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THE FERTILISER INDUSTRY AND ITS ENERGY USE

Prospects for the Dutch Energy Intensive Industry

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Framework of the study

This report results from the project ‘The future of the Dutch Energy Intensive Industry’, ECN project 7.7089.

Abstract

This report discusses the present and future situation of the Dutch fertiliser industry. Process technology, markets, cost structure and environmental impact are described. Several future developments are analysed, including foreign competitors, agricultural and environmental policy and new technologies. The natural gas based ammonia production will remain at the core of fertiliser industry within the coming decades. The position of the Dutch fertiliser industry is relatively strong because of proximity to markets. Decreasing demand of fertiliser is compensated by demand for plastic production. Energy and feedstock efficiency can be improved. Overall a modest decrease of energy consumption is expected.

CONTENT

GLOSSARY

AN	Ammonium Nitrate (fertiliser, intermediate product)
ATR	Autothermal reforming
CAN	Calcium ammonium nitrate, (fertiliser)
CAP	Common Agricultural Policy (within the EU)
CBS	Dutch Statistics
CEE	Central and Eastern European Countries
CHP	Combined Heat and Power generation (cogeneration)
CIS	Com. of Independent States (former Sowjet Union)
CO_2	Carbondioxide, the most important greenhouse gas
Dfl	Dutch florin (guilder)
DSM	Dutch State Mines (fertiliser producer)
ECN	Netherlands Energy Research Foundation
ECU	European Currency Unit
EFMA	European Fertiliser Manufacturers Association
EFTA	European Free Trade Association (Western non-EU countries)
EU	European Union
FAO	United Nations Food and Agricultural Organisation
FSU	Former Soviet Union
GATT	General Agreement on Tariffs and Trade
GHG	Greenhouse gases
GJ	Gigajoule (10^9 Joule)
IPCC	Intergovernmental Panel on Climate Change
K	Potassium
KCl	Potassium chloride, raw material for potassium fertiliser
kton	kiloton (10^6 kilogram)
LEI	Netherlands Agricultural Economic Institute
Mton	Megaton (10^9 kilogram)
N	Nitrogen
NEEDIS	Netherlands National Energy Efficiency Data Information System
NEH	Netherlands Energy Statistics
N_2O	Nitrous Oxide (powerful greenhouse gas)
NPK	Mixed Nitrogen phosphorus and potassium fertiliser
OECD	Organisation of Economic Co-operation and Development
P	Phosphorus
P_2O_5	Phosphorus pentoxide (fertiliser intermediate)
PJ	Petajoule (10^{15} Joule)
PS	Production Statistics
SEC	Specific Energy Consumption (energy per unit of production)
SBI	Standard industrial classification (SIC)
VKP	Dutch Association of Fertiliser Producers

1. INTRODUCTION

1.1 Background and purpose

This study results from the project ‘The Future of the Dutch Energy Intensive Industry'. Within this project, future developments in energy intensive industry sectors are analysed. Because these industries are important energy consumers, they determine to a considerable extent the future energy consumption of the Netherlands. Recently, a modest economic upswing in the Netherlands in which basic chemicals and basic metals took part, disrupted national energy forecasts and CO_2 reduction prospects. Therefore, studying the future of the energy intensive industry is important for describing and forecasting future national energy consumption.

The general background of industrial allocation and energy consumption is discussed in a separate volume of this study. The energy consumption in the petrochemical and basic metal industries is already analysed. [1,2] This volume focuses on the fertiliser industry. This includes processes which make nitrogen, phosphorus and potassium based fertilisers out of natural gas, phosphate ore and potassiumchloride. The fertiliser industry is an important sector from an energy consumption point of view, mainly because of the nitrogen based fertiliser production. Table 1.1 lists the industrial primary industry consumption.

Table 1.1 *Industrial primary energy and feedstock consumption, average early nineties*[1]

	Energy	Feedstock	Total	
	[PJ/year]	[PJ/year]	[PJ/year]	[%]
Petrochemicals	160	200	360	31
Refineries	160	-	160	14
Basic metals	107	45	152	13
Fertilisers	53	75	128	11
Food	114	-	114	10
Inorganic chemicals	34	28	62	6
Paper & printing	48	-	48	4
Building materials	43	-	43	4
Other	70	20	90	7
Total	801	338	1162	100

[1] Assuming 40% efficiency for electricity production.

Table 1.1 shows that the fertiliser industry represents 11% of the total industrial primary energy and feedstock consumption. It also shows that the main use of primary energy carriers in this industry is not the energetic use but the use as feedstock (feedstock refers to a selection of processes where energy carriers are applied as raw material or for specific chemical reactions). This study analyses factors that are vital to the future of the Dutch fertiliser industry and its energy use, in absolute levels and composition. Both the supply and demand side and the developments in the next two decades (period 2000-2020) are discussed.

This study will be used as a building block for studies on energy and the environment. These studies include national energy consumption forecasts and scenarios, analysis of energy policy instruments, studies on interactions of the energy and the materials system and assessment studies of future R&D activities. Therefore, this study serves no specific policy issue and is intended to discuss all factors that are considered to be important for the future developments within this industrial sector.

1.2 Key questions and method

The following questions concerning the future of the Dutch fertiliser industry serve as a guideline for the analysis:
- How does the fertiliser industry deal with competitive production abroad?
- Which technology developments are expected in fertiliser industry and how do these affect the energy consumption?
- Are there major developments on the market for fertilisers regarding alternative production and feedstock that affect the position of the fertiliser industry and its energy consumption?
- What is the effect of environmental, economic and agricultural policy strategies regarding the fertiliser industry, and what are the strategy options and strategy consequences?

To answer the questions put above, it is necessary to study the cost structure of the fertiliser industry, as well as factors of a less quantitative nature. The Dutch situation is the reference case. For many issues no univocal data could be found, moreover, assumptions had to be made e.g. for long-term averages in a volatile market. Starting from the national reference situation, comparisons can be made in a systematic way for different settings. These settings include:
- alternative locations with a different energy and raw material supply,
- expected process technology developments in the next 20 years,
- substantially higher energy prices or energy taxes evolving from changes in policies at home or abroad,

Naturally these settings can coincide and interact. Therefore, the presented settings and calculations are to be regarded as the initial situation in which a certain development occurs.

Several studies have been made about this sector concerning energy, economy, technology and CO_2 reduction. Policy studies are made on taxes [3] and on voluntary agreements [4]. This study contains an extensive review of the EU fertiliser industry, with an outlook for the next decades and an analysis of the competitiveness. An analysis of the energy use in the fertiliser industry is given by NEEDIS [5]. The potential for energy-savings in the production processes is also analysed by Utrecht University [14], answering the energy related questions from a technical point of view. Economic and financial data and analyses were found by the CBS (Central Bureau of Statistics) [6,7] and the LEI (Agricultural Economic Institute) [8]. This present study tries to find a new viewpoint by integrating energy and process technology dynamics with market developments, competition and policy.

1.3 Structure of the Study

This case study can be divided into an analysis of the current situation (Chapter 2-6) and alternatives for production and energy consumption of the Dutch fertiliser industry within their Western European context (Chapter 7-11). Chapter 2 analyses the current fertiliser industry production structure and the historical developments. Chapter 3 discusses current fertiliser production technology. Chapter 4 analyses markets for Dutch fertilisers and their competition. Chapter 5 analyses the fertiliser industry economics in the Netherlands in terms of costs and revenues. Chapter 6 provides information on institutional factors that influence industrial activities. Most important are the Common Agricultural Policy (CAP) from the EU and the environmental legislation concerning acidification of the soil and groundwater and concerning greenhouse gases. Chapter 7 deals with technological developments, Chapter 8 investigates present and potential competition. In Chapter 9 an analysis is made comparing cost structures. Finally, in Chapter 10 a long-term energy demand forecast is presented, and in Chapter 11 conclusions are drawn.

2. THE PRESENT DUTCH FERTILISER INDUSTRY

This report deals with the Dutch fertiliser production. In the national statistics, the national industry is divided into groups of companies with similar main products. The fertiliser industry is one group of the chemical sector. The main products are Nitrogen, Phosphor and Potassium based fertilisers. From an energetic and quantitative point of view the Nitrogen-based industry is by far the most important. Therefore this study will focus on the Nitrogen-based fertilisers. In Chapter 4 the importance of N-based fertilisers on the demand side will be shown. In this chapter the present industry will be described. The description starts with an overview of the energy use of the fertiliser industry. Furthermore, the industry will be analysed from a historic and a strategic point of view. At the end some remarks will be made on the energy efficiency of the fertiliser industry.

2.1 Energy Use

Energy data are available from the CBS for 1996 [9] including figures on fuel conversion, CHP (cogeneration of heat and power) and non-energetic purposes. Table 2.1 gives a summary of these figures. These figures show the in- and output of the fertiliser plants. It shows that the Dutch fertiliser industry depends on the use of natural gas. The share of non energetic use (feedstock for N-based fertilisers) is over 70%, and the use of CHP is limited.

Table 2.1 *Energy balance of the fertiliser industry, 1996 [9]*

Energy carrier	Apparent energy consumption [PJ]	Conversions Input CHP [PJ]	Conversions Output CHP [PJ]	Final Use Total [PJ]	Final Use Non-energetic [PJ]
	1	2	3	4=1-2+3	
Natural gas	104.2	7.3	-	96.9	71.7
Electricity	1.5	0.1	2.5	3.9	
Steam/hot water	4.3	1.2	0.5	3.6	
Total fuels	110.2	8.6	3.0	104.7	71.7

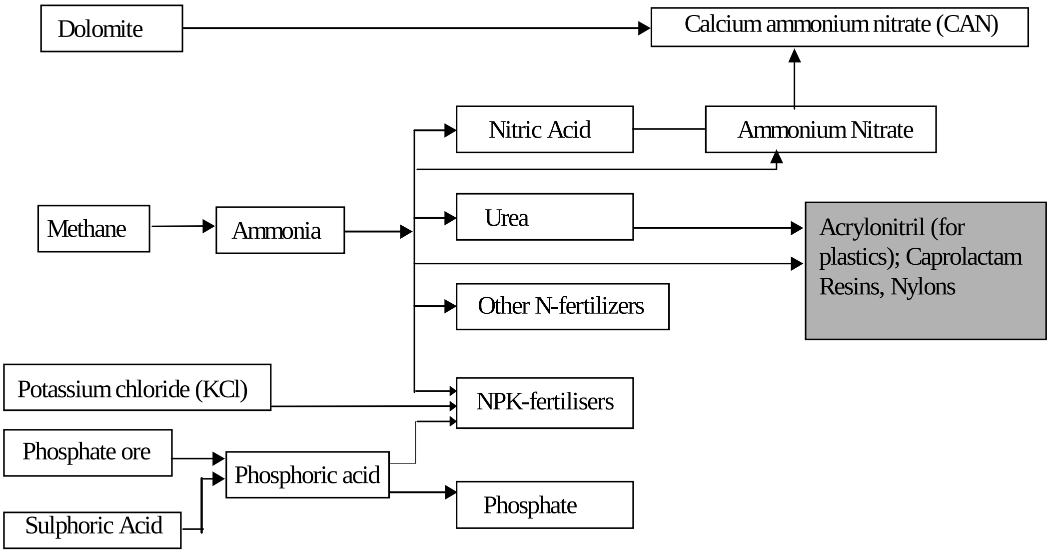
Table 2.2 shows that over 90% of the energy used in the fertiliser industry is used for the ammonia production. This production is concentrated on 3 out of 10 fertiliser industries. This study is therefore focused on these industries: DSM in Geleen, Hydro Agri in Sluiskil and Kemira in Rozenburg/Pernis. Table 2.2 also shows the importance of the nitrogen based fertilisers in relation to phosphorus and potassium based fertilisers. These are mainly used in mixtures.

Table 2.2 *Energy use in the fertiliser industry (1986) [5]*

Product	Production [kton]	Energy use [PJ]
Ammonia	2,621	93.0
Nitric Acid	2,100	0.2
Urea	833	2.5
Calcium Ammonium Nitrate (CAN)	1,753	0.4
Other (e.g. NPK-fertilisers)	6,667	4.0
Total		100.2

2.2 Products and processes

The products of the fertiliser industry are fertilisers based on nitrogen, phosphorus and potassium. The nitrogen based fertilisers were made out of ammonia, which is produced out of natural gas. The ammonia synthesis is in the core of the fertiliser industry, as is shown in Figure 2.1.



Note: The blocks on the left represent the feedstocks, the grey block represents use of urea and ammonia outside the fertiliser industry.

Figure 2.1 *Product survey of the fertiliser industry*

The main process for ammonia production worldwide is the synthesis based on steam reforming with natural gas as feedstock. Five to ten percent of the world production is based on oil or coal where mostly partial oxidation is used. The advantage of this method is the high range of hydrocarbons which can be used. Disadvantage is the high energy consumption. 80% of the world ammonia production and 100% of the Dutch ammonia production is based on steam reforming out of natural gas. Therefore this study initially will focus on this process.

As shown in Figure 2.1 the ammonia production is the first step in all N-based fertiliser production processes. It also shows that ammonia is used for other then fertiliser purposes. Ammonia for other applications is produced in the fertiliser industry installations. For this reason the whole ammonia production is considered as part of the fertiliser industry in the energy statistics. This should be noted when the fertiliser production is compared with the energy consumption of the industry.

The ammonia production was separately monitored in the CBS production statistics until a few years ago [6]. For this moment an important data source for Dutch ammonia production is the emission registration. Comparison with the LEI (Agricultural Economic Institute) fertiliser statistics [8], giving a survey of the ammonia production for fertilisers, shows about 30% of the ammonia is used for other purposes. A survey of the capacities for the three ammonia production locations is given in Table 2.3 [14]. Production and energy use figures for all plants in the Netherlands were also found. It is important to notice the differences in year of construction between the plants. The oldest plants have an age of approximately 30 years. This can still be extended by revamping and replacing parts susceptible to wear and creep.

Table 2.3 *Survey of the ammonia production capacity in the Netherlands 1993*

Company	Place	Capacity [ton/day]	Year of construction
DSM	Geleen	1360	1971
		1360	1983
Kemira Oy	Rozenburg	1500	1967
	Pernis	900	1967 (closed 1993)
Hydro Agri	Sluiskil	900	1973
		1500	1984
		1750	1987

Assuming output would be only 85% of capacity, present annual production is still in the range of 2.6 Mton. On stream efficiencies are normally above 90% and plants are running at full capacity.

Fertiliser production, trade and sales are summarised in Table 2.4, based on the LEI annual fertiliser statistics. Nitrogen is dominant, and CAN takes an important position, especially in domestic consumption. It also shows that production in the Netherlands is predominantly exported, in fact the Netherlands is the largest N-fertiliser producer and exporter of the EU.

Table 2.4 *Production, imports, exports and sales of N-fertilisers in the Netherlands, [kton N, 1994/1995] [8]*

	Production	Imports	Exports	Sales
Ammonium Sulphate	129.2	0.4	134.3	4.7
Calcium Ammonium Nitrate	816.8	96.1	597.1	288.0
Nitrogen Magnesia	63.7	10.7	26.7	45.3
Urea	311.4	1.0	278.1	1.8
Mixed Nitrogen fertilisers	143.5	0.1	158.0	0.8
Mono-Ammonium Phosphate	13.4	0.1	9.4	0.1
Di-Ammonium Phosphate	13.0	0.8	7.2	6.4
Liquid Ammonia	1.4	-	-	1.4
Ammonium Nitrate	150.2	4.5	156.0	0.5
NPK-, NP- and NK-fertilisers	143.0	21.8	109.1	52.3
Nitrogen, Total N	1,785.4	144.2	1,480.0	405.8
Phosphate, Total P_2O_5	*600*[1]	*100*[1]	*600*[1]	*61.8*
Potassium, Total K_2O	-	*300*[1]	*200*[1]	*68.5*
Magnesia, Total Mg_2O	*172.1*	*37.9*	*116.5*	*84.7*
Lime and others[2]	*172.6*	*31.8*	*24.9*	*171.1*

[1] rough estimates [7, 42].

[2] in terms of acid neutralising potential.

The phosphorus and potassium based fertiliser industry are of minor importance from an energy point of view. Within the fertiliser sector the annual phosphate fertiliser production is roughly estimated at 600 kton P_2O_5. Production of phosphoric acid only takes place at Kemira in Pernis and Hydro Agri in Vlaardingen [5]. The phosphate ore is imported and dissolved in sulphuric acid. The main by-product is gypsum. Superphosphate is produced by mixing phosphate ores and sulphuric or phosphoric acid without removing gypsum and pollutants.

Superphosphate is almost completely used in NPK-fertilisers (75%) and triplephosphate (20%). Potassium is only used for the mixtures with nitrogen and phosphorus. There is no potassium production plant in the Netherlands, it is imported as potassiumchloride from Germany and from Israel. Energy use related to these processes is limited as already indicated and will not be analysed in more detail in this study.

2.3 History of the Dutch fertiliser industry

In the middle of the 19th century phosphorus was the first component that was discovered to be an artificial source of nutrients, which stimulated the growth of the crops. Some small local (demand) orientated companies started on several places in the Netherlands. The possibility of fertilising with nitrogen was known, but without a synthesis process to create useful nitrogen for agricultural purposes, only ammonia separated out of the wastewater of syngas plants could be used. Until the 1920's this was only a minor industry.

Table 2.5 *Location and construction of major fertiliser production units [1929-1996]*

Based		
1907	Amsterdam	Phosphorus/Potassium
1910-1921	Pernis, Sas van Gent, Vlaardingen	Phosphorus
1929-1930	Velzen, Geleen, Sluiskil, Ijmuiden	Nitrogen
1960-1968	Geleen, Rozenburg, Sluiskil,	Nitrogen
1984-1988	Sluiskil, Geleen	Nitrogen
1996	Sluiskil	Nitrogen

An important development in the fertiliser industry was the introduction of the ammonia synthesis out of syngas by Haber and Bosch [10]. This process was developed between 1903 and 1915. The reason for the fast development of the ammonia synthesis in Germany was the need for ammonia for the military industry during the first world war. The German patent expired in 1929, and in this year the first ammonia plant in the Netherlands was built. The first fertiliser plants were located in the vicinity of coke plants, for example in Sluiskil, Geleen and IJmuiden. The cokegas (containing about 50% hydrogen) was a cheap feedstock for the ammonia production. After World War II the coke gas became an important fuel for heating buildings. Some fertiliser industries started their own production of cokegas out of coke [10].

Most Dutch fertiliser industry substituted the coke by natural gas between 1965 and 1968 when natural gas was introduced. Within a few years the whole industry was based on natural gas, several large plants were built (Table 2.5), for example the DSM plant in Geleen. The ammonia produced by DSM was mainly used as feedstock for several basic chemicals like acrylonitril and caprolactam which in turn are feedstocks for resin production. The fast growing consumption of fertilisers in the 1970's stimulated the building of new plants. In 1984 another wave of new plants started their production which resulted in overcapacity. This effect was magnified by the drop of fertiliser use in the Netherlands (see 4.1).

New environmental and agricultural policies resulted in a change in agricultural practice. The main reason for this change was the growing interest in environmental issues, most important the water pollution as a result of the high levels of nutrient use in agriculture. Another reason was the European policy to decrease surpluses in agricultural production. Increasing imports from Eastern Europe industry reduced the West European fertiliser industry further during the first half of the 90's. The overcapacity and heavy competition resulted in a wave of mergers and acquisitions. On this moment five international orientated companies dominate the European market. The two largest, Norsk Hydro (Norway) and Kemira (Finland) operate two major fertiliser production plants in the Netherlands (see Table 2.3).

2.4 Importance of location and infrastructure

More insight in the historical factors influencing location choice will help to make proper forecasts for the future of the fertiliser industry. These factors are availability of (cheap) feedstock, good infrastructure, integration in other processes and proximity to consumer markets.

Feedstock
In most cases it is easier and cheaper to transport fertilisers than to transport feedstocks like cokesgas or natural gas. The main locations of the Dutch fertiliser industry were chosen in the 1930's. In these years the main feedstock was syngas from coke plants. For these plants obviously the feedstock was the main reason for location choices. On a world scale nowadays this factor is still of main importance. An example is the Middle East. The fertiliser industry shows great interest in starting fertiliser production on a large scale in this region [11].

Infrastructure
The plants built after 1960 were export oriented and therefore export possibilities and infrastructure were important. Two out of three main nitrogen fertiliser plants in the Netherlands are built near deep-sea harbours. Also, connections to inland waterways are of vital importance and available for all fertiliser plants.

Integration
The production of ammonia and urea is part of the production chain of the resin and plastic industry as far as Nylon, ABS, SAN, UF and Melamine are concerned. In the Netherlands this production chain is integrated at DSM in Geleen. Here the plant is built in the vicinity of the polymer production. In the Rotterdam Rijnmond area Kemira is located near large chemical production plants of Shell, Arco and Exxon. The Hydro Agri plant is not far from the Dow chemical site in Terneuzen. Approximately 30% of the ammonia produced in the Netherlands is used for non fertiliser purposes. Integration of fertiliser production with other processes like resin production is a major advantage of the large fertiliser companies in the Netherlands. The heavy price and demand fluctuations of the last years were fatal for small fertiliser companies. Companies which do not depend completely on fertilisers are relatively independent towards these kind of fluctuations. This is one of the reasons Kemira Oy and Norsk Hydro acquired their Dutch settlements.

Demand
Agricultural practise in the Netherlands and surrounding countries is characterised by very high application standards for fertiliser, both on arable land and pasture. The Dutch fertiliser industry is therefore located near large markets. High transport costs influence the choice for a location. Therefore most investments nowadays taken place in countries with a growing demand and (relatively) low production like India and China. For example, Norsk Hydro tries to increase its production capacity in Latin-America by participating in three ammonia plants in Trinidad [12]. The high investments made in India, China and Indonesia by several companies are also related to the fast growing demand in these countries.

2.5 Energy Use and Efficiency

A study on the N-based fertiliser industry [14] shows great differences in specific energy use (GJ/ton ammonia) of the several plants used by Hydro Agri in Sluiskil. The older plants (built around 1970) use up to 40 GJ/ton and the best process developed until now uses 28 GJ/ton. The average energy use for the Netherlands in 1990 was 33,5 GJ/ton. It is clear that replacement of old plants by new ones can lead to considerable energy savings. The industry has stated that specific energy use has increased considerably and the high figures are presently outdated.

For the period 1989-2000, the chemical industry, including the fertiliser industry, has made a long term agreement with the Ministry of Economic Affairs on energy efficiency. The improvement to be achieved in 2000 is 20% on average compared to the 1989 level. Feedstock (non-energetic consumption) is excluded in this agreement, for the fertiliser industry this is 70%. As a part of this agreement Kemira Agro Netherlands reports a 12% improvement between 1989 and 1995 [13]. Recently in april 1999, the chemical industry has expressed its intentions to enter a new agreement for the next decade with Dutch government on benchmarking energy efficiency. This Benchmarking Agreement obligates industry to operate at the world top by 2012 at latest concerning energy efficiency. The world top and the applied accounting method has to be determined by independent consultants. Although benchmarking seems feasible for ammonia installations, it is not yet clear to what extent the fertiliser industry will actually enter and fulfil such an agreement.

3. TECHNOLOGIES

One way to look at the fertiliser industry is to consider the whole system as a network of conversion processes (technologies). In order to understand the fertiliser industry and its link to national energy consumption, the most important technologies (from an energy point of view) will now be described and discussed in more detail. The focal point is the steam reforming process (ammonia synthesis) and the N-based fertiliser production out of ammonia. Several studies already describe fertiliser production. [5,10,14]. [14] Focuses on the N-based fertilisers and will be used as main data source in the next paragraphs.

3.1 Ammonia (the steam reforming process)

The steam reforming process is can be divided in two steps. First hydrogen is formed out of steam and natural gas. This hydrogen reacts further with nitrogen to ammonia. The chemical reactions are:

$$\begin{array}{rcccccc} CH_4 & + & 2\,H_2O & \rightarrow & 4\,H_2 & + & CO_2 \\ 3\,H_2 & + & N_2 & \rightarrow & 2\,NH_3 & & \end{array}$$

These simple reactions require complex catalyst, temperature and pressure circumstances. An overview of all processes is given in figure 3.1. They will be described in this paragraph.

The input for the reforming process is natural gas (methane), water (steam) and air. Because sulphur poisons the catalyst, desulphurised natural gas is used. This is heated to 500°C and led into the primary reformer. In the reformer the gas is led over a tube filled with nickel catalyst. In this tube CO and H_2 are formed by the next reactions.

$$\begin{array}{rcccccc} CH_4 & + & H_2O & \rightarrow & CO & + & 3\,H_2 \\ CO & + & H_2O & \rightarrow & CO_2 & + & H_2 \end{array}$$

Since this is an endothermic (energy demanding) reaction, the reformer is heated externally. For the secondary reformer preheated air (containing nitrogen that is used in the synthesis reactor) is mixed with the gas and passed over a nickel catalyst at 1100°C. This temperature is required by the catalyst. This reaction is heated by the combustion of natural gas.

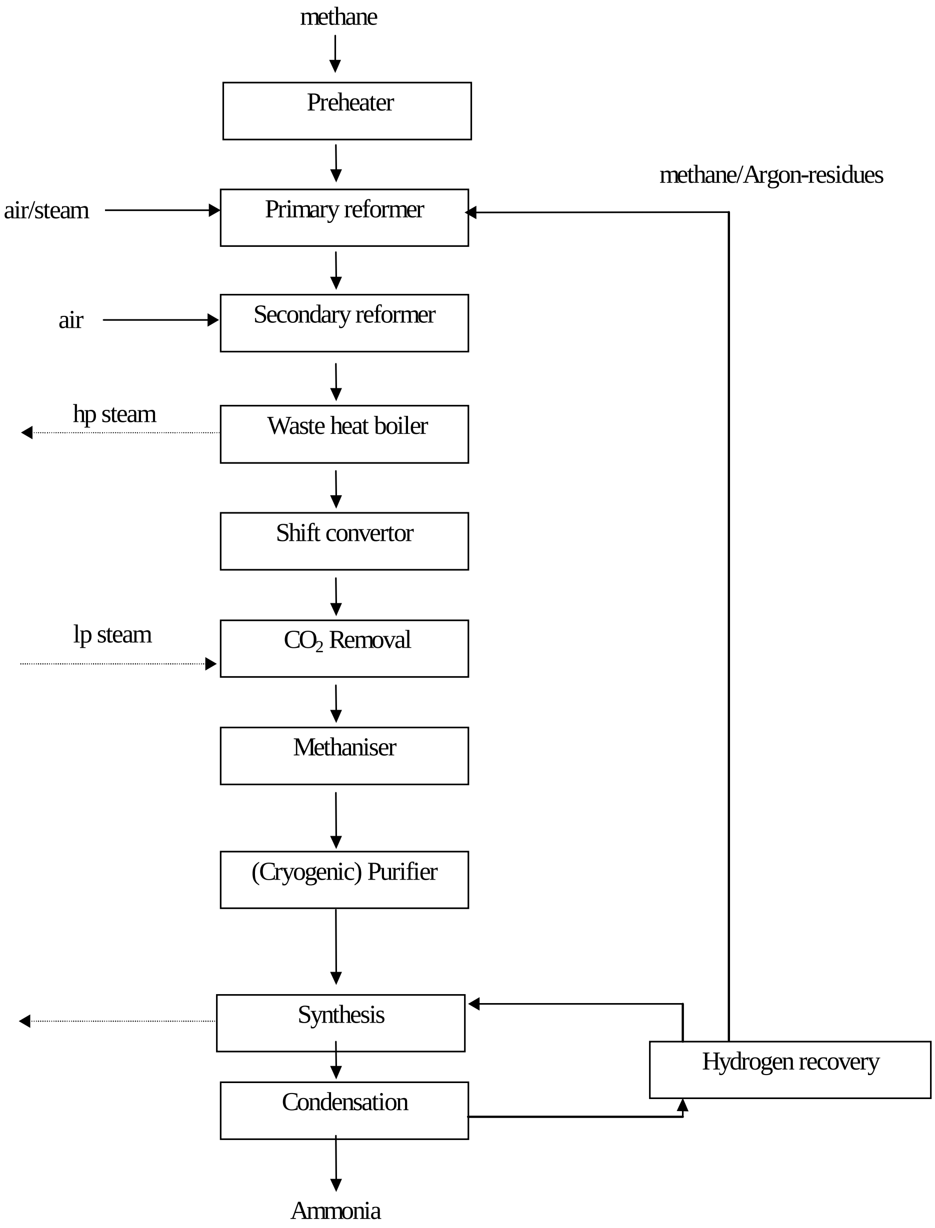


Figure 3.1 *Ammonia synthesis [14]*

The mixture is cooled in the waste heat boiler to 350°C. This temperature is needed for the shift reaction in the next step. The heat is used to produce high-pressure steam (30 -100 bar). In the shift converter the 10% CO left over in the reformer is converted to CO_2 and H_2, with the water-gas shift reaction.

$$CO \quad + \quad H_2O \quad \rightarrow \quad CO_2 \quad + \; H_2$$

A two step reaction is used. An Ironoxide-Chromium catalyst is used at 350°C and a Copper-Zinc catalyst at 250 °C. Between these steps the stream is cooled. The excess heat is used for the production of steam.

After this reaction a mixture of N_2, H_2, approximately 18% CO_2 and some inert gases is formed. The CO_2 has to be removed. In most plants the CO_2 is removed by washing with chemical absorption agents like ethanolamines or potassiumcarbonates, or with a physical absorption agent like selexol. The removed CO_2 can be used in the urea synthesis (see also 3.2). Small amounts of CO and CO_2 (e.g. 0.4% CO and 0.01% CO_2) left over in the gas have to be removed before the ammonia synthesis step to prevent poisoning of the catalyst. Therefore these compounds are converted into methane which does not affect the reaction used in the reformer. The reaction is the same as used in the reformer, but now in the reverse direction.

$$CO, CO_2 + H_2 \rightarrow CH_4 + H_2O$$

The mixture of nitrogen, hydrogen, steam and traces of inert gases and methane can be treated in several ways. In some processes, the methane, inert gases and surplus of nitrogen is separated from the nitrogen/hydrogen mixture.

By using the right methane air mixture at the input, after all these steps a syngas of about 75% H_2 en 25% N_2 is left. From a thermodynamic point of view, low temperature and high pressure are favourable for the final ammonia reaction

$$3\,H_2 + N_2 \rightarrow 2\,NH_3$$

From a kinetic point of view high temperatures and from a practical point of view low pressures are favourable. The reaction temperature and pressure is therefore a typical compromise, namely 450°C and 140 bar. Iron oxide is used as a catalyst. Most processes consist of four catalyst beds with decreasing temperature. The heat distribution is an important design feature. The final result is a 10-20% ammonia yield. This is separated out of the mixture by condensation. The unreacted gas is recirculated. To prevent high CH_4 en Argon concentrations these gases are separated and methane is used for the heating of the primary converter.

3.2 Urea

Urea is formed by a reaction of ammonia with carbondioxide, a (waste) product of the ammonia synthesis (3.1). The process can be divided in two parts. First the ammonia and carbondioxide react at a pressure of 120-250 bar to form carbamate

$$2\,NH_3 + CO_2 \rightarrow NH_4\,COONH_2$$

This product is dehydrated to form urea.

$$NH_4\,COONH_2 \rightarrow NH_2\,CONH_2 + H_2O$$

This last reaction is an equilibrium. The products are therefore separated, and the left-over carbamate is recycled. In most cases the urea is dried and treated in a prilling tower, to produce granulate. There are several processes for drying and dehydration. The urea plants in Europe consume between 3.2 and 4.6 GJ primary energy/ton.

3.3 Nitric Acid

Ammonia is oxidised over catalysts to form nitrous oxides (NO_x). The pressure of this process is about 6 to 10 bar. The nitric acid HNO_3 is produced by the absorption of water. The reaction is exothermic, and so high-pressure steam can be formed. Many variations were constructed on this main principle. Nitric acid is used mainly for the production of ammoniumnitrate, but is also used for non-fertiliser products. In the process of nitric acid production, substantial residues of nitrous oxide (N_2O) are released. Nitrous oxide contributes substantially to the greenhouse effect. Per ton, it is 310 times as powerful as CO_2. On a total nitric acid production of 2.1 Mton, about 25-30 kton is emitted. This emission is equivalent to 8 Mton CO_2.

3.4 AN (ammonium nitrate)

Ammoniumnitrate is formed by neutralisation of ammonium with HNO_3. This is a (strong) exothermic reaction.

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

The produced heat can be used internally to preheat the nitric acid, evaporate the liquid ammonia or evaporate the water of the nitric acid solution. Another possibility is producing steam. Older plants work at atmospheric pressure and require the import of steam. Modern processes at elevated pressures are net producers of energy.

3.5 CAN (Calcium ammonium nitrate)

CAN is produced by mixing ammonium nitrate with dolomite.

$$NH_4NO_3 + MgCa(CO_3)_2 \rightarrow CAN$$

This mix, containing approximately 75% AN and 25% dolomite is granulated before use. Mostly a fluidised bed process is used. The new granulate plant from Hydro Agri in Sluiskil with a production of 3600 ton CAN per day is the largest plant in the world. Primary energy consumption in Europe for CAN production varies from 0 to 1.3 GJ/ ton. New processes consume no fuel and can even deliver steam.

3.6 Phosphorus and potassium fertilisers

Most important phosphorus and potassium fertilisers are mixed products of N- P- and K components (75%) and Phosphate fertilisers (20%). Phosphate fertilisers include Triple Super Phosphate (TSP) and Single Super Phosphate. Single super phosphate (20% P_2O_5) is made out of phosphate ore, acidulated with sulphuric acid. The ore dissolves in sulphuric acid, where phosphate (and gypsum) are formed. Triple super phosphate (45% P_2O_5) is made out of phosphate ore acidulated with phosphoric acid. After drying fertilizers are produced with 20% or 45% P_2O_5.

Several options can be used for the production of mixtures of fertilisers. The energy use of these processes is low compared to ammonia production. Most of them are mixing and drying processes. Several possibilities can be found in literature, the differences come from the feedstock they are based upon.

4. PRODUCT DEMAND

This chapter will provide an overview of the present demand for fertilisers and some information on the use of it. It is also important to discuss developments which influence the demand and expectations for the coming years. The focus will be on applications for products of the Dutch fertiliser industry. After a market description, remarks will be made on the developments of the Western European market and prices.

4.1 Applications and markets

Intensity of use

The Dutch agriculture has one of the most intensified practises in the world in terms of production and fertiliser use. Although it has a relatively small agricultural area it is the second largest exporter in the world of agricultural products and the largest on potted plants and flowers. The production of diary products per ha grassland is also very high compared to other countries [33]. The high production level in the Dutch agriculture is related with high fertiliser use standards. The Netherlands have the highest N-fertiliser use per ha of agricultural land in the world (Table 4.1)

Table 4.1 *Global use of different types of fertiliser in 1994 [8]*

	Nitrogen [kg N/ha]	Phosphorus [kg P_2O_5/ha]	Potassium [kg K_2O/ha]
Netherlands	195	32	38
Belgium/Lux	114	34	68
Germany	98	25	38
France	75	34	45
other EU	55	20	22
Russia	20	2	2
USA	26	9	8
India	52	16	5
China	48	15	4
Africa	2	1	1
World	15	6	4

The major agricultural land use in the Netherlands is grassland which includes about 50% of the agricultural land use. The specific N-fertiliser consumption for Dutch grassland is 314 kg/ha. Another crop that requires high fertiliser application is potatoes with 196 kg/ha. [15,33]. The high fertiliser use standards not only lead to high production levels. Negative impacts are the acidification of the soil and saturation and pollution of the soil and groundwater with phosphates and nitrates [16]. Therefore a decrease of nutrient use, including the use of fertilisers, is the main effort of the combined agricultural and environmental policy of the Dutch government [17]. A closer look at this policy will be given in Chapter 6. Although the Dutch fertiliser use is relatively high, the Dutch market is of secondary interest for this study, because of the high export of fertilisers. Therefore an analysis of the Western European market is more appropriate.

Type differences

Phosphate and potassium are world wide used in the oxide form (expressed in P_2O_5 and K_2O). For nitrogen fertilisers several types are available. The main forms are nitrate (NO_3^-) and ammonium (NH_4^+). This paragraph describes their differences and their uses. Differences in types are related to differences in solubility, acidification and release. Nitrogen dynamics in soil are complex. Quick acting nitrate fertilisers are directly available for the crops. Disadvantage of nitrate is its high solubility in water, which makes the leaching towards ground water high. Furthermore a high accumulation of nitrate at once can harm the crops. The other nitrogen form is ammonium, which has a slower release, though the nitrogen remains fully available. Ammonium is partly nitrified (converted into nitrate by bacteria) before it is used by the crops. This nitrification is a source of acidification of the soil and a major disadvantage of ammonium fertilisers. This acidification can be mitigated by using a mixture with a bicarbonate (e.g. dolomite) like in CAN or a sulphate. Urea is the world's most widely used fertiliser. Before it can be useful for crops, urea first had to be transferred to ammonium by microbes. This transfer only takes place by temperatures around 20-25°C. For this reason, urea is hardly used in Dutch agriculture. Further N-forms are cyanide and slow release fertilisers. The latter are prills from a N-compound packed in a shell which regulates the release of the nutrient. In this way the demand of the crop and release of the nutrients can be better tuned. Major advantage nowadays is the reduction of leaching, major disadvantage is the price. Table 4.2 gives an overview of the main fertiliser types.

Table 4.2 *N-fertiliser types, their release, acidification and disadvantages*

N-form	N [%]	Acidification	Release	Disadvantages
Nitrate	16	no	quick	liable to leaching
Ammonium	17-21	high	moderate	nitrification of ammonium leads to acidification
Ammonium nitrate	34	moderate	moderate/quick	
Calcium Ammonium Nitrate (bi-carbonate)	27	low	moderate/quick	
Urea	45	moderate	temperature	only useful at 20-25°C sensitive
Ammonia	82	high	quick	gaseous

Export markets

The Dutch fertiliser industry is internationally orientated.

Figure 4.1 gives an overview of the destinations for the N-based fertilisers produced in the Netherlands. It shows that almost 90% of the produced fertilisers is exported to mostly other Western European countries.

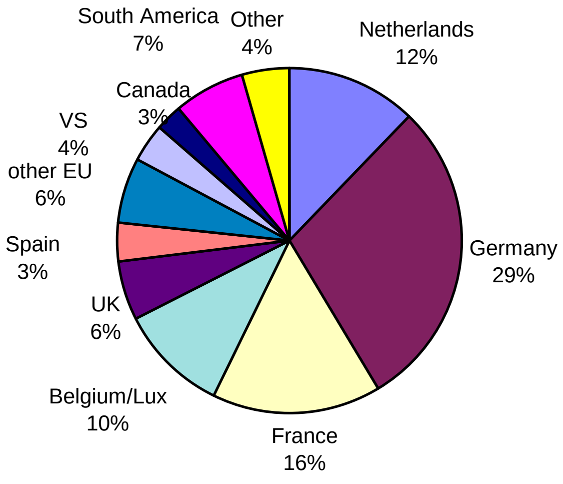


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Figure 4.1 *Consumption of fertiliser produced by the Dutch fertiliser industry*

Most important for the Dutch industry are the neighbouring EC-countries Germany, Belgium/Luxembourg and France. From these countries the fertiliser use and the importance of the Dutch export is described in Table 4.3.

Table 4.3 *Importance of the Dutch export for fertiliser demand in neighbouring countries [kton N 1996/1997] [21]*

Use	Production	Net	Total	Import from NL	Import NL	Use of NL	
		Import	Import			[%]	[%]
	a	b	a-b	c	d	d/c	d/a
Netherlands	370	1418	-1048	186			
Germany	1758	1276	482	1194	381	32	22
Bel/Lux	172	757	-585	350	141	40	82
France	2525	1417	1108	1348	410	30	16

Table 4.3 shows the fertiliser industry in the Netherlands and Belgium depend on exports with a high production compared to the consumption of fertilisers. Furthermore the German market is important for the Dutch industry with an import of 381 Mton N-fertilisers, this is 32% of the total import, and 22% of the German fertiliser consumption. The other important market, France, depends for 16% on Dutch fertilisers. The Belgian fertiliser industry is similar to the Dutch as it is producing over four times its national use. The market in Belgium is unclear because imports already exceed consumption. From the Netherlands, an amount is imported in Belgium that covers almost its entire demand. The import figures represent not only use in Belgium and 82% gives no adequate indication of the real use of Dutch fertilisers.

The world market for fertilisers is dominated by demand from Asia, especially in China and India (Figure 4.2). Not just the highest consumption but also growth of consumption is found in these countries. Concerning the world market of fertilisers, China and India are more and more selfsupporting, resulting in less imports. The Western European production and consumption decreased in the same time. Another observation for this market is that the balance between consumption and production changed sign between 1988 and 1993.

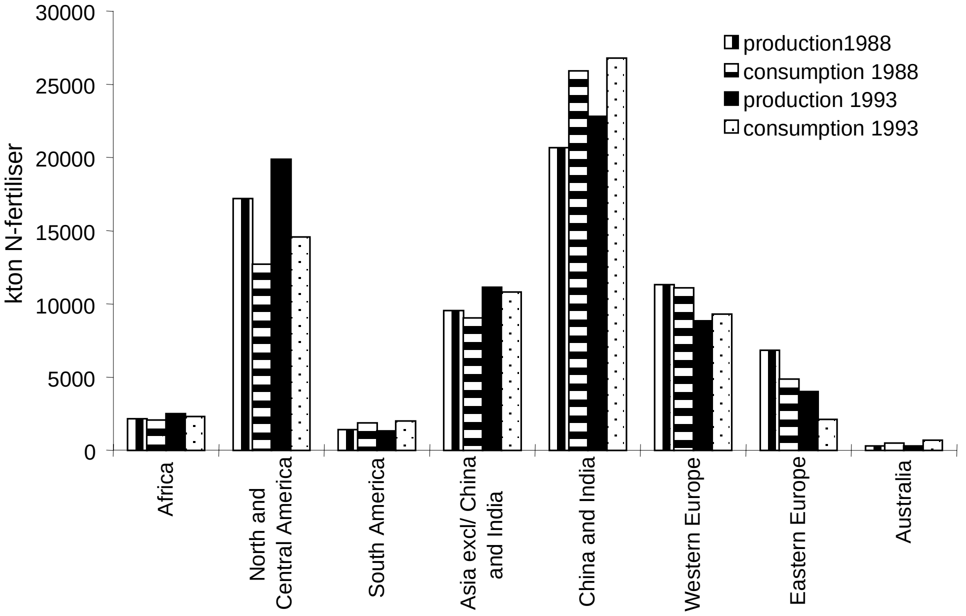

Figure 4.2 *Global production and demand for fertilisers for 1988 and 1993 [21]*

4.2 Price developments

Product prices of the fertiliser industry have a strong cyclical character which is typical for large continuous chemical processes [20]. Supply cannot be easily adjusted to demand, so markets have to deal with surpluses and shortages. The last decade showed very well the impact of this cycle. Table 4.4 shows some recent data on prices.

Table 4.4 *Recent price fluctuations of N-fertiliser products [Dfl/ton]*

Source	Kemira, annual report 1995	Fertecon	
	Ammonium nitrate	CAN	Urea
1991	331	246	
1992	312	224	
1993	279	202	
1994	320	224	290
1995	318	280	320
1996			319
1997			253

Between ‘90 and ‘95 the prices for several fertilisers like CAN and ammonium nitrate first decreased to 80% of the 1990 price level in 1993. In the next period, as a result of the growing demand the prices started to rise again. The growing demand led to a decrease of the surplus capacity in Western Europe. Recently, some figures for 1997 and 1998 show that prices are going down again. The balance between supply and demand is still under pressure because of uncertainty about imports from Eastern Europe. Different developments were reported in recent years including high demand expectations, efforts to increase the Western European production capacity and heavy competition with Eastern Europe [18,19]. Imports from the FSU have risen steadily since 1992.

At the same time the ammonia price fluctuated heavily between 90 and 250 US$/ton, affected by high uncertainties on the market for basic organic chemicals. These fluctuations do not influence the fertiliser industry directly because they use ammonia from their own company. The amount of ammonia sold outside the producing companies is limited. For these companies not ammonia but natural gas is the most important feedstock, and therefore the gas price is more relevant.

In the long run prices for fertiliser industry products show a decreasing trend. This is caused by a gradually improving factor productivity, combined with only moderately increasing cost levels for inputs and other requirements.

4.3 Fertiliser demand forecasts

Analysis of the fertiliser demand development during the next decades shows different trends for the World and Western Europe. Insight in these developments can help to analyse the demand prospect of the Dutch fertiliser industry. According to LEI the world demand will grow in the next years [8]. World population growth leads to an increase of food consumption and the demand for fertilisers accordingly. The last decade shows a decrease in global production from 86 mil. ton N-fertilisers in 1988/1989 to 79 mil. ton in 1993/1994. This decrease is mainly caused by production stops in Eastern Europe and .Russia as a result of the political reform in these countries. From 1988 to 1995 production of N-based fertilisers decreased by 80%. Last year an increase in world production is found (81 mil. ton 94/95). An increase of production and consumption is shown in South and East Asia and this trend dominates the last years and is expected to dominate global fertiliser demand for the next decades. The FAO [23] estimated the demand for N-based fertilisers will grow with 18 mil. ton between 1995 and 2004, implying a growth of 1,2% per year. This growth is concentrated in South East Asia and Latin America

(3,8%). For Europe, a small decrease is expected by the FAO (-0.4%). The EFMA expects for the coming years up to 2002 a decrease of about 2% annually [20,8,21]. An estimation of the relevant market development for Dutch fertiliser industry is made in Paragraph 10.1.

For phosphorus based fertilisers the global demand decreased between 1988/89 and 1993/94 from 39 to 29 mil. ton. The potassium demand decreased in the same period from 28 to 19 mil. ton. Demand for both fertilisers is expected to remain at the 1993/94 level.

These trends and the demand forecasts are closely related to the Dutch and European agricultural policy. The environmental impact, related issues and legislation will be described in Chapter 6. The influence of this policy is uncertain, but it seems reasonable to assume that the use of fertiliser in the EU will not increase substantially within the next decades. Because the EU market is of major importance for the Dutch fertiliser industry this will have a major influence on their market prospects. Most sources expect a stabilisation or about 2% decrease in the next 5 year period compared to the current fertiliser use [22,23,33].

4.4 Conclusions

The World demand for fertilisers is growing fast but this development takes place outside the market of the Dutch fertiliser industry. This market includes mainly the Netherlands and neighbouring countries with high agricultural fertiliser use standards. The main product here is calcium ammonium nitrate. A decrease in fertiliser use and production during the last decade in both Western and Eastern Europe has taken place. The demand is continuously decreasing. The price can fluctuate but has a general tendency to decrease due to overcapacity and increasing imports from Eastern Europe. Heavy fluctuations in demand or price are presently not expected. Uncertain are still future imports of Eastern European fertilisers and the influence of environmental legislation on fertiliser use.

5. COSTS AND REVENUES

Until 1993 a detailed survey of the costs and revenues of the Dutch fertiliser industry is given by the CBS [24]. From 1993 on only statistics of the entire basic chemical industry are available. The figures in this chapter are based on the 1992 CBS results. Some information can be compared with other sources that give insight in the cost and revenue structure of the fertiliser industry for more recent years. For instance prices and production figures give insight in the revenues of the industry [7]. The CBS figures consider the whole industry, and are not available for the several specific processes or plants. On the national level information on e.g. investments is also confidential because the fertiliser industry is dominated by only a few companies. To provide this information other sources were used and assumptions were made. In this chapter first the cost structure and next the revenues structure will be described.

5.1 General cost structure

The costs made by the fertiliser production can be subdivided in capital, independent cost and utilisation costs. These three categories are estimated for the year 1992. Capital costs are the costs related to interest and depreciation of the installations and equipment. The utilisation costs are those which are directly related to the production process. Energy, feedstock and transportation are the main utilisation costs. Independent cost are neither directly related to investments nor a result of the utilisation of the plant. Most important of these are the labour costs. Other examples are R&D-investments and maintenance. All these will be considered in this chapter.

5.2 Capital costs

The fertiliser industry is considered as capital intensive. The most important cost are the ammonia plants. An estimation of the capital cost can be made on the basis of total depreciations of the value of the installations. The investment necessary for an ammonia plant (850 kton/year) is about 600 mil. Dfl [25]. Exact figures are confidential and depend on the available infrastructure and capacity of the plant. The depreciation mostly takes less time than the economic lifetime reaching up to 25-30 years. The annual report of Kemira Agro shows depreciation was approximately 8% of the total costs for 1994 and 1995 [26]. The CBS-statistics on 1992 indicate that 212 mil. Dfl (approximately 10% of the total costs for the Dutch fertiliser industry in 1992) is related to depreciation [6].

5.3 Utilisation costs

The utilisation costs in the fertiliser industry refer for a large extent to the costs for feedstocks and energy required by the process. Most important feedstock is natural gas. The production statistics show no difference between natural gas used as feedstock and as energy supply. For 1992 the CBS accounts these costs at 630 M Dfl. The gas is delivered by special separate contracts between the industry and the Gasunie. These prices are lower then for other industries, approximately 0.15 Dfl/m^3 or Dfl 5/GJ [27]. With some more recent information it is possible to calculate the energy costs for 1994. In Table 5.1 cost calculation results are added based on two other CBS publications, the National energy statistics (NEH) and the Statistical Yearbook. This method is also applied for 1992. The natural gas and electricity can be compared in this way, but the costs for other feedstocks in the SBI table are not found in the energy survey. Table 5.1 shows the energy costs were approximately 6% reduced between 1992 and 1994. The non energy feedstock refers to raw materials which are produced outside the Netherlands, for example phosphates, potassium chloride and dolomite.

Table 5.1 *Costs for feedstock and energy for fertiliser production, 1992 and 1994, different CBS sources [mil. Dfl] [28,27,9]*

	SBI 29.1	NEH and Yearbook	
	1992	1992	1994
Natural Gas	524		508
Feedstock		394	376
Energy		137	132
Electricity	43	531	38
Other primary energy	63	8	2
Non energy feedstock (e.g. dolomite, phosphate ore)	491		
Total utilisation costs	1,121		

The transportation costs are not included separately in the fertiliser industry statistics. As was indicated in Paragraph 2.4 transportation costs are a major limitation in fertiliser trade, and therefore these costs cannot be neglected. Most transportation takes place by ship. Inland shipping plays an important role in transportation to Germany, and bulk carriers, sea tankers and coastal ships for the harbour facilities of the plants in Rozenburg and Sluiskil. For short distances in most cases road transportation is the cheapest solution [2, 26]. The break-even distances for road transportation versus inland shipping and railway transportation lie between 300 and 700 km. The choice of mode largely depends on the available infrastructure. For locations situated near waterways river transportation is the best option but the possibilities are limited compared to road transportation [29]. Shipping rates for deep-sea vessels are very unstable depending on available capacity. [30,31]. Price fluctuations of 50% within six months are not uncommon. It is assumed that transportation to Germany, Belgium, Luxembourg, France and locations in the Netherlands is taken by train, truck or inland ships and the other destinations are reached by sea ships. The transportation costs for Dutch shipments are given in Table 5.2.

Table 5.2 *Transport means and costs for the fertiliser industry [1,7]*

	Share [%]	Quantity [kton]	Price [Dfl/ton]	Total [mil. Dfl]
Bulk carriers	37	3,300	100	330
Truck, train and inland shipping	63	5,500	50	275
Total		8,800		605

These results serve only as an indication of the transportation costs and are important in relation to the competitiveness of the Dutch fertiliser industry which will be described in the second part of this report.

From interviews with fertiliser industry, more detailed transport costs are derived for fertiliser shipments. No information is found on the amount for separate modes. In the calculated transportation costs of fertilisers, the following assumptions are made:

- The use of ships is always preferred when possible.
- The final distance to users is from a local inland depot (fertiliser trading point/ agricultural co-operation) to individual farmers, covering 0-100 km, costs for end user estimated average 20 Dfl per ton, not in sacks.
- The local inland depots are supplied by trains or trucks covering 50 to 1000 km, average costs 30 Dfl/ton; or inland ships covering 50-1500 km, average costs 20 Dfl/ton.
- Supply of local inland depots is either directly from fertiliser plants, from deep-sea harbours or by train or truck from inland harbours.
- From Dutch industries, western European deep-sea transport covering 200-2000 km costs 20 Dfl/ton; intercontinental deep-sea transport covering 2000-10000 km costs 50 Dfl/ton.

This leaves a number of alternatives for the local inland depot supply. Depending on transport possibilities, transport costs vary from 40 Dfl/ton, (Netherlands, Belgium) to 120 (Africa). Transport of Dutch fertiliser to end users in the Netherlands and Western European countries typically costs 40-70 Dfl/ton. Transport costs for locations outside Europe typically range from 90-120 Dfl/ton.

5.4 Independent Costs

Independent costs are defined as costs that are neither investment related nor utilisation costs. They occur independent of the degree of utilisation of production plants. Independent costs are for example costs of maintenance of installations, labour, insurances and taxes.

Labour

From these costs, labour is the most important in the fertiliser industry. There are approximately 3400 employees in Dutch fertiliser industry. Average costs per worker amount Dfl 90-100 thousand. The cost structure for labour is relatively similar to other European countries. The operator costs which include costs for premiums, gratification's, non-working days and social securities is relatively low in the Dutch chemical industry. For Belgium and Germany the costs are approximately 10% higher. In the USA and Japan the salaries are 30% and 100% higher respectively but the operation costs differ less: 10% and 70%. This reflects less social security in these countries which is compensated by higher basic salaries. Moreover, it is important to notice that the comparison depends on the exchange rate used. With 1990 exchange rate there is no difference between American and Japanese labour costs level.

Other independent costs

No detailed information on R&D-budgets and maintenance costs were given by the CBS for 1992. Therefore the latest available data from 1991 were used to get insight in the other costs of the fertiliser industry. These figures show that 7% of the total costs are related to maintenance. Furthermore, research and development take 0.7%. The other costs included in the independent costs are: payments to holding companies, rent and lease of buildings, hires, insurance-, communication-, travel- and administrative costs. According to the production statistics these costs cover 8% of the total costs.

5.5 Revenues

Most recent consistent figures for revenues are derived from production statistics of 1992 (Table 5.3).

Table 5.3 *Revenues for the Dutch fertiliser industry, 1992 [6]*

	[mln kg]	[mln Dfl]
Calcium (and Mg) ammonium nitrate (CAN)	2,990.2	535.6
Mixed nitrogen/phosphorus/potassium (NPK)	700.5	256.3
Other phosphorus and mixed fertiliser	1,062.8	277.6
Other fertilisers (urea, ammonium nitrate)		542.5
Non-fertiliser raw materials	1,492.4	376.2
Total revenues		1,988.2
(Total costs including depreciations)		(2026)

The revenues of the fertiliser industry were also estimated for the year 1994. The production and prices are compared with the revenues reported by the main fertiliser producers. The 1994 prices for fertilisers could be derived from the industrial trade statistics [7]. The trade statistics refer to 1994, the fertiliser statistics refer to 1993/1994 and 1994/1995. The 1994 production in

Table 5.4 are averages of these figures [8, 32]. Revenues of the fertiliser industry from production of inorganic raw materials were based on the production statistics of 1992 and 1994 trade statistics.

Table 5.4 *Estimated revenues for the fertiliser industry in 1994*

	Production [kton fertiliser]	Prices [Dfl/ton fertiliser]	Value [mln Dfl]
CAN	2,889	180	520
Urea	712	243	173
Ammonium nitrate	474	226	109
Rest N-fertilisers	1,825	115	209
P-based fertilisers	609	375	228
NPK, NP, NK-fertilisers	1,370	334	457
Inorganic Raw materials			450
Total			2,146

5.6 Discussion

An overview of the costs is given in Figure 5.1. Estimated transportation costs paid by consumers of about 200 mil. Dfl were added. Beside this, transport costs also include some of what is already part of labour, capital and e.g. other costs. To avoid double counting, this is subtracted from other costs. In this way, total transport costs of about 15% are derived, and will be used for further analysis in Chapter 9.

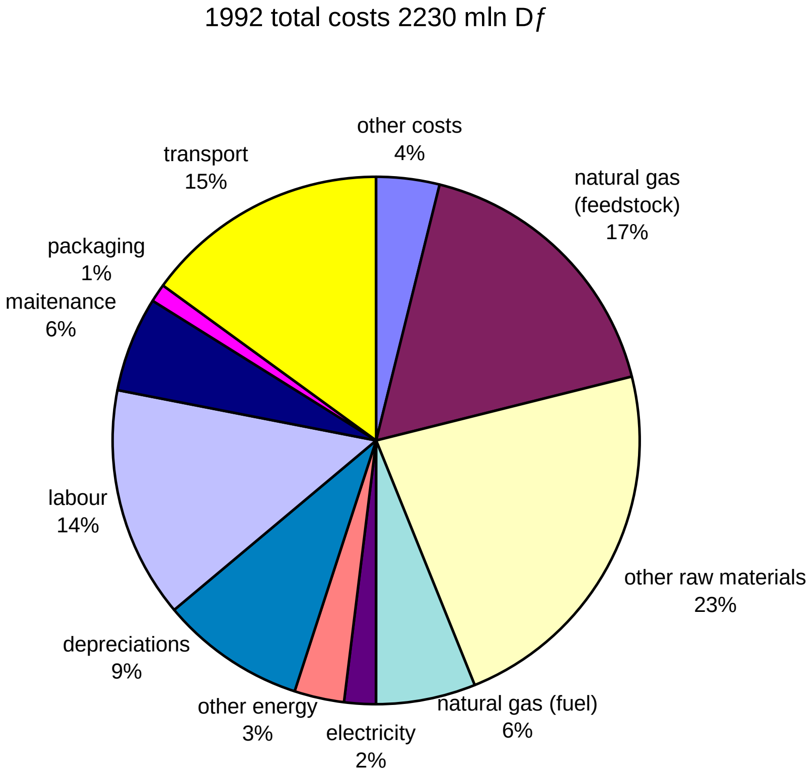

Figure 5.1 *An overview of the costs in the Dutch fertiliser industry 1992 [6]*

The cost survey shows the importance of feedstock for the fertiliser industry although it has the lowest natural gas prices of all industries in the Netherlands (Dfl 0,15/m^3). The cost structure is similar to the structure found for the Dutch petrochemical industry [1]. Only transportation costs are, if taken into account, relatively high for the fertiliser industry, because of the low prices per mass unit. It is obvious that low energy prices are crucial for the competitiveness of the fertiliser industry. In the second part of this report this issue will be elaborated. When comparing costs and revenues for 1992 according to production statistics (Table 5.3), there were no net profits. The losses were compensated on the financial balance by lowering the resources of the companies. In previous years, net profits ranged from 5-10% of turnover.

6. OTHER FACTORS

Additional to the aspects which were quantified in Chapter 5, several factors that are difficult to quantify may be important in the choice of production locations and the possibility to compete with other countries. Also, market development and technology are affected by these factors.

This chapter will provide an overview of those aspects, which seem to be the most important. Most issues are policy related, both National and European. By far the most important is the European Agricultural Policy (CAP). This can lead to a major reform in the agricultural practise in Western Europe, influencing the fertiliser use to a high extent. Within this reform, sustainable development, including decrease in fertiliser use, plays an important role.

Further political influences are the free trade treaties and industrial policy within the Netherlands and Europe. Also, National environmental regulations are an important factor. At the end of this chapter a few remarks on capacity to compete of the Dutch industry will be given.

6.1 Industrial policy

Subsidy and import tariff control

The European Union tries to achieve an open market within the union by prohibiting National governments to provide subsidies that disturb competition. All subsidies are forbidden unless approved by the commission. A set of rules is issued by the commission that allows structural subsidies for industries that are considered of vital importance for the economies. Fertiliser industry does not belong to this category. The GATT agreement is a further step in abandoning world-wide trade barriers. For the EU it led to a decrease in subsidies and other options protecting the European market. Furthermore, in 1992 the EU decided to grant totally free access to imports from Central and Eastern European countries, with the exception of the former Soviet Union and Yugoslavia. This opening of the EU market made it vulnerable to competition out of these regions. In conclusion, the Dutch fertiliser industry cannot count on protection for imports from foreign countries.

Last years the fertiliser industry complained about the dumping of fertilisers from Eastern Europe. The Russian industry has to deal with a completely collapsed demand for fertilisers at home. For the Western European fertiliser industry it was nearly impossible to compete with the Russian prices. Main concern of the European fertiliser manufacturers association (EFMA) was the dumping of ammonium nitrate from Russia. The EU wants to protect its industry against injury caused by dumping, which is allowed within the World Trade Organisation rules. In this case the EU used minimum import prices of 102.9 ECU per ton to control a fair competition. Because of the difficulties with enforcing this measure a specific duty of 26.3 ECU per ton is proposed by the European commission [20, 44].

These measures are reactions on recent developments and give only limited insight in policy in the long run. Long run policy is orientated on fostering free trade, therefore taxes and minimum import prices are only expected in case of market distortions.

6.2 Common Agricultural Policy

For decades the European Common Agricultural Policy (CAP) has been based on product subsidies which guaranteed farmers prices that cover production costs. As a result of these guaranteed prices the production in Europe is high, which led to expensive overproduction. Moreover, productivity increasing inputs like capital, fertiliser and pesticides were intensely used. In the

1980’s the awareness grew that the environmental impact of this practise was rather negative. Especially high nitrate and phosphate concentrations in the ground water led to the demand for a more accurate policy.

The first limitation was set on diary products, to control surplus production. Already in 1984 milk quota were introduced in the CAP. This reform has an positive environmental side effect, it led to decreasing milk production, which included decrease in fertiliser use [33]. A far more drastic reform of the CAP appeared in 1992. This reform was induced by the overproduction and several other developments at the same time, these were:

- The agricultural subsidies were over 50% of the EU budget and a drastic reduction of these expenditures was needed.
- Limiting of the agricultural subsidies in Europe was a main issue within the GATT negotiation. The GATT-agreement of 1994 makes a reduction of subsidy levels necessary.
- The high production standards were reached at cost of high nutrient use, and as a result high nutrient losses.

The environmental impact of nitrates and phosphates showed the urgency of integrating environmental and agricultural policy [34]. Within the new CAP program about 160 projects were started aimed at environmental, nature and resources protection. The main goals were extensification, lowering production, more chances for nature development and a more sustainable agriculture. These issues overlap to some extent. Extensification automatically results into reduction of the production. Set-aside land can be used for nature development. A reduction of fertiliser and pesticide use for environmental reasons results in an extensification and lower production in the EU. The final influence of the CAP reform on the fertiliser demand is difficult to estimate. The estimated decrease in use of about 0.4% annually in the next decades, as described in 4.3 is mainly based on assumed impacts of the agricultural policy.

6.3 Environmental aspects

Nutrient loss

The deposition as a result of the manure and fertiliser use leads to a nitrate and phosphate accumulation in the soil and drinking water supplies in the Netherlands. An overview of the available nutrients is given in Table 6.1. Here also an overview is given of the nitrogen and phosphor leaking to soil and ground water. The nutrients losses shown were found in the Dutch ground water reservoirs. Water samples taken all over the Netherlands show that 80% exceed the drinking water standards put for nitrate. This standard is 50 mg nitrate per litre.

Table 6.1 *Balance of nitrogen in the Dutch agricultural land 1997 [35] (average kg/ha N and P)*

Supply	N	P	Use an losses	N	P
Fertiliser	200	14	Crops	226	28
Manure	261	43			
Deposition	34	1			
Crops	10				
Other	10	3	Soil/Ground water	290	33

The high losses shown in Table 6.1 led to maximum loss standards for nitrogen and phosphate in the Dutch agriculture. It is difficult to estimate the nutrients needed to optimise crop production with limited losses, because the differences in application level between crops and soils are high [36]. Therefore the loss standards are defined for the different land use types (Table 6.2). For manure, use standards have been set. These standards were described in the Integrated Memorandum on Manure and Ammonia Policy. As a result of these standards several regions in the Netherlands have manure surpluses. This manure has to be transported to other regions in the Netherlands (or abroad). This can lead to a more effective manure use, resulting in a decrease of fertiliser use. The standards were set for 1998 and are to be further intensified in the period 1998-2008. New legislation is no longer based on use standards but on loss standards [37]. The manure production of phosphorus will be higher than these standards for the Netherlands within a few years. No doubt this will lead to a reduction of the phosphate fertiliser use. For nitrogen the same development will be required (compare tables) [38].

Table 6.2 *Max. loss standards for phosphate and nitrogen for the Dutch agriculture*

Year	1998	2000	2002	2005	2008
Phosphate [kg P_2O_5/ha]	40	35	30	25	20
Nitrogen					
Pasture [kg N/ha]	300	275	250	200	180
Arable land [kg N/ha]	175	150	125	110	100

Within this policy scenario the agricultural policy plays an important role. This situation differs from other European countries where the nutrient burden is less high. These countries concentrate there legislation on the manure use without considering fertilisers. Only the Dutch legislation considers the whole nutrient balance. Therefore a decrease of the fertiliser use is expected in de Dutch agriculture.

Sustainability

The EU-policy towards a more sustainable agriculture is still developing. The consequences for the agriculture are still uncertain but some remarks can be made when we compare current agriculture with the result of some research done on sustainable agriculture. Research on several alternatives for agriculture is done by the Agricultural University in Wageningen (NL). This project is aimed at developing sustainable farming for the 21st century. In the Ir. A.P. Minderhoudhoeve mixed and ecological farming are tested in practise. The project is still developing, but some first results give at least an indication of development options towards sustainable agriculture. The calculated N-balance of the ecological and the integrated farm are compared with a Dutch farm in 1985/86 in Table 6.3.

Table 6.3 *Calculated nitrogen balance of two mixed farm projects [kg N/ha year]*

	Ecological	Integrated	Netherlands (85/86)
Input			
Fertiliser	0	61	248
Manure	0	0	98
Deposition	34	34	45
Biological fixation	64	41	4
Imported feed	20	29	65
‘Green’ household disposal	32	0	0
Total Input	150	165	460
Output			
Crops	34	70	48
Milk	27	30	35
Animals	4	5	8
Total Output	65	105	91
Losses [kg/ha]	85	60	369
N-surplus [kg losses/kg output]	130%	60%	410%

Source: Ir. A.P. Minderhoudhoeve, compared with the ‘open’ Dutch agriculture (1985/86) [39].

Both alternatives include a substantial decrease of fertiliser use. Comparing Table 6.3 and Table 6.2 shows the possibility to reach the loss standards by changing the agricultural practice. Both the ecological and the integrated farming include a combination of diary farming, arable farming (including field-grown vegetables) and sheep farming. Both farms are based on lower external inputs and a (more) natural crop protection. The most important objective of the integrated farm is an efficient production by minimising the nitrogen surplus and maintaining the high production level.

Industrial pollution.

For fertiliser production, several emissions can be distinguished. The airborne emissions are mainly caused by the nitrogen based fertiliser industry. Here the main greenhouse gases are CO_2 and N_20, whereas the acidification emission is mainly caused by NH_3 and NO_x. The phosphoric acid production causes emission to the surface water. At Kemira and Hydro Agri gypsum waste from the phosphoric acid production is purged. Main pollution in this case is the contamination of the gypsum with several heavy metals. In Table 6.4, an overview of emissions from the fertiliser industry is presented. For CO_2 and N_20 these figures are updated by recent research [63].

Table 6.4 *Emissions of Dutch fertiliser plants [42]*

	N-fertiliser industry 1993 [ton/year]	P-fertiliser industry 1989 [ton/year]	Dutch emission [%]
CO_2	2,910,000[1]	130,000	2
N_20	17,000[1]		33
NH_3	2,210		2
NO_x	5,770	1,400	1
SO_2	769	3,300	1
Waste gypsum		1,460,000 [41]	100[2]

[1] outdated figures, updated further on in this study.

[2] to surface water (most waste gypsum is stored or recycled).

The CO_2 and N_2O emissions play an important role in the greenhouse effect and in national and global climate policy. The N_2O emission seems low related to the CO_2 emission, but the global warming potential of N_2O per ton is 310 as large.

Basically the high energy and feedstock demand of natural gas leads to a high CO_2 emissions accordingly, as the basic product ammonia contains no carbon. So about 6.2 Mton CO_2 emission would actually occur in the industry, however of this CO_2 part is used for urea production, and some is captured and sold as gas for carbonated beverages. There are also plans to provide CO_2 from the ammonia plant of Kemira for an acetic acid production plant. As far as urea and other carbon carriers are used for short life products like urea fertiliser, solvents, detergents, etc. they are regarded as instant CO_2 emissions according to IPCC accounting methods [40]. Carbon contained in plastics like melamine or nylon (based on urea) is accounted when (and if) it is released in landfills or incineration. CO_2 sold as an input for carbonated beverages or for other purposes is logically assigned to these products or industries. There are no exact figures on this flow available. In conclusion, it is estimated that at least 4 Mton CO_2 can be assigned to fertiliser industry. Additional CO_2 is involved in dolomite use in e.g. CAN, which contains carbonates from natural origin, but these are not accounted in the IPCC method.

The nitric acid production is with an estimated emission of 25-30 kton also a main source of N_2O in the Netherlands, about 40%. This equals the effect of 8 Mton CO_2. The other main source of N_2O emissions of about 40% comes from chemical reactions of nitrates and ammonia on agricultural soil, which is related to both manure and fertilisers. This is assigned to the agricultural sector. Total greenhouse gas emission assigned to the fertiliser industry is about 12 Mton CO_2 equivalents, which equals about 5% of the total Dutch greenhouse gas emissions.

Options to reduce greenhouse gas emissions are dealt with in Paragraph 9.3. Here the impact of energy and climate policy is analysed. The ammonia, NO_x and SO_2 emission were already reduced during the last decades. These levels can be further reduced by the construction of new plants. Gypsum is a major side product of the phosphoric acid production. The plants at stake have permission to discharge gypsum into the surface water. Main pollutants in this case are several heavy metals like cadmium, mercury and lead. Most emissions have been reduced with 80% within the last 6 years [41]. New regulation is based on the best available technology [42].

6.4 Capacity to compete

The Dutch Ministry of Economic Affairs has published a report about the capacity to compete of the Dutch economy at the end of 1997 [43]. This report gives insight in the general advantages and disadvantages of the Dutch economy. It is compared with several other OECD-countries like VS, Germany, France, Japan and the UK. The results which might influence the fertiliser industry are presented here. They are combined with some remarks on the competitiveness of the fertiliser industry in West Europe from the EFMA [44,45]:

- The Monetary and budget stability are considered favourable in comparison with other industrial countries like Japan, VS, UK, Germany and France.
- Another positive aspect is the rigid and institutionalised labour market. High productivity and moderate wages are combined with a high degree of inactivity.
- Education level is high but connection to the labour market is regarded low. Skilled work is a West European advantage compared to other regions world wide
- Research activities are internationally competitive, but the industrial influence on the research is relatively low.
- Environmental legislation is strict but transparency is high. Most high environmental standards are considered as a positive incentive to industrial development.
- Low energy prices are a positive side of the Dutch economy compared with other OECD countries. Compared to the gas and oil prices for industry in the Middle East and Russia prices are still relatively high.
- High transportation costs for fertilisers make Russian and Middle Eastern fertiliser production not competitive on the Western European market. Other former Sowjet, Central and Eastern European countries have to pay approximately same prices for the Russian gas as Western European prices and therefore are not competitive. Nevertheless Eastern and Central European products appear at very low prices on the West European markets; in several instances the EC has issued anti-dumping measures against the concerned producers.

7. IMPROVEMENT OPTIONS

Because of increasing competition, pressure on fertiliser production will increase on the long term. Cost control and innovation are important to gain a competitive edge. With respect to energy issues an overview will be given in this chapter.

The discussion in this chapter will be limited to the nitrogen based fertiliser industry. Within this industry the ammonia production is part of almost al important improvements. Paragraph 7.1 describes several new production technologies. Paragraph 7.2 describes the use of alternative processes for hydrogen and syngas production for ammonia synthesis. Paragraph 7.3 describes several alternatives for N-fixation without the use of ammonia. These options are alternatives for meeting nutrient demand, not necessarily with fertilisers.

7.1 Current technology improvements

The 'best practice' processes found for ammonia production have a specific energy consumption (SEC) of 28-29 GJ/ton ammonia [46,47,48]. Lower SEC-values were even found for some other process options that are under development [49]. A brief description of these options will be given here. The options improve the energy management of the syngas production. The options concerning catalysts and membranes increase the efficiency of the ammonia reactor within the plant.

Modern ammonia production concepts are measured by their total net energy consumption. These values must be interpreted with caution because they depend on many plant variables. Besides that, the accuracy of the data is often highly overestimated. Some plant variables influencing energy requirement are the following:

- The water temperature within a water-cooled ammonia plant influences the energy consumption. An increase from 20°C to 30°C of the cooling water decreases the energy requirement with 0.7 GJ/ton ammonia.
- Natural gas containing 10% CO_2 increase the energy requirement with 0.2 GJ/ton
- The delivery temperature and pressure of ammonia can vary. Delivery at production pressure would decrease the energy requirement with 0.6 GJ/ton.
- The imported and exported steam and power could be taken into account in many ways, influencing the efficiency of the system.

These remarks should be kept in mind when energy requirement data are compared.

Current developments

The first energy efficient optimisation of the ammonia synthesis was made by Braun (now Brown & Root) in the 80s. This process was remarkably efficient for this time with an energy requirement of around 28.5 GJ/ton ammonia. During the last decade several industries improved their processes to even lower energy requirements. The main developments are:

- A simple construction change that influences the energy use of the ammonia production is the ICI-AMV-process. The process excess air is supplied to the secondary reformer, so the primary reformer can be smaller. By this design milder conditions can be used and an energy use of 28 GJ/ton ammonia is reached.

- Kellog developed a low energy process design known as LEAP (Low Energy Ammonia Process). This concept optimises mainly the energy requirement for the secondary reformer. Most important feature is a further decrease of the heat demand by less severe temperature changes within the process. This reduces the required heat recovery. Further optimisation of the ammonia synthesis and improving the CO_2 recovery reduce the energy requirement of this concept to 27.9 GJ/ton. When use is found for large quantities of exported steam this could probably be brought to 27 GJ/ton.

Other contractors have made other optimisations of the traditional ammonia synthesis concept but with completely different technical concepts. Other efficiency improvements were found by Uhde in processes were this technology is combined with partial oxidation. In practise the steam reforming process is combined with the combustion of natural gas to carbonmonoxide and hydrogen (syngas). The method is used for both ammonia and methanol production processes, which is also based on syngas. Development of this technique takes place by Uhde in Germany, which has built a demonstration plant. In Canada the same technique is used in a 5 to 10 Mt/day pilot plant built by Haldor Topsoe. The SEC for ammonia by this process is estimated at 28 GJ/ton. Uhde engineers expect values below 27 GJ/ton ammonia with the introduction of large surplus steam export. Haldor Topsoe gives energy consumption figures around 27.9 GJ/ton for newer concepts.

New catalysts

The activity of the traditionally used iron based catalyst can be increased considerably by promotion with cobalt. A lower pressure in the ammonia synthesis reactor and/or a lower recycling rate can also be achieved. Another more active catalyst is ruthenium. An energy reduction of 1.2 GJ/ton ammonia can be reached compared to the traditional iron-based catalyst. A ruthenium based process is developed by BP and Kellog. These technologies are applicable in new steam reforming and partial oxidation plants [46, 47].

Absorption and Membrane processes

Further improvement on energy efficiency can by reached by a new reactor design [50]. Again two options were investigated, the use of absorbents and membranes within the ammonia reactor. The first idea is to remove the ammonia in the reactor by an absorbent. By this product removal the equilibrium of the synthesis is shifted towards complete conversion. Processes with a gas absorbent and a liquid absorbent were designed for methanol synthesis but should also by applicable to ammonia synthesis. By reducing the pressure ammonia can be recovered from the absorbent. The main advantage of this process is the 100% conversion in one pass. In conventional plants the recycling of unconverted reactants is a high energy consuming part of the process that can be avoided by. Though promising, the development of this process is still uncertain, because of the lack of good absorbents until now.

At ECN [51], research on membranes for the ammonia synthesis reactor is in progress. This membrane separates the ammonia from the other gases. It also leads to a shift of the equilibrium towards ammonia and leads to a high conversion rate in one pass. This rate depends on the quality of the membrane. A second advantage influences not just the reactor but the whole plant. A stoichiometric mixture of nitrogen and hydrogen in the feed gas to prevent build up of reactants in excess due to recycling is no longer required. The state of the development is uncertain [52].

Using all these options, the specific energy consumption of the ammonia synthesis can be reduced to about 24 GJ/ton ammonia. The development and testing of new reactors and catalysts is a specialised and expensive process. Only a few companies take part in this development. The process design is concentrated by Braun (D), ICI (UK), M.W. Kellog, Haldor Topsoe A/S (VS, Dk) and Uhde GmbH (D). The catalytic research is concentrated by Haldor Topsoe A/S, Katalco (VS), United Catalysts (VS), BASF (D) and ICI [50]. Implementation of these technologies in the near future is uncertain and will at most only be part of new plants. The high costs of retrofit implementation makes them not cost-effective in existing plants.

Integration with urea production
An integration of the urea production with the ammonia production can lead to a reduction of the energy consumption. The efficiency of this integration depends on the energy consumption in the CO_2 removal system of the ammonia plant in question. The concept of an integrated ammonia-urea plant has been discussed already some 20 years ago. The concept never made it because operators were and still are very reluctant to accept this concept due to the operational risks involved. In the mean time the specific energy consumption for the CO_2 removal in the ammonia plant decreased drastically and therefore the advantage of integration disappeared.

7.2 Alternative ammonia production

There are various other routes to ammonia production beside the methane based processes described in Chapter 3. As nitrogen is freely available, most important is the source of hydrogen in NH_3. Hydrogen sources mentioned in this chapter are coal and water.

Syngas from coal gasification
As was mentioned in 2.3, ammonia derived from syngas in coke plants was already known in 1903. With present coal gasification technology, it is possible to combine ammonia production with electricity production. A study on the production of several co-products for the electricity production by Integrated Gasification Combined Cycle (IGCC) includes the possibility to produce ammonia in the electricity generation off-peak periods [53]. With the present low gas prices and moderate CO_2 policies, electricity generation in the future is expected to be mainly gas based. With higher gas prices and rigid CO_2 policies, coal gasification combined with CO_2 removal may become an attractive option. However, with liberalisation of electricity production, investments in expensive integrated plants combined with ammonia production are unlikely. There are no substantial new reasons for ammonia production to return to coal.

Other syngas sources
In the oil industry, hydrogen from natural gas is presently used for upgrading of oil products. Therefore, there are no surpluses of hydrogen available for e.g. ammonia production. Other products like methanol are already produced from natural gas. Steam reforming of oil residues or biomass may be a possible source of syngas. This in turn is a source of hydrogen, but this technology is not likely to be applied to the extent that ammonia production can be based on it. Natural gas is still largely preferable because of its high hydrogen content, purity and wide availability.

Electrolysis [47]
The production of hydrogen and oxygen by the electrolysis of water has been practised on an industrial scale since the beginning of this century. Electrolytic produced hydrogen can be directly used for the production of ammonia. Such operations exist today in Egypt, Iceland and Peru. The scale of production is small and the technology is simple but economically not feasible if electricity can be sold elsewhere. The costs were estimated at 5 times the costs of steam reforming. However under certain circumstances, when hydroelectric power is abundantly available it can be a competitive technology. Main advantages are:
- Water and air as feedstock
- Low pollution
- Simplicity in operation and maintenance.

Within an European market with high gas resources and developing electricity markets it is not to be expected that this technology will compete with the gas based ammonia production.

7.3 Ammonia demand reduction options

The entire world supply of nitrogen-based fertilisers in 1995 was produced by steam cracking and partial oxidation processes based on the Haber-Bosch synthesis of ammonia. As nitrate is the form in which nitrogen is used by crops, nitrate production from other sources seems of interest to substitute energy intensive ammonia. In theory, many other options are available for the fixation of nitrogen, like electric arc oxidation, or high pressure synthesis from atmospheric nitrogen and oxygen. These are even more energy intensive than ammonia synthesis and have no potential to compete with the Haber-Bosch-synthesis [54]. The main research projects are aimed at biological fixation by bio-engineering for the fixation of nitrogen. The prospects of these technologies are limited.

Other nitrate sources

Potential nitrate sources include manure surpluses from cattle breeding, excrements in sewage water or sludge from water purification plants. These sources of nitrate recycling make sense from a sustainability point of view, although the quantity of available nitrate from these sources is only limited. Manure is applied in agriculture and is a large source of nitrates already. Although in parts of e.g. the Netherlands a substantial manure surplus exists because of intensive livestock breeding, the general European practise is application on nearby farmland. However, there are two main reasons why ammonia fertiliser is not replaced. First, optimisation of these nitrogen flows would require huge amounts of water and organic compounds to be transported to processing plants. Nitrogen from human sources is proposed for fertilising purposes, this would require a separate sewage infrastructure. Second, extensive chemical and physical processing is required to control the composition of the product and to remove pollutants. Compared to current fertiliser production, these alternative nitrate routes are far too costly.

Biological fixation

Biological fixation of nitrogen has always played an important role in nitrogen balance. Table 6.3 shows that ecological agriculture uses biological fixation as a main source of nitrogen. The most promising option of biological fixation seems white clover, which has a high nitrogen fixation capacity. For example, some results were reported by the energy crops production. A two year production of phosphor and potassium fertilised willows intermixed with clover gave (a comparable to normal fertilised) 23 ton dry wood per ha, whereas the willow without intermixed clover only produced 2.4 ton [55]. The main disadvantage of biological fixation as used until now is the need for mixed crop planning, which is uncommon and costly within the current agricultural practise. Within an analysis of options to improve the energy efficiency of N-fixation De Beer [56] distinguishes several options for biological fixation. The three main sources are:

1. *Symbiotic systems*

   In this case micro-organisms are used which in natural circumstances fix atmospheric nitrogen (N_2) in soils as ammonium (NH_4^+). This is a natural source of nitrogen but in some cases micro-organisms can be added to the soil to increase the fixation. Several sources are already commercially available, but the potentials are very unclear. Another option is a crop mixture were a nitrogen-fixation crop is introduced. An example is the introduction of clover between commercial crops. These methods are natural, that means no genetic engineering is involved.
2. *Genetic Engineering of crops to enable symbioses*

   In this case plants are genetically manipulated to make symbiotic nitrogen fixation possible. The genes that allow natural symbiosis as described in the first point are introduced in other crops. The fixation is still done by micro-organisms but the ability of the crops to use this fixed nitrogen is improved. Research on this issue, mainly used for rice-production, is under development in Manila on the Philippines and Wageningen in the Netherlands. This option is in the stage of applied research.

3. *Genetic engineering of crops to enable nitrogen-fixation*
   In this case crops are genetic changed is such a way that they can fix nitrogen themselves. It is very unclear whether this method will ever become available because the nitrogen-fixation process from micro-organisms like Rhizobium should be introduced in a completely different organism. The sensitivity of the enzyme necessary for this synthesis (e.g. for oxygen) makes the approach very difficult to apply. Therefore it can be concluded that much R&D is required for this method, and that commercialisation of this option, if possible, will take several decades.

The use of biological fertilisation is interesting but requires a high research effort and drastic change within the agricultural practice. Therefore it is very unlikely that biological fertilisation will become common practice within the next decades. The research is developing fast and promising but prospects cannot yet been given. It is still focused on the fundamental issues of methods [57].

Improving efficiency of fertiliser application

A more technical solution to the high losses suggested by the fertiliser industry is the use of slow-release fertilisers. Until now these fertilisers are relatively expensive and their use is limited because of the low prices of conventional fertilisers. With the expected EC and USA legislation concerning the run off of nutrients it is necessary for the industry to continue developing this kind of fertilisers [58]. Large scale introduction probably can only be enforced by legislation. It should be noted to more selective fertilisers are just another way to decrease fertiliser standards.

For specific crops in e.g. horticulture, special customised mixes of fertiliser are already made and delivered. Losses can be reduced and fertiliser efficiency can be improved by adjustment to crop and soil type and dedicated timing for application. In greenhouse horticulture, closed water loop systems are already feasible that can avoid nutrient losses completely.

7.4 Conclusions

Significant technological improvements are still possible in ammonia production plants, increasing efficiency with 15% on total gas input for energy and feedstock compared to 1990. Alternatives for ammonia synthesis out of natural gas are not likely to be implemented, and neither are alternative nitrate sources. Fertiliser demand reduction is possible in various ways, that fit into policy requirements to reduce nitrogen losses.

8. COMPETITORS

In this chapter, current and potential competitors for the Dutch fertiliser industry are identified, and their advantages and disadvantages are dealt with. First, current production and trade are analysed, then the global feedstock availability is looked at. In the second part of this chapter, different regions are evaluated for their advantages and disadvantages.

It should be noted, that competition in fertiliser products takes place in an international arena where companies are the main players and not countries. Companies choose their production locations where conditions are favourable to them. These conditions are for example the availability of high skilled labour, the proximity of a consumer market, a developed infrastructure and low energy and feedstock prices. Also strategic considerations like risk spreading play an important part in investment decisions.

8.1 Competition factors

Current production capacity and trade

Historically, the fertiliser industry is primarily orientated on the demand of the local market. The main reason is that fertilisers are bulky and cheap, which makes transportation costs a major limitation for competition. Therefore supply capability for fertilisers matches the demand pattern for most regions, as shown in Figure 4.2. Intercontinental transport is limited. Europe, North America and South East Asia make up the bulk of the existing production capacity. As an example, nitrogen capacity is shown in Table 8.1.

Table 8.1 *Nitrogen production capacity 1995/96 and estimation 1999/2000 [Mton N]*

	1995/96	1999/2000
Africa	4	4
North America	17	17
South America	5	7
East Asia	31	33
West/South Asia	19	22
Western Europe	11	11
Eastern Europe	8	8
FSU	21	20
Oceania	1	1
Total	117	123

Source: [23]

Some trade figures are summarised in Table 8.2 and Table 8.3. Present long distance trade flows occur between Russia, CEE and Western Europe, and from Russia and the Middle East to Asia. From Figure 4.2, relevant trade flows can be derived from North America to South America, India and China. Most destination regions depend for less than 20% of their use on imports. Imports in the EU are related to the present overcapacity in Russia and CEE countries.

Table 8.2 *Fertiliser trade balance and flows to and from the EU, 1994 [kton] [20,44]*

Origin			Destination	
Production	11,000		Use	13,200
Imports	3,500		Exports	1,300
Russia	600	(N)	EFTA	229
Poland	300	(N)	USA	65
Lithuania	260	(N)	China	58
Bulgaria	250	(N)	Brazil	42
Morocco	396		Rest	906
Tunisia	312			
EFTA	560			
Rest	822			

(Russia and CEE figures for N, Morocco is phosphate rock)

Table 8.3 *Most important fertiliser trade flows, million ton N, 1994 [44]*

	Production	Imports	Exports	Use	Imports [% of use]	Exports [% of prod.]
China	18	4,5	0	22,5	20	0
USA	11,7	2	2,5	11,2	18	21
EU	8,4	2,5	1,1	9,8	26	13
Russia	4,8	0	3,6	1,2	0	75
CEE	4,5	0,2	2,8	1,9	11	62
Middle East	2,8	0,1	2	0,9	11	71

Feedstock availability

The main feedstock for fertiliser production world wide is natural gas. The high energy use in the fertiliser industry makes a reliable and cheap gas supply very important. The main gas locations of interest for the European market are shown in Table 8.4. The production costs are not directly related to the energy prices in the different countries. But for a competitive industry at least the production costs should be low and the supply reliable.

Table 8.4 *Natural gas resources for the EU market [60]*

Country of Origin	Production Costs[1] [$/TJ]	Deposit size
Netherlands (Groningen)	7	Very large
Algeria	34	Very large
Norway, offshore	69	Large
UK, offshore	103	Small & Medium
Nigeria	48	Small
Russia, West Siberia	34	Very large
Qatar (Middle East)	34	Very large

[1] including delivery to the EU continental gas grid.

Cheap gas and large scale capacity are major advantages in competing on the fertiliser market. High transportation costs towards Europe make the European market less attractive for industries in the Middle East and South East Asia. Further competition out of Middle East and South East Asia on the European market is not realistic because of the fast growing demand in these regions.

Other factors
The reduction of trade barriers may significantly enhance international trade. Whether such a shift occurs will eventually depend on production costs. Cost price structures abroad may differ from the price structure in the Netherlands because of differences in:

- raw material and energy prices,
- production technology,
- investment costs,
- labour costs,
- cost increasing legal constraints,
- transportation costs.

The choice which fertiliser will be produced depends on production location and demand location. The availability of dolomite makes it possible for the Dutch fertiliser industry to make CAN, which is an attractive form of fixed nitrogen for the Western European market, because of the limited acidification caused by the use (Table 4.2). For competitors CAN contains the disadvantage that it has a low N-concentration, which makes it expensive in transportation. Therefore we assume that competitors produce ammoniumnitrate which can be mixed with dolomite to CAN in the vicinity of the user market.

8.2 Regions

Potential competitors are chosen outside the EU, because European competitors are assumed to be in the same position as Dutch industry. Differences within the EU are limited to transport factors. Compared to other EU countries the gas supply and vicinity of high demand areas is a relative advantage of the Dutch industry.

Western Europe
Western European fertiliser industry produces mainly for the own European market. The production capacity is concentrated in France, Germany, Belgium, UK and the Netherlands. The position near main gas resources, (North Sea and Slochteren NL), close to major petrochemical industry and the proximity of a large consumer market seems advantageous for the Dutch industry. But in the Dutch case all neighbouring countries are also major fertiliser producers and local demand is decreasing as a result of nutrient legislation. Growth in Dutch commodity fertilisers at the expense of other producers seems in this situation hardly feasible. Western European competition will grow unless the Dutch cost structure is protected from the European developments. With the trend of liberalisation of markets in the EU this seems unlikely. Production in the Northern areas (UK, Norway) is predominantly based on North sea gas. Such facilities can produce at significantly low costs, and can compete with the already low production costs of the Dutch gas. The reserves in the Northern European region were estimated to last for at least 30 years. The gas supply and cost structure in North Norway are almost the same as the Dutch structure. Price differences depend on the market and the willingness to sell the gas at the production cost level. Dutch prices were high, but production costs are low. For North Norway we assume the local spot market price of 0.11 Dfl/m^3 NG (1.6 \$/mln Btu) [59].

Central and Eastern Europe (excluding Russia)
The low natural gas prices and the very large resources in Russia make the feedstock and energy part of the production cost low [60,61]. Gazprom, the biggest gas supplier in the world supplies gas to its own fertiliser industry at extremely low prices. Until the break-up in 1993 most Eastern European and former CIS countries were supplied at similar low prices. After 1993 natural gas prices for the fertiliser industry in the Ukraine and Poland increased towards Western European levels. The competitive advantages of this industry on the European market disappeared and only the disadvantages of the low energy efficiency in these countries remained. The energy use is estimated to be up to 30% higher than in Western European industry.

It is to be expected that several Eastern European countries will join the EU within the next decade. This will lead to a larger EU fertiliser market and a different structure of industry. The industrial integration is already started. The EFMA has welcomed seven fertiliser producers from the Czech Republic, Lithuania and Poland [44].

Russia

The Russian industry market share in Western European nitrogen fertiliser market grew between 1992 and 1997 from approximately 0 to 17%. This fast increase was a result of the continuing low agricultural product revenues and a stop on fertiliser subsidies in Russia. Because of this, the domestic market collapsed and the fertilisers were exported to, or dumped on, the Western European market. The competitiveness of the industry decreased the last years as a result of lack of funds for modernisation and increasing transportation and port handling costs. The privatisation of the fertiliser industry on the other hand leads to interesting take-over opportunities for Western companies. Uncertainties are the dollar vs. rouble exchange rate and the agricultural (policy) development in Russia. A revival of the Russian agriculture will restore the local demand/production equilibrium. On the long term high transportation costs will dominate the competition of the Russian industry on the Western European market. Also, Russian producers will need investment capital for modernising their installations.

North Africa (Algeria)

Production costs in North Africa are relatively low because of vast gas resources and low labour costs. The natural gas infrastructure has a high reliability because of the major importance of gas for the North African economies. Most important uncertainties are political. Both Algeria and Libya have a political climate that makes investment from international fertiliser companies unlikely. The risks of political violence (Algeria) and risks of nationalisation (Libya) makes foreign investments relatively risky and therefore costly. On the other hand, it is not to be expected that any government, no matter its political colour would stop the oil and gas export because they represent about 90% of the export value.

Others

Middle Eastern countries show vast gas reserves, South and East Asian countries show a fast growing production capacity and North America shows high quality standards with a production comparable to the Western European industry. For all these three locations it is unlikely to become competitive on the Western European market within 20 years for two main reasons. These are relatively high transportation costs and a rapidly growing domestic market. The fast growing fertiliser market in developing countries makes it necessary for the Asian industry to increase production with about 5% annually. Beside its own agricultural demand, the Middle Eastern production is also supplying the Indian and Chinese market. For the North American industry the fast growing Caribbean and South American market seems more interesting.

8.3 Conclusions

All locations have major advantages and disadvantages, but overall several locations can be pointed out as real competitors on the Western European market. The discussion in preceding chapter shows that feedstock availability and low transportation costs are essential issues for the fertiliser industry. Within Europe, Norway and Russia are attractive options with large gas resources and transportation facilities. The Middle East and South Asia have also significant additional gas production capacity. This capacity seems however largely occupied by increasing demand in the South and East Asia. The high gas resources in North America make this region competitive, but it is more likely for this industry to supply the fast growing South American market. North Africa is interesting because of gas resources and the relatively short transportation routes to Western Europe. Almost all advantages are combined in Algeria, where only the relatively unstable political situation may influence the willingness to invest. In case of a more stable internal situation and an internationally open economic policy, this region is a potential competitor. Furthermore Norway has cheap gas and short transportation routes to the Western European market. This will be considered as the second important competitor in the analysis. Russia is not included, because investment costs and transportation costs are uncertain, but probably will be higher than the Algerian alternative. Nevertheless, they are considered to be the most important competitor in the coming years due to the presently existing overcapacity.

9. COMPARISON OF PRODUCTION OPTIONS

In this chapter, several production options are now compared and analysed in more detail. Alternative locations are based on the selection in the preceding chapter. Investments in ammonia based fertiliser plants are assumed to be made by the international companies. The best current practise is available on all compared locations and ammonium nitrate is the final product. Comparison is based on one ton of ammonium nitrate to be delivered in North West Europe. The considered production locations are: 1. Netherlands, 2. Norway, 3. Algeria. The reference situation in the Netherlands is also compared to environmental policy scenario's, involving energy and greenhouse gas taxation. Russia is not chosen as a potential new location, although present competition is a major concern for the Dutch industry. For the time horizon considered here, Russian industry will at its best be in a situation comparable to the Algerian alternative.

9.1 Alternative locations

The cost structure for the Dutch industry is already defined in Chapter 5. The cost structure for Norway and Algeria is given in Table 9.1 and based on an ammonium nitrate plant. The comparison with the figures in Chapter 5 is not straightforward because data in Chapter 5 refer to the whole fertiliser industry, including the phosphorus and potassium based fertiliser industry and several other nitrogen based products. The cost group maintenance refers to external process maintenance contracts. All overhead costs like management, insurance, research and marketing are called 'other costs'. These costs are estimated, but in accordance with the cost structure analysis in Chapter 5.

The assumed plant is a stand alone ammonium nitrate plant with 500 kton annual production via ammonia production by steam reforming of natural gas. Investments for this kind of plant are in Western Europe approximately 600 mil. Dfl. Investment costs in Norway and North Africa were assumed to be 15% and 30% higher due to additional facilities, infrastructure and transportation costs for equipment [62]. Annual maintenance costs are estimated at 60% of annual investment costs.

Table 9.1 *Cost structure for the different locations*

	Netherlands	Norway	Algeria
Investment [mln Dfl/plant]	600	690	780
Production capacity [Mton N/year]	500	500	500
Availability rate	0.9	0.9	0.9
Interest rate	8%	8%	8%
Energy prices [Dfl/GJ]			
- gas	5.9	3.4	1
- electricity	30	30	30
Energy/feedstock costs [Dfl/ton]	72	43	14
Maintenance [Dfl/ton AN]	22	26	29
Labour [Dfl/ton AN]	29	37	22
Sea transportation costs [Dfl/ton]	0	25	40
Inland transportation costs [Dfl/ton]	45	45	45
Total transportation costs [Dfl/ton]	45	70	85

Transportation costs for fertiliser are substantial. For Algeria and North Norway transportation by bulk carrier to Western Europe is assumed. Transportation costs were estimated to be 40 Dfl/ton for Algeria and 25 Dfl/ton for Norway to the Western European market. From seaports, additional inland transportation is required at the same cost as Dutch industry faces. It is assumed that inland ships, trucks and trains are the inland transportation options. Cost figures are based on the transportation cost analysis in Chapter 5. Import duties are not incorporated in these cost figures.

A survey of the cost structure in absolute and relative terms is given in Figure 9.1 and Figure 9.2 In the latter figure the production is compared with the high and low level of ammonium nitrate prices during the last price cycle.

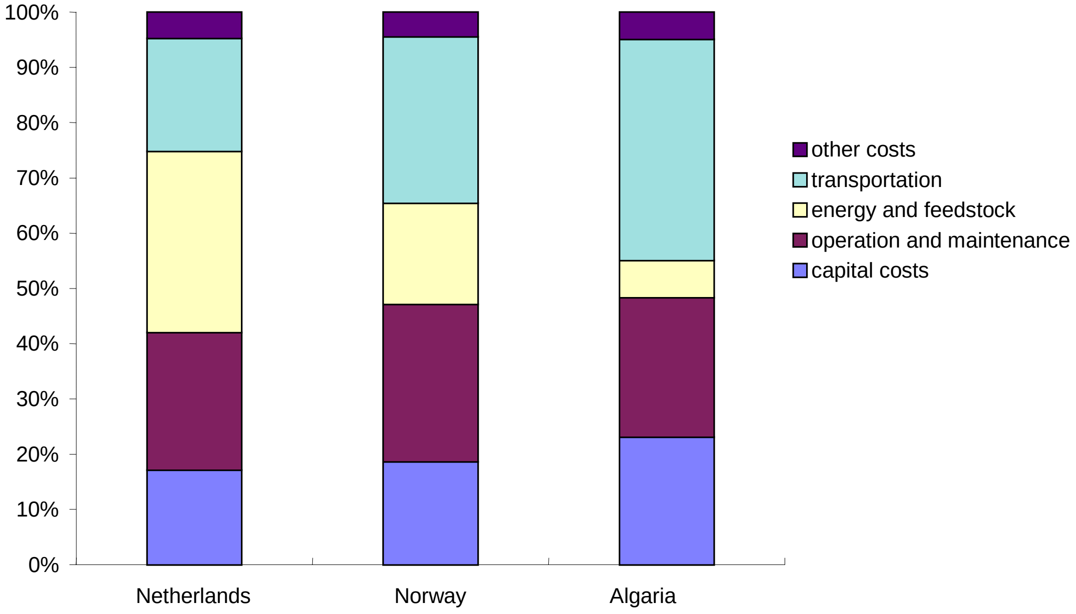

Figure 9.1 *Cost structure for ammonium nitrate production on several locations*

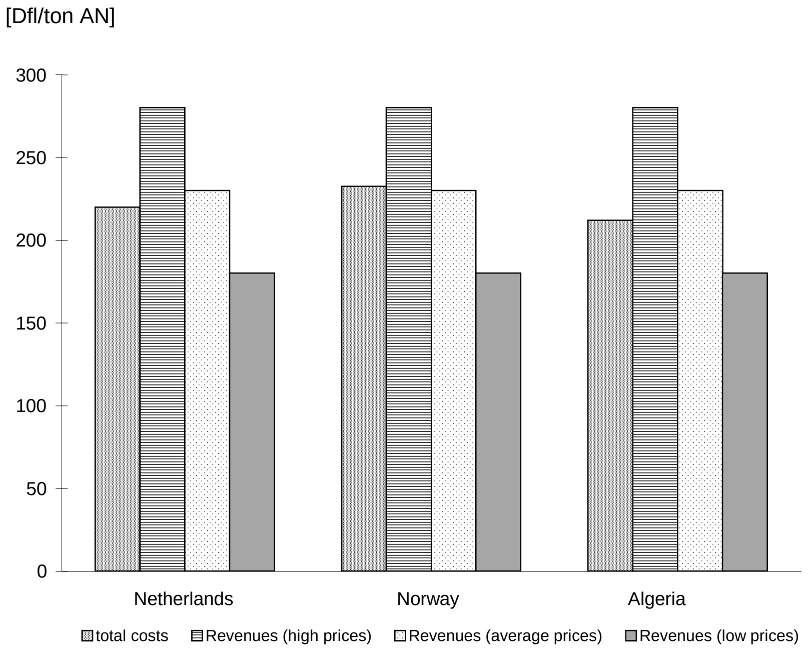

Figure 9.2 *Costs and revenues of ammonium nitrate production on several locations*

It can be concluded, that costs in North Africa are only slightly lower than in the Netherlands, although differences for the cost components are large. Compared to market price fluctuations, cost advantages are of minor importance. Investments in North Africa by the international companies do not deliver substantial advantages. Because of the present instability of this region, these initiatives are therefore unlikely to occur. Costs in Norway turn out slightly higher than in the Netherlands, so there are no major advantages to expand European capacity in that region. As was found in 4.3, European demand will not grow, so additional capacity that supplies the Western European market is not expected in the further analysis. Therefore, competition is expected to arise only from the current capacities in the Western European region.

9.2 Sensitivity analysis

The preceding chapters show the complexity of estimating costs and revenues for the fertiliser industry. Each component requires a number of assumptions that determine the outcome to some extent. In order to provide more insight in the determining variables and the impact of certain assumptions, sensitivity analyses are presented for the calculations in the previous paragraph.

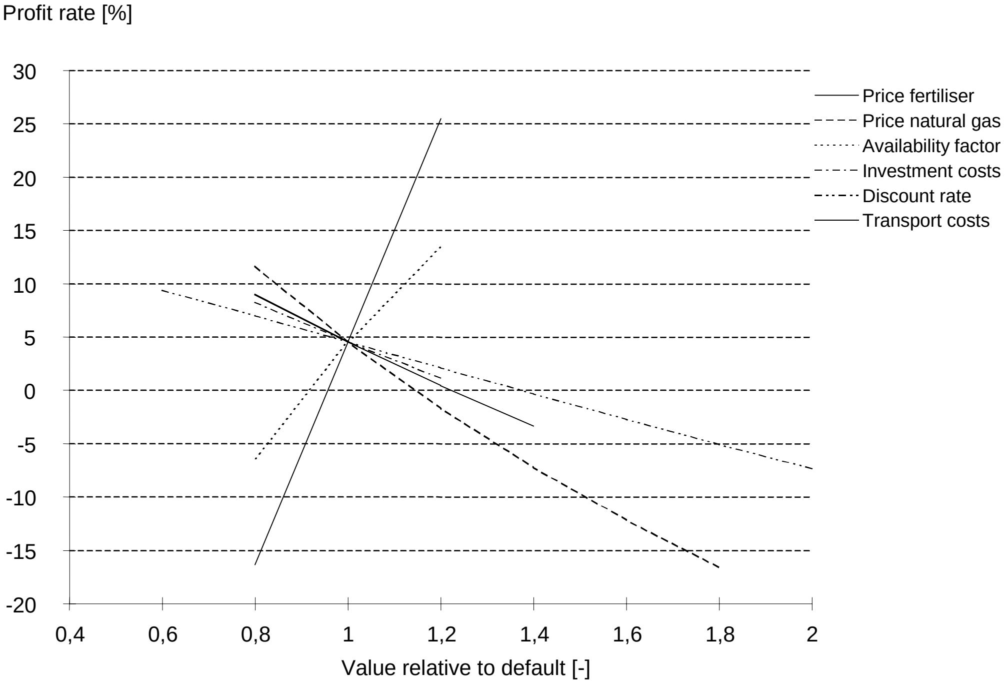

Figure 9.3 *Sensitivity analysis of the fertiliser industry*

In order to evaluate the sensitivity of different fertiliser production options, data from Paragraph 9.1 are varied in order to show the impact on profitability for such variations. The results are shown in Figure 9.3 for the ammonium nitrate production. Profit at average market prices is set on the vertical axis as a percentage of total costs. On the horizontal axis the reference value for the present Dutch industry is set at 1. The variables are depicted in a range where both ends represent extremes that could occur in coming decades. Steep lines represent variables with large impact on profits. The picture shows that profits can have a considerable range. The industry is in particular sensitive for market factors such as fertiliser prices and occupation rate. From the costs components, gas prices are the most influential. Discount rate and investment costs are of relatively minor interest for the industry.

The most important cost factor in the Dutch situation is the purchase of natural gas as energy and feedstock. These costs are varied in order to show the impact of gas price developments on the plant performance. To assess long term sensitivity, a price range is assumed for natural gas between 3,5 and 9,5 Dfl/GJ. On the short term, feedstock prices are mostly stable. Long-term contracts are an essential factor in the considerations of the industry to start production on a certain location. Fluctuating feedstock prices are considered a high risk.

The sensitivity of the profits for different gas prices on the three evaluated locations is shown in Figure 9.4. It shows that the profit rate for the Dutch industry is equal to the profit rate of competing foreign plants in case of a gas price difference of about 4 Dfl/GJ between the locations. In view of developing gas markets and gas grids, a narrowing gas price difference between competing locations seems likely. Therefore, with regard to long run gas market developments, the position of the Dutch fertiliser industry will improve.

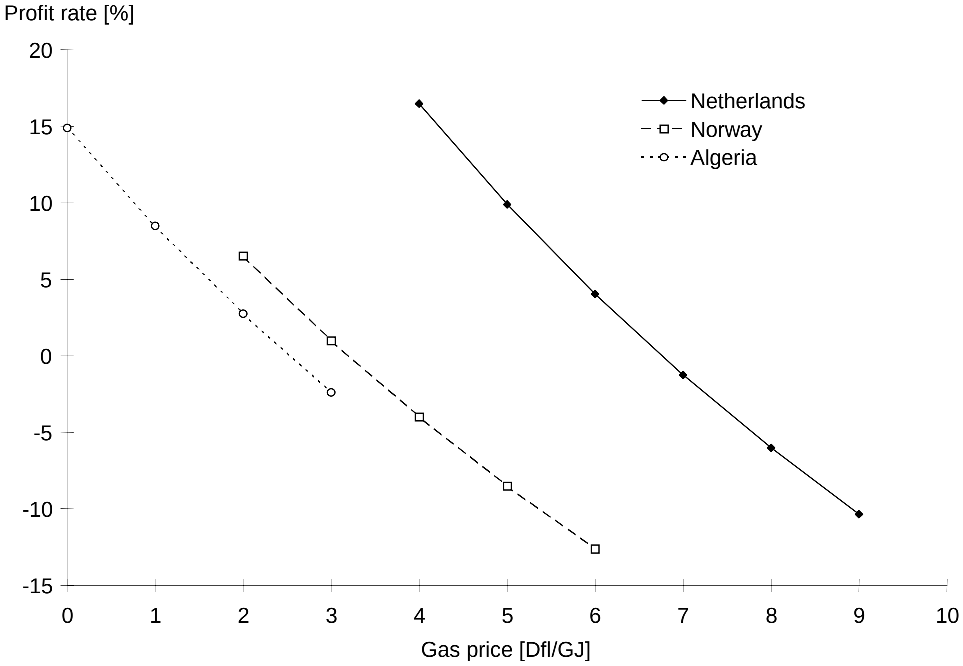

Figure 9.4 *Shift in profitability due to relative shift in energy + feedstock prices for different ammonium nitrate plants*

The cost of transport is another important factor which is analysed with respect to profitability. In Figure 9.5, profit rates are depicted in case individual companies would succeed in improving transport efficiency of fertiliser. By using large bulk carriers for sea transport, costs may decrease substantially. Other transport efficiency improvements, e.g. by avoiding intermediary steps, may decrease overall transport costs. This would only be feasible with substantial logistic adjustments (storage facilities).

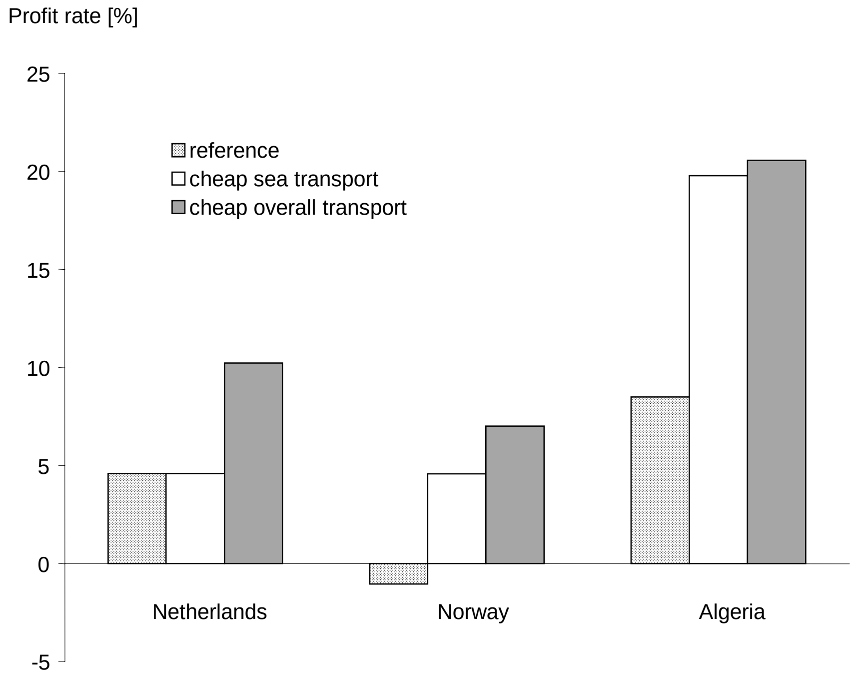

Figure 9.5 *Shift in profitability due to cheaper transport for individual producers*

The cases in Figure 9.5 refer to a 50% reduction in sea transport costs and a 25% reduction of overall transport costs. Especially the North African alternative would benefit from such improvements, and might gain a decisive advantage.

9.3 Impact of energy and environmental policy

In this paragraph, several types of environmental policy are analysed, including reduction of nitrogen losses, energy efficiency improvement and reduction of greenhouse gas emissions. Based on the policies described in Paragraph 6.3 and costs structure analysed in Paragraph 9.1 the impact of energy and greenhouse gas taxes on the cost prices in the fertiliser industry can be shown. The level of these costs will be compared with the costs of CO_2 removal and storage.

The reduction of nitrogen losses is already subject to environmental regulation, as stated in Chapter 6. Policy is therefore partly aimed at reduction of fertiliser use in Dutch agriculture, and this might be extended in future to neighbouring countries if similar drinking water problems occur. The required reduction of N-nutrient losses in the Netherlands by 40% can lead to a proportional decrease of fertiliser use. When a substantial effort is taken towards a more integrated agriculture (see Paragraph 6.3), fertiliser use can be further reduced to 30% of the Dutch current standards, maintaining current output levels. The impact of such an integrated approach in neighbouring countries would be less profound. When this practise would be implemented on 50% of the arable land and pasture in Northwest Europe, it would reduce total fertiliser demand for the Dutch industry with an extra 4-8%. Nitrogen reduction policy primarily affects the sales volume of the Dutch fertiliser industry, and not its costs structure or technology. A tax on nitrogen fertiliser would basically have the same effect, but would not fit into the ongoing policy efforts. The expected sales volume reduction is partly compensated by increasing sales for other countries, for non-fertiliser applications and for special products with higher added value.

An inventory of major options to reduce greenhouse gas emissions is recently made for the Netherlands [63]. In a limited number of industrial installations CO_2 is released as a pure gasflow, and removal and storage can be relatively easy applied. Costs are estimated at 35 Dfl/ton CO_2. It is estimated that this is an annual flow of 4.3 Mton, half of which is from ammonia production (see 3.1). N_2O emission is expected to be avoided by catalytic reduction for which technologies are developed and applied before 2010. Reduction costs are estimated at only 3.50 Dfl/ton CO_2 equivalent. These are relatively cheap options for greenhouse gas emission reduction within the fertiliser industry. The industry states that this technology still has to be developed and the estimated costs are far too optimistic. For CO_2 from furnace firing and various other sources, the energy efficiency agreement policy is applied (see 2.5). Replacement of old installations with state-of-the-art technology can improve energy efficiency significantly (see 7.1). However, the industry expects that major replacements will not be required to meet environmental targets.

An energy or CO_2 tax directly influences the fertiliser cost price as is depicted in Figure 9.6. The first tax considered is a 50% energy tax only levied on the consumption of energy, excluding feedstock. The second is a 50% tax on both. Effects on energy and feedstocks are of course more significant because energy and feedstock are together approximately 34% of the production costs of ammonium nitrate.

A GHG-emission tax applies also to both energetic and non-energetic energy use because the CO_2 emission is proportional to the energy use. However, in present Dutch fertiliser industry about 1,3 Mton CO_2 is already removed and used for several purposes like urea-production, drinks, fire extinguishers, CO_2 fertilising in greenhouse horticulture. For 2010 this is expected to be about 2.3 Mton. When N_2O is taken into account, the GHG tax will be raised on 8 Mton CO_2 equivalents extra (see 6.3). When no additional measures are taken, each ton of ammonium nitrate leads to a GHG-emission of approximately 1.33 ton. Taking the measures described above would only cost 12 Dfl per ton AN and reduce emissions to 0.24 ton. Figure 9.6 shows that compared to taxation (fourth and fifth bar), dedicated funding of reduction options is more effective (sixth bar). It would increase energy/feedstock costs by 15-20% and total costs by about 5.5%. Although this seems a small markup, for the industry it is a large burden in a competitive market.

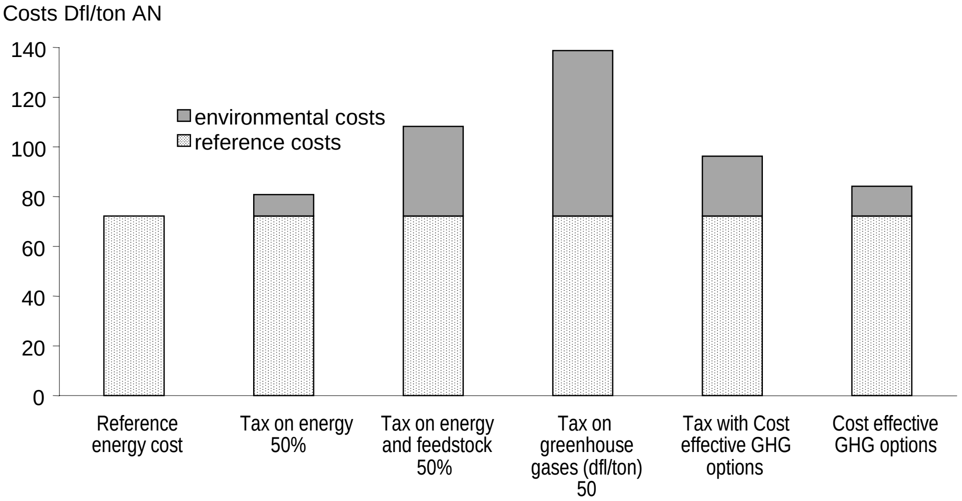

Figure 9.6 *Influence of several energy taxes, GHG-taxes and GHG reduction options on the energy + feedstock costs of ammoniumnitrate*

In Figure 9.7, effects on the profit rate for environmental policies is shown. Taxation only is assumed to have little effect on energy consumption, and so this is neglected here. Only the energy tax of 50% leaves some profit, the other taxation options will have decisive negative impact on the industry. If only GHG reduction measures are required without taxation, impacts on profitability are relatively small. In this analysis, no environmental subsidies or redirection of tax revenues is assumed.

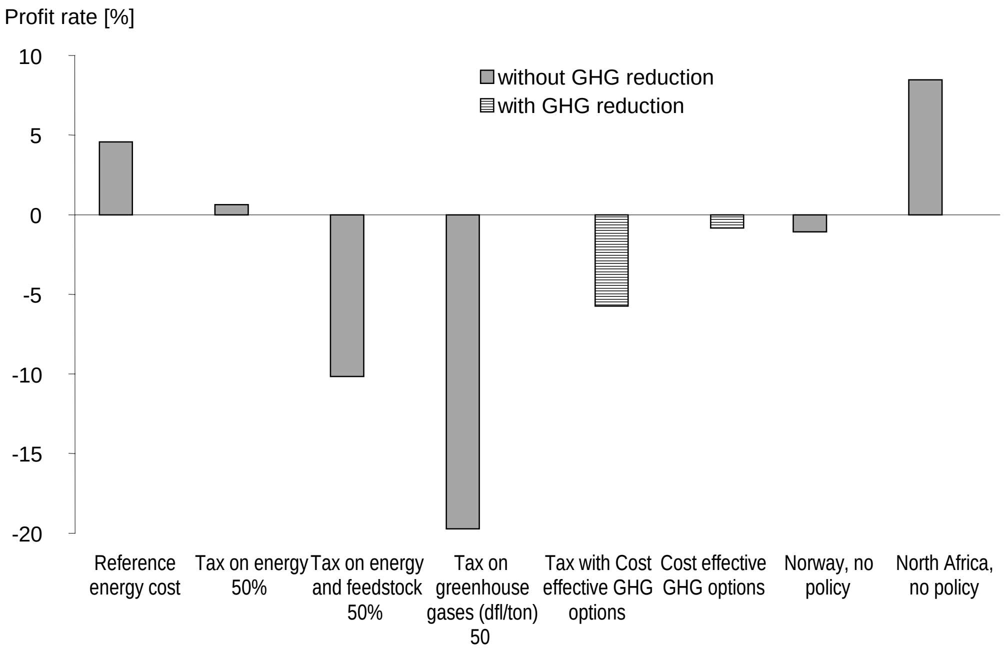

Figure 9.7 *Influence of several energy taxes, GHG-taxes and GHG reduction options on the profit rate of ammoniumnitrate production*

9.4 Conclusions

From the analysis of this Chapter some general conclusions can be drawn. First, when choosing a new location for nitrogen fertiliser production to serve the European market, the existing Dutch locations score relatively well in comparison with cheap feedstock locations. Second, because transport costs are relatively important, possible threat can occur when competitors succeed in reducing these with logistic improvements. Third, climate policy has to be carefully applied and customised, to avoid serious impacts on profitability. Nevertheless, the sector can take relatively cost-effective measures in the coming decade to reduce more than 80% of its greenhouse gas emissions.

10. PRODUCTION AND ENERGY FORECAST 2020

The goal of this Chapter is to forecast energy demand development for Dutch fertiliser production. The analysis will therefore refer to N-fertiliser and the required ammonia production. The next steps will be described:

- fertiliser demand forecast for Western Europe,
- international competition and trade,
- production development forecast,
- calculation of energy intensity of the ammonia process,
- calculation of energy demand.

10.1 Demand forecast

For the Dutch fertiliser industry, markets in the Netherlands and the neighbouring countries seem of prime importance to determine demand. The use of fertilisers in this region depends on two factors that will be considered in this paragraph. These are:

- factors influencing the area used for agriculture,
- developments of the agricultural practice resulting in fertiliser use per area unit.

As for intermediary chemicals produced by the fertiliser industry, a prognosis is based on the demand for organic basic chemicals in general [1].

Agricultural Area

The area used for agriculture in the Netherlands, Belgium, Germany and France has decreased slowly with 0.35-0.5% annually in the past 35 years [64,65]. This is caused by gradual urban development and expansion of forests. It is unlikely that these trends will change significantly in the next 20 years. Therefore, a 10% reduction will be reached by 2020. The agricultural policy of the EU (see also 6.2) also points in the same direction. Its influence is concentrated on the issues of lowering the surpluses in agriculture and land reservation for nature and forest development. The impact of policy is estimated to be small compared to the autonomous trend, possibly 2% over the whole period.

Agricultural fertiliser use per unit of land

In the past 35 years, application of fertiliser per unit of land in the relevant countries showed the highest level around 1980-1990. After a rapid growth during the sixties and seventies of 3-6% annually, fertiliser use declined after 1985 with 1-3% annually. France has a relatively low use level compared to Belgium, Germany and the Netherlands, but showed higher growth across the whole period. It can be concluded that countries with high user levels tend to decline most, whereas countries with lower use levels will maintain or even increase these levels. For Dutch fertiliser industry, this means that the main market shows a declining trend of about 2% annually. The influence of the agricultural policy of the EU on the fertiliser use is not negligible. Within most countries a stabilisation of the fertiliser use as a result of changing European legislation is expected [23], so this refers mostly to southern European practise. In the neighbouring countries, current declining trends are continued. The Dutch legislation on nutrient use in the agriculture will have major influence within the Netherlands (see Paragraph 6.3 and 9.3). This legislation would imply a decrease of N-losses of 3-4% annually in the coming decade. Assuming a similar development for fertiliser use, it leads in 2010 to almost half the intensity of today. Alternative agricultural practise (ecological and integrated) is expected to take a significant part in this development. For markets outside Europe, still an annual growth of 1-2% is assumed. Overall, changes in agricultural area and practise will lead to a decrease of the fertiliser demand for Dutch industry with approximately 25% in 2020 compared to 1998.

Demand for intermediate chemicals
As was already mentioned in Paragraph 2.2, the present share of ammonia production for intermediate chemicals is 30%. It is mainly applied for the production of various plastics like UF resins, ABS, Nylons and Melamine. DSM has announced to increase melamine capacity by 30% in 2000. This is based on global demand developments of 5-6% annually. The expected average demand growth for ammonia based products is higher than bulk polymers like PE and estimated to be around 3% annually. This will lead to a 100% increase in ammonia demand for intermediate chemicals in 2020 compared to 1998. By that time it has surpassed production for fertiliser purposes.

10.2 Production and energy use forecast

Trade balance estimate
The Dutch industry is located near relatively large gas resources and in the vicinity of the major fertiliser demanding countries in Europe. Chapter 9 shows that transportation costs are a major limitation within international competition. The production of fertilisers will remain predominantly regionally orientated, which means no large shifts to external competition are expected for the Western European market. The current equilibrium between demand and production makes it reasonable for the industry not to expand current capacity (Paragraph 4.1). As demand on this market is not growing, installing new capacity can only be combined with scrapping old capacity. Within the EU market the competition is not between countries but between companies. If new production locations for ammonia would be chosen, older ones have to be closed down, which would disrupt connected production facilities and logistics. Combined with the moderate advantages in profitability, competition from new plants in Norway or Algeria is therefore unlikely and not taken into account. For the same reasons, it is not to be expected that industries on the Western European continent will increase their share substantially. Neither will the Dutch industry increase its share of the European and intercontinental market.

Energy use of ammonia production
The analysis of the production process in Chapter 3 shows that the energy use by fertiliser production almost completely depends on the quantity of ammonia produced. This means that for an estimation of the energy use in the fertiliser industry within the next decades only the N-demand is relevant.

Two main issues determine the energy use of the production process:
- The type of N-fertiliser produced,
- The efficiency of the production process.

The only N-fertilisers that would affect the amount of ammonia produced would be from biological origin or specially adjusted, like slow release fertilisers that increase efficiency of use (see Paragraph 7.3). These types will not gain large markets, and their effect is already part of the demand reduction forecast for Western Europe. Because of the low production costs of the common fertilisers, shifts to relative expensive slow-release fertilisers are not assumed.

Within the next decades several ammonia plants will be revamped, replaced or simply closed. The efficiency of the fertiliser industry depends mainly on the replacement of old ammonia installations. The limited growth of the demand makes it not reasonable to assume that this will take place rapidly. A limited growth of capacity of about 5-15% between 1998 and 2020 seems reasonable. New plants will have a specific energy consumption of approximately 28 GJ/ton ammonia, which is the best technology current available. Depending on existing plant conditions, modernisation can also lead to similar values. An increase in average energy efficiency of the fertiliser industry of about 15% is assumed (Chapter 7). This improvement would be necessary to meet the requirements of benchmarking agreements with Dutch government (see 2.5).

The sensitivity towards the energy and fertiliser prices will not influence the position of the fertiliser industry as such. Fluctuations of feedstock and product prices tend to affect all companies. The steam reforming based on natural gas is the most energy efficient ammonia production process available, and shifts on feedstock are very unlikely. Energy supply contracts are mostly long term and the high efficiency standards nowadays make it unlikely for the fertiliser industry to loose its competitiveness as a result of new environmental legislation.

Calculation of energy demand

The energy use of the industry within the first decades of the next century can only be estimated roughly. Prospects are an indication and no precise forecast of what will happen because of the high level of uncertainties described in this report. Overall a decrease in energy demand is estimated between 0 and 10% (Chapter 4, this chapter). Compared to the 100 PJ used by the fertiliser industry in 1995 this leads to an energy use between 90 and 100 PJ for the fertiliser industry in 2020.

11. SUMMARY AND CONCLUSIONS

The fertiliser industry is an important industrial sector in the Netherlands as far as energy consumption is concerned. Large international companies dominate the sector. This industry produces nitrogen (N) phosphor (P) and Potassium (K) based fertilisers. The phosphor and potassium based are of minor importance for the Dutch fertiliser industry as far as the energy use is concerned. Because of the importance of the N-based fertiliser this study is focused on this part of the fertiliser industry. Eleven percent of the Dutch industrial energy (including feedstocks) is consumed by the fertiliser industry, this is about 100-125 PJ. The first step of all N-fertiliser synthesis is the production of ammonia by steam reforming out of natural gas. This process represents almost 90% of the energy consumption of the fertiliser industry. Almost 60-70% of the natural gas is used as feedstock.

The results of this study are included in five main subjects: the product market, competition, technological developments, the impact of environmental policy and finally a demand forecast for future energy and feedstock consumption.

Product market

The Dutch fertiliser industry produces more than four times the N-fertiliser demand in the Netherlands and 88% of the N-fertiliser production is exported, mainly to Germany, France and Belgium/Luxembourg. Main products are calcium ammonium nitrate (CAN), ammonium nitrate and urea. The Western European N-fertiliser demand is relatively stable. The world demand for fertilisers is growing fast but this development mainly takes place in developing countries, most important in India and China.

In Eastern Europe, fertiliser use decreased 80% after the transformation. As a consequence, the present overcapacity makes Eastern European fertiliser industry a large exporter to the Western European market. In the coming decade, agricultural production in Eastern Europe is expected to grow again, but fertiliser demand can be met by the existing capacity. The present dumping of fertiliser from Eastern Europe on the EU market is expected to decrease accordingly. However, in the coming decade competition from the existing plants in Russia will remain a serious threat for the Western European fertiliser industry.

Efforts are taken to reduce the fertiliser use in the Netherlands because of the negative environmental impacts. Dutch agriculture has very high fertiliser use standards and is aiming at reducing nitrogen losses by 40% in 2010. Belgium France and Germany, apply on average about 50% of the Dutch level. Within the EU, average standards are not expected to increase and agricultural area will decrease slowly. Therefore reduction of fertiliser use is mainly a Dutch issue and the impact on the demand for the Dutch fertiliser industry is limited to a 25% reduction. Ecological or integrated agriculture is expected to play a part in this reduction, but will not gain a major share of the EU agricultural area. If a substantial policy effort would be taken towards a more integrated agriculture in Northwest Europe, it would reduce total fertiliser demand for the Dutch industry with another 4-8%. As for ammonia production, increasing demand for other purposes in the plastics industry compensates a decreasing demand for fertilisers. By 2020 this is expected to exceed ammonia production for fertilisers.

Nitrogen fertilisers will remain bulk products within the next decades, but there are trends to customise fertiliser application for e.g. horticulture. Also, with increasing environmental restrictions, dedicated products like slow release fertilisers can find a market. This offers opportunities to increase the added value of Dutch fertiliser industry. Manure surpluses from the intensive cattle industry do not match the nutrient composition requirements of most agriculture, and therefore cannot easily replace fertilisers.

Cost structure and competition

The cost structure of the fertiliser industry is dominated by the costs for feedstock and energy. Labour, maintenance and depreciation costs are limited (all about 10%). Transportation costs on the other hand play an important role in fertiliser industry. The cheap and bulky character of the products and the widespread end user market makes transport over long distances expensive. Therefore, global competition is mitigated.

Competition from Russian producers due to abundance of natural gas at low costs and receding home demand has recently caused disturbance on the EU market. A new equilibrium in demand and production in Russia is expected within the next 20 years. As long as demand from agriculture in the former Soviet Union is still low, the threat of fierce competition and dumping is still large. Further competition for the Western European market may in future arise from regions with natural gas surpluses like Northern Africa and Norway. Norway has a disadvantage of high transportation costs. North African countries like Algeria could pose a serious threat for Dutch fertiliser industry in the long run. This will happen in case political stability would improve the investment conditions, improvements in sea transport efficiency can be made or environmental policies would disregard the Dutch industry's vulnerability. Competition from the Middle East and South America seems unlikely in near future, in view of the growing markets in Asia and South America. On the other hand, substantial export growth for Dutch fertilisers to other continents seems unlikely in absence of significant other production cost advantages.

Technology

Production of ammonia, the basic intermediate for all N-fertiliser in the Netherlands, is completely based on the steam reforming of natural gas. In relation to alternative nitrogen-fixation technologies this is the most efficient technology available. The technology is standardised and available on markets. However, technology development still leads to a significant increase of energy efficiency and therefore a decrease in average specific energy consumption for ammonia synthesis of about 15% from 33.5 GJ per ton in 1990 to 28 GJ per ton in 2020. This is in accordance with the best available technology at present. More improvements are under development, most promising is the use of membranes in the ammonia synthesis. When available, this technology cannot be implemented in existing plants. Therefore it will be implemented as part of future replacements of old plants. It will take almost 30 years before a new technology is completely implemented. Other feedstocks like syngas from coal, biomass or waste remain problematic and expensive compared to natural gas, so they seem not likely to gain a market share within the next 20 years.

Impact of agricultural and environmental policy

The most important current policy is the EU Common Agricultural Policy (CAP). During the last 40 years this policy has led to high production, stimulated by production subsidies. The CAP will be reformed within the next years, because of the high expenditures on subsidies and the GATT requirements on free trade. According to the EU, European agricultural development has to be changed to a more sustainable and extensified practise. Although the consequences are still unclear for Western Europe, for the fertiliser industry a decrease in demand is expected.

Both energy and feedstock consumption in fertiliser industry lead to emissions of CO_2, moreover, N_2O emissions from the fertiliser industry are substantial. Both gases contribute to the greenhouse effect and may become subject of climate policy in the near future. When greenhouse gas taxes are implemented in the Netherlands, or emissions have to be reduced at high costs, this will lead to a decrease of the competitiveness of the Dutch fertiliser industry. However, substantial reductions of over 80% are expected to be possible at moderate costs, if policies are carefully implemented, preferably for producers in Western Europe as a whole. If this greenhouse gas reduction policy is implemented in the EU by 2010, the main economic effect will be a 5% price increase that will have negligible effect on fertiliser demand. In case of continued competition from e.g. Russia, this price increase may nevertheless be harmful for Dutch industry.

Energy consumption development

Energy consumption in the Netherlands for fertiliser industry is likely to decrease with 0 to 10% in 2020. This is caused by both demand growth for ammonia (5-15%) and energy efficiency improvements (15%). In the Netherlands and neighbouring countries new process plants will only replace existing capacity and therewith improve efficiency. Proximity to markets remains a vital cost advantage and competition from cheap feedstock locations is less likely.

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