cannot be measured on the day of the ribbon-cutting ceremony. It is the performance of the site over time that will determine whether the investment was worthwhile from the perspective of economic, environmental and other objectives.

Some of the factors that will play a role are

•How well the technology package conforms to local conditions

•Economic considerations

•Synergy of the technical revamp with other modifications (such as capacity upgrades)

•Qualifications of the teams that construct and operate the facility

•The number and integration of engineering teams

•The compatibility of software and other crucial equipment

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Factors Influencing the Success of Technology and Knowledge Transfer (cont'd)

- **Centralized reference data files**
- **Capital development and staff training**
- **Capacity of in-house engineers to solve operational problems**
- **Competency of engineers in receiving country**

[LIST CONTINUES]

•Centralized reference data files which can help prevent the introduction of errors through miscopying of data

•Investments in capital development and staff training

•The capacity of in-house engineers to solve running problems

•The overall competency of engineers in the reciopient country.

For more information

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