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Knowledge grows

Fertilizer Industry Handbook 2022

December 2022

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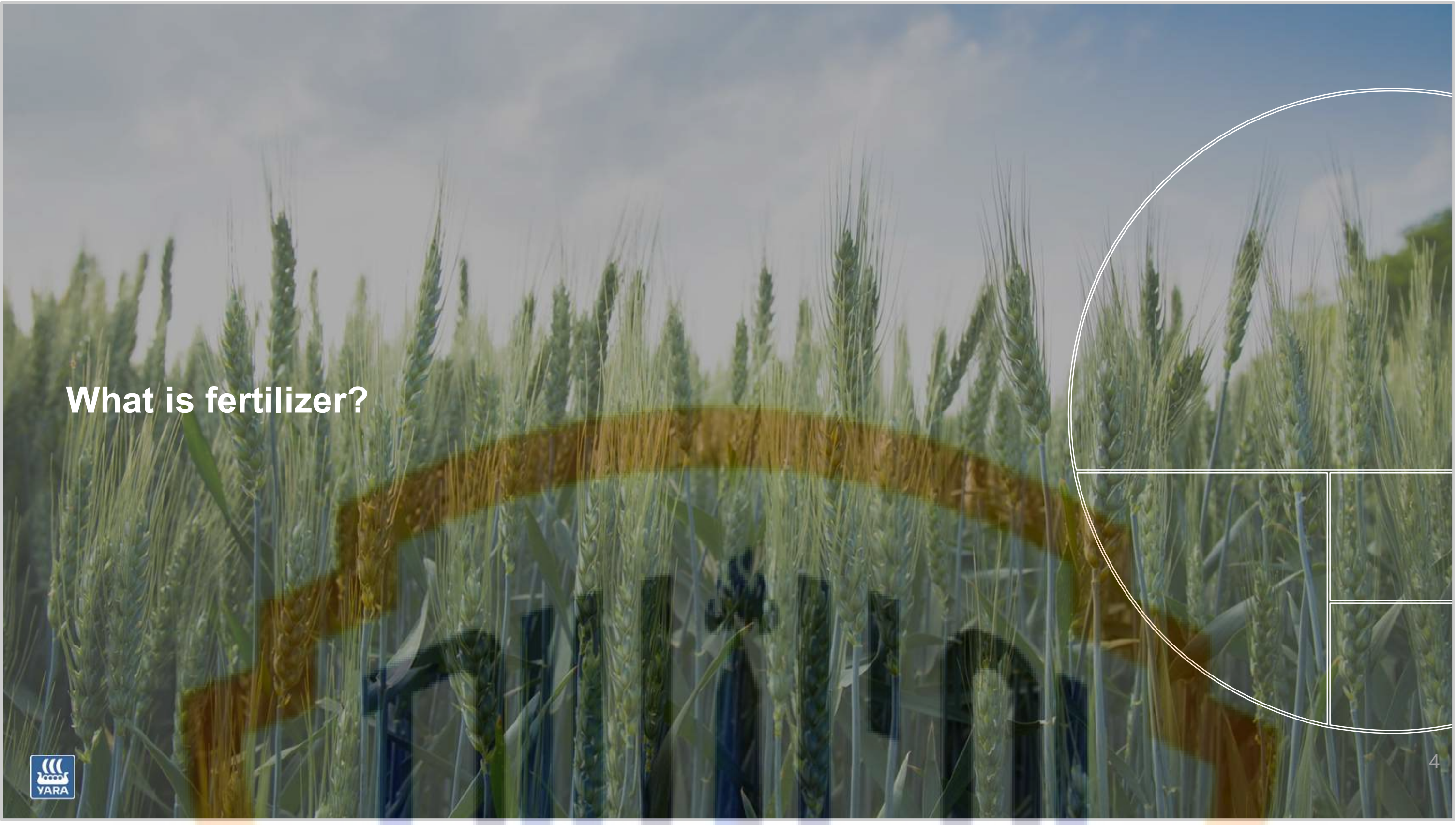
Yara Fertilizer Industry Handbook

This handbook describes the fertilizer industry and in particular the nitrogen part which is the most relevant for Yara.

The document does not describe Yara or its strategies to a great extent. For more information on Yara-specific issues please see Yara's quarterly and Capital Markets Day presentations, and the 2020 ESG day presentation. All are available on www.yara.com/investor-relations/reports-presentations/

Fertilizers are essential plant nutrients that are applied to a crop to achieve optimal yield and quality. The following slides describe the value and characteristics of fertilizers in modern food production.

Cutoff for data points in this presentation is December 2021 for annual data, and October 2022 for monthly data.


What is fertilizer?
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Fertilizers are plant nutrients, required for crops to grow

Crops need energy (light), CO_2, water and minerals to grow

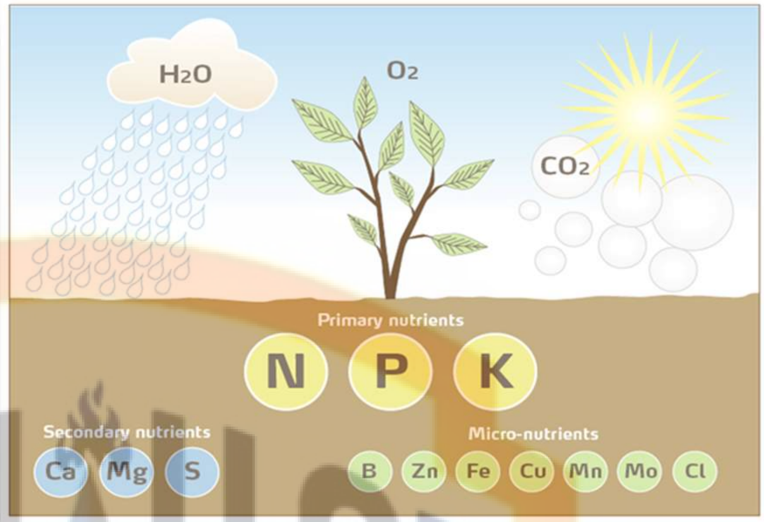
The carbon in crops originates from CO_2 absorbed through the leaves

Crops absorb water and plant nutrients from the soil

Plant nutrients are building blocks of crop material. Without nutrients, the crops can not grow

Mineral fertilizers provide plant nutrients for crops

Three main nutrients: Nitrogen, Phosphorus and Potassium are primary nutrients



Three main nutrients: Nitrogen, Phosphorus and Potassium

Nitrogen (N), the main constituent of proteins, is essential for growth and development in plants. Supply of nitrogen determines a plant's growth, vigour, colour and yield. Phosphorus (P) is vital for adequate root development and helps the plant resist drought. Phosphorus is also important for plant growth and development, such as the ripening of seed and fruit. Potassium (K) is central to the photosynthesis of crops. Potassium helps improve crop quality and crop resistance to lodging, disease and drought.

In addition, the secondary nutrients sulphur, magnesium and calcium are required for optimum crop growth. Sulphur is especially important in the initial growth stages, to produce essential amino acids, proteins, and oils. Magnesium is needed for photosynthesis, converting light into chemical energy for nutritional purposes. Calcium is particularly important for the yield, quality and shelf life of fruit and vegetables.

Each plant nutrient has unique physiological functions which cannot be replaced by any other nutrient.

Mineral fertilizers are produced from natural elements, into a form which makes them easily available for plants

Nitrogen (N)	Nitrogen originates from the air (78% of the earth's atmosphere is nitrogen). The most common process in nitrogen fertilizer manufacturing is to create ammonia from a mixture of nitrogen from the air and hydrogen from natural gas
Phosphate (P)	Phosphate is sourced from insoluble calcium phosphate rocks. Rock phosphate is made available for the plant usually through a chemical process to create plant-friendly fertilizers
Potash (K)	Potassium is sourced from old sea and lake beds formed millions of years ago. Since potassium sources are often located far below the soil surface (1-2km depth), plant roots are unable to reach them naturally

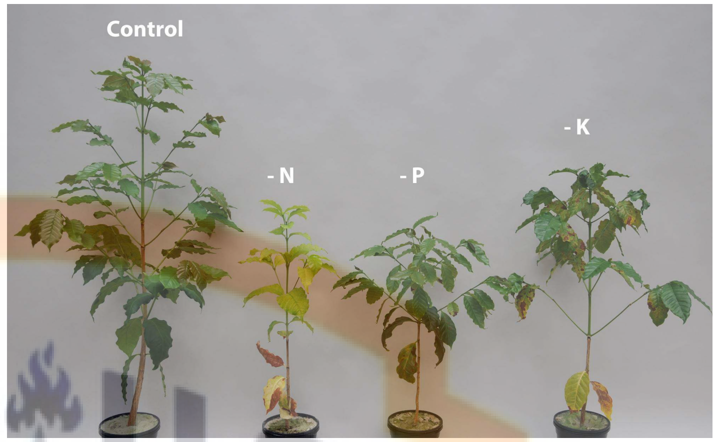


Illustration: lack of either N, P or K typically leads to plant deficiencies including reduced crop growth, reduced crop quality and/or lower resistance to drought and diseases

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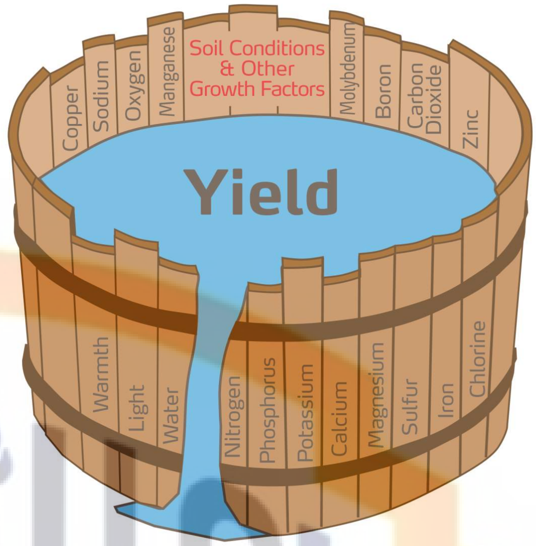
All the nutrients contained in different fertilizers are found in nature.

Nitrogen comprises 78% of the atmosphere and is the most abundant uncombined element on Earth. However atmospheric nitrogen is not directly available to plants and needs to undergo a process, whereas nitrogen is "fixated" into a usable form to be taken up by plants.

MOP is the most common potash, representing approximately 95% of agricultural potash worldwide. The second major form of potash is SOP, which unlike MOP is produced chemically.

Principle of crop nutrition: crop growth is limited by the most deficient nutrient

- Law of the Minimum” (Liebig, 1843): “Crop yields are proportional to the amount of the most limiting nutrient.”
- Plant nutrients have specific and essential functions in crop metabolisms
- They cannot replace each other, and lack of any one nutrient limits crop growth
- It is therefore essential to focus on balanced nutrition of all plant nutrients



JUSTUS VON LIEBIG 1803 - 1873

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The law of minimum

The ‘law of minimum’ is often illustrated with a water barrel, with staves of different lengths. The barrel`s capacity to hold water is determined by the shortest stave. Similarly, crop yields are frequently limited by shortages of nutrients or water. Once the limiting factor (constraint) has been corrected, yield will increase until the next limiting factor is encountered.

Nutrients are classified into three sub-groups based on plant growth needs:
Macro or primary nutrients: nitrogen (N), phosphorus (P), potassium (K)
Major or secondary nutrients: calcium (Ca), magnesium (Mg) and sulphur (S)
Micro nutrients or trace elements: Chlorine (Cl), Iron (Fe), Manganese (Mn), boron (B), selenium (Se), zinc (Zn), copper (Cu), molybdenum (Mo) etc.

Yield responses to nitrogen are frequently observed, as nitrogen is often the most limiting factor to crop production, but not the only factor. Balanced nutrition of all plant nutrients is required to obtain maximum yield and avoid shortages of nutrients.


Why mineral fertilizer?
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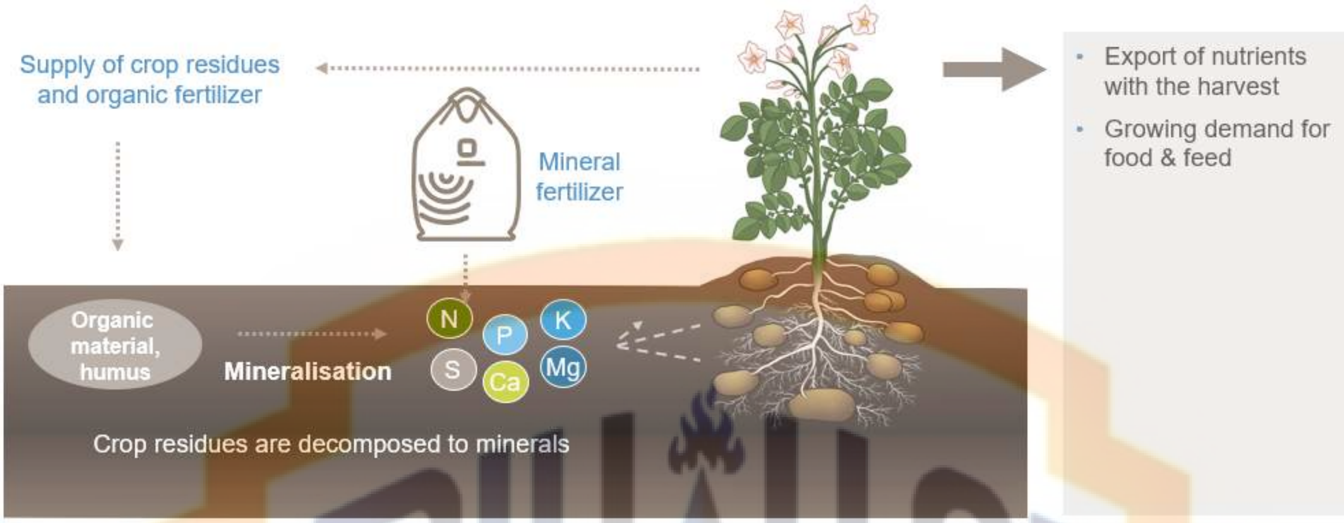
Mineral fertilizers replace nutrients removed from the soil with the harvest



Nutrients are depleted with the harvest

As crops take up nutrients from the soil, a substantial proportion of these nutrients are removed from the field when the crops are harvested. While some nutrients can be returned to the field through crop residues and other organic matter, this alone cannot provide optimum fertilization and crop yields over time.

Mineral fertilizers can provide an optimal nutrient balance, tailored to the demands of the specific crop, soil and climate conditions, maximising crop yield and quality whilst also minimizing environmental impacts.

Mineral and organic fertilizers supply the same inorganic molecules to crops, but have different characteristics

Characteristics	Mineral fertilizer	Organic fertilizer
Nutrient source	Nitrogen from the air, Phosphate and Potassium from deposits / mines	Crop residues and animal manures, other organic material
Nutrient concentration	High nutrient concentration Low logistical cost	Low nutrient concentration Large volumes to transport and store
Nutrient availability	Immediately available for the crop	Variable, organic material needs to be decomposed to release nutrients
Quality	Traceable and consistent	Often inconsistent Dependent on source

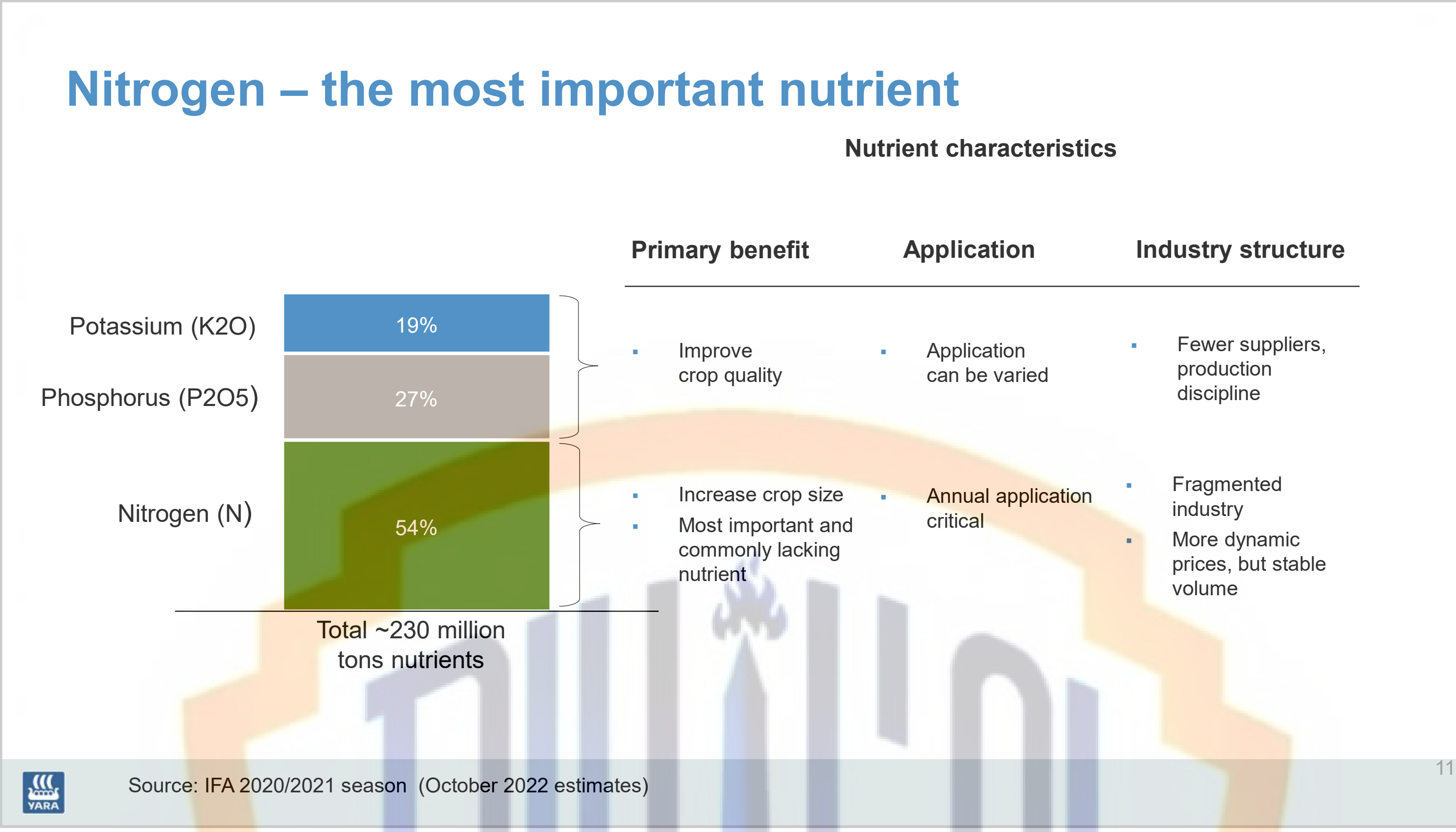
Mineral and organic fertilizers are not mutually exclusive. When using the right source, at the right rate and time and in the right place, both can improve farmers' livelihoods, support soil health on the farm and protect the environment.

Organic and mineral fertilizers both supply the same inorganic molecules to crops

Crops can be fed with mineral or organic fertilizers (e.g. manure), and in both cases the crop will utilize the same inorganic molecules. A complete nutrient program must take into account soil reserves, use of manure or other organic fertilizers, and an accurate supplement of mineral fertilizers.

Organic fertilizers contribute to the build up of the organic content of soil and at the same time support beneficial micro flora (e.g. bacteria) to grow on plant roots. The efficiency of organic fertilizer is dependent on the microbial content in the soil. Bacteria and fungi decompose the organic content in manure and supply the minerals as nutrients for plant growth. But the quality and quantity of nutrient supplied to plants via this process is inconsistent and is very much dependent upon multiple factors such as soil health and climatic conditions. Plant productivity achieved by supplying only organic matter is on average low compared with mineral nutrients supplied in the form of fertilizers.

The separation of livestock and arable farming regions has led to nutrient distribution inefficiency, with a manure surplus in the animal farming regions. The low nutrient content and bulky nature of manure makes transportation inconvenient and costly.

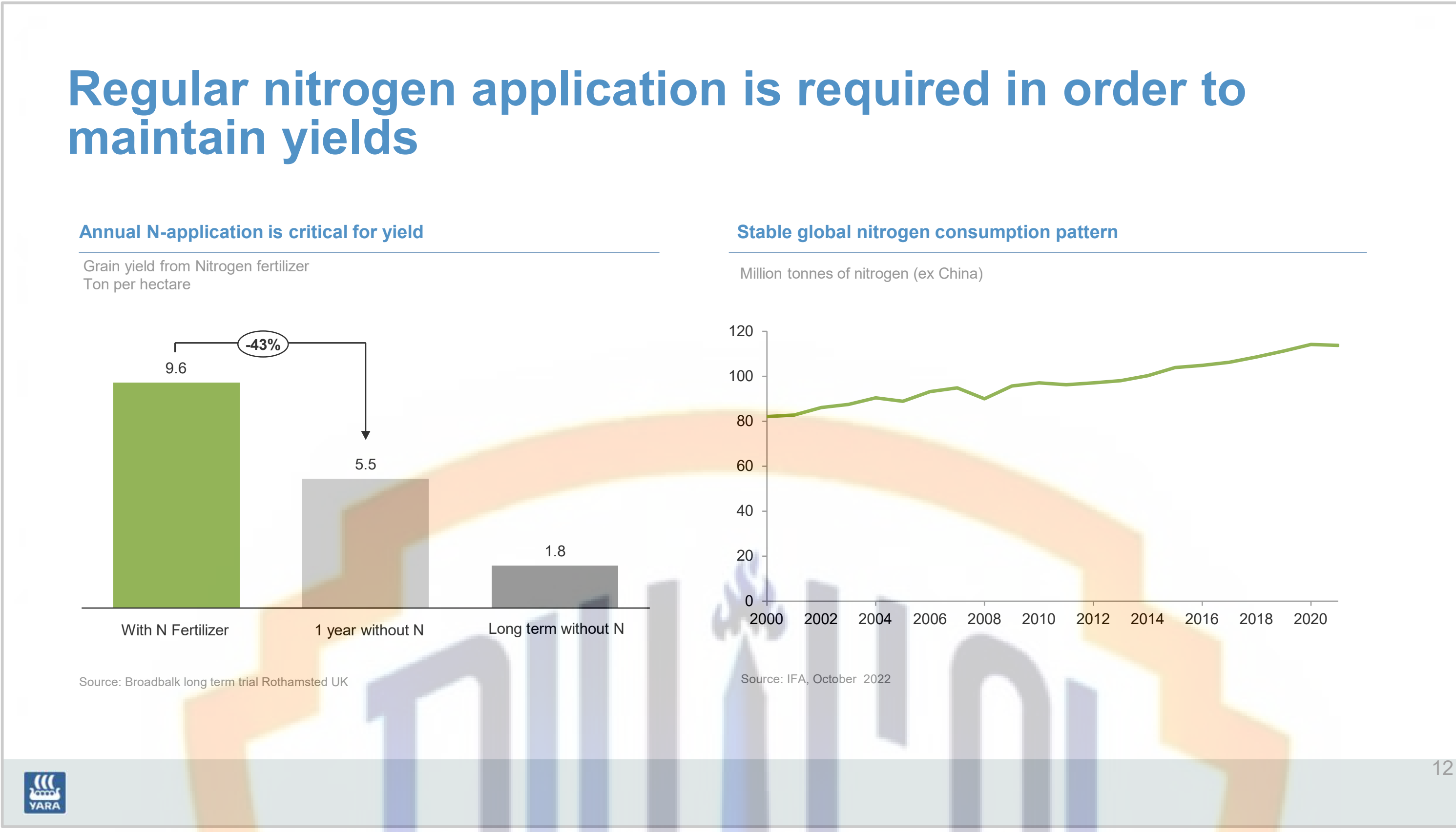


Among the plant nutrients, nitrogen is most important for higher crop yields

Nitrogen is the most important primary nutrient, accounting for 54% of total consumption, and is also the main nutrient for Yara's crop nutrition solutions.

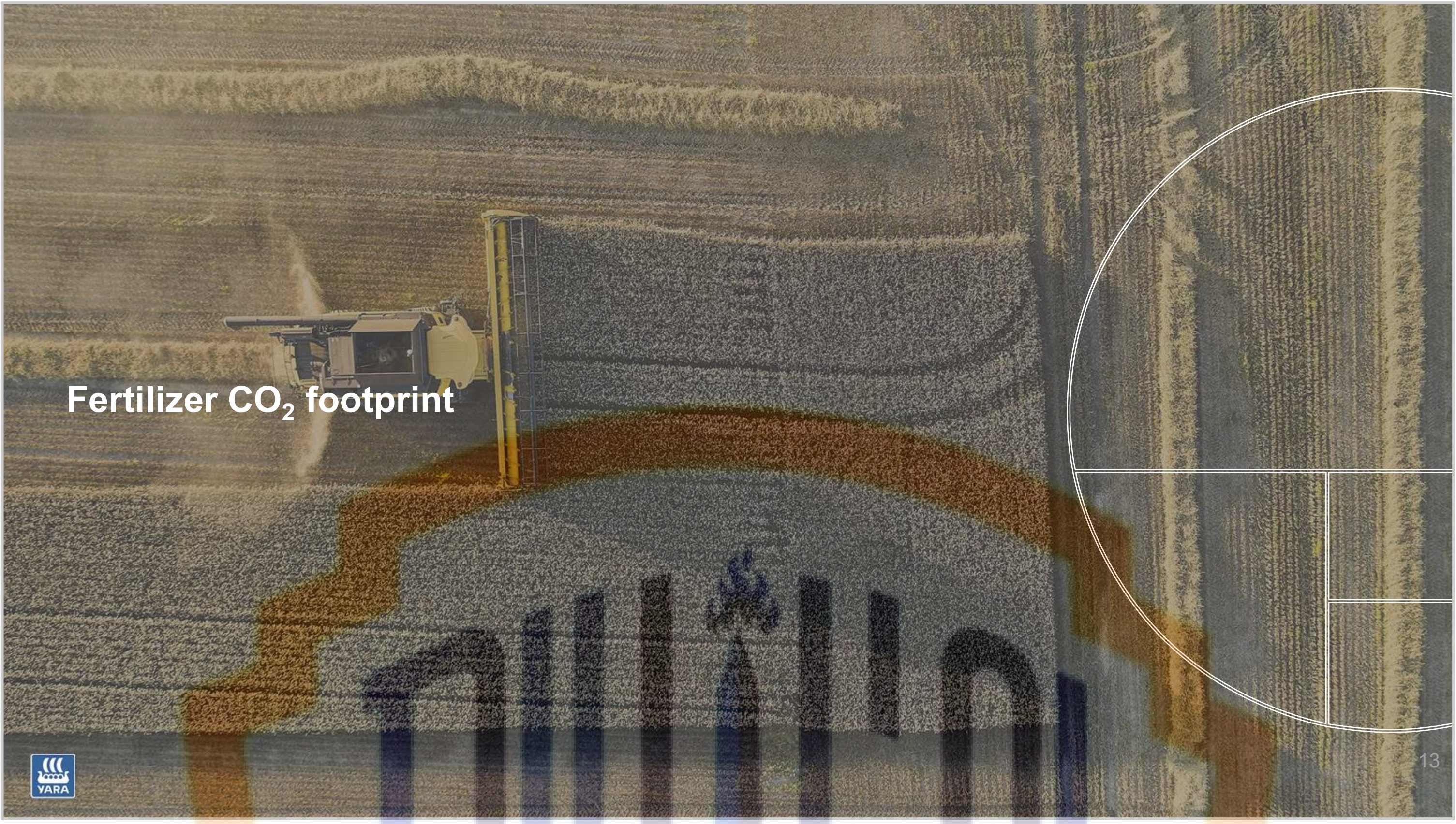
Phosphorus (phosphate) and potassium fertilizers are primarily applied to improve crop quality. Annual application is not always needed, as the soil absorbs and stores these two nutrients for a longer period compared with nitrogen. Nitrogen must be applied every year to maintain yield and biomass.

Phosphate and potash fertilizers are supplied by a small number of large industry players, as phosphate rock and potash mineral deposits are only available in certain regions of the world, while Nitrogen fertilizers are produced in many countries, reflecting the wide availability of key raw materials - natural gas and air, needed for its production on an industrial scale. The global nitrogen market is therefore less consolidated.



Annual application of nitrogen is critical for crop yields

Applying nitrogen is fundamental to crop production. Annual application of nitrogen can increase the yield with more than 80%. The global consumption of nitrogen fertilizers has been steadily increasing to meet the demand for food production of a growing population.


Fertilizer CO_2 footprint
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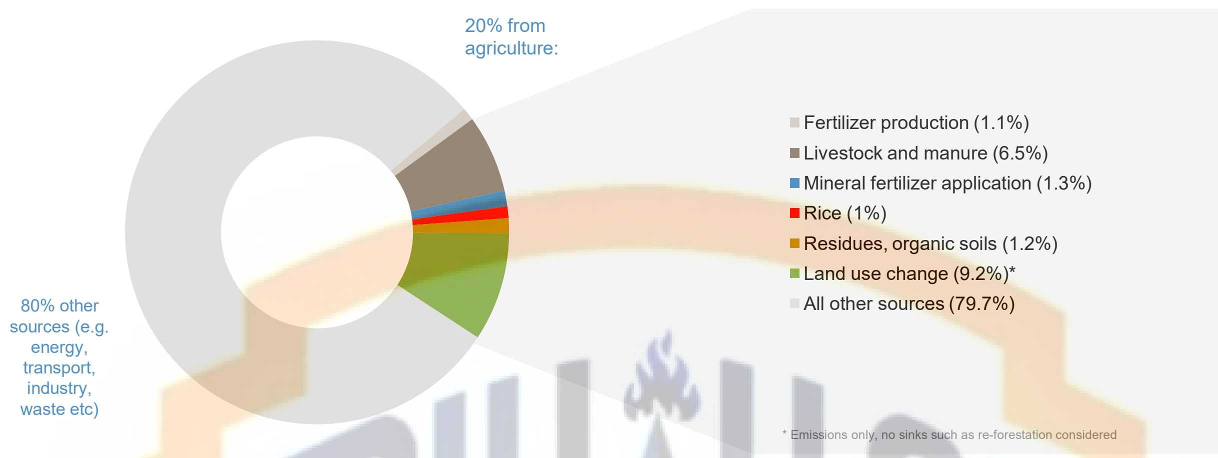
Ag sector represents 20% of global greenhouse gas emissions



Source: FAOSTAT (2020)
* Calculated based on IFA and FE for 2015; not disaggregated from industry in FAOSTAT

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Ag sector represent 20% of global greenhouse gas emissions

Agriculture is a major source of greenhouse gas emissions, accounting for around 1/5 of total global greenhouse gas emissions. The largest contributor within agriculture is land use change: transforming nature into agricultural land in order to grow more food. Improving land use efficiency is therefore key to reduce total emissions from agriculture. Fertilizer can play an important role in this, because optimizing fertilizer use could enable reversing land use to abate rather than emit.

Fertilizer reduces the carbon footprint of farming

Fertilizer - an efficient solar energy catalyst

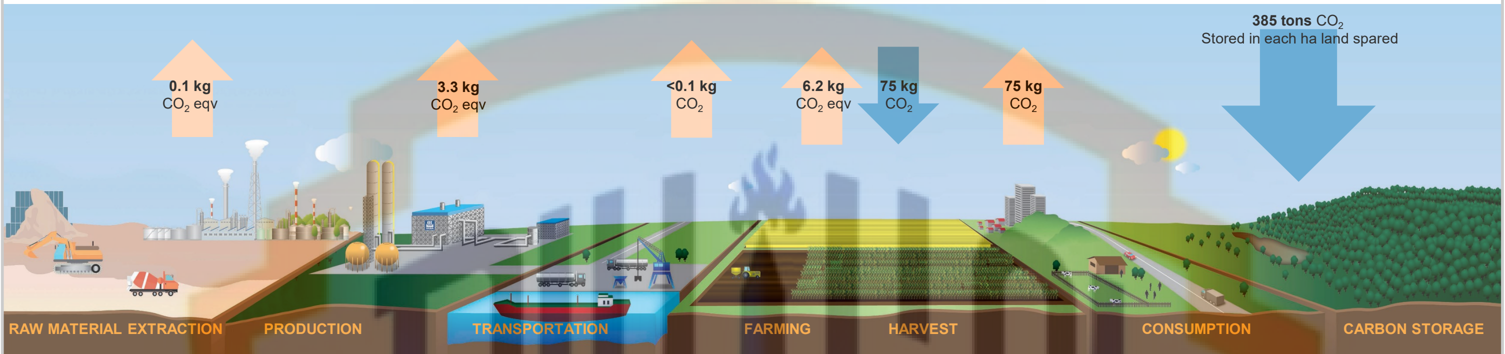
- Production is a marginal part of the carbon footprint; efficient application is more important
- Huge positive effects of fertilizer use, since higher yields enable lower land area use

Production

- Yara's production is more energy-efficient than the competitor's average

Application

- Higher efficiency with nitrates
- Precision farming tools



Numbers show emissions as CO2eqv per kg Nitrogen in fertilizer product for Calcium Ammonium Nitrate 27%

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A life-cycle perspective on fertilizer is important

Life-cycle analysis of fertilizers determines the greenhouse gas emissions and absorptions in fertilizer production, transportation and storage, as well as during application and crop growth.

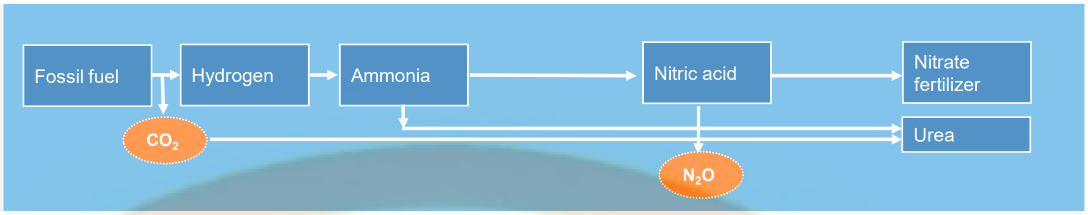
When new acreage is converted to cropland, above ground carbon is immediately removed, whereas carbon stored in the ground will leak out more gradually and is converted to CO_2.

With the ambition to minimize total carbon footprint from global biomass production, efficient use of land, based on modern agricultural practices, is of great importance. Efficient farming with high yields contributes to preserve forests and soils, which are the real "carbon sinks". Organic farming with low yields can create economic drivers for increased deforestation and emissions.

Different fertilizer types have different carbon footprints. Urea emits less CO_2 during production than nitrates, but upon spreading the situation is reversed since urea releases the CO_2 contained in its molecule. Urea also often releases more N_2O during farming. The life cycle carbon footprint is therefore higher for urea than for nitrates produced with best available technology.

Emissions occur mainly in the ammonia production step, catalyst technology invented by Yara has almost eliminated N_2O emissions

Standard fertilizer production



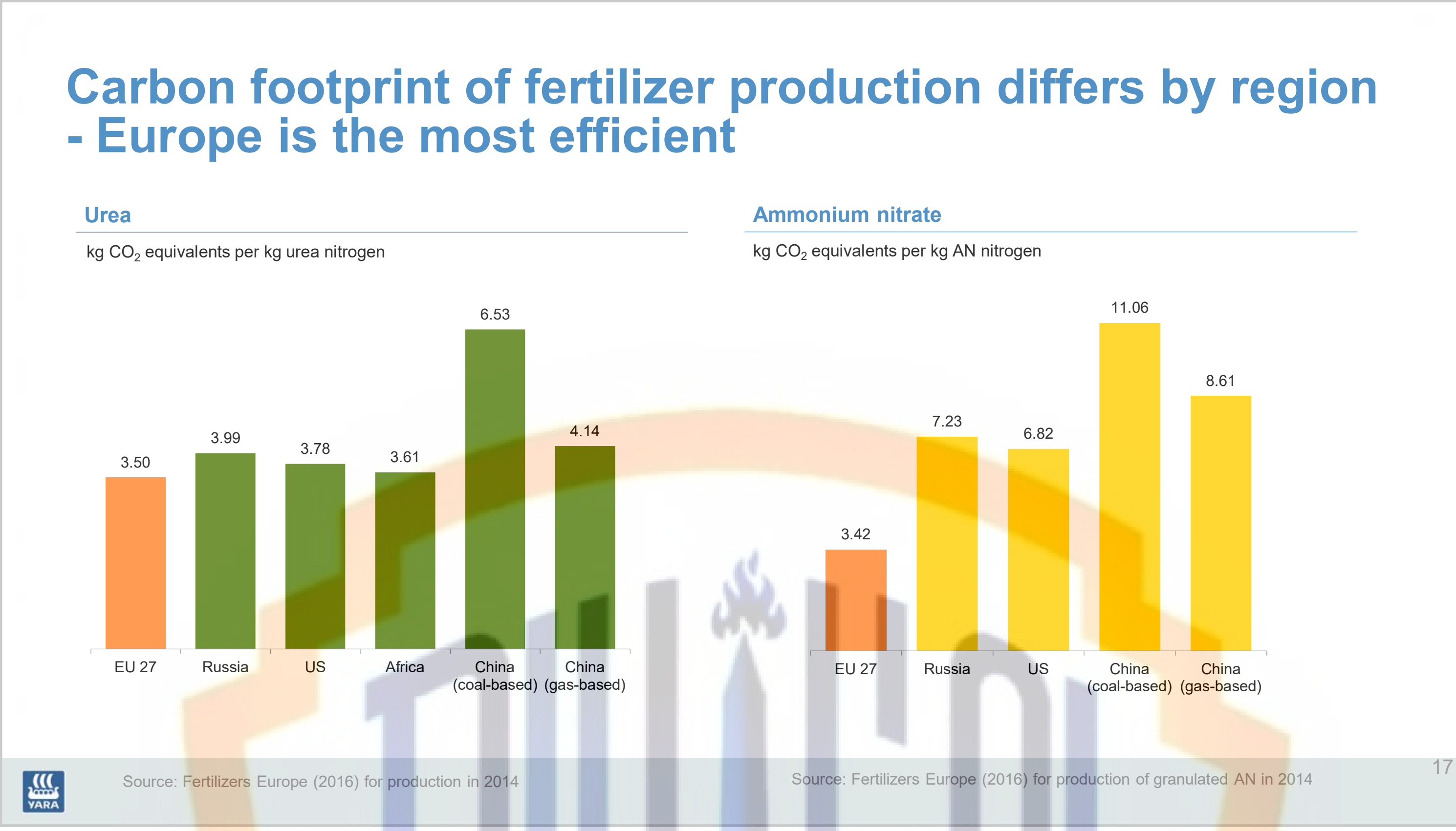
Emissions	1.8-.2.4 mt CO_2 per mt ammonia *)	0.03 -0.2 mt CO_2e per**) tonne nitric acid
Decarbonization routes	• Carbon capture and storage (blue ammonia) • Replace fossil fuel with hydrogen from electrolysis (green ammonia)	• Catalyst abatement technology

*) Source: IFA
**) Source BT Large Volume Inorganic Chemicals Ammonia, Acids and Fertilizers (2007) new plants

Emissions from nitrogen fertilizer production

There are two sources of emissions from nitrogen fertilizer production based on natural gas Carbon dioxide (CO_2) and nitrous oxide (N_2O). The first occurs when the methane molecule is split to produce hydrogen and carbon monoxide (CO) and CO further reacts with water to form CO_2. For these reactions to occur energy is needed, and CO_2 is also emitted from combustion of the fossil fuel to provide this energy. Emissions at this step can be reduced through improved energy efficiency, but cannot be eliminated without either eliminating fossil fuels through green ammonia production (electrolysers) or by capturing the CO_2 with CCS (carbon capture and storage) technology.

The second emission occurs when ammonia is converted into nitric acid, where N_2O (laughing gas) is emitted. N_2O is a very potent greenhouse gas, with a global warming potential 265 times that of CO_2. These emissions can be significantly reduced with catalyst technology, an invention from Yara. The catalyst converts N_2O into harmless oxygen and nitrogen. Thanks to this invention Yara reduced its CO_2 emissions with 13 million tonnes per year between 2005 and 2019, roughly equivalent to the oil- and gas emissions from the Norwegian continental shelf. The technology is licenced and sold to other nitrate producers which has contributed to also reduce emissions from the fertilizer industry outside of Yara.



Nitrogen fertilizer production using coal-based ammonia almost doubles high greenhouse gas emissions per unit

The first and most energy-intensive step to produce urea is ammonia production. Ammonia producers in Western Europe have invested heavily in energy-efficient technology due to the historically high cost of energy in the region. According to Fertilizers Europe, several ammonia plants in Western Europe run on the lowest possible energy consumption levels given current technology and have the lowest CO_2 emissions per ton of ammonia produced. The Western European ammonia industry is on average more energy efficient than ammonia producers in other parts of the world. This is also driven by EU environmental regulations, which give incentives to run plants at higher standards than elsewhere.

For nitrates, the European fertilizer industry has upgraded its nitrate plants with catalysts that significantly reduce greenhouse gas emission (nitrous oxide = N_2O), enabling lower emissions than the best urea plants.

More than half of total GHG emissions from fertilizer take place in the field

Share of total emissions:

Fertilizer production:

20-50%

Share of total emissions

Main source: CO_2 and N_2O emissions from the ammonia and nitric acid production process

Major sources of variation: energy source, fertilizer product type

Fertilizer use:

50-80%

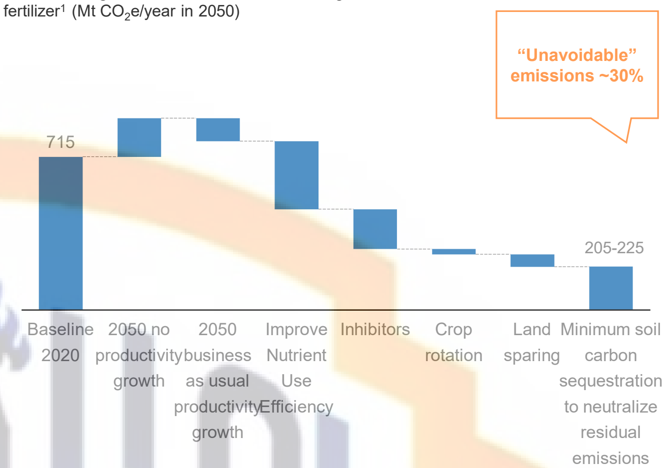
Share of total emissions

Main source: microbiological processes in soil (nitrification and denitrification)

Major sources of variation: application rate, method and timing, soil and climatic conditions, crop type and rotation

Industry scenario: emission reductions from application

Greenhouse gas emissions from mineral nitrogen fertilizer[1] (Mt CO_2e/year in 2050)



Source: IFA 2022, Systemiq

1) Not showing the uncertainty ranges in the results

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The largest GHG emissions from fertilizer happen in the field of the farmers

When applying nitrogen to soil, either as mineral fertilizer or as organic matter, microbiological processes within the natural nitrogen-cycle (nitrification and denitrification) result in release of N_2O. N_2O is a potent greenhouse gas (265 times higher global warming potential than CO_2 in a 100-year time horizon).

Correct fertilization practices (right type of fertilizer, water management and precision nutrition management) can reduce in-field emissions, but not eliminate it as the emissions come from the natural nitrogen cycle. For these emissions other solutions such as soil carbon sequestration or offsets/"insets" are needed to neutralize residual emissions.

Digital solutions enable optimized application, improving food production per hectare and reducing emissions

A wide range of digital solutions at Yara

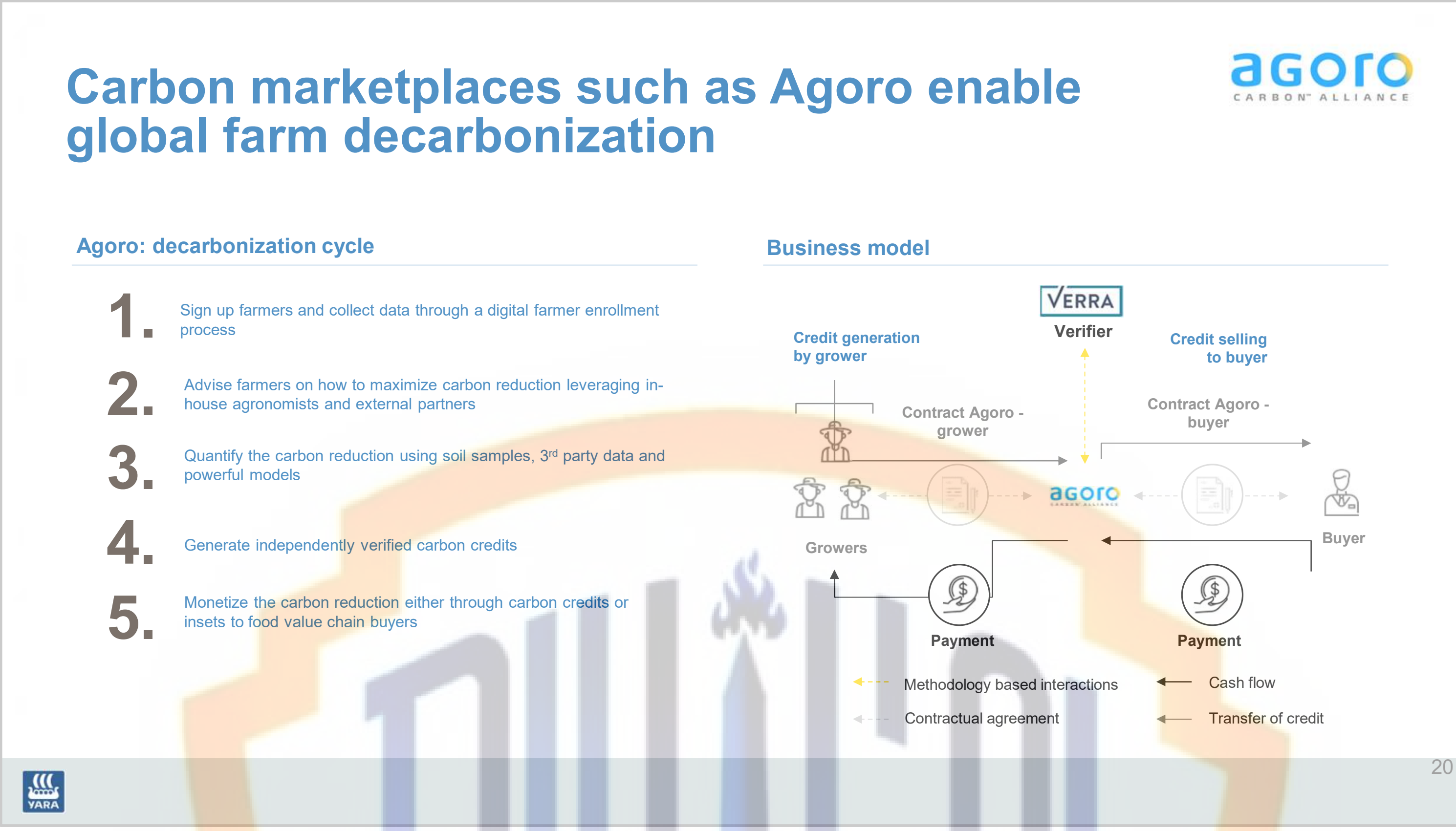
Example: Yara AtFarm

- Atfarm uses state-of-the-art satellite imagery combined with Yara’s expertise and products to create variable rate fertilizer application maps.
- Proof points; up to 6% yield gain, up to -12% fertilizer use[1], up to -20% carbon emissions from fertilizer[1]

1) By using best practices and solutions that exist today, farmers* can already in average reduce nutrient losses by 20%, increase yields and incomes by 5-7% and reduce their carbon footprint related to mineral fertilization up to 20%**
*Assumption are built with major crops in major EU countries (e.g. cereals)
**CFP considers mineral fertilizers produced with BAT-Best Available Technology, as mineral fertilizers without BAT may have around +30-40% carbon footprint. It does not consider the potential of using carbon sequestration farming practices

Precision farming promotes best agricultural practices

As seen on the previous slide, emissions generated from fertilizer application amount to between 50-80% of total GHG emissions in the fertilizer cycle. Helping farmers use the right amount of fertilizer at the right time and the right place through our products, agronomic knowledge and digital solutions is an important way Yara is contributing to reduce the overall footprint of food.



Regenerative agriculture enables carbon to be stored in the soil

All mineral soils sequester CO_2 from air, however increased soil carbon content can be achieved through agricultural practices aiming at increasing biomass production and reduce soil mechanical disturbance.

Agoro Carbon Alliance is taking action across the global food value chain to grow a permanent, farm-based carbon solution through Farm Carbon Credits and climate-smart crops. Agoro Carbon Alliance is working to enable all farmers to sequester carbon in their soils and decarbonize their farms while boosting profitability.


Other environmental topics
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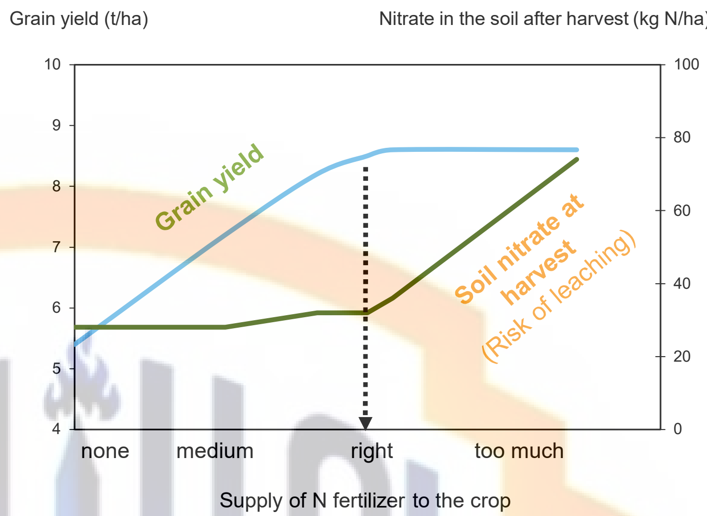
Leaching: The right nitrogen fertilizer rate is key to avoid nitrate leaching

- Leaching of nitrate into groundwater affects water quality and can contribute to eutrophication
- Oversupply of organic and mineral nitrogen fertilizer is the main driver for nitrate leaching
- Nitrogen fertilizer application according to crop demand does not increase the risk of nitrate leaching
- The risk of nitrate leaching increases only when too much N fertilizer has been applied



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Soil nitrate content at harvest is a measure for the risk of nitrate leaching. This relationship has been confirmed in numerous trials and measurements.

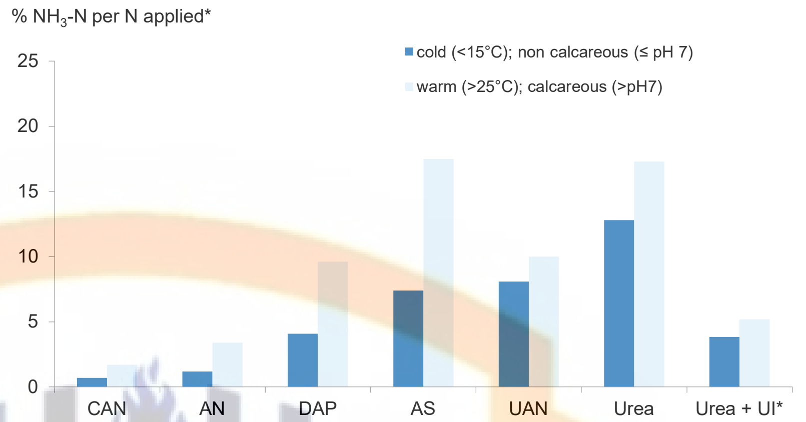
Elevated nitrate concentrations in ground and surface water are undesirable. Nitrate leaching occurs when the soil is saturated with water and nitrate is washed below the root zone by percolating rainfall or irrigation.

Nitrate leaching is independent from the source of nitrogen, it can be caused by mineral fertilizer, organic manure or even soil organic matter. Most loss of nitrate to water occurs during winter.

The overall objective is therefore to minimize soil nitrate concentrations at the end of the vegetation period. Nitrogen leaching can be effectively avoided through well managed fertilization practices, e.g. by using fertilizer with a quick, predictable nitrogen release, such as nitrates.

Ammonia volatilization: Choosing the right nitrogen fertilizer is key to avoiding ammonia volatilization losses

- Volatilization of ammonia gas affects air quality and induces soil acidification
- The use of organic or urea-based nitrogen fertilizer is the main driver for ammonia losses
- Nitrate-based N fertilizer or immediate incorporation of urea into the soil avoids volatilization losses
- Urease inhibitor is a chemical compound which delays the conversion of urea to ammonium



* Urea + Urease Inhibitor (Urea + UI) assuming 70% reduction of ammonia emissions

**NH_3-N per N applied* is the amount of nitrogen as ammonia (NH_3) released per tonne of nitrogen applied
Source: http://www.eea.europa.eu/publications/emep-eea-guidebook-2016

Ammonia can be lost upon spreading of fertilizers

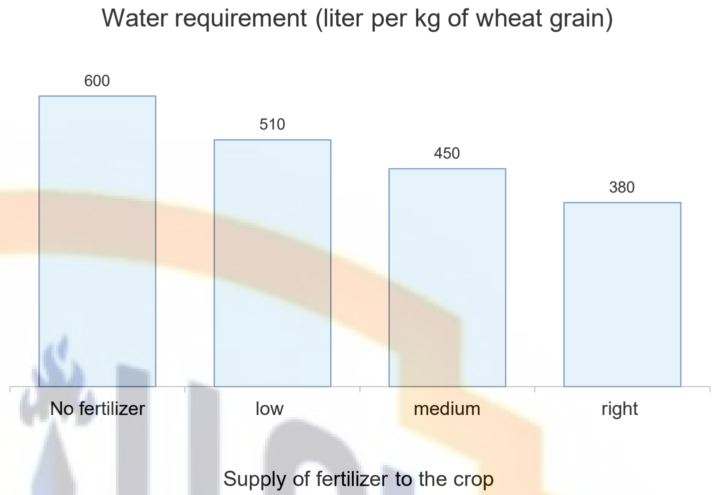
Ammonia volatilization occurs when ammonium is converted to ammonia and lost to the atmosphere. Ammonia volatilization into the atmosphere can have negative consequences for agriculture, ecosystems and human health:

• Ammonia volatilization from agricultural land is a loss of nitrogen for plant growth. It therefore comes at a cost for the farmer that needs to be minimized.
• Ammonia reacts with air humidity to form ammonium (NH_4). Ammonium depositions contribute to acidification of land and water.
• Deposition of ammonium degrades the biochemistry of natural ecosystems and can cause eutrophication (i.e. excess nutrient supply leading to e.g. algae proliferation).

A high soil pH level increases conversion of ammonium to ammonia, and the losses are highest if conversion takes place at the soil surface. These two conditions are met when urea is spread and not immediately incorporated to the soil. Urea and UAN cause higher volatilization losses than nitrate-based fertilizer.

Water: Good crop nutrition enables increased water efficiency: “more crop per drop”

- Water is a key input for crop growth
- About 70% of global water consumption is for agriculture
- Optimized crop nutrition improves water use efficiency, mainly because a well-nourished crop creates a soil cover which reduce evaporation of water from the soil



Source: Yara research

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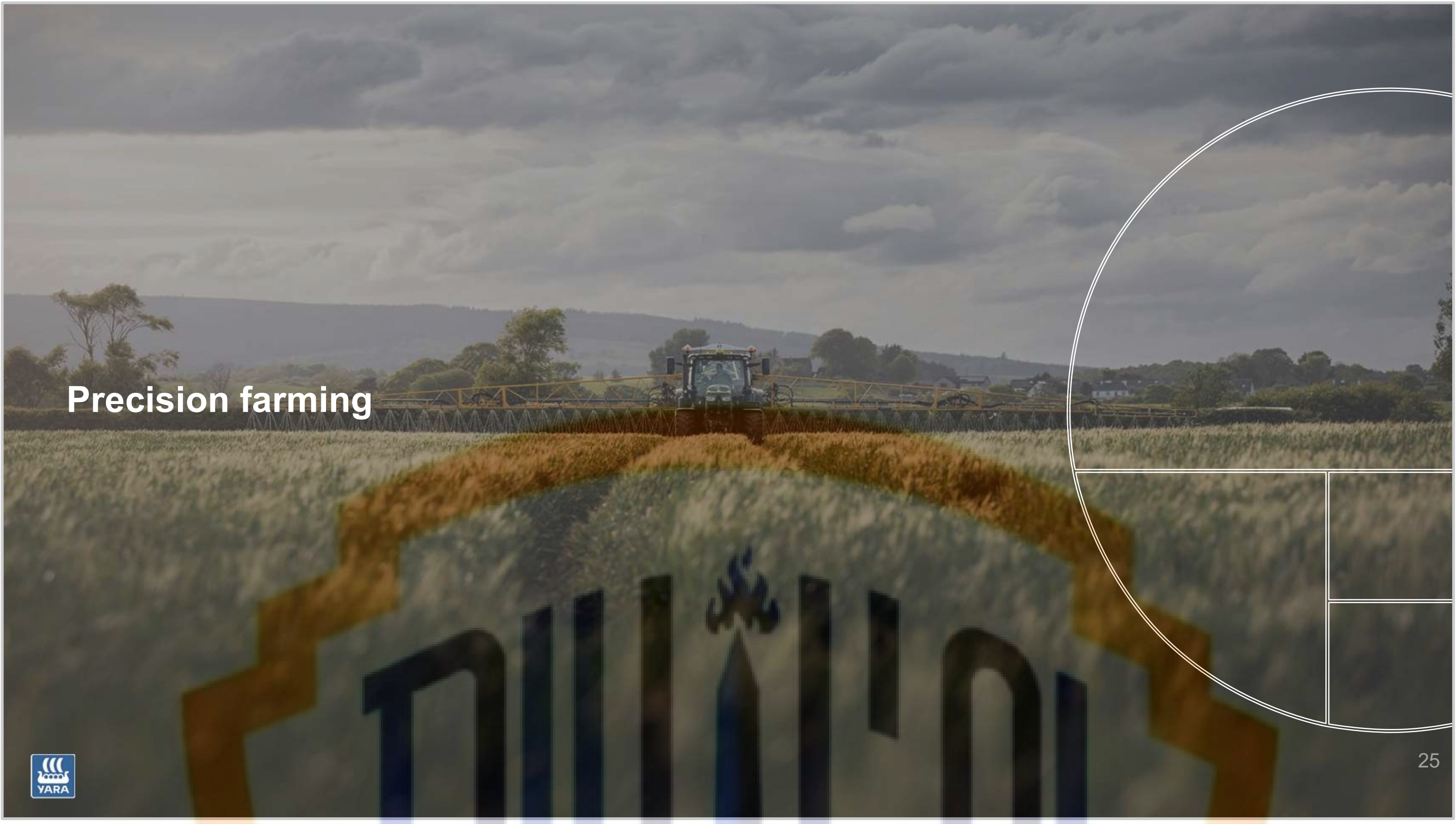
Increased water scarcity drives demand for new agricultural solutions

A steadily increasing population and food consumption continues to be the main driver for agricultural water use. Today most of the water globally used in agriculture does not reach the crop, as water is lost during transportation, through evaporation, runoff and drainage.


Precision farming
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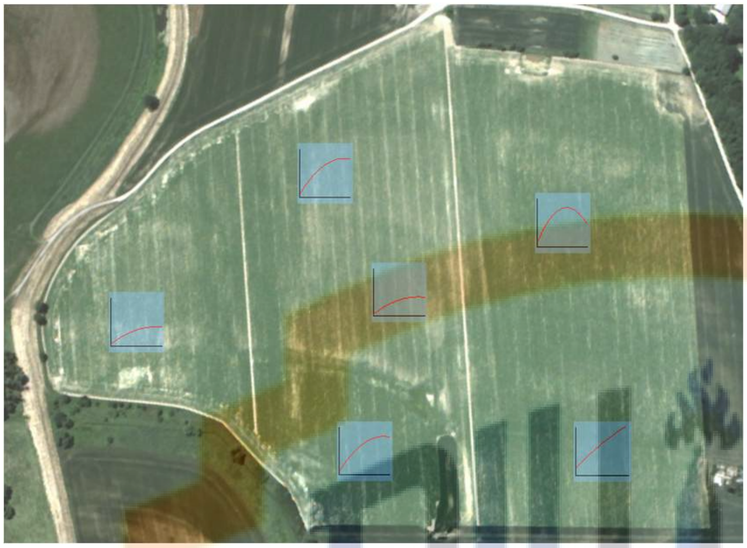
Precision farming: applying the right nutrients in the right quantity at the right time



- Growth conditions within fields are heterogeneous, affecting the crop yield and fertilizer demand
- Estimation of the nitrogen status of crops is a requirement to respond to this heterogeneity
- Digital tools enable growers to estimate the nitrogen status of crops and use this information to determine how much fertilizer to apply and when to apply it

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- **Benefits of precision farming** include higher yields, improved crop quality, lower emissions and other environmental impacts and cost savings for the farmer

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Precision farming consists of practices aimed to meet each plant's need for nutrients with minimal waste

Growth conditions within fields are heterogeneous, affecting the crop yield and fertilizer demand. Digital tools enable growers to estimate the nitrogen status of crops at precise points within a field.

Digital crop sensing tools enable variable rate nitrogen application

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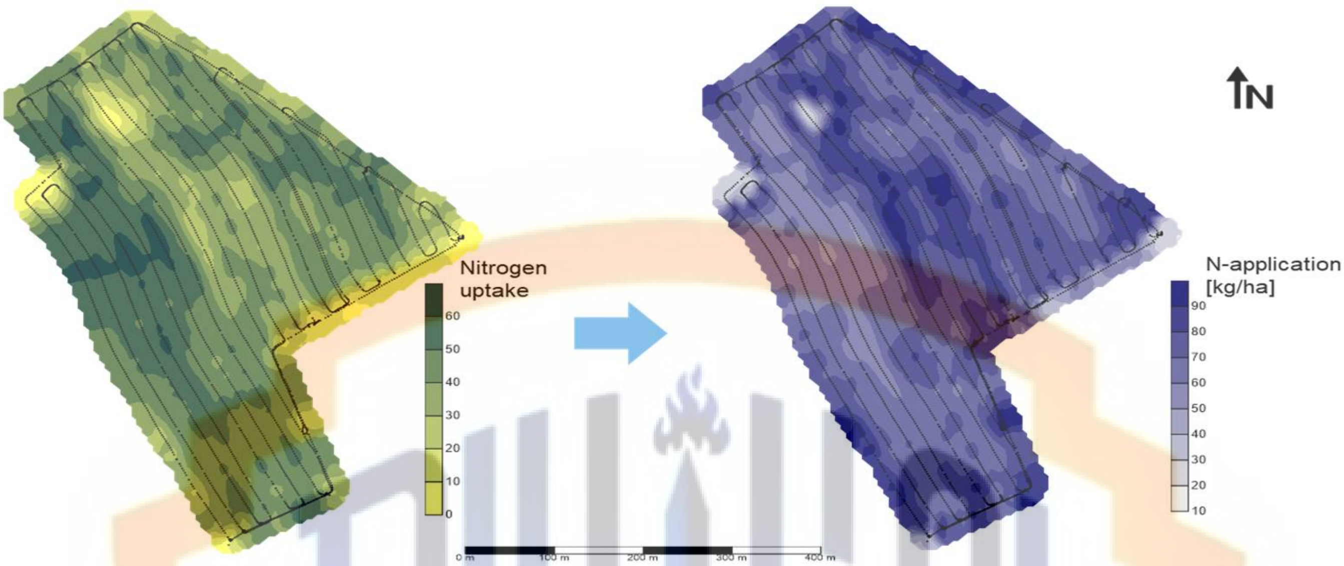
Digital tools are key in precision farming

Digital crop sensing tools enable variable rate nitrogen application. These tools include e.g. the Yara N-Sensor, a tractor-mounted tool that allows farmers to measure a crop's nitrogen requirement as the tractor passes across the field and to vary the fertilizer application rate accordingly. N-Sensor ensures that the right and optimal rate of fertilizer is applied at each individual part of the field.

Another tool is the hand-held N-tester BT. The device uses an LED and light sensor to instantly measure the chlorophyll content of a crop when you clamp it onto the newest fully developed leaf of a crop. This green level shows the N content of the plant. These N-Tester values are automatically sent to your mobile device via Bluetooth™ connection. No internet or cellular signal is needed to record or take measurements.

Atfarm uses an algorithm powered by Yara agronomists to calculate the current N balance of your field based on the N-uptake measurements from the N-Tester BT. Decades of field trials by Yara ensure these calculations are accurate. All you have to do is enter information about your field: crop type, variety, growth stage, target yield estimate, Soil N supply, N already applied. After measuring your crops, you get an N recommendation that shows you the exact N needs of your crops.

N-Sensor measures crop nitrogen uptake and creates a prescription map for variable rate application



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Repeated field trials confirm that variable rate nitrogen fertilization has multiple benefits

Replicated trials to estimate the effect of variable rate nitrogen fertilization compared to a uniform nitrogen fertilization

Trials: Winter wheat

Yield:	+3.6%
Nitrogen rate:	-2%
Nitrogen surplus:	-10 kg/ha

Trials: Winter oilseed rape

Yield:	+4.4%
Nitrogen rate:	-6%
Nitrogen surplus:	-18 kg/ha

→ *Improved crop yield, reduced nitrogen fertilizer rate and higher nutrient use efficiency*

Source: Agri Con GmbH

Variable rate nitrogen fertilization improves crop yield, reduce N fertilizer rate and N surplus


The fertilizer industry
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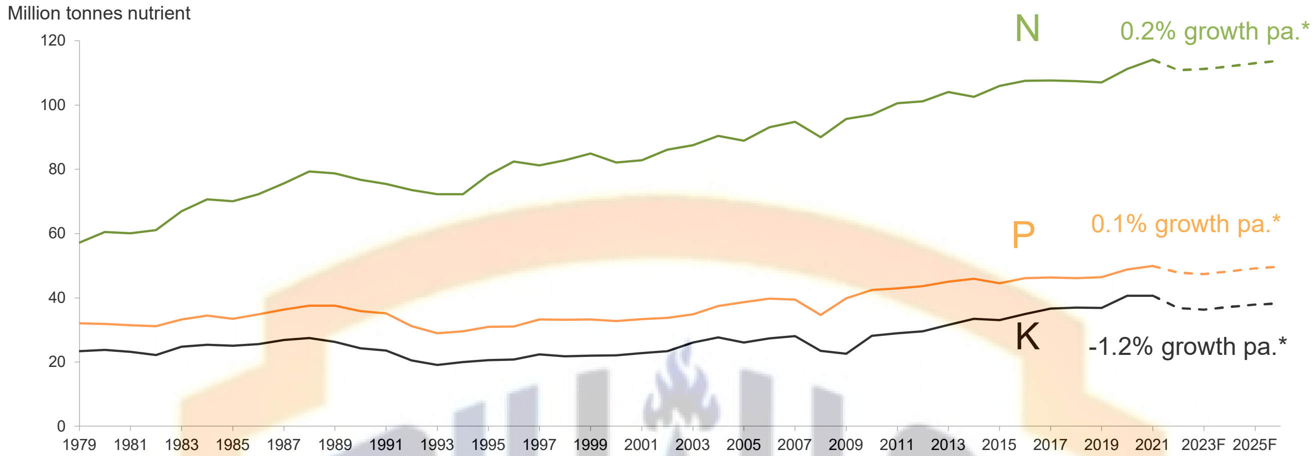
Global consumption trend per nutrient, currently restricted by supply availability



* CAGR avg. 2020-2021 to 2026

Source: IFA 2022

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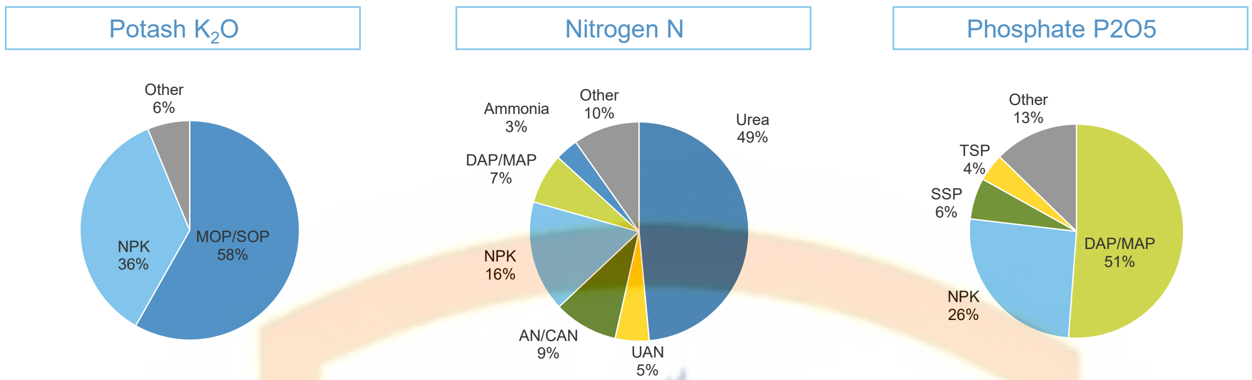
Nitrogen is the nutrient with highest consumption

Going forward, The International Fertilizer Association (IFA) forecasts nitrogen fertilizer consumption growth at 0.2% per year through 2025. Consumption growth is restricted by supply availability and does not necessarily reflect demand growth. A consumption growth rate of 0.1% a year is estimated for phosphate and -1.2% for potassium. A higher growth rate is forecasted for urea, since most new N-capacity additions are in the form of urea.

Key global fertilizer products



40 million tonnes

112 million tonnes*

* Does not include industrial nitrogen applications

49 million tonnes

Source: IFA 2022, data for 2020

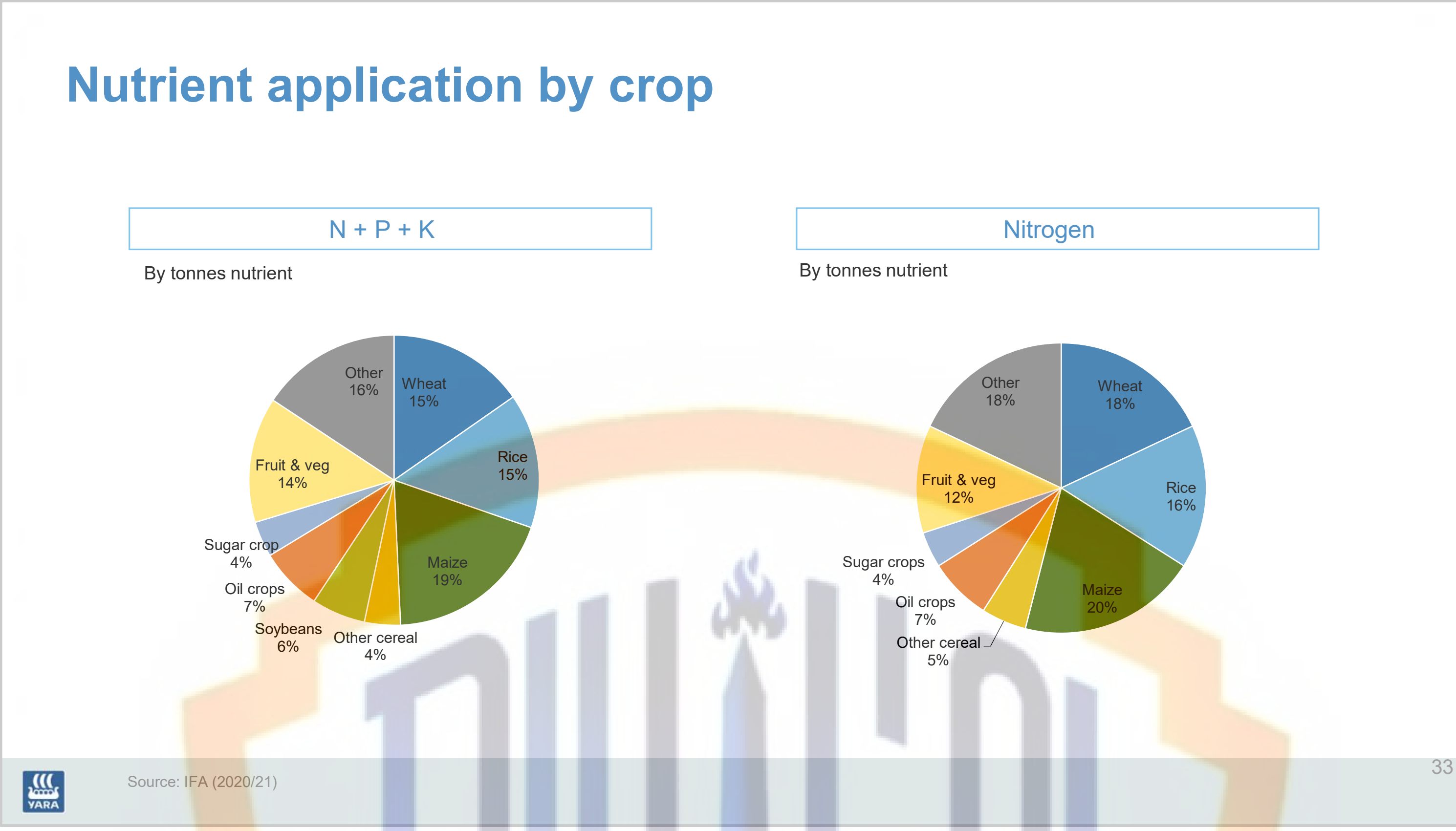
The key nitrogen, phosphate and potash products are urea, DAP and MOP respectively

Urea, DAP and MOP are the key products for respectively nitrogen, phosphorus and potassium fertilizer. They have a large market share and are widely traded around the world.

Urea contains 46% nitrogen, and its share of nitrogen consumption is increasing. The majority of new and pipeline nitrogen capacity in the world is in the form of urea.

Diammonium phosphate (DAP) contains 46% phosphate (measured in P_2O_5) and 18% nitrogen. Monammonium phosphate (MAP) contains 46% phosphate and 11% nitrogen.

Potassium chloride (MOP) contains 60% potash, measured in K_2O.



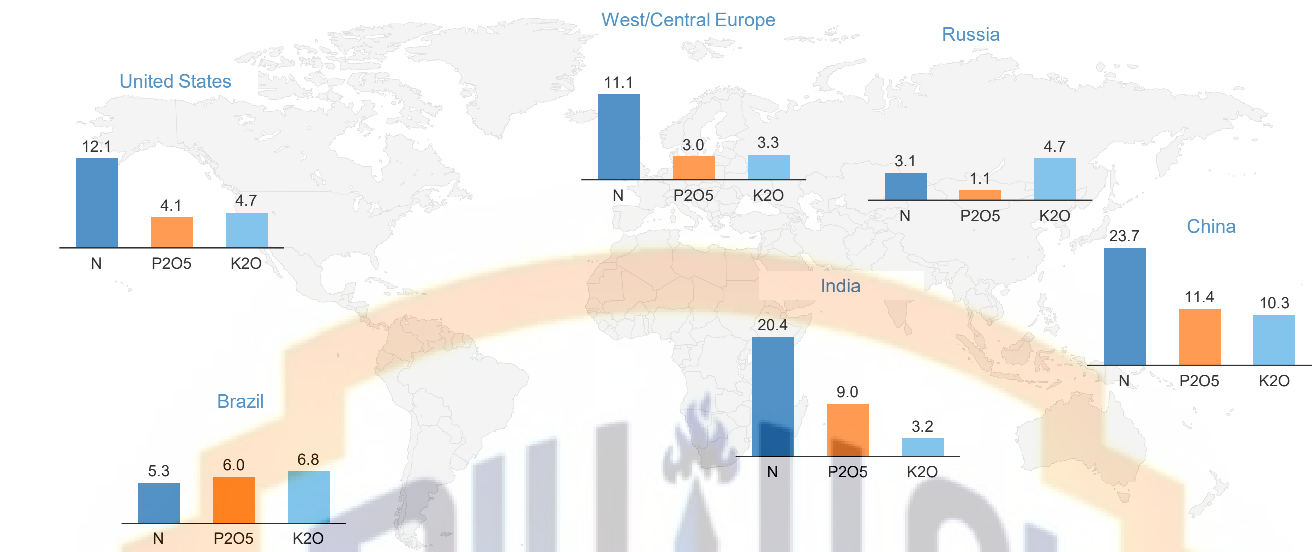
The three main grain crops, wheat, rice and corn (maize), consume about half of all fertilizer globally

The fertilizer market is not only a significant market in terms of size, but also an essential industry serving global food production. Grain production is the largest agricultural activity, with global output estimated (USDA) at 2.725 billion tonnes for the 2021 harvest.

It would not be possible to achieve this scale of production without intensive agriculture and use of mineral fertilizers. Grains are the largest end-market for fertilizers followed by cash crops such as vegetables, fruit, flowers and vines. In order to gain a good understanding of the fertilizer market, it is necessary to analyse both the grain market and the market for cash crops.

Fertilizer consumption by region – 5 key markets

Million tons nutrient consumption



Source: IFA 2022, data for 2020

34

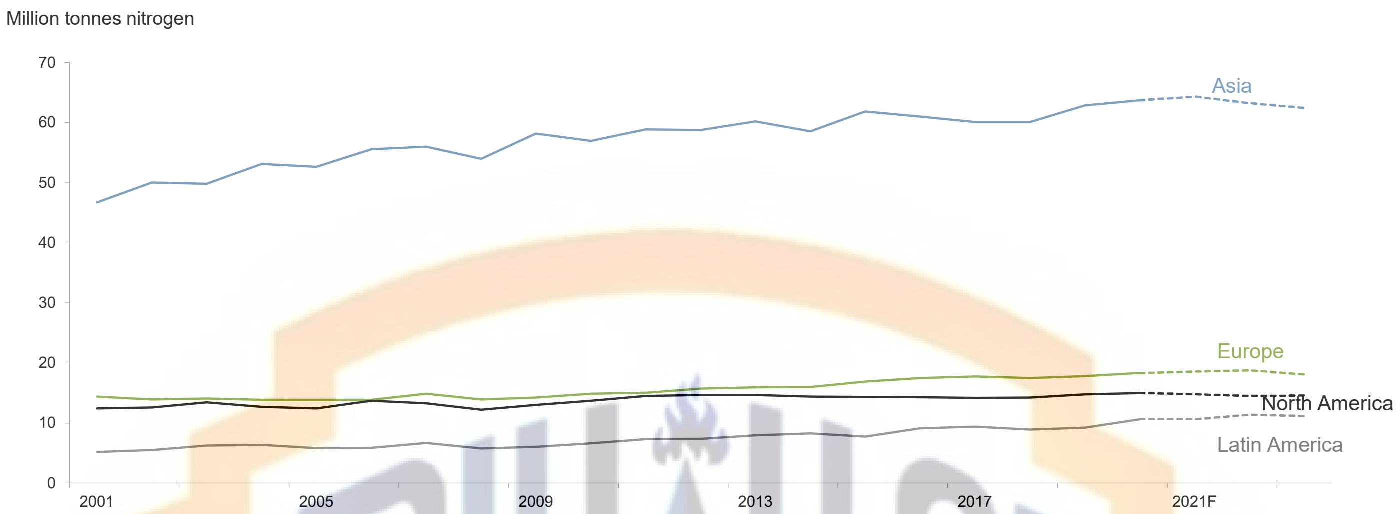
Geographical variances in fertilizer application

Fertilizer demand is influenced by the evolution of planted area and yields, the crop mix, crop prices and fertilizer-to-crop price ratios, soil conditions, fertilizer subsidy regimes, nutrient management regulations, nutrient recycling practices and innovation.

Nitrogen is by far the largest nutrient, accounting for 54% of total consumption. The highest consumption is seen in China and India where it is used for rice and wheat production, followed by the US with a large consumption due to corn production (including for use in biofuels) and Europe (wheat).

Brazil consumes substantial amounts of phosphate and potash due to its significant soybean production.

Nitrogen consumption in key regions



Source: IFA, June 2022

35

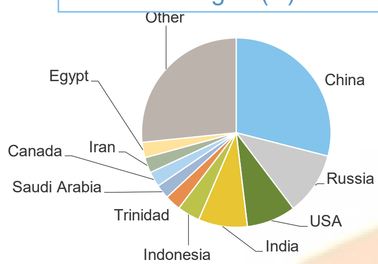
Asia is the largest fertilizer market

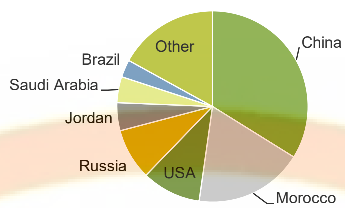
Asia's share of global nitrogen consumption was 57% in 2020, whereof around 2/3 of this was China (23.7 mt) and India (20.4 mt). Africa accounted for less than 4.4 mt or 4% of global nitrogen consumption in 2020. Going forward IFA estimate a decline in consumption growth across regions as a result of restricted supply availability globally. For the same reason and due to affordability issues, IFA expect Africa to be a much smaller contributor to global growth in nitrogen consumption than what was expected in the past.

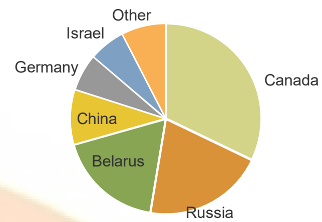
The N industry is fragmented, while the P and K industries are more concentrated

2021 figures[1], million tonnes nutrient

Nitrogen (N)	Phosphate (P)	Potash (K)







- Despite a consolidation trend, the industry is still highly fragmented
- The world largest nitrogen producers are CF, Yara, Nutrien, Ostchem, OCI, TogliattiAzot, Koch and Eurochem

- More concentrated than N-industry
- The biggest producers are Guizhou Phosphorus Chemical Group in China, Nutrien and Mosaic in USA, OCP in Morocco, Ma'aden in Saudi Arabia and Phosagro in Russia

- Highly concentrated industry, with top 3 producing countries representing appx 70% of global market
- The main producers in Canada are Nutrien and Mosaic, Belaruskali in Belarus, Uralkali in Russia and K+S in Germany

Source: IFA

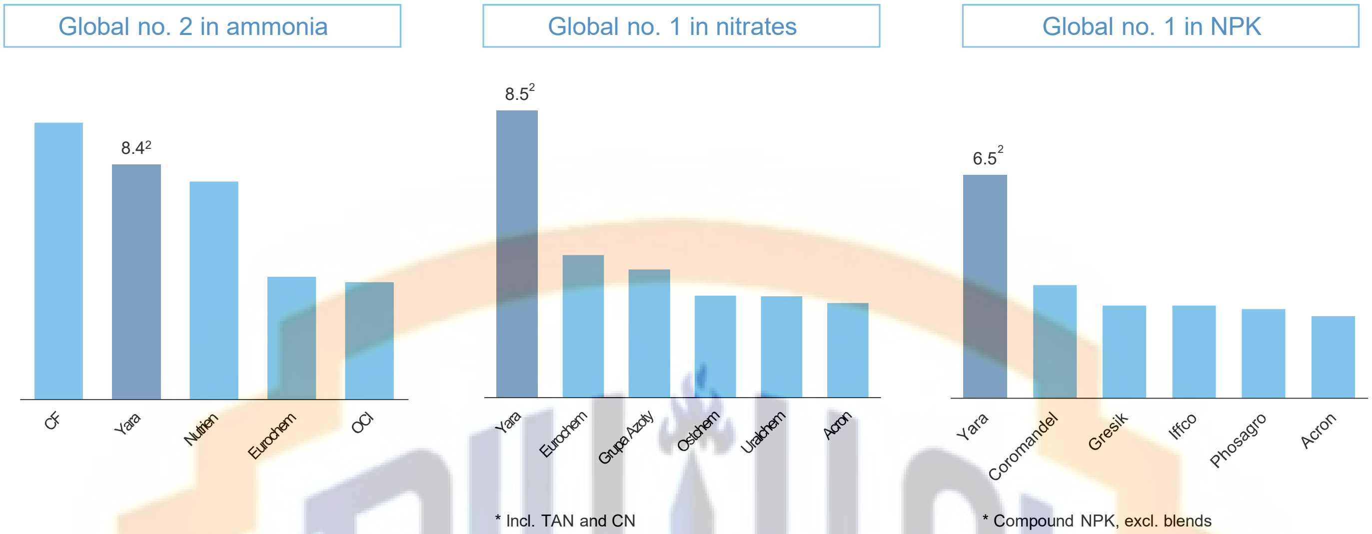
Nitrogen market is more fragmented than potash and phosphate markets

Nitrogen fertilizers are produced in many countries, reflecting the wide availability of key raw materials (natural gas and air) needed for production. The global nitrogen market is therefore less consolidated, but some regions such as Europe and the US have seen significant restructuring and consolidation in the last decade.

There are fewer large suppliers of phosphate and potash fertilizers, as phosphate rock and potash mineral deposits are only available in certain regions of the world. The potash industry is the most consolidated fertilizer industry, with Canada, Russia and Belarus accounting for around 70% of the total market.

Yara – the leading crop nutrition company

2018 production capacity, excl. Chinese producers[1] (mill. tonnes)



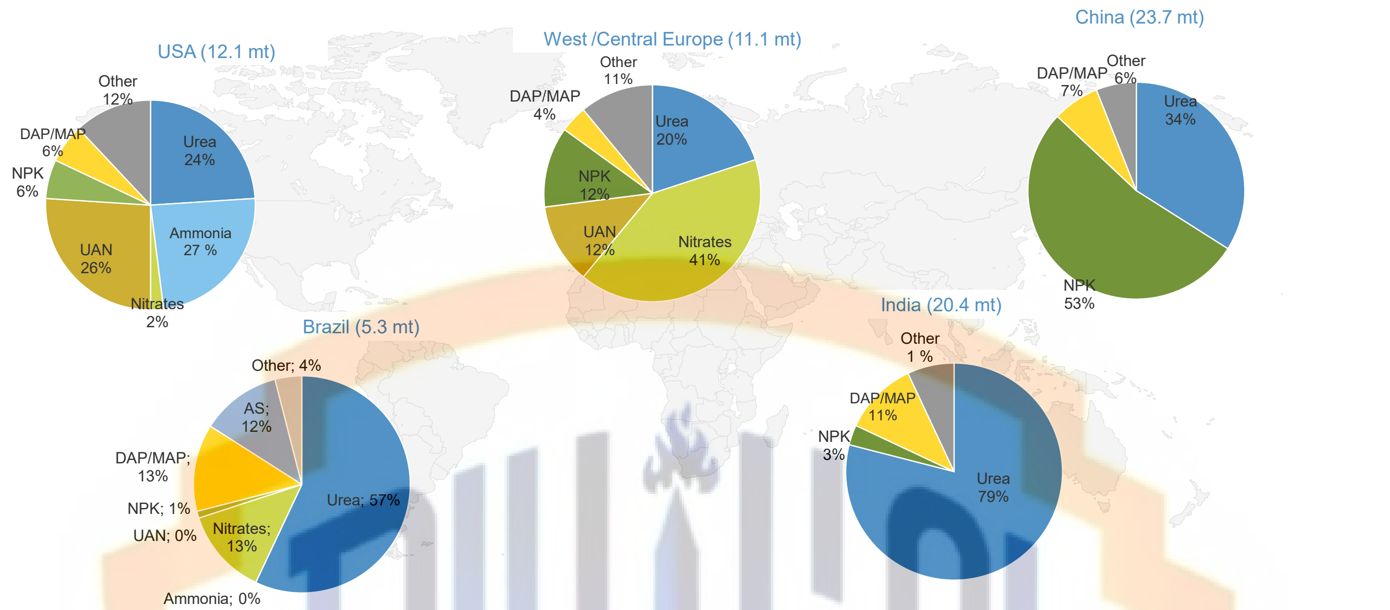
Source: Yara estimates, company info
1) Incl. companies' shares of JVs
2) Yara capacity as of Dec 2021

37

Yara is the global no. 1 producer of nitrates and NPK, and global no. 2 producer of ammonia

Yara's position gives it unique opportunities to leverage economies of scale and drive best practice across a large network of plants. Scale and global reach, combined with agronomic knowledge and closeness to the farmer, are key drivers for Yara's competitive edge.

Nitrogen fertilizer application by region and product



Source: IFA 2022, data for 2020

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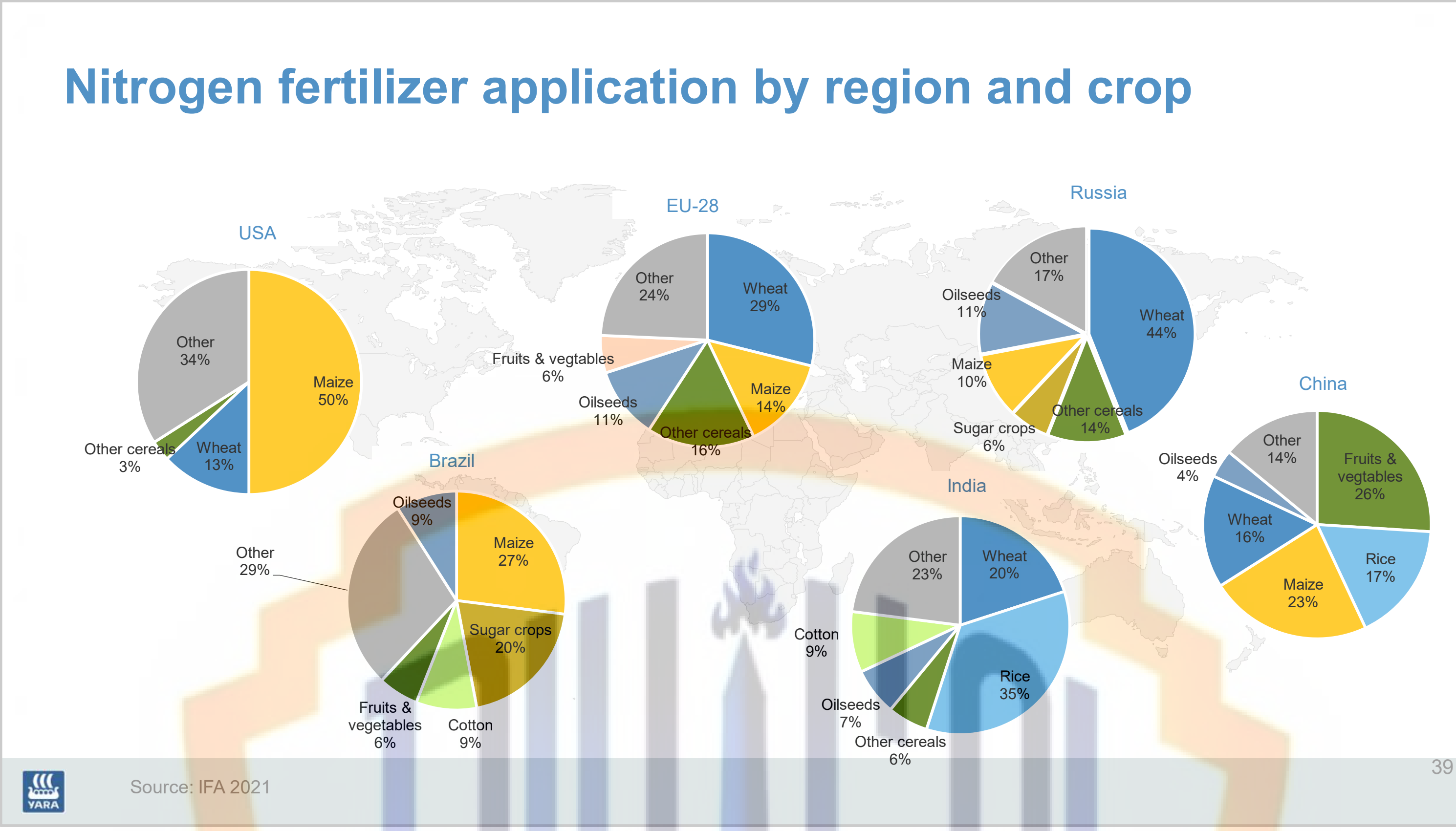
Geographical variances in nitrogen fertilizer product application

There are large variations in nitrogen fertilizer use in different regions and countries. Urea, the fastest growing nitrogen product, is popular in warmer climates. UAN (liquid fertilizer containing urea and ammonium nitrate) is mainly used in North America, while nitrates are mainly used in Europe. In the US ammonia is also used as a direct source of nitrogen in agriculture, especially for fall application.

Brazil consumes relatively more phosphate and potash compared with nitrogen, due to a large soybean production and local soil nutrient content.

Ammonium sulfate (AS) is less common today but is still used in Brazil, accounting for 12% of total application. AS contains sulfur and is highly water-soluble.



Geographical variances in nitrogen fertilizer crop application

There are large regional differences also in terms of crop demand for nitrogen fertilizer.

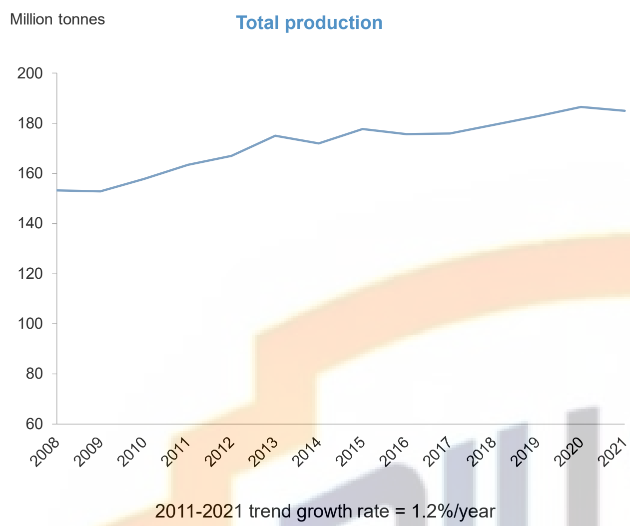
Due to strong growth in bioethanol production in the US in the last decade, maize/corn has become by far the biggest nitrogen-consuming crop in the US. Wheat and other cereals like barley dominate in Europe and Russia, while in Asia rice is a big nitrogen-consuming crop in addition to the fruits & vegetables segment in China.

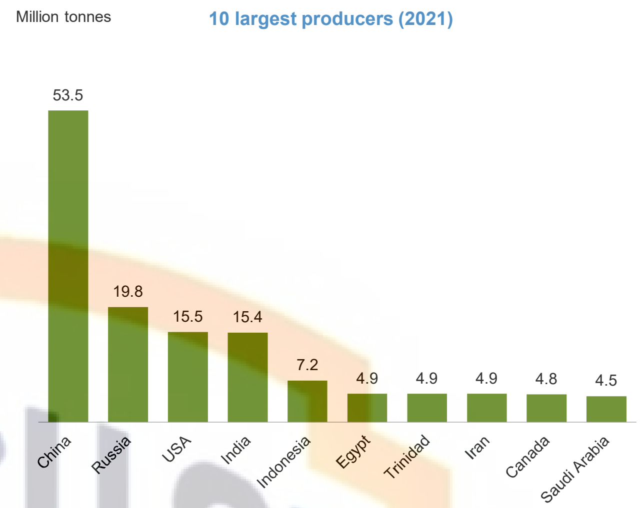
These regional differences impact regional demand patterns as soft commodity prices develop differently and hence impact farmer economics and farmer incentives to apply fertilizer differently.

Yara's strong European presence means that wheat is a key crop for its fertilizer sales.


Ammonia
YARA

Global ammonia production





Source: IFA

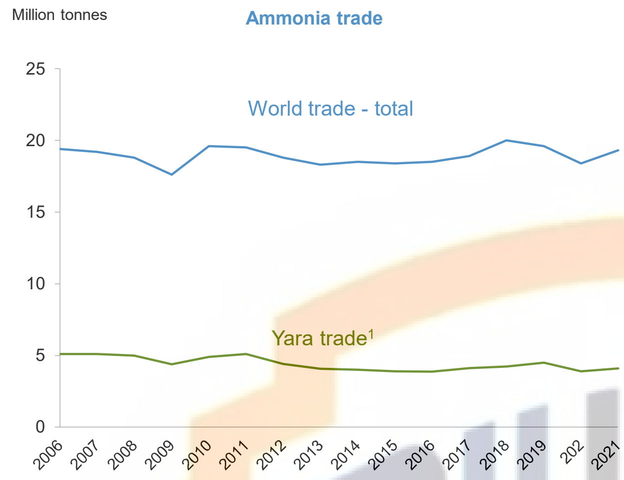
41

China is the largest ammonia producer

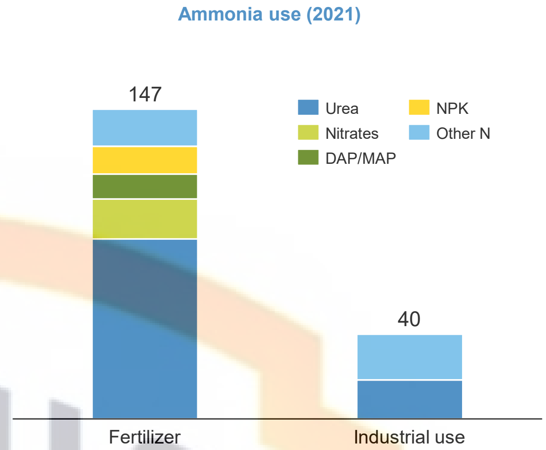
Ammonia is the key intermediate for all nitrogen fertilizer products and large nitrogen-consuming countries are also large producers of ammonia.

Ammonia production reached 185 million tons in 2021. The trend from 2011-2021 shows a growth rate of 1.2% per year.

Most of global ammonia production is upgraded to urea and other finished fertilizer



Source: Yara, IFA



Source: Fertecon

1) From 2019 Yara trade is based on sales volumes in the Yara Clean Ammonia ("YCA") reporting segment, which leads to some minor variations compared with previous years.

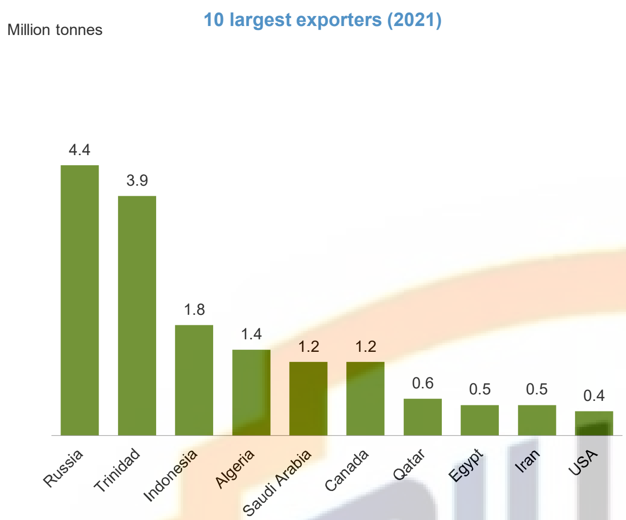
Only 10% of ammonia production is traded

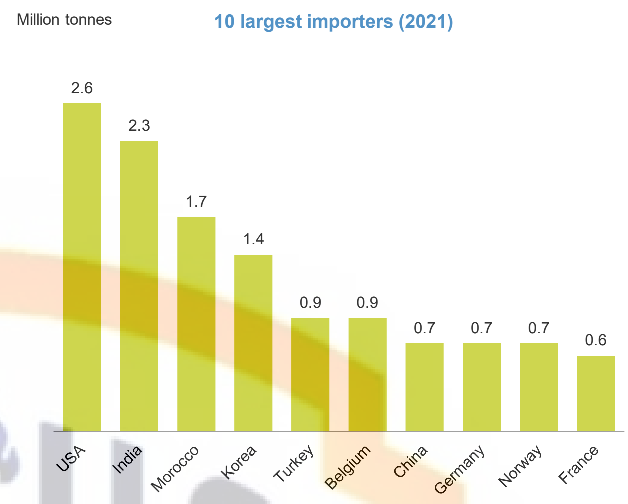
In 2021, world ammonia trade increased by 5% to 19.3 million tonnes, representing only 10% of world ammonia production. Urea production consumes 46% of all ammonia production. This ammonia needs to be upgraded on site as urea production requires CO_2 which is a by-product of ammonia production.

For traded ammonia, there are four main categories of customers:
- There is a substantial industrial market for ammonia
- Producers of the main phosphate fertilizers (DAP, MAP and some types of NPK) import ammonia, as the regions with phosphate reserves often lack nitrogen capacity
- Some nitrate production capacity is also based on purchased ammonia (non-integrated sites)
- Direct application on the field (only common in USA)

Yara has a market share of >20% of global traded ammonia (in 2021). Building on its long experience and leading position within ammonia production, logistics and trade, the Yara Clean Ammonia unit has a unique starting point to deliver ammonia to new applications and enable the hydrogen economy.

Global ammonia trade





Source: IFA

43

Russia and Trinidad are the world's largest ammonia exporters

The large ammonia exporters in the world have access to competitively priced natural gas, the key raw material for its production.

Trinidad has large natural gas reserves and also lies in close proximity to the world's largest importer of ammonia, the USA. Trinidad has large stand-alone ammonia plants and excellent maritime facilities that cater for export markets.

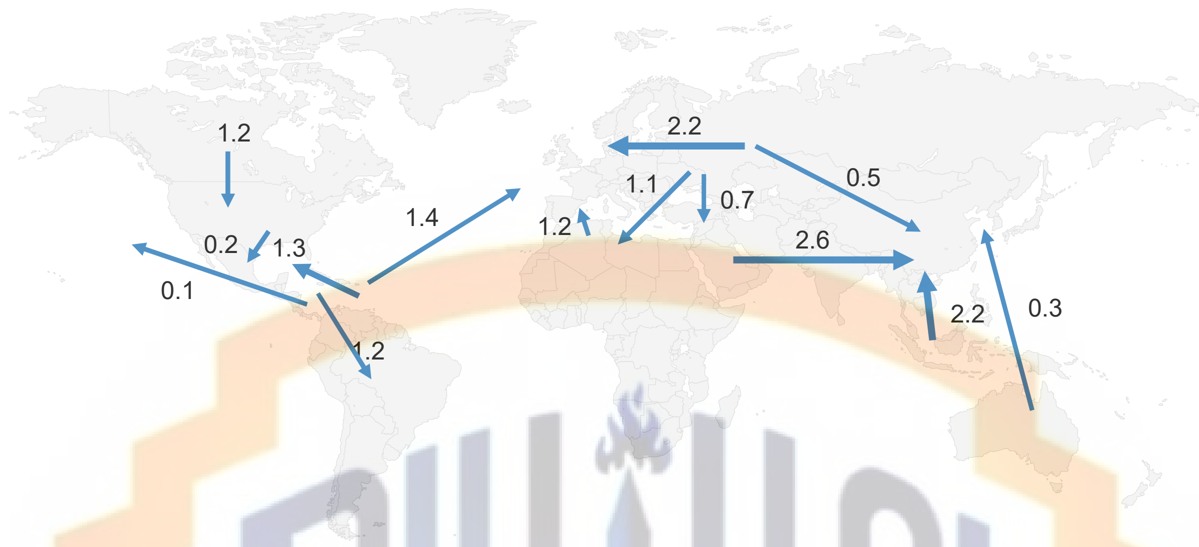
The Middle East also has some of the world's largest reserves of natural gas. The Qafco fertilizer complex in Qatar produces significant amounts of ammonia, but most of the ammonia produced in Qafco is upgraded to urea. Therefore, Qafco is a major exporter of urea and there is a relatively small surplus of ammonia left for exports.

In the US, imported ammonia is used for DAP/MAP production, for various industrial applications and directly as a nitrogen fertilizer.

India uses its imported ammonia mostly to produce DAP.

Main ammonia flows 2021

Million tonnes



Source: IFA 2021, 83% of trade shown. Asia deficit equals roughly 0.6 million tons, supplied from Russia and Trinidad

44

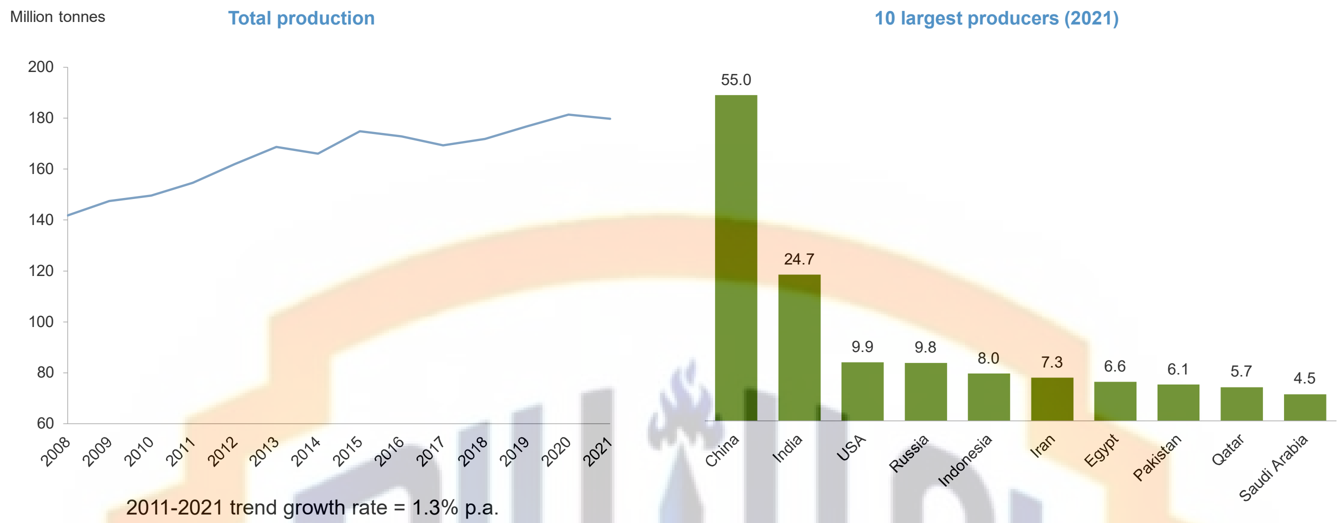
The majority of ammonia trade follows the routes shown in the map, mainly from countries with lower-cost gas

The main center for ammonia trade is Yuzhnyy in the Black Sea, the most liquid trade hub, and where most spot trades take place. Russian and Ukrainian ammonia is typically sold wherever netbacks are the highest and relative to pricing to the US, Europe and other markets. West of Suez is typically consistent with prevailing freight rates. Asia is almost in a balanced supply situation for ammonia. If there is a deficit, fob prices in Asia increase to attract imports from the Black Sea. If there is a surplus, Asian exporters will compete West of Suez, and Asian fob prices typically reduce.

In 2022 there has been a significant shift in trade flows with hardly any Russian exports from the Black Sea as a result of the Russia-Ukraine war. In addition, the Asian balance has been turning from a modest deficit to large surplus driven by new plants in Saudi Arabia and Oman, in addition to China not importing due to high global prices.


Urea
YARA
45

Global urea production



Source: IFA

46

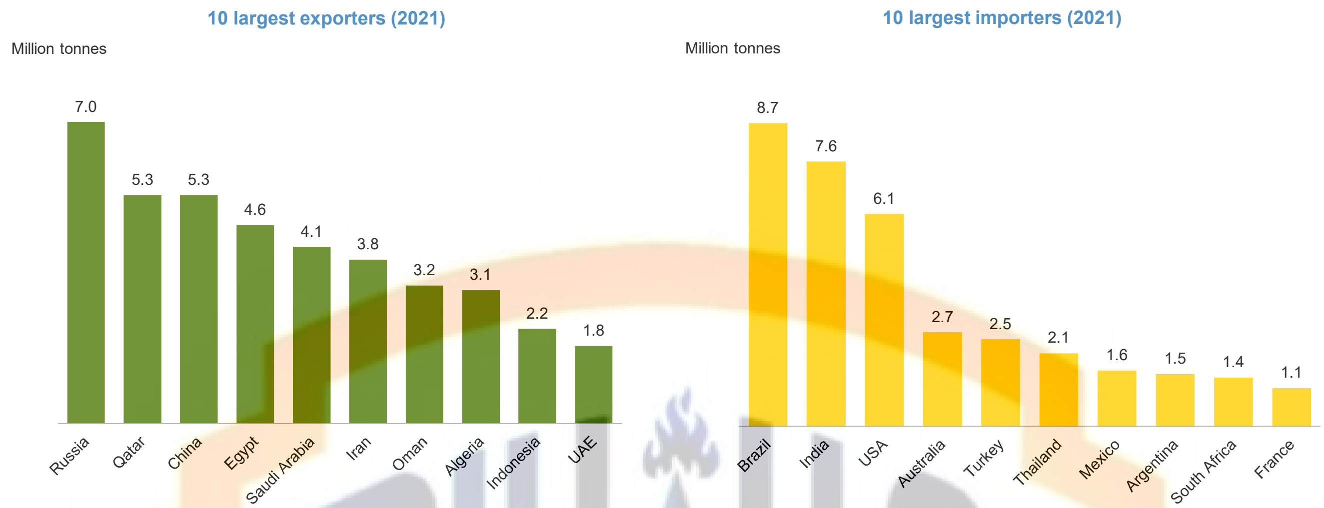
Urea is the main nitrogen fertilizer product

Urea production decreased to 179.8 million tonnes in 2021, down 0.9% from 2020. The reduction was partly driven by weather events and production stops affecting major urea producers in the US and India. During the years 2011-2021, urea production had a trend growth at 1.3% per year. The largest producers are also the largest consumers, namely China and India. China is self-sufficient on nitrogen fertilizer, but India's imports requirement is substantial.

Most of the new nitrogen capacity in the world is urea, so it is natural that production/consumption growth rates are higher for urea than for ammonia/total nitrogen.

As urea has a high nitrogen content (46%), transport is relatively inexpensive compared with other products.

Global urea trade



Source: IFA

Natural gas-rich regions generally tend to be big exporters of urea

Urea is a global fertilizer and is more traded than ammonia. Global trade of urea was 52.4 million tonnes in 2021.

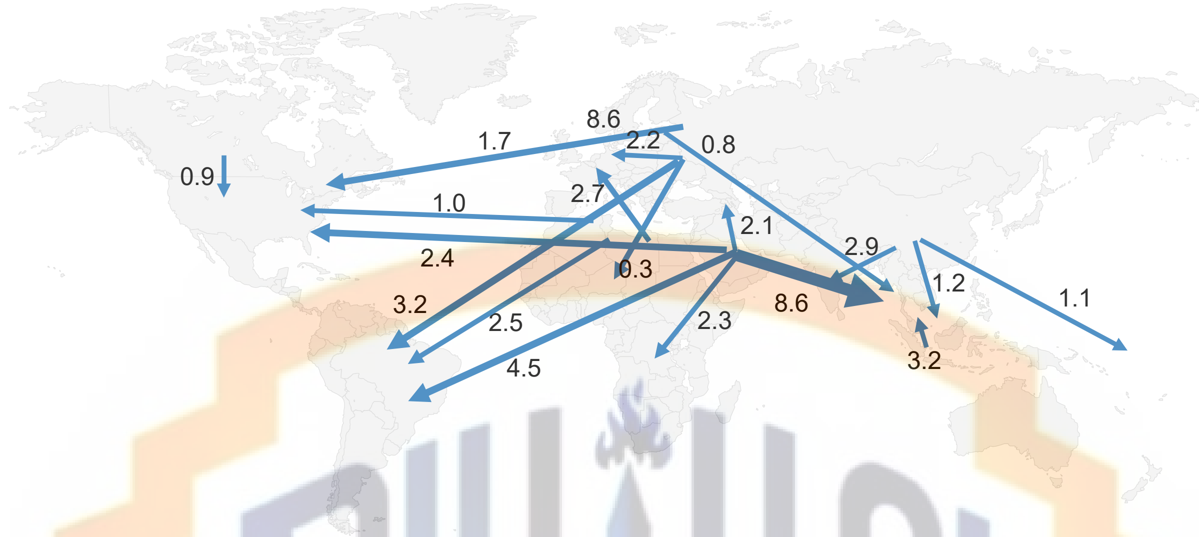
The main urea exporters are gas-rich countries/regions with small domestic markets. However, there are some exceptions.

China has huge domestic capacity. Although the main purpose is to supply the domestic market, there has in recent years been excess capacity resulting in exports. However, Chinese exports have been minimal since late 2021 due to export restrictions, driven by a desire to keep domestic fertilizer prices below the global price level.

North America, Latin America and South and East Asia are main importing regions.

Main urea flows 2021

Million tonnes



Source: IFA 2021, 83% of total trade shown

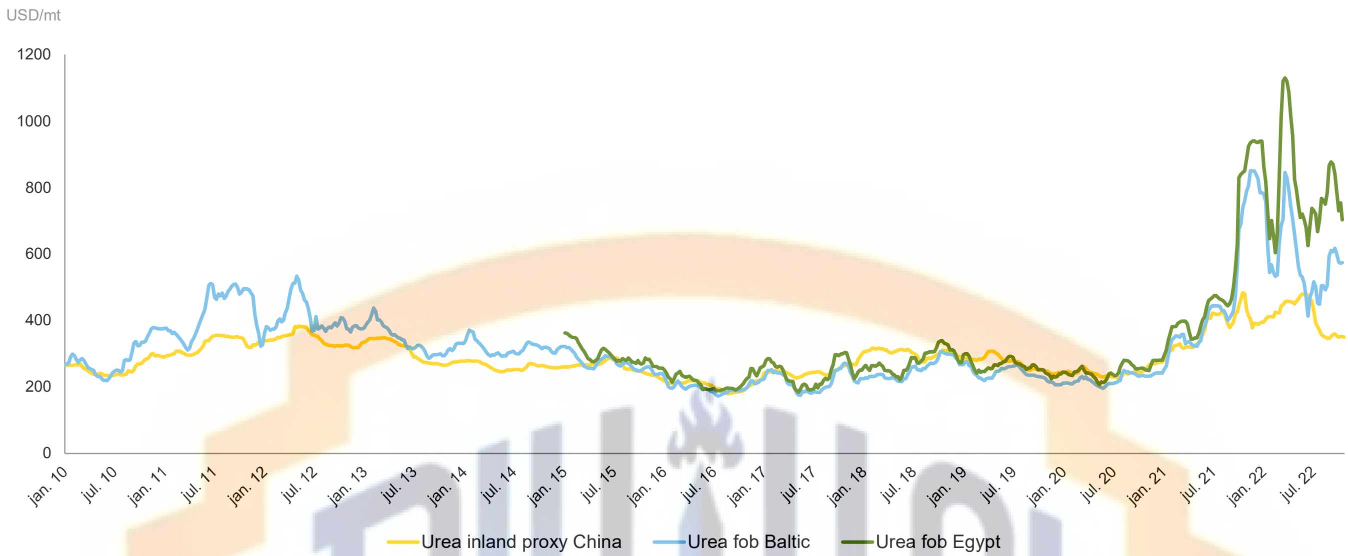
48

Russia, China, North Africa and Arab Gulf are main urea export hubs

Russian exports supply to Europe and Latin America, while Arab Gulf exports supply to North America and Asia/Oceania. All the other flows, of more regional nature, like Venezuela to USA, Indonesia to other Asian countries etc, are only interesting to the extent that they affect the need for Black Sea/Arab Gulf material. As an example, if China reduces its export, the Arab Gulf is not able to supply Asia on its own. Black Sea urea will flow to Asia, and an upward price movement will tend to take place.

The relative pricing between Black Sea, Egypt and Arab Gulf depends on where the competition on the marginal volumes takes place. If the main demand pull is from Latin America/Europe/Africa, Black Sea/North Africa will lead pricing. If it is Asia/North America, Arab Gulf will lead.

High and volatile urea price since late 2020



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Larger spreads between urea price references the past year

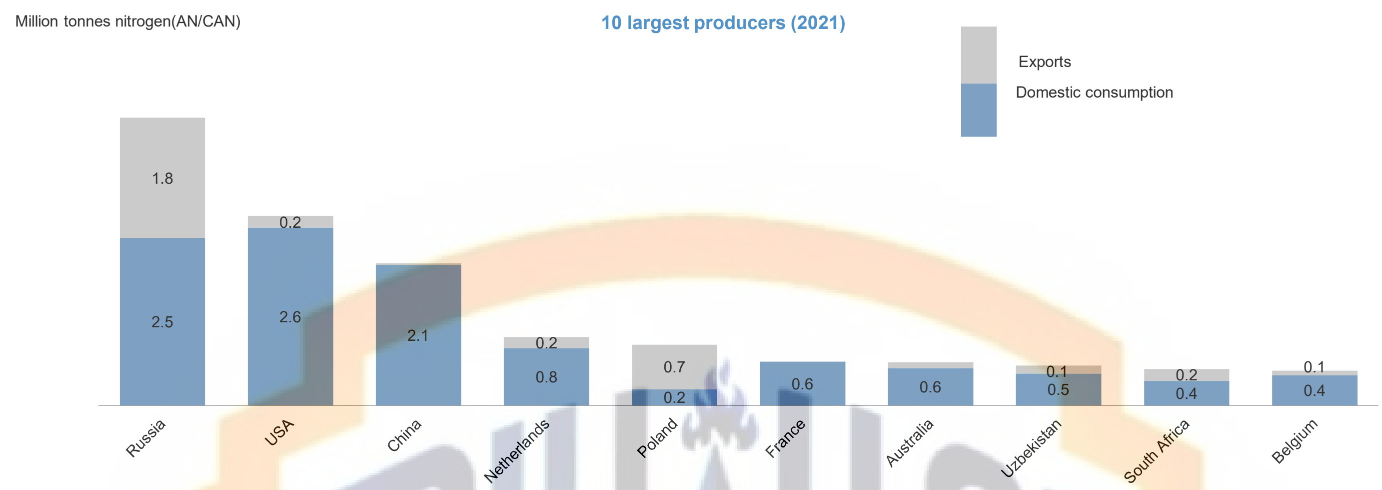
Since 2021 urea prices decoupled from the Chinese cost floor logic and the market moved to become more demand driven as food prices started to increase. In late 2021 and into 2022 the EU energy crisis led to curtailments of production in Europe and has pushed prices up and led to significant price volatility.

Urea prices in Egypt have been trading at a premium lately driven by strong demand from Europe.

Chinese urea prices have remained significantly below the global price level since 2021 as the Chinese government has introduced “soft restrictions” on exports.


Nitrates
50

Global nitrate production



Source: IFA, AN/CAN including nitrate part of UAN, as are industrial grades

51

Ammonium nitrate (AN, 33.5% nitrogen) and Calcium ammonium nitrate (CAN, 27% nitrogen) are the main nitrate fertilizer products

Nitrate production was 20.5 million tonnes N in 2021, of which AN was 16.3 mt and CAN/MAN was 4.2 mt. During the years 2011-2021, nitrates production had a trend growth of 0.5% per year.

Russia is the largest producer of nitrates, followed by the USA and China. AN solution for UAN production is included in the US figures.

Nitrates (AN/CAN) is biased towards Europe and contains only 27-34% nitrogen making it less attractive to transport than urea.

Calcium Nitrate (CN) provides soluble and strength-building calcium and nitrate-N (15.5%). Calcium Nitrate is mainly applied to cash crops, such as fruit and vegetables as calcium is good for rooting, stress-free growth, strong cell walls, improved fruit quality and better storage.

Nitrates are products with a nitrate content of 50 % or more

N fertilizer	N content	Nitrate (% of total N)	Other nutrients
CAN (calcium ammonium nitrate)	27%	50%	4% MgO
AN (ammonium nitrate)	33.5%	50%	
NPK	various	about 50%	P & K
CN (calcium nitrate)	15.5%	93%	19% Ca
Urea	46%	0%	
UAN (liquid urea ammonium nitrate)	28%	25%	
ASN (ammonium sulfate nitrate)	26%	25%	13% S
AS (ammonium sulfate)	21%	0%	24% S

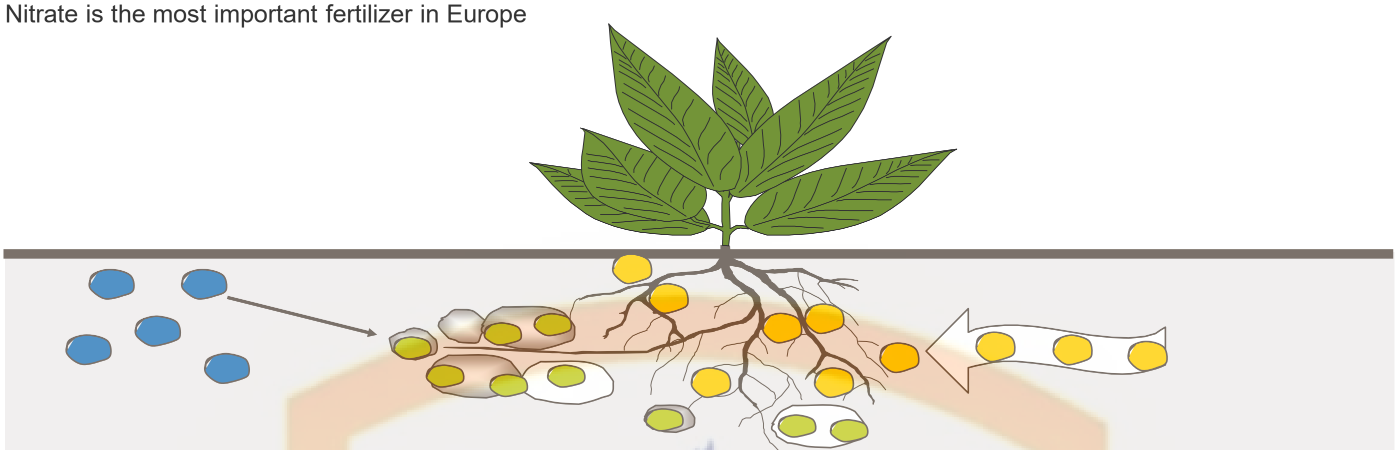
52

There are several types of nitrogen fertilizers, from urea to straight nitrate fertilizers

Nitrates are defined as products containing 50% of the nitrogen in the form of nitrate. Nitrate-based fertilizers are the most efficient and most reliable nitrogen source available. In addition, these products have a significant lower environmental impact than urea-based products through better control of leaching, lower volatilization and a lower life cycle carbon footprint.

Nitrates vs. urea

Nitrate is the most important fertilizer in Europe



Urea (CON_2H_4)

Urea-N needs to be converted into ammonium-N before it is plant available.

Ammonium (NH_4^+)

Ammonium-N is fixed onto clay minerals in the soil and therefore immobile. The plant roots have to grow actively towards the nutrient.

Nitrate (NO_3^-)

Nitrate-N is always dissolved in the soil water and is transported passively together with the water into the plant root. Thus, nitrate is rapidly effective.

53

Nitrate is immediately and easily taken up by plants

Ammonia (NH_3) is the basis for all nitrogen fertilizers and it contains the highest amount of nitrogen (82%). Ammonia can be applied directly to the soil, but for several reasons, including environmental, it is common to further process ammonia into, e.g., urea or nitrates before application. If ammonia is applied directly to the soil, it must be converted to ammonium (NH_4) and nitrate before plants can use it as a source of nitrogen.

While ammonium and nitrate are readily available to plants, urea first needs to be transformed to ammonium and then to nitrate.

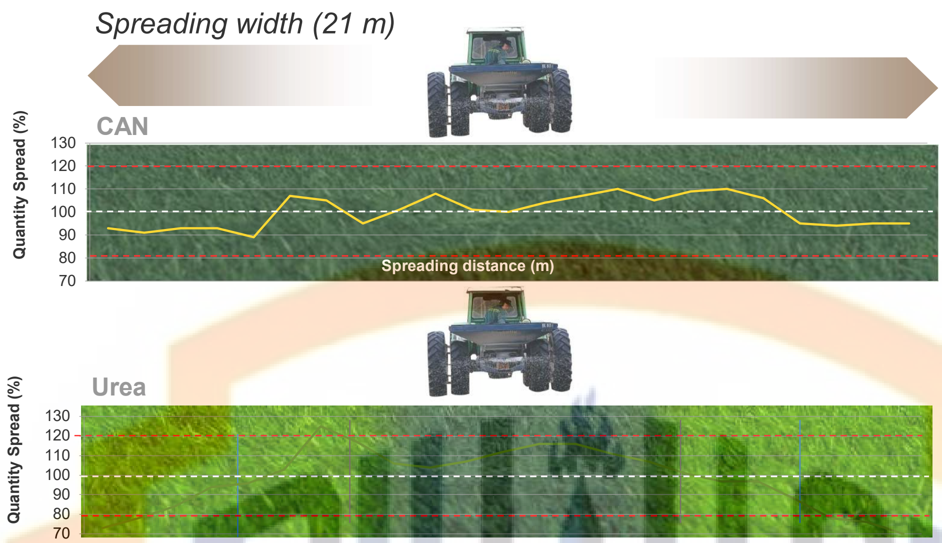
The transformation process is dependent upon many environmental and biological factors. E.g., under low temperatures and low pH (as seen in Europe), urea transformation is slow and difficult to predict with resulting nitrogen and efficiency losses. Nitrates, in comparison, are readily absorbed by the plants with minimum losses. Therefore, nitrates are widely regarded as a quality nitrogen fertilizer for European agricultural conditions. This is reflected in their large market share.

Better spreading with nitrates

The poor spreading patterns with Urea cause striped fields and considerable yield loss

Good uniformity with CAN:

Lower uniformity with Urea:



Due to better spreading quality of CAN a higher yield equivalent is achieved in field trials

Source: Yara research, trial studies in Germany (n=112, 2007-2017) on different soil types

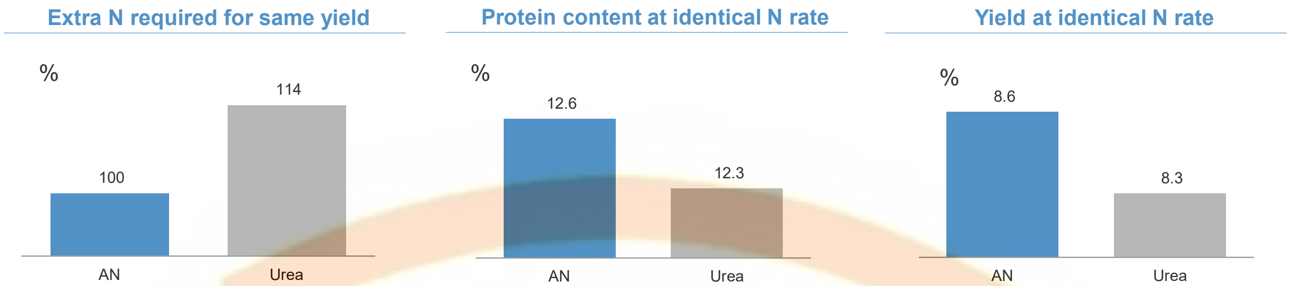
54

Striping reflects poor distribution of nutrients

Spreading tests have shown the deviation in actual nutrient application rate compared to target nutrient rate can be considerable. Deviation in nutrient rates will cause a major impact on the quality and yield of grains/fresh fruit and vegetables. Nitrates has a better spreadability compared to urea. The reason is that fertilizer grains of urea are lighter and smaller and are more easily affected by wind.

Nitrate outperformance compared with commodity nitrogen products

Trial results for arable crops (cereals, UK)



To maintain the same yield, significantly more nitrogen was needed from urea than from ammonium nitrate

Protein content was significantly lower on fields fertilized with urea than with ammonium nitrate

Yield was also significantly lower with urea than with ammonium nitrate

Source: DEFRA

55

The more nitrate in fertilizer, the higher the yield

There are numerous examples that support the superior performance of nitrates in arable, fruit and vegetable crop production, both with regard to yield and quality.

For arable crops, nitrogen fertilizer containing 50% nitrate and 50% ammonium such as CAN or AN are likely to be the financially optimal choice, due to the relatively low crop value.

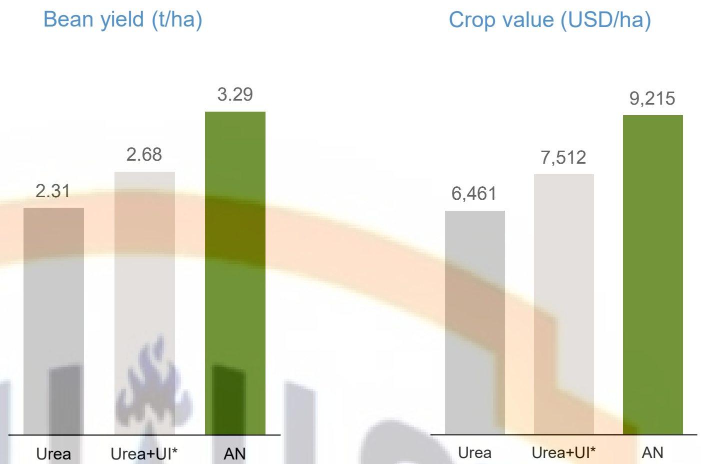
For higher-value cash crops such as fruit and vegetables, fertilizer products containing a high proportion of nitrate nitrogen are likely to be the optimum choice, especially for rapidly growing vegetables which need nitrogen readily available.

The most extensive study comparing different forms of nitrogen fertilizers was performed on behalf of the UK government between 2003 and 2005 (Department for Environment, Food and Rural Affaires - DEFRA). Besides quantitative differences, the study highlighted the variability of results observed with urea and UAN. The required nitrogen application rates can therefore not be predicted with the same reliability as with ammonium nitrate.

Yield advantages with nitrates in tropical climate

Trial study in Brazil, higher coffee bean yield with nitrates as compared to urea

- Research shows that the benefits of nitrates are even more pronounced in the tropics than in colder climates
- Nitrates provide direct and efficient uptake of N



* UI = Urease Inhibitor
Source: trial 2018/2019 - Lavras University, Minas Gerais, Brazil & Yara Research

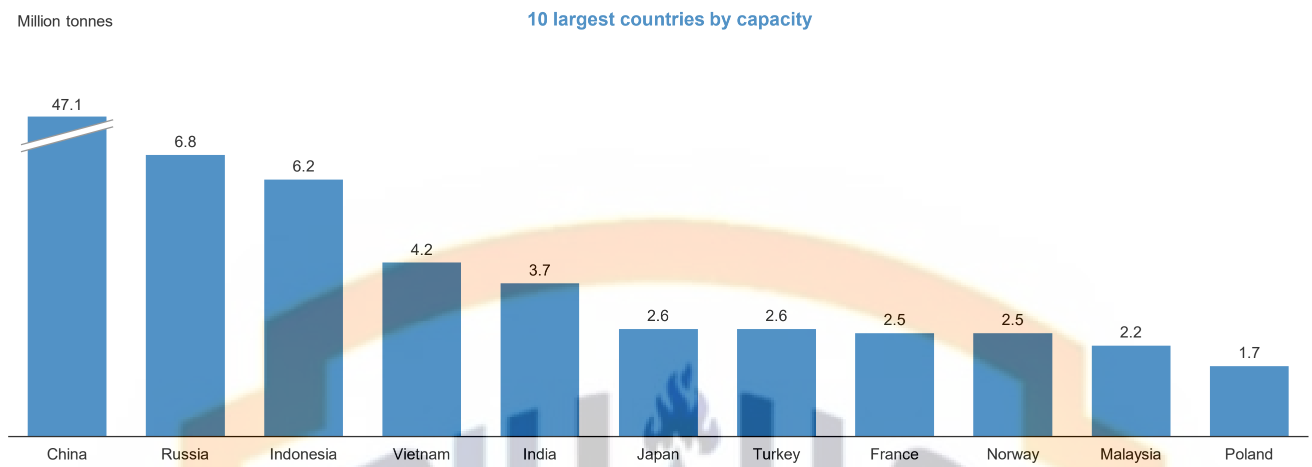
56

Field trials confirm the benefits of nitrates

Also in tropical climates nitrates can have significant benefits compared to urea, as nitrates are a direct and efficient source of nitrogen for plants.

NPKs

Global compound NPK capacities



Source: IFA 2016, data for 2013/2014

58

China is the world’s largest producers of NPK fertilizer

Since all fertilizers containing potassium are exposed to export taxes, little or no compound NPK is exported out of China. Of the 10 largest producers of compound NPKs, Russia and Norway are the main exporters. Excluding Chinese companies, Yara is the largest compound NPK producer globally.

Compound NPKs contain all nutrients in one particle

Compound NPKs

All nutrients in each and every particle

Even spreading of all nutrients

NPK bulk blends

A mix of products with different spreading properties

Risk of segregation and uneven spreading

59

Different quality between blended and compound NPK

In compound NPKs, the same mix of all the N, P and K nutrients is present in every particle of product, while in a blended NPK, separate particles of straight fertilizer like urea, nitrates, DAP, TSP, MOP, SOP etc, are mixed, or blended together.

The photo on the right shows a typical low quality blended product with a wide variation of particle sizes, shapes and nutrient contents. Larger, denser particles will spread further, and smaller lighter particles will spread the least distance. Where different sized particles have different nutrient content, this leads to segregation of nutrients upon spreading. In turn this will create uneven crop growth, and typical striping on crops such as cereals or rice. Compare this to the picture on the left of compound NPKs. The particle sizes are different, as this helps achieve uniform spread pattern, but all the nutrients are in every particle so that no segregation of individual nutrients takes place. All together this ensures accurate supply of nutrients to crops.

Bulk blend segregation during loading and unloading

Urea + DAP + MOP 15-15-15	Compound NPK 15-15-15

N – P_2O_5 – K_2O analysis in a pile of poor quality blend

N – P_2O_5 – K_2O analysis in a pile of compound NPK 15-15-15

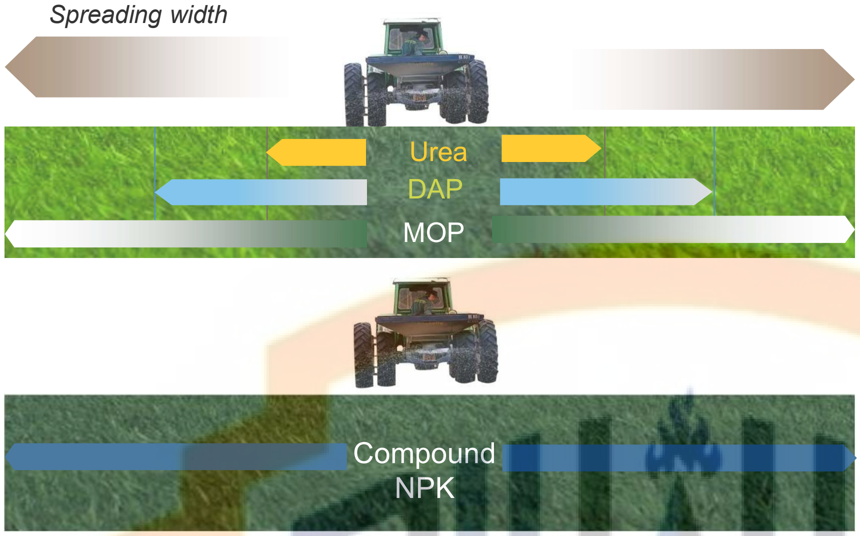
Segregation due to differences in specific weight and granule size

60

Careful handling of blended NPKs important to avoid segregation

Segregation of fertilizer blends can occur on loading into ships or bulk heaps, as larger particles will round to the edge of the heap. Careful handling of blended products is required to prevent segregation. With compound products, segregation of individual nutrients is not possible. However, it is also important to handle these products carefully, as separation of smaller as larger particles will alter the particle size distribution and spreading pattern.

Better spreading with compound NPKs



The spreading width of light particles like Urea is less than those of heavier particles like DAP and MOP

Poor spreading patterns cause striped fields and significant yield losses

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Striping reflects poor distribution of nutrients

Spreading tests have shown the deviation in actual nutrient application rate compared to target nutrient rate can be considerable. Deviation in nutrient rates will cause a major impact on the quality and yield of grains/fresh fruit and vegetables.

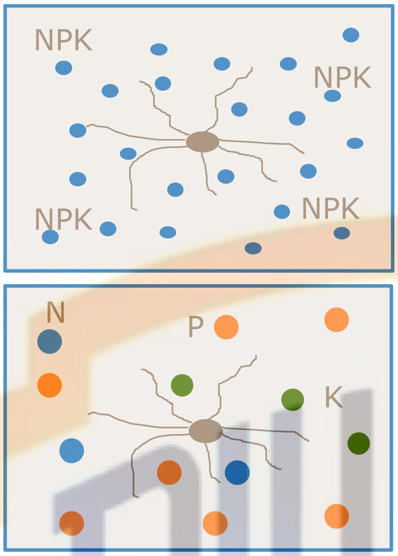
Compound NPKs give excellent spatial distribution of nutrients and higher crop yields as a result

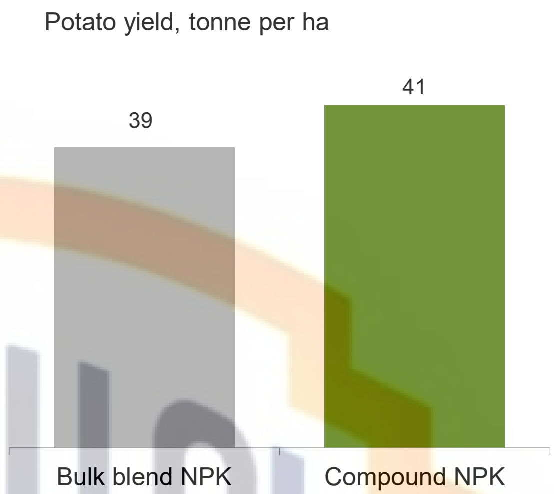
Compound NPKs
16+16+16

more particles and
better distribution

Bulk blend
Urea-DAP-MOP

fewer particles,
longer distance to roots





Source: Yara field trials, Hanninghof research center (9 harvest dates)

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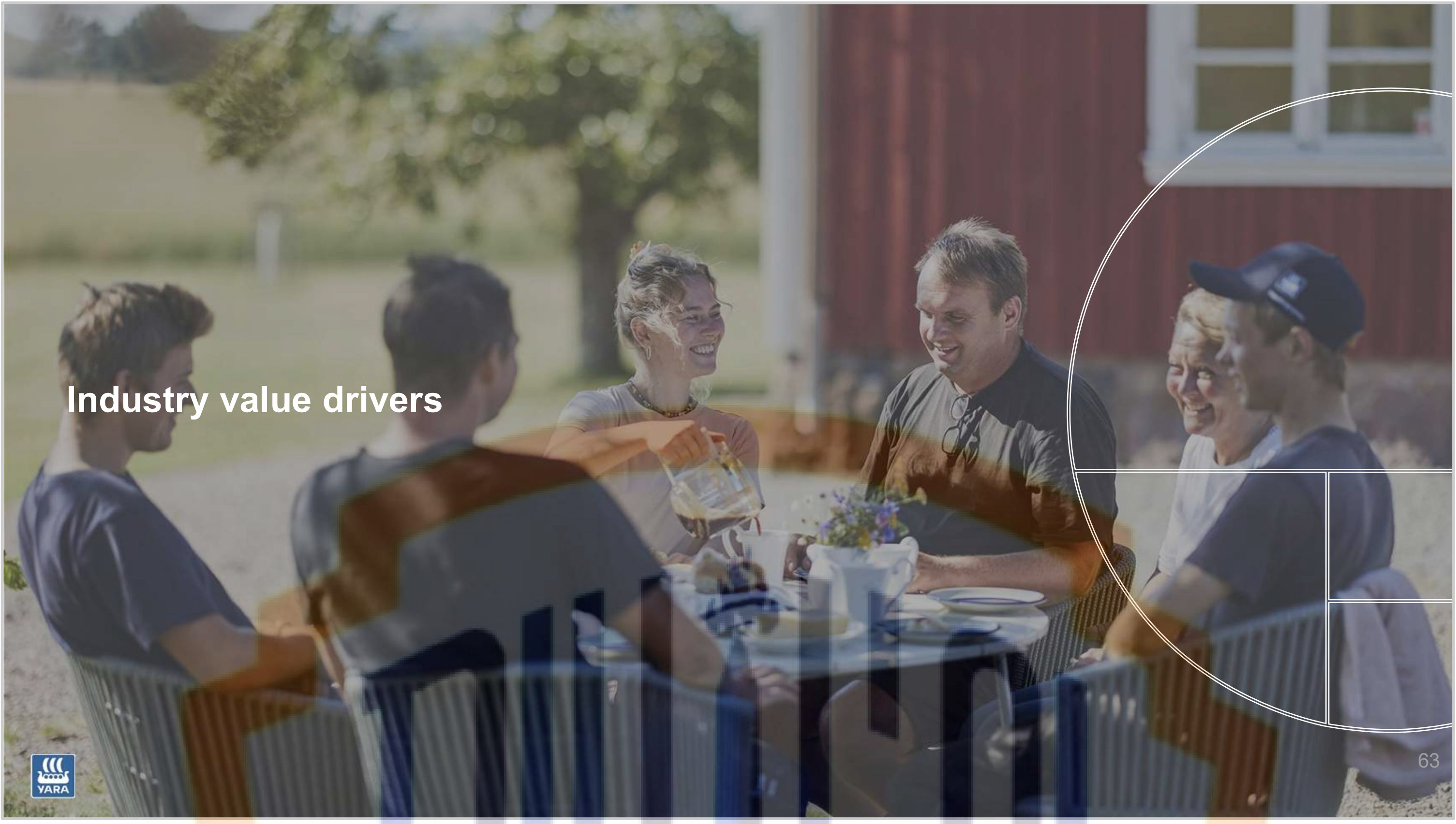
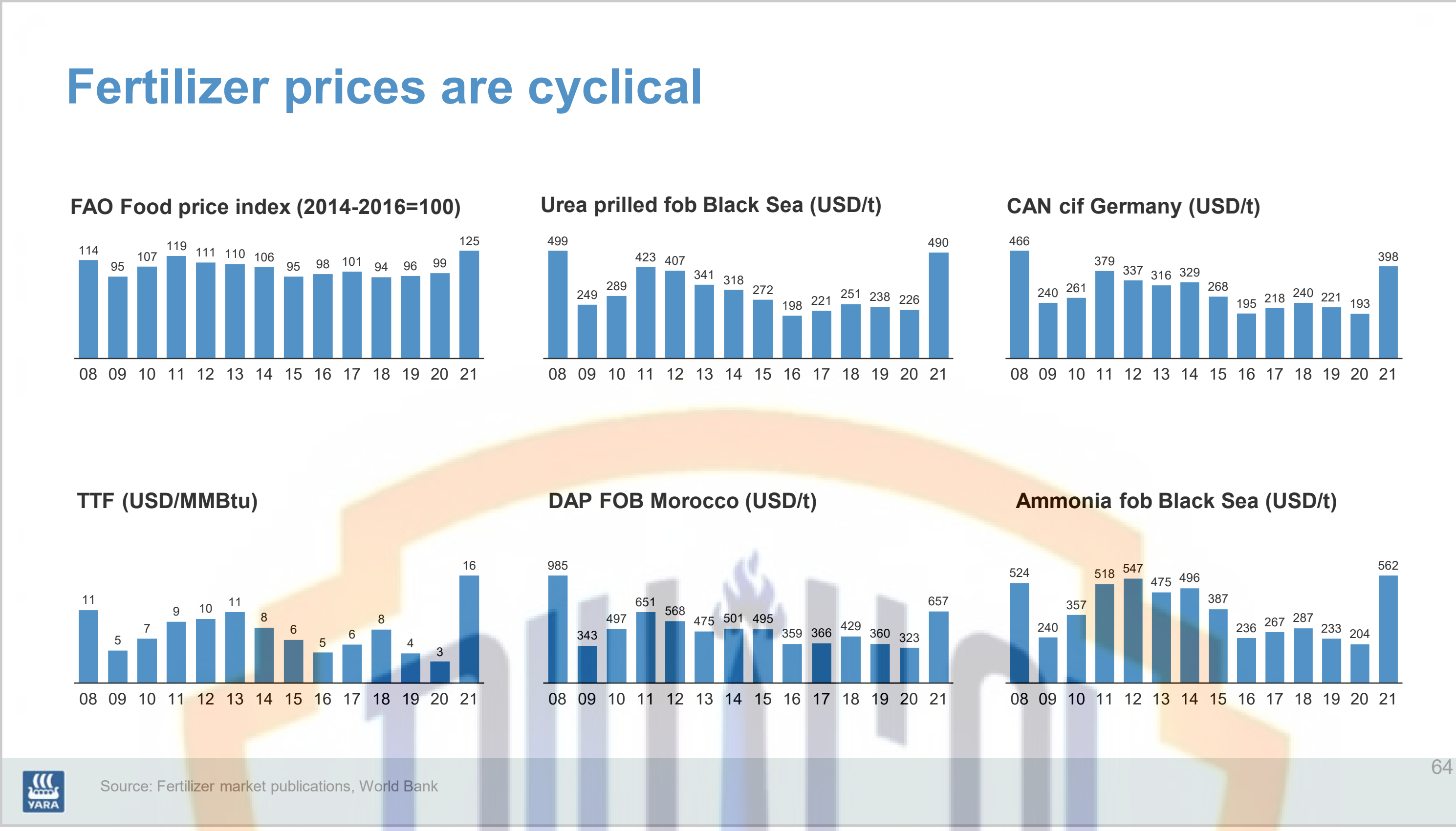
Compound NPKs provide better distribution of nutrients

Deviation in nutrient rates will cause a major impact on the quality and yield of the crops. Compound NPKs includes all N, P and K nutrients in one fertilizer particle and therefore better distribution of nutrients to the crop.

Field trials confirm that compound NPKs improves crop yield compared to the bulk blend (commodity) alternative. Further, as NPKs are typically used for “cash crops” (fruit and vegetables), a compound NPK is typically a highly profitable investment for farmers.


Industry value drivers
63



Fertilizer prices are cyclical

Fertilizer prices are cyclical. The cyclicality is primarily caused by the “lumpiness” in supply additions resulting in periods of overcapacity and undercapacity.

Nitrogen fertilizer value drivers

	Drivers:	Effect on:
Revenue drivers:	Global urea demand vs. supply	Urea price
	"Marginal producer" production costs	Supply-driven urea price
	Crop prices/grain inventories	Urea demand / demand-driven urea price
	New urea capacity vs. closures	Urea supply
	Urea price	Most other nitrogen fertilizer prices
	Cash crop prices	Value-added fertilizer premiums
Cost drivers:	Gas demand vs. supply	Gas costs
	Manning and maintenance	Fixed costs
	Productivity and economies of scale	Unit cost

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Drivers of supply and demand

In general, when demand is low, there tends to be a "supply-driven" fertilizer market in which the established "price floor" indirectly determines fertilizer prices. This price floor is set by the producing region with the highest feedstock prices (natural gas or coal).

When fertilizer demand is high, there is typically a "demand-driven" market with fertilizer prices above floor prices for swing (highest cost) regions. The fertilizer market balance and capacity utilization are other key factors that impact prices for urea and other N-fertilizers.


Drivers of demand
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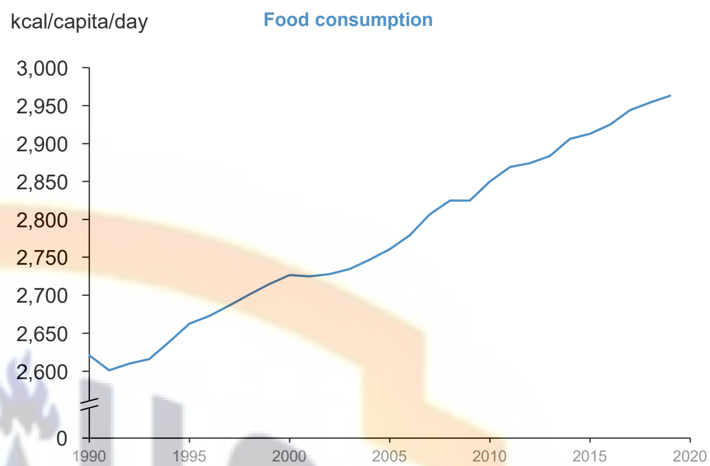
Drivers of fertilizer consumption growth

Fertilizer consumption is mainly driven by food demand

- Population growth
- Economic growth and diet changes
  - More protein-rich diets
  - More fruit and vegetables
  - Reduced hunger
- Nutrient use efficiency in farming
- Waste and loss across the food value chain

Industrial consumption is mainly driven by economic growth

- Economic growth
- Environmental limits (e.g. reduction of NOx emissions)



Source: FAO, food supply kcal/capita/day

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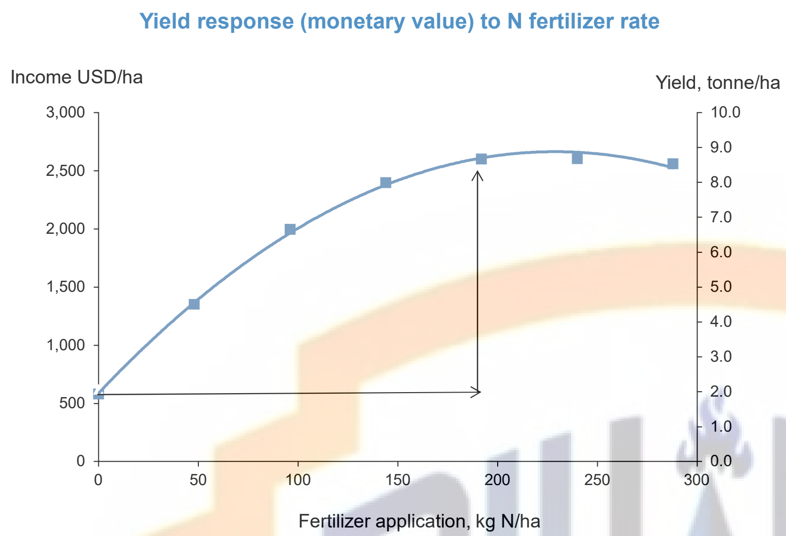
Nitrogen consumption growth exceeds global population growth

Population growth and economic growth are the main drivers for increased fertilizer consumption. Industrial consumption of nitrogen is mainly driven by economic growth and environmental legislation.

Profitability of investment in mineral fertilizers



- The investment in nitrogen fertilizer is highly profitable for growers
- Fertilizer investment: 332 USD/ha
- Net return: 2,036 USD/ha
- **Net return ~ 5 x investment**

Source: Winter wheat yield data: Long term trial, Broadbalk, Rothamsted (since 1856).

Correct use of fertilizers can yield huge returns on investment

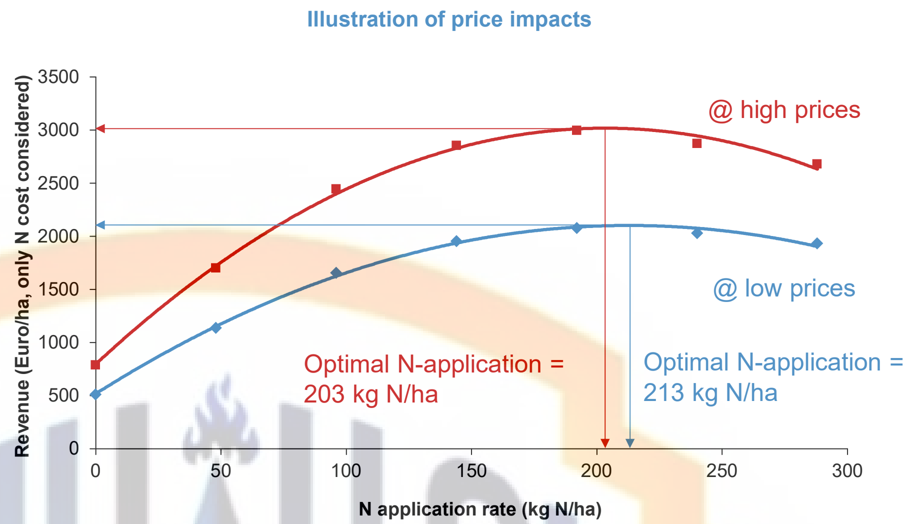
Using 192 kg N/ha (winter wheat in Europe), it is possible to produce 9.3 tonnes of grain per hectare. The fertilizer cost at this application level using urea (46% N) at USD 765/t (1.73 USD/kg N) would be 192 kg x 1.73 USD = 332 USD/ha

Using a wheat price of 281 USD/t, the farmer gets the following alternative revenue scenarios:
Optimal nitrogen level: 9.30 t grain/ha * 281 USD = 2,619 USD/ha
No nitrogen fertilizer added: 2.07 t grain/ha * 281 USD = 583 USD/ha

The difference in revenues is 2,036 USD/ha resulting from an input cost of 332 USD/ha, i.e. a return n investment of 514%.

Higher grain prices allow for increased nitrogen fertilizer values

- High crop prices provide much-needed incentives to farmers and global food production
- Farmers get the full revenue effect of yield improvement while fertilizer is a relatively smaller component of their margin, hence optimal nitrogen application is only slightly lower in this example with high prices vs a scenario with low prices.



High prices (red line) = 248 EUR/t for grain and 518 EUR/t urea, low prices (blue line) = 381 EUR/t for grain and 1625 for urea.
Source: Winter wheat yield data: Long term trial, Broadbalk, Rothamsted (since 1856).

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Higher crop prices improve farmer incentives

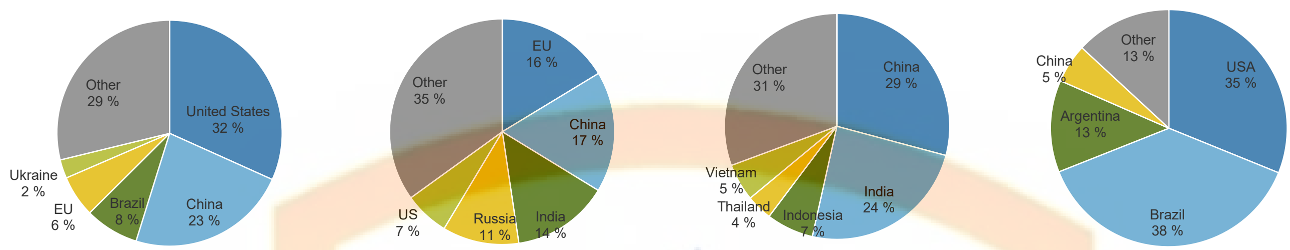
In the above example, while the fertilizer price is 3 times as high in the “high prices” scenario vs. the “low prices” scenario but the grain price is only 1.5 times higher, the revenue increase per hectare is far higher than the cost increase. The optimal nitrogen application rate in this example is 5% lower, but the economic incentive to plant and apply is clearly stronger.

This is a simplified example, assuming all other factors are held constant. Different crops will typically have different yield effects from nitrogen and prices.

Key crops by region

Global production:

Corn	Wheat	Rice	Soybeans



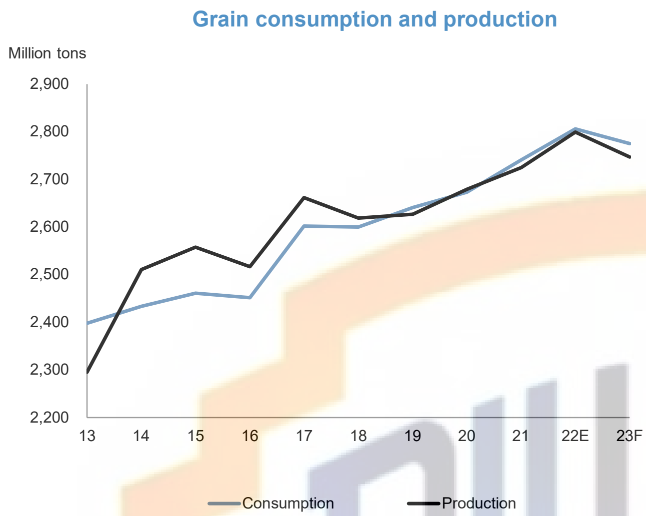
1,129 mt	***775mt***	***509 mt***	***368 mt***

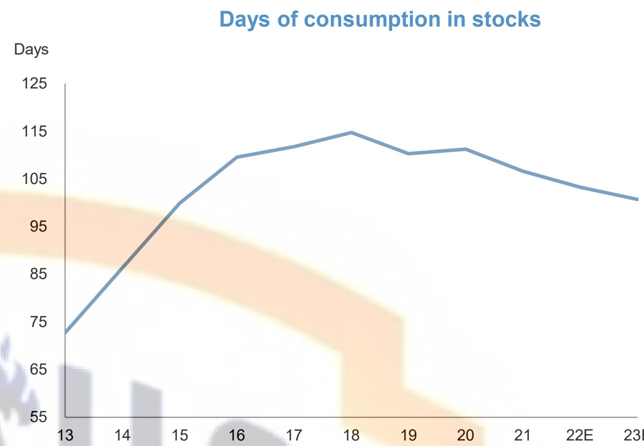
Source: USDA October 2022, data for 2020/21 season

Crop producing countries

The United States and China are large producers of agricultural products. While the US is the biggest producer of maize/corn and soybeans, China is the biggest producer of rice.

Grain production forecasted to fall short of consumption for the 2022/23 season





Source: USDA October 2022

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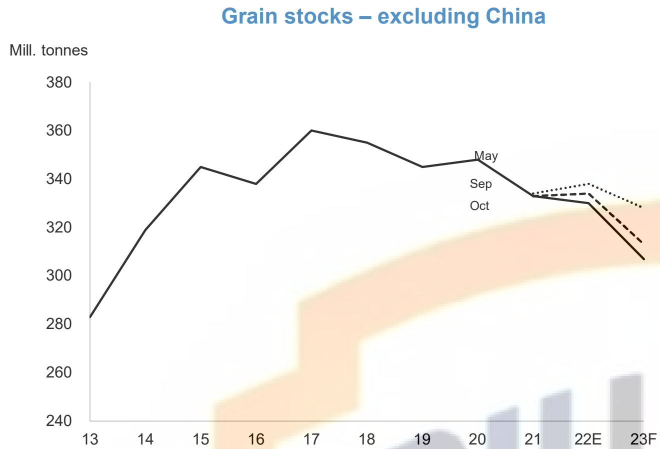
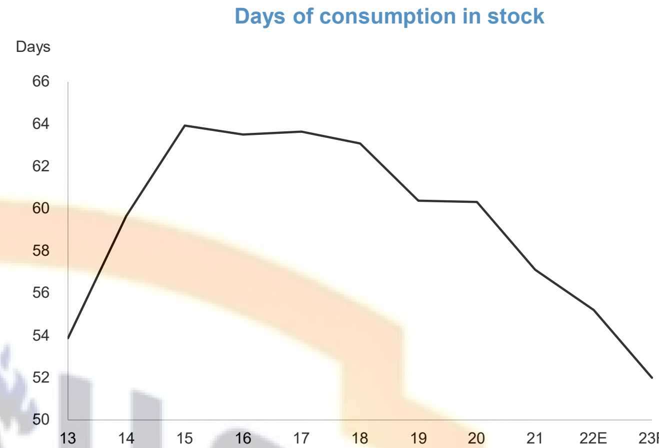
Global grain production needs to keep up with demand

Production needs to keep up with a steady growing consumption increase. With a growing world population, the demand side will continue to grow going forward. Over time food prices need to be high enough to attract investment and growth in production. If prices are low and less grain is produced, demand will exceed supply and prices will increase.

Global grain production has been slightly below consumption four years in a row, according to USDA, resulting in lower global grain inventories. The USDA projections are updated monthly and are available on https://www.usda.gov/oce/commodity/wasde/

Grain inventories outside China seen declining this agricultural year (July-June)





Source: USDA October 2022

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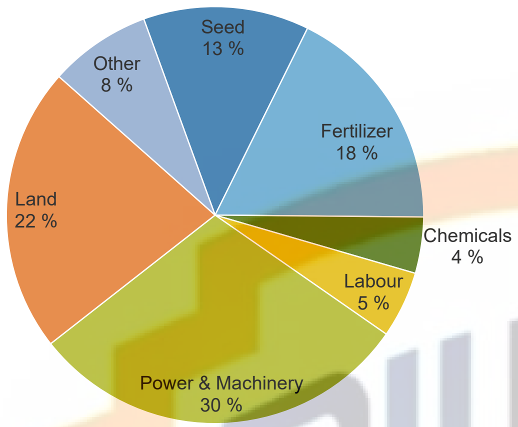
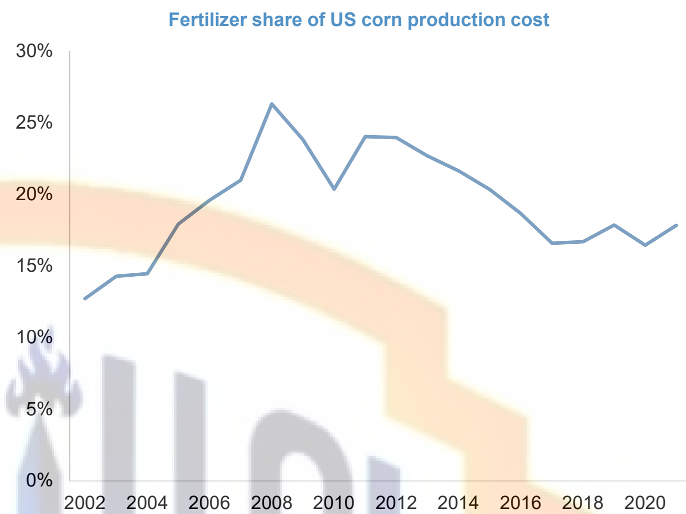
Grain stocks excluding China are declining

The war in Ukraine has led to lower global grain stocks. For the 2022/23 season a key uncertainty is how much grain Ukraine will manage to export, as the key trading route for this is though the Black Sea.

Breakdown of grain production costs

Example: 2021 average US corn production costs





Source: USDA (Commodity costs and returns)

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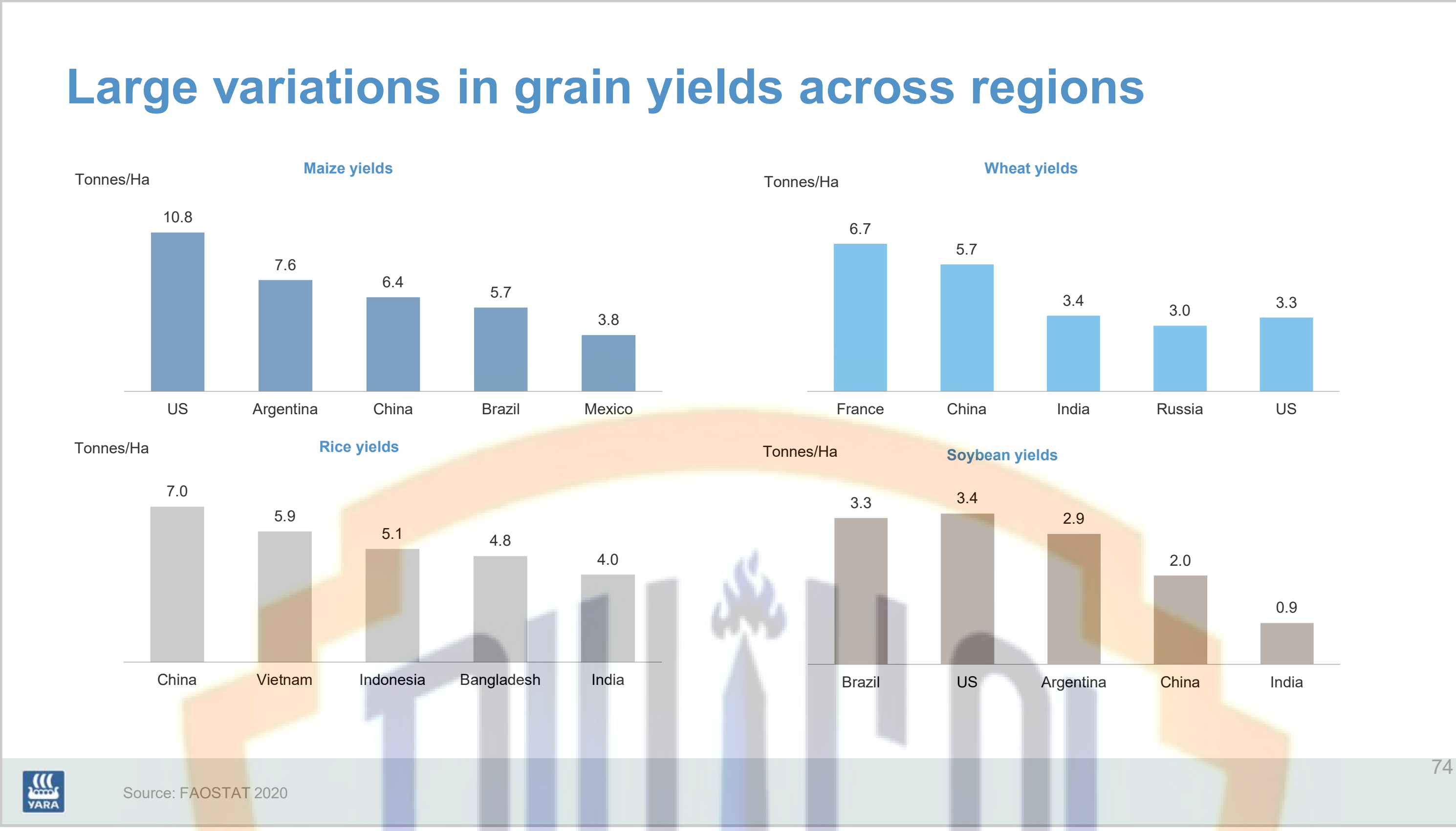
Fertilizer cost is less than 1/5 of total grain production cost

Fertilizer costs relative to total production costs of corn has declined since 2011 and represent appx 18% in 2021. For other major crops, the relative share is smaller varying from 6% for soybeans up to 14% for wheat.

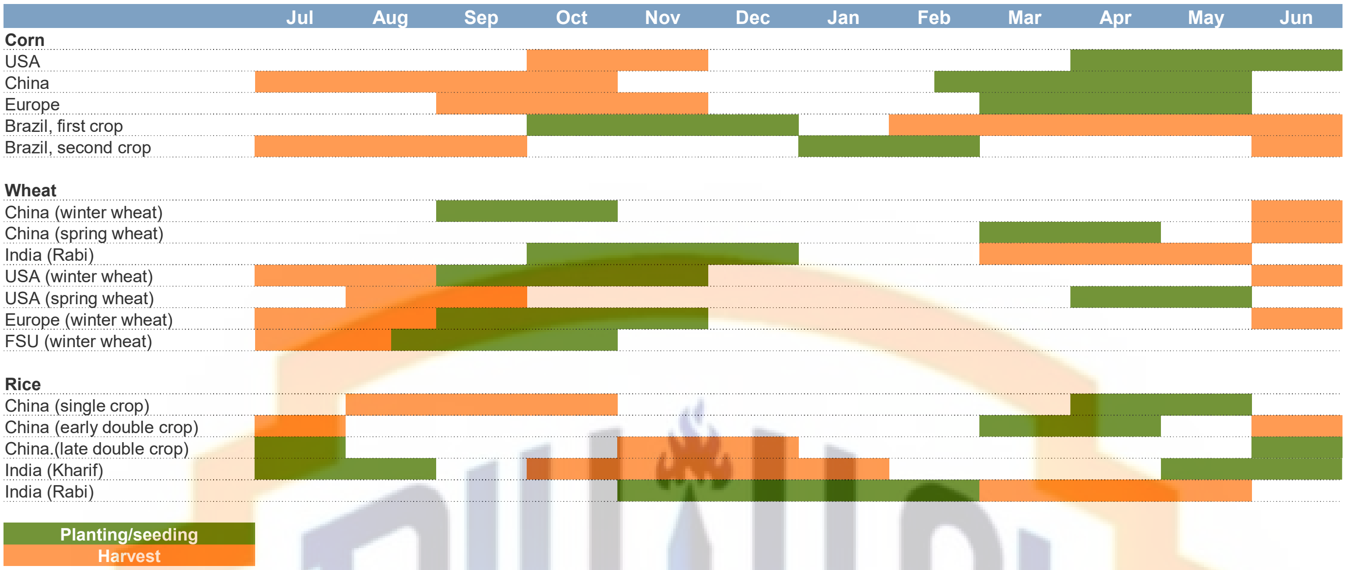


Yield differences

There are large regional yield variations. These variations reflect among other things differences in agricultural practices including fertilization intensity as shown on the previous page.

Weather and differences in soil quality mean that not all regions can achieve the same yields. However, the large differences observed clearly indicate that by using the right techniques, including a correct fertilization, yields and grain production can be increased significantly.

Seasonality in fertilizer consumption



Source: USDA

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Fertilizer is a seasonal business

The seasonality is to a large extent linked to weather. Hence, there are large regional differences in when crops are planted and harvested and therefore when fertilizer is being applied.

Fertilizer is typically applied when seeds are planted, implying that the main application on the northern Hemisphere is during the first half of the calendar year while on the southern Hemisphere it is during the second half of the calendar year. Winter wheat is an exception, while planting typically is done in the second half of the year, fertilizer application is done in the spring.

In certain countries, certain crops are harvested twice a year, this applies especially to countries on the southern hemisphere like India and Brazil.


Drivers of supply
YARA
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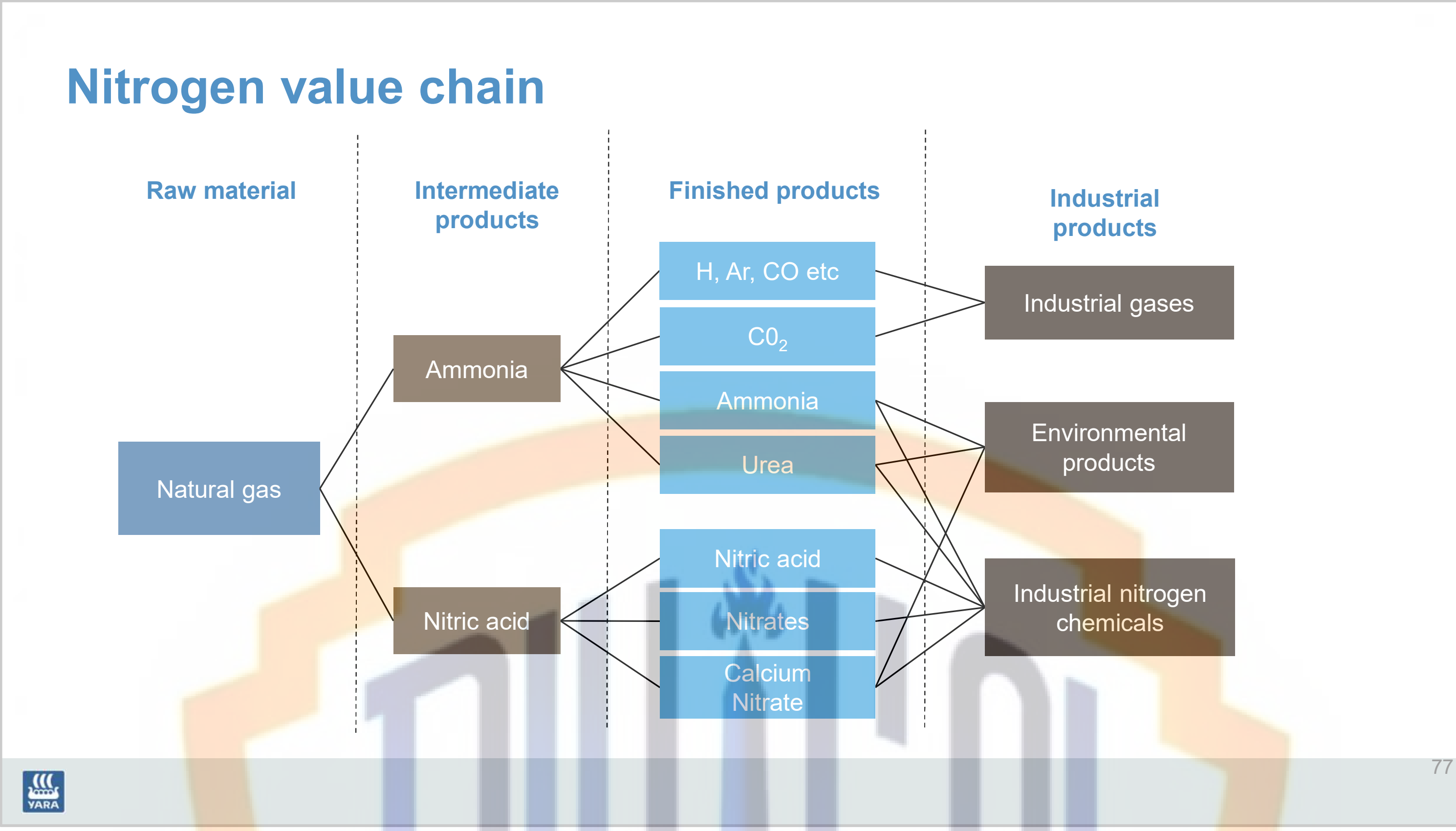
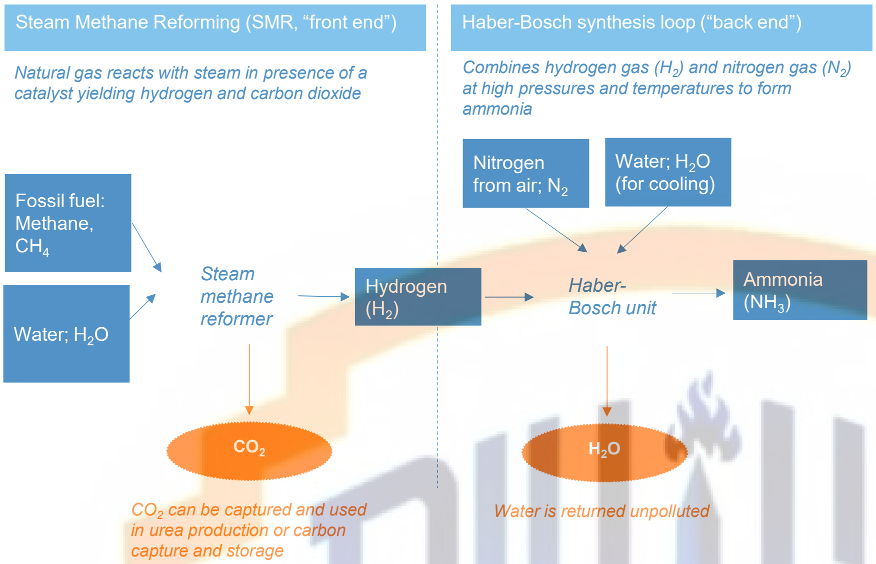


Natural gas is the major nitrogen cost driver

With a gas price of 7 USD per MMBtu, natural gas constitutes about 90% of ammonia cash production costs which is why almost all new nitrogen capacity (excluding China) is being built in low cost gas areas such as the Middle East, Northern Africa and North America.

Ammonia is an intermediate product for all nitrogen fertilizer, while nitric acid is a second intermediate product for the production of, e.g. nitrates. Finished fertilizer products are urea, nitrates (CAN, AN), NPK and others. Industrial products range from high purity carbon dioxide and basic nitrogen chemicals to industrial applications of upgraded fertilizer products.

Ammonia production process based on natural gas



- Production process requires high pressure and temperatures
- Ammonia is a hazardous gas and requires expertise for safe handling
- At -33 degrees/pressure ammonia is a liquid and can be stored and transported in tanks / specialized vessels

YARA

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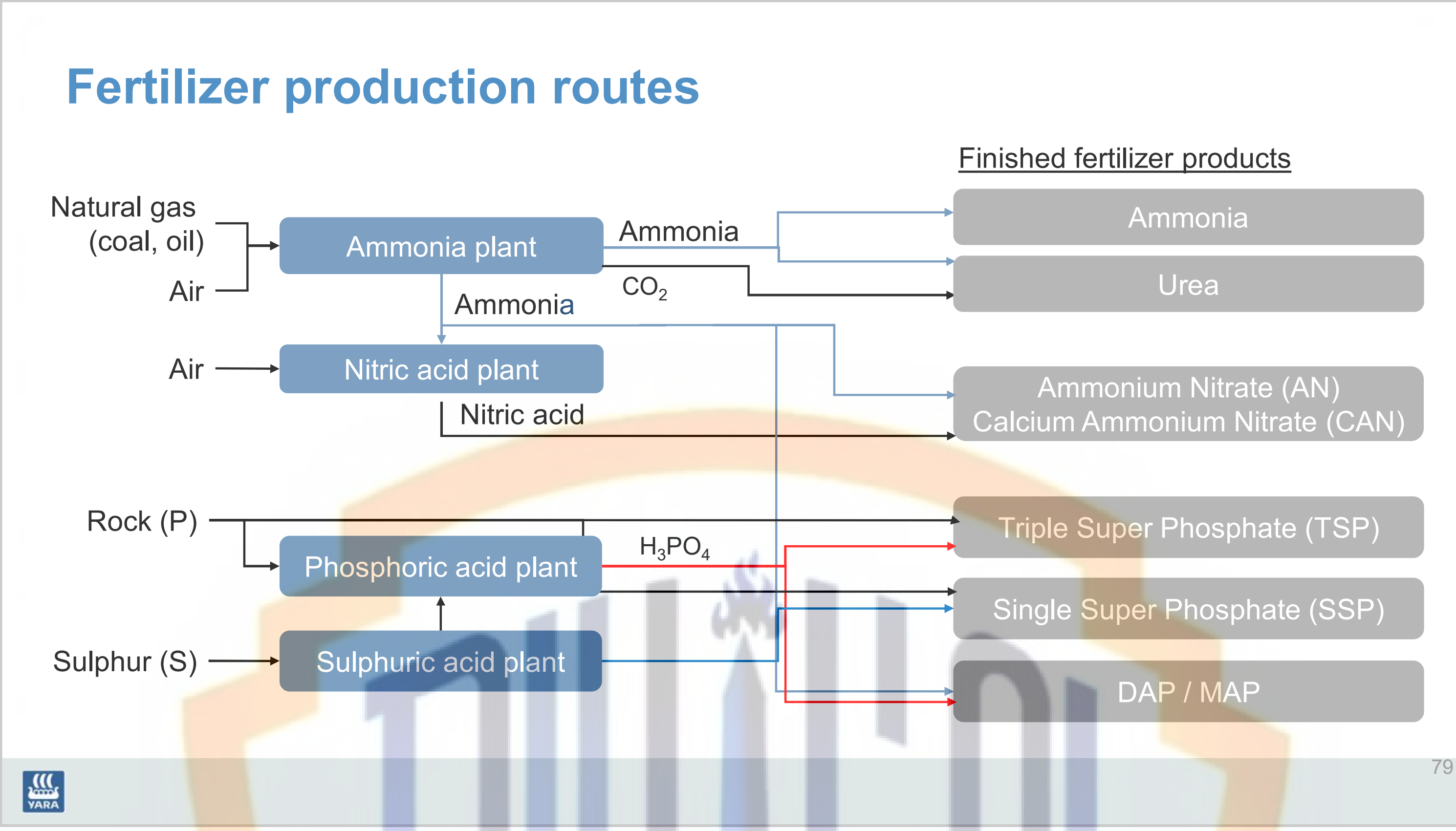
Ammonia production happens in two steps

The Steam Methane Reforming separates the hydrogen molecule in methane to produce hydrogen. In the Harber-Bosch process the hydrogen is reacted with air binding together the hydrogen and nitrogen molecule to ammonia. Water is used in the process mainly for cooling purposes and is returned unpolluted.

Ammonia is a gas but becomes liquid at -33 degrees and has a high concentration of nitrogen (82%) which makes it ideal for transportation. Ammonia is also set to play a key role in the hydrogen economy as a potential zero-carbon maritime fuel and as a hydrogen (energy) carrier.



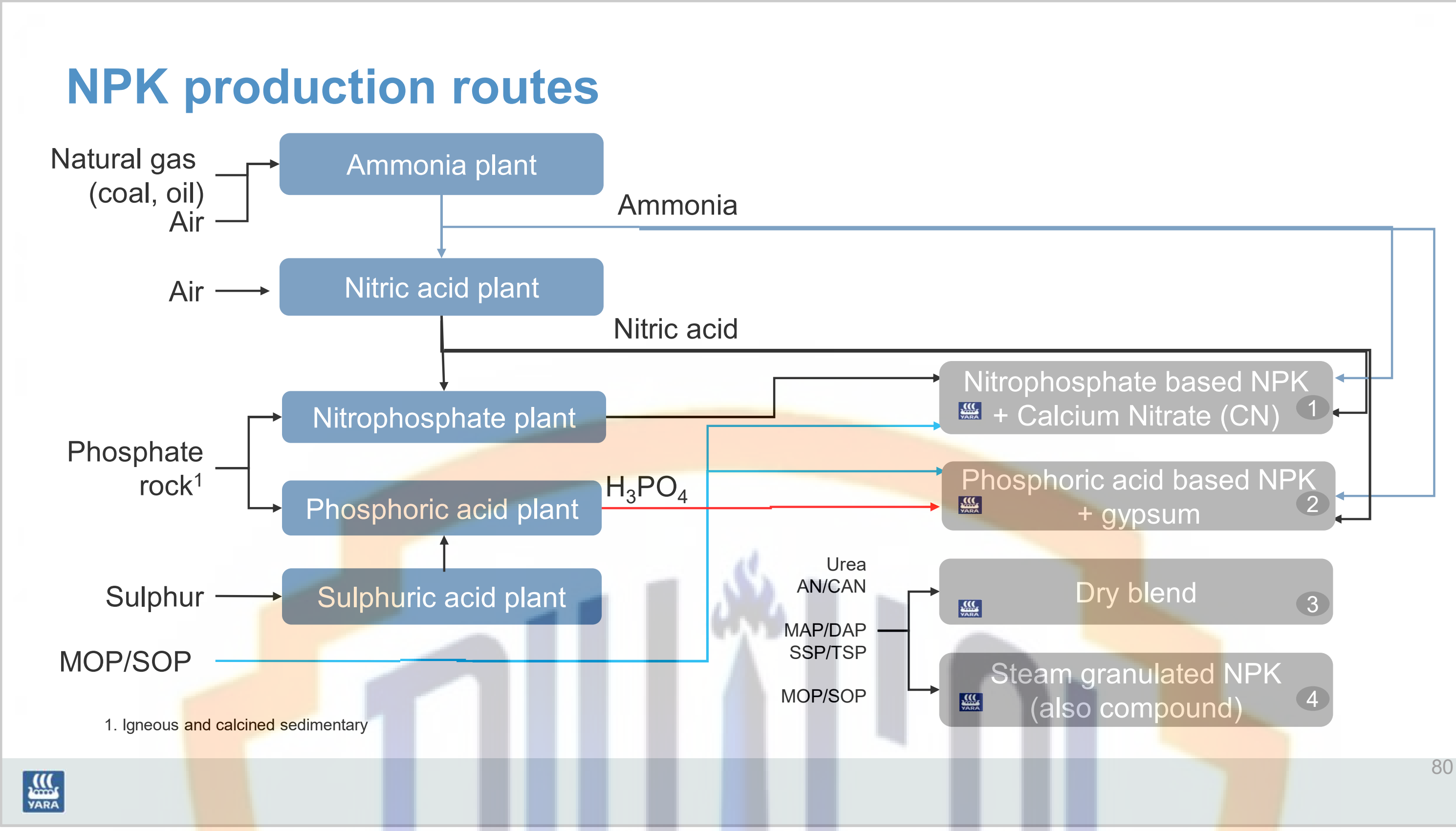
Industrial production of fertilizers involves several chemical processes

The basis for producing nitrogen fertilizers is ammonia.

Phosphorus is produced from phosphate rock by digesting the latter with a strong acid. It is then combined with ammonia to form Di-ammonium phosphate (DAP) or Mono-ammonium phosphate (MAP) through a process called ammonization.

Potassium is mined from salt deposits. Large potash deposits are found in Canada and Russia, which are the world's major producers of this nutrient.

Phosphate and potash are sold separately or combined with, e.g. nitrogen, in NPK fertilizers.
The side streams of the main production process (e.g. gases, nitrogen chemicals) can be utilized for industrial products



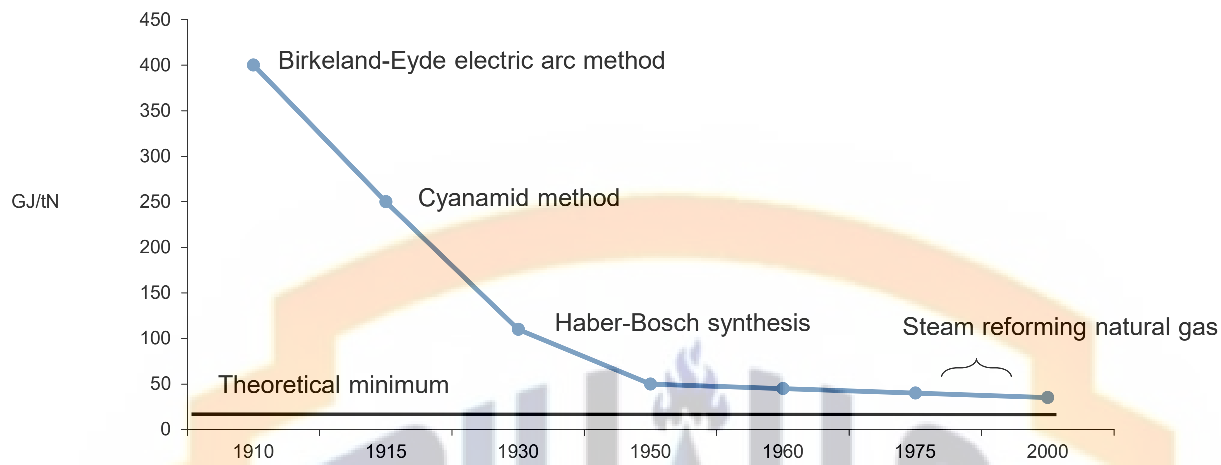
Four different ways to produce NPK fertilizers

Chemically produced NPK fertilizers are made by one of two production routes:
the nitrophosphate process or
2) the sulphuric acid (mixed-acid) process.

Phosphorus is produced from phosphate rock by digesting the latter with a strong acid (nitric acid or sulphuric acid). Potassium and other salts are added. The solution containing nitrogen in ammonia (NH_4) and nitrate (NH_3) form, phosphorus and potassium is either granulated or prilled. The result is a compound NPK where all the nutrients are included in one fertilizer particle. In addition the fertilizers may contain secondary nutrients (sulphur and magnesium) and/or micronutrients such as boron, zink and iron.

3) In a dry blended NPK, nitrogen, phosphorus and potassium raw materials in solid form are blended together in a bulk mixer.
4) The production of compound fertilizers by steam granulation, all the raw materials are in their solid (powder) form and mixed and granulated in the presence of water, steam and heat.

Nitrogen technology evolution



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Reduced energy consumption in nitrogen manufacturing

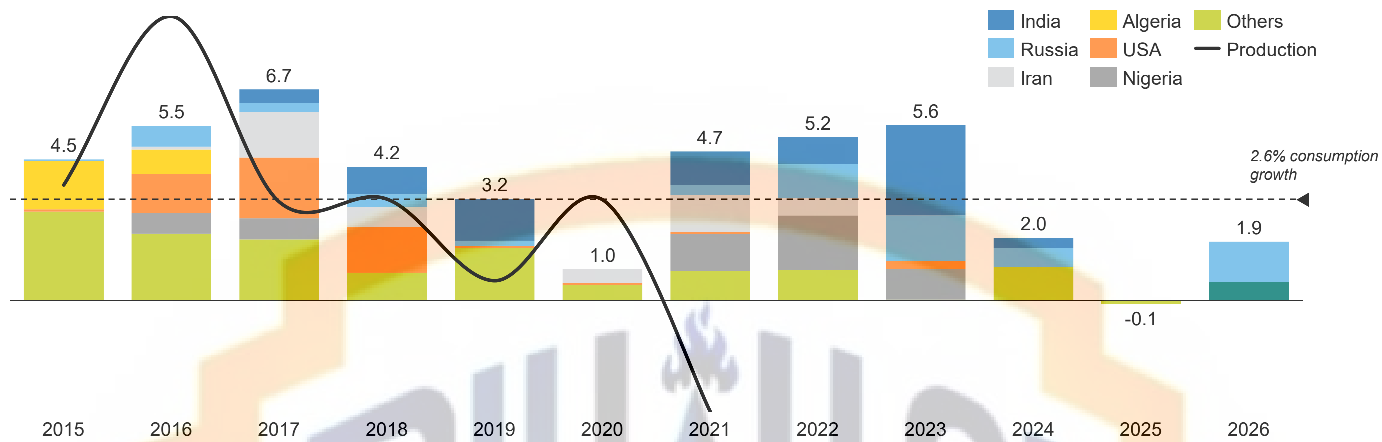
The Haber-Bosch synthesis has not been challenged for more than 80 years, but technology development in the 20th century has reduced energy consumption down towards the practical and theoretical minimum.

The energy base has changed, and technological advances have improved energy efficiency significantly. The graph illustrates that the industry is now more sensitive to energy price than developments in technology.

Most nitrogen fertilizer plants utilize natural gas. However, any type of hydrocarbon or coal can be used. In China most plants use coal. Energy consumption can vary significantly. For an efficient plant using natural gas it takes approximately 33 MMBtu of natural gas to produce one tonne of ammonia (35 GJ). This translates into 40 MMBtu per ton nitrogen (42 GJ/tN). Converting ammonia to urea requires another 3 to 4 MMBtu per tonne urea. This translates into about 48 MMBtu per ton nitrogen (51 GJ/tN)). As a rule of thumb, ammonia plants using coal require between 50 per cent and 100 per cent more energy per unit of nitrogen produced.

Peak of supply additions is now, limited new projects from 2024

Global urea capacity additions ex. China [1] (mt)



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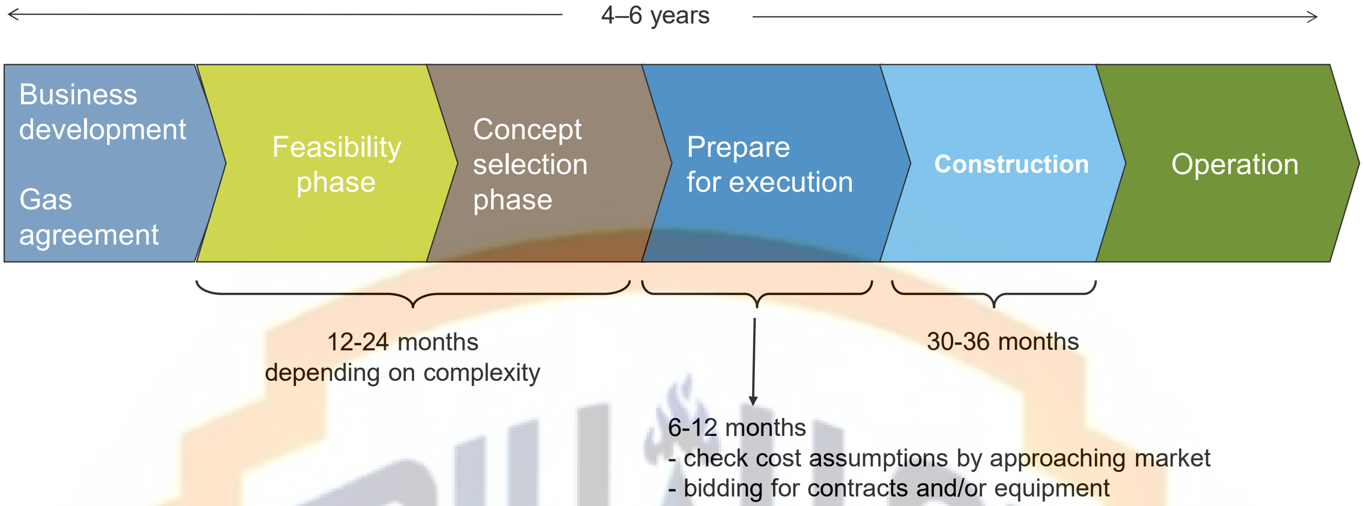
1) Urea projects assessed as "probable" by CRU
Source: CRU Aug 2022

Urea capacity growth higher than consumption growth for the last years

Excluding China, considerable growth in nitrogen capacity over the last few years. In 2021, actual production growth was significantly lower than forecasted new capacity, reflecting reliability issues in existing plants as well as delays in new additions. Earlier studies have shown that only approx. 30% of announced nitrogen projects are realized on time. The illustration does not take into consideration the need for replacement capacity. Investments in maintaining production rates at an existing plant is needed to keep it running reliably. A significant portion of global installed urea capacity is more than 60 years old.

5-year typical construction time for nitrogen fertilizer projects*



* Ammonia and urea plant example

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Long lead-time on projects

Over the last years it has typically taken at least 5-6 years from a project for a new ammonia and urea plant is initiated until the new plant is operational, even without unexpected delays.


Price relations
YARA
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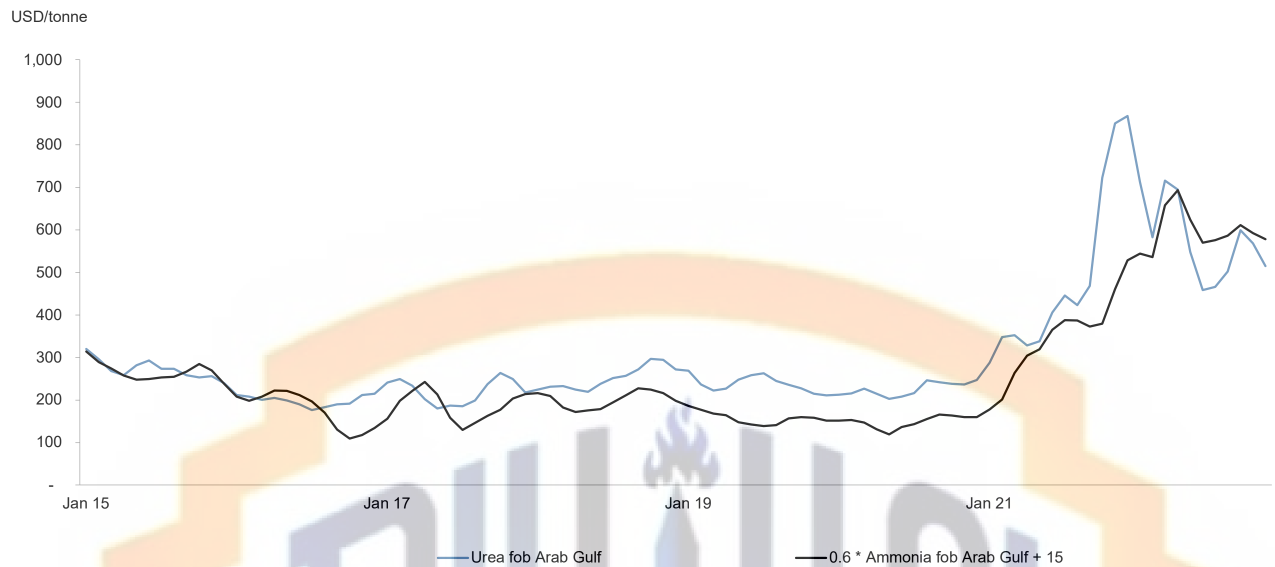
Upgrading margins from ammonia to urea



Source: Average of international publications

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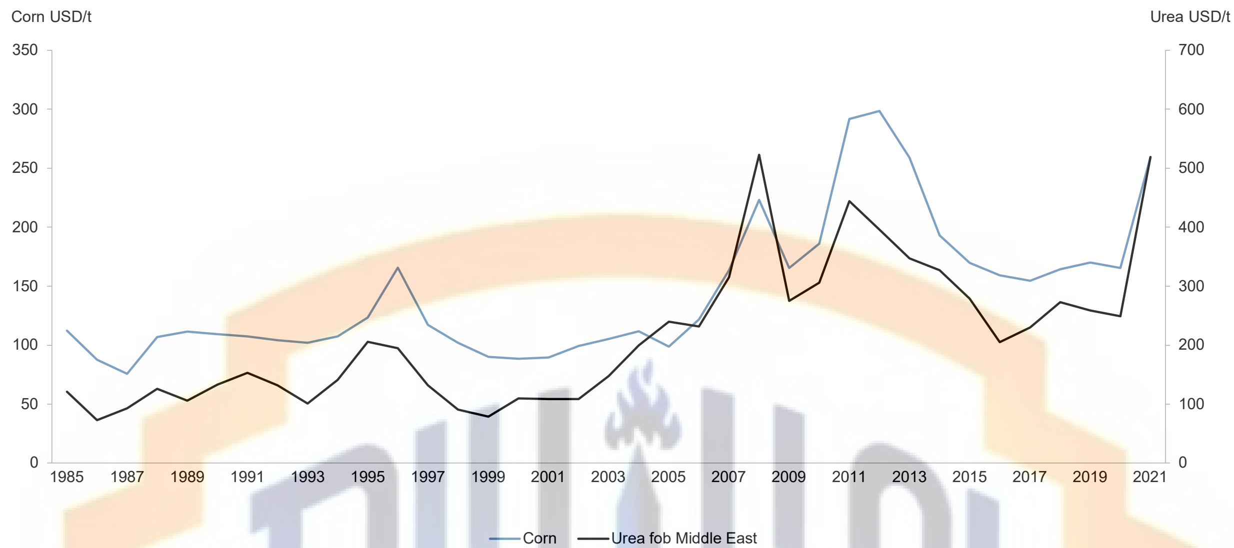
Upgrading margin for converting ammonia into urea

While energy costs for the ammonia swing producers set a price floor for ammonia, the ammonia price sets a floor for the urea price. If the urea price drops below this floor, more ammonia will be offered for sale, less urea will be sold, and the relationship will be restored.

In a tight supply/demand scenario for nitrogen where there is a demand driven urea margin, the correlation is lower. Such a scenario is often seen during periods with strong prices for agricultural soft commodities. In the period 2017-2021, the main swing producer for urea, China, had a higher cost base than the swing producer for ammonia, generating significant upgrading margins even if supply was plentiful.

In 2022 there have been periods with negative upgrading margins, driven by demand from Europe where parts of the industry has curtailed production as a result of the high gas prices. This has led some ammonia producers to increase exports of ammonia.

Grain prices important for fertilizer demand and pricing



Source: World Bank, Fertilizer publications

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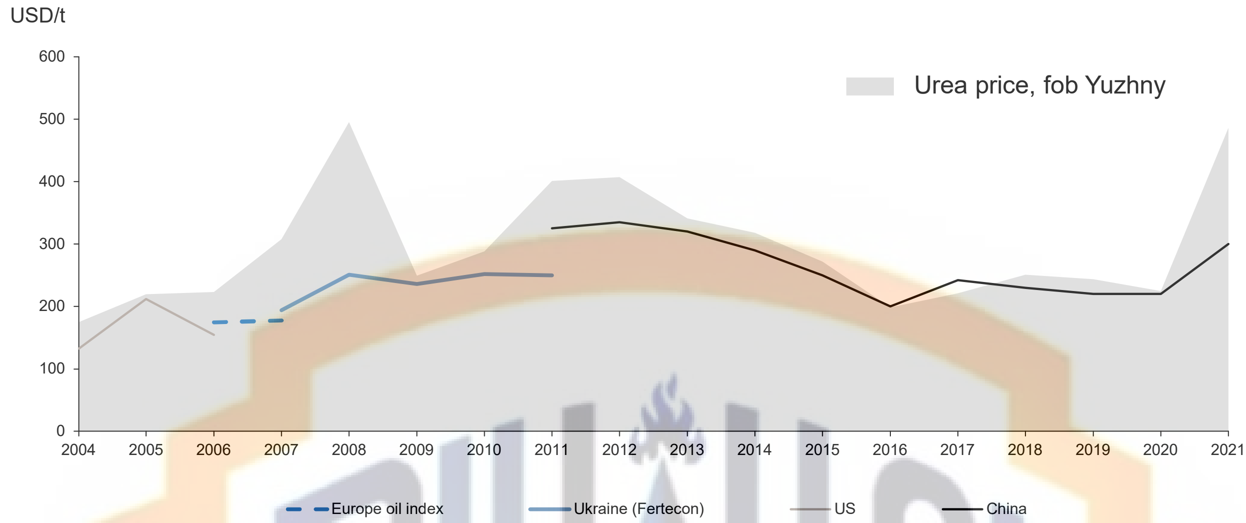
Correlation between long-term grain and fertilizer prices

Variations in grain prices (corn or wheat) explain approximately 50% of the variations in the urea price, making grain prices one of the most important factors driving fertilizer prices.

The urea market has been increasingly demand-driven since 2020



Source: Fertecon (Ukraine), Yara estimates. The cost lines are drawn for illustration purposes only and not intended as exact cost estimates.

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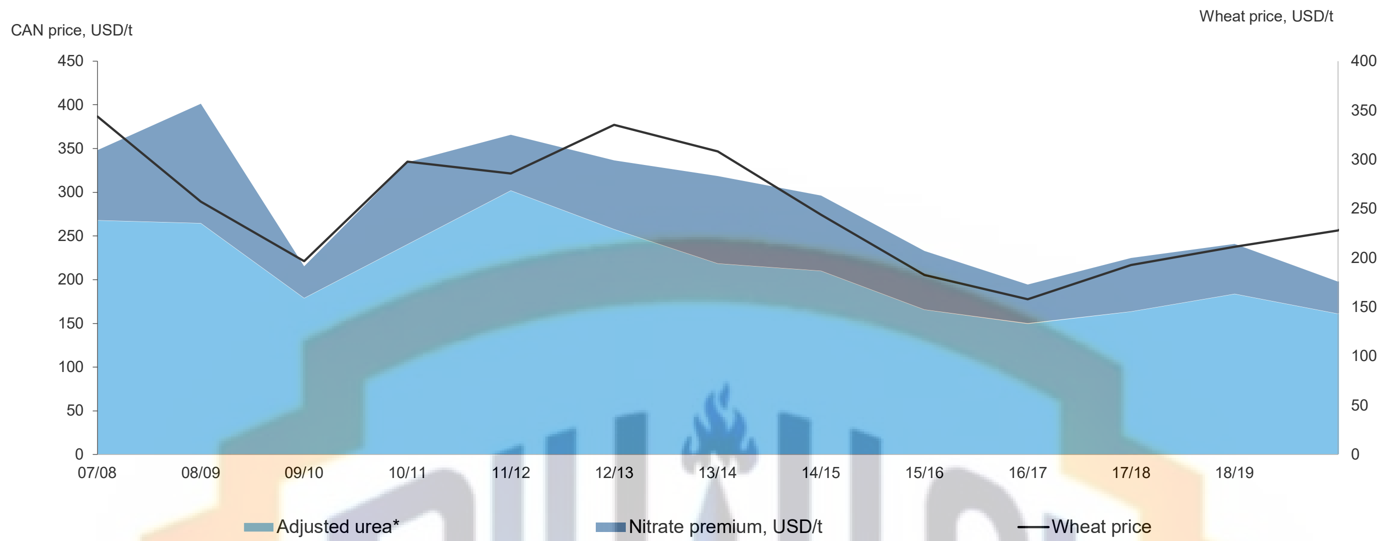
In a demand driven market margins can be significantly above the cost floor of the marginal producer

The location of swing urea production has varied over the past decade, from the US Gulf, via Ukraine and to China. However, urea prices have historically only been supply-driven for shorter periods at a time, with the average demand-driven margin for the period 2004 – 2013 approximately USD 70 per ton. From 2014-2021 the market was been supply-driven, with China as the swing producer. In 2017, global prices at times dropped below the Chinese floor, as required volumes from China dropped substantially. Since 2021 high gas prices in Europe has lead to significant curtailments across producers as the global urea price has been below the production cost, at the same time that China has put in place export restrictions. This has resulted in a supply curve which is vertical around the current market price, resulting in significant urea price volatility.

Nitrate premium is mainly a function of crop prices



* Urea fob Black sea adjusted for import costs into Europe and nitrogen content similar to CAN

Source: World Bank, Fertilizer publications

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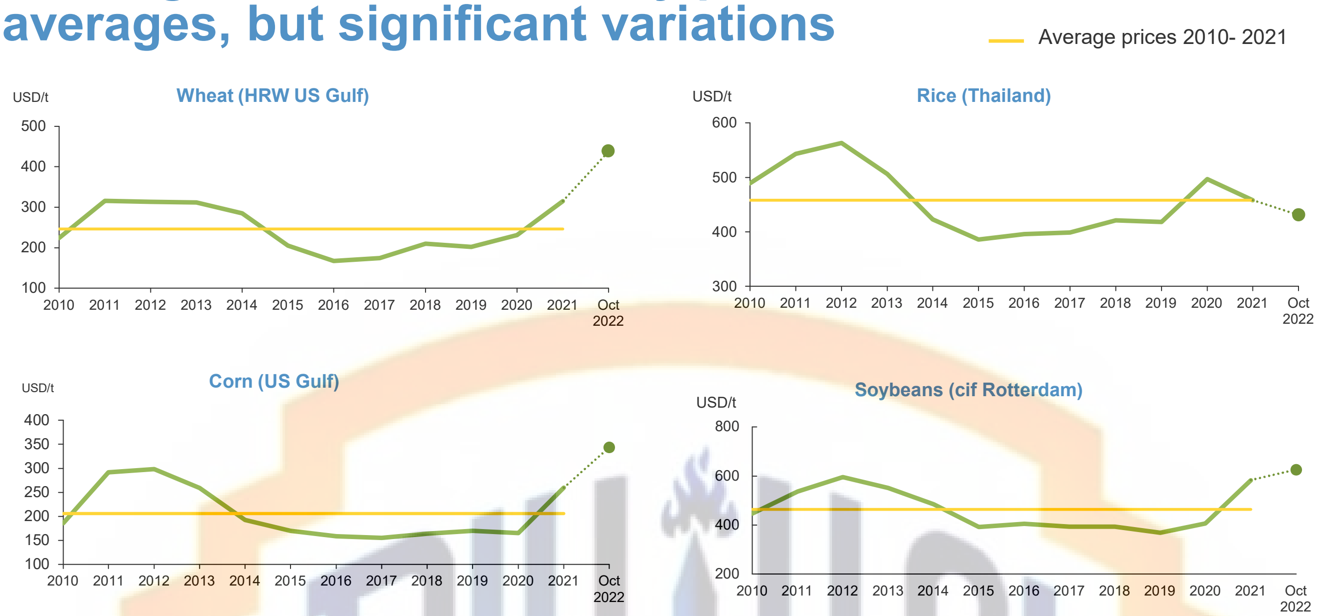
Urea prices determine the price range for nitrates

There is a strong correlation between urea and nitrate prices, as they to some extent are substitutes. For agronomic reasons linked to the effectiveness of the nitrogen form, farmers are willing to pay a higher price per unit nitrogen from nitrates than from urea. The correlation is stronger in the medium to long term than within a season. However, crop prices are also an important factor that impacts the nitrate price and the nitrate premium. The higher the crop value is, the more willing the farmer is to pay a premium for a product that gives a higher yield and quality.

Main agricultural commodity prices above historical averages, but significant variations



Source: World Bank

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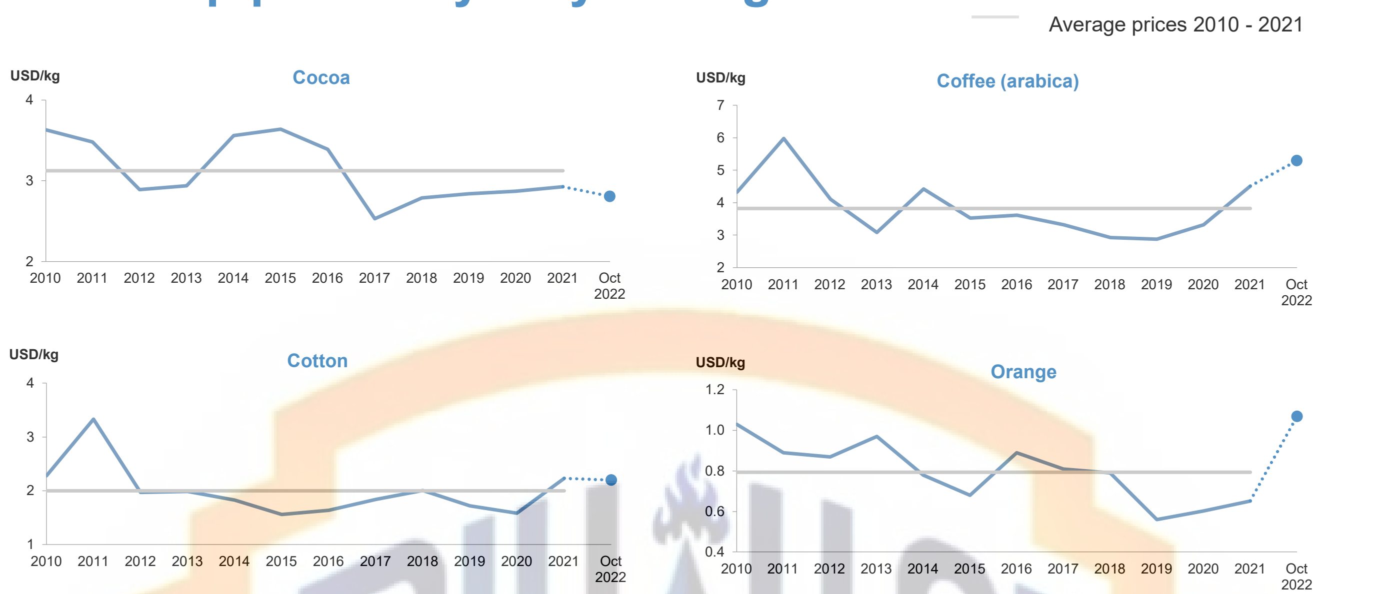
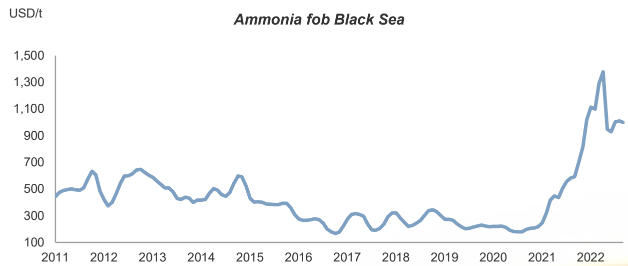
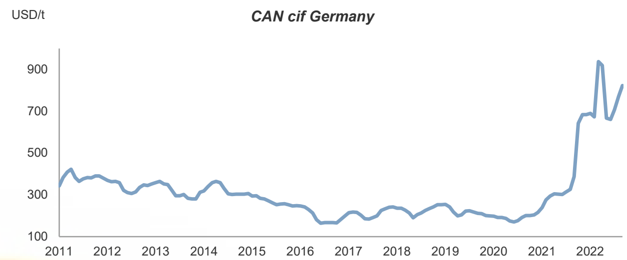
Cash crop prices – yearly averages

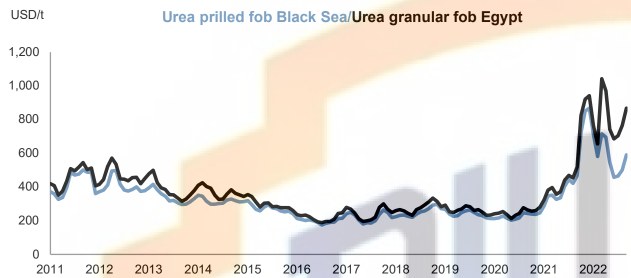


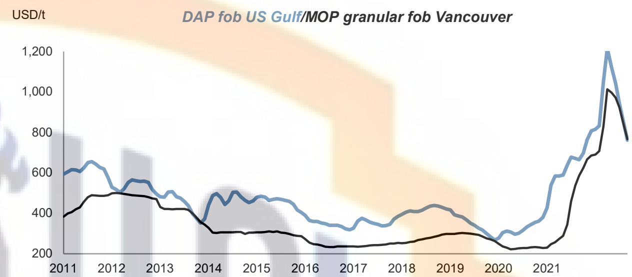
Source: World Bank

10-year fertilizer prices – monthly averages









Source: Average of international publications

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Production economics
YARA
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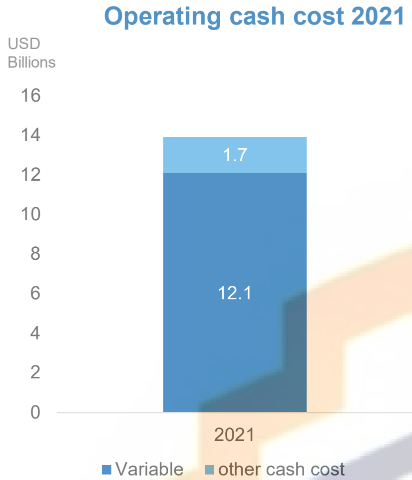
Yara’s operating cash costs are mainly variable



Other cash cost (12%)

Variable costs (88%)

- Dry raw materials
- Energy
- Freight
- 3rd party finished fertilizer

- Temporary plant closures can be carried out with limited stop/start costs
- Example for ammonia/urea plants:
  - Typically, half a week to stop and up to a week to start
  - Cost of stopping is 2 days energy consumption
  - Cost of starting is 3 days energy consumption

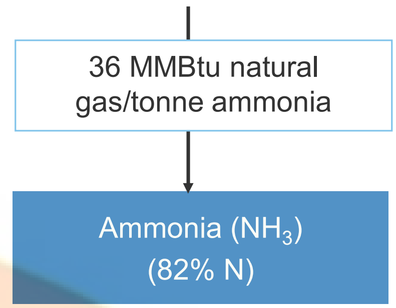
Production economics

Approximately 88% of Yara’s operational cash costs are raw materials, energy and freight. A major part of these purchases can be terminated on short notice, reducing the financial consequences of delivery slow-downs.

Yara’s plants can be stopped at short notice and at low cost as response to decline in deliveries or to take advantage of cheaper imported ammonia for non-integrated sites (approx. 70% of Yara’s production capacity in Europe). In times of high gas prices the option to switch to imported ammonia gives a valuable flexibility.

Ammonia cash cost build-up – example

	Gas price:	7	USD/MMBtu
x	Gas consumption:	36	MMBtu/mt NH_3
=	Gas cost:	252	USD/mt NH_3
+	Other prod. cost*:	39	USD/mt NH_3
=	Total cash cost	291	USD/mt NH_3



Typical natural gas consumption for ammonia production

* Source: other production cost is based on Fertecon (2022) for 2021, estimates for US Gulf

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Natural gas costs - the most important cost component

With a natural gas price of USD 7/MMBtu gas cost represents around 87% of the ammonia production cash costs in this example. One dollar increase in gas cost gives USD 36 higher gas costs.

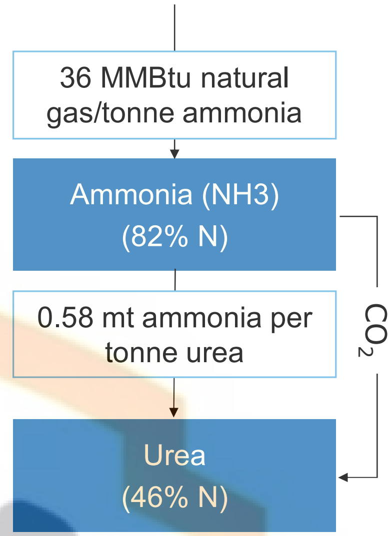
Most of the “other production costs” are fixed costs and therefore subject to scale advantages.

A new highly efficient plant may use natural gas in the low thirties range to produce one tonne of ammonia; the corresponding figure for old, poorly maintained plants will be in the mid-forties.

The cost estimates in this slide is intended as an illustration. Actual cost will vary between plants and location.

Urea cash cost build-up – example

	Ammonia cost:	291	USD/mt NH_3
x	Ammonia use:	0.58	NH_3/mt urea
=	Ammonia cost	169	USD/mt urea
+	Process gas cost*	36	USD/mt urea
+	Other prod. cost**:	46	USD/mt urea
=	Total cash cost	251	USD/mt urea



* Process gas cost is linked to natural gas price, 5.2 MMBtu gas per 1 mt urea

** Excl. freight & loading cost (~8 USD/t)

* Source: other production cost is based on Fertecon (2022) for 2021, estimates for US Gulf

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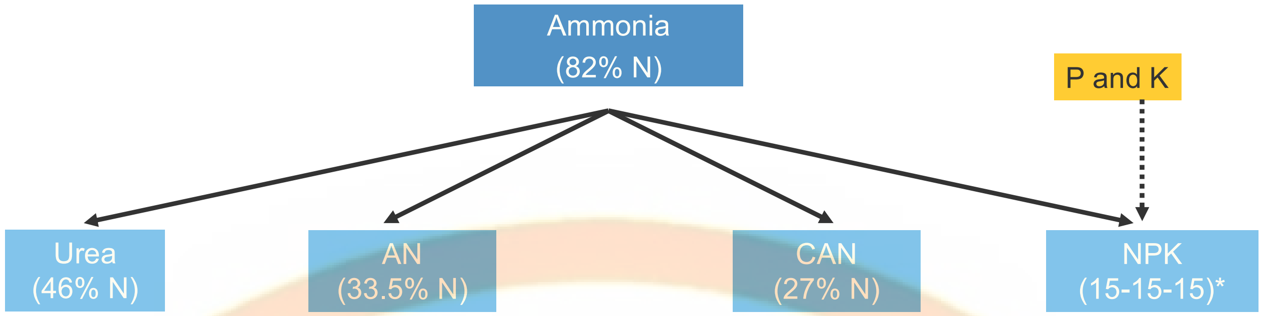
Ammonia is the main input for urea production

Typically, it takes 0.58 tonne ammonia for each tonne urea. If we add the gas cost in ammonia (0.58 x 36 MMBtu x USD 7/MMBtu = USD 146) and the additional process gas costs needed for the production of urea (5.2 MMBtu x USD 7/MMBtu = USD 36), natural gas represents around 72% of the total production cash cost.

The cost estimates in this slide is intended as an illustration. Actual cost will vary between plants and location.

Theoretical consumption factors



- Price comparisons should always be based on nutrient tons, not product tons

* There are many NPK formulas; 15-15-15 is one example

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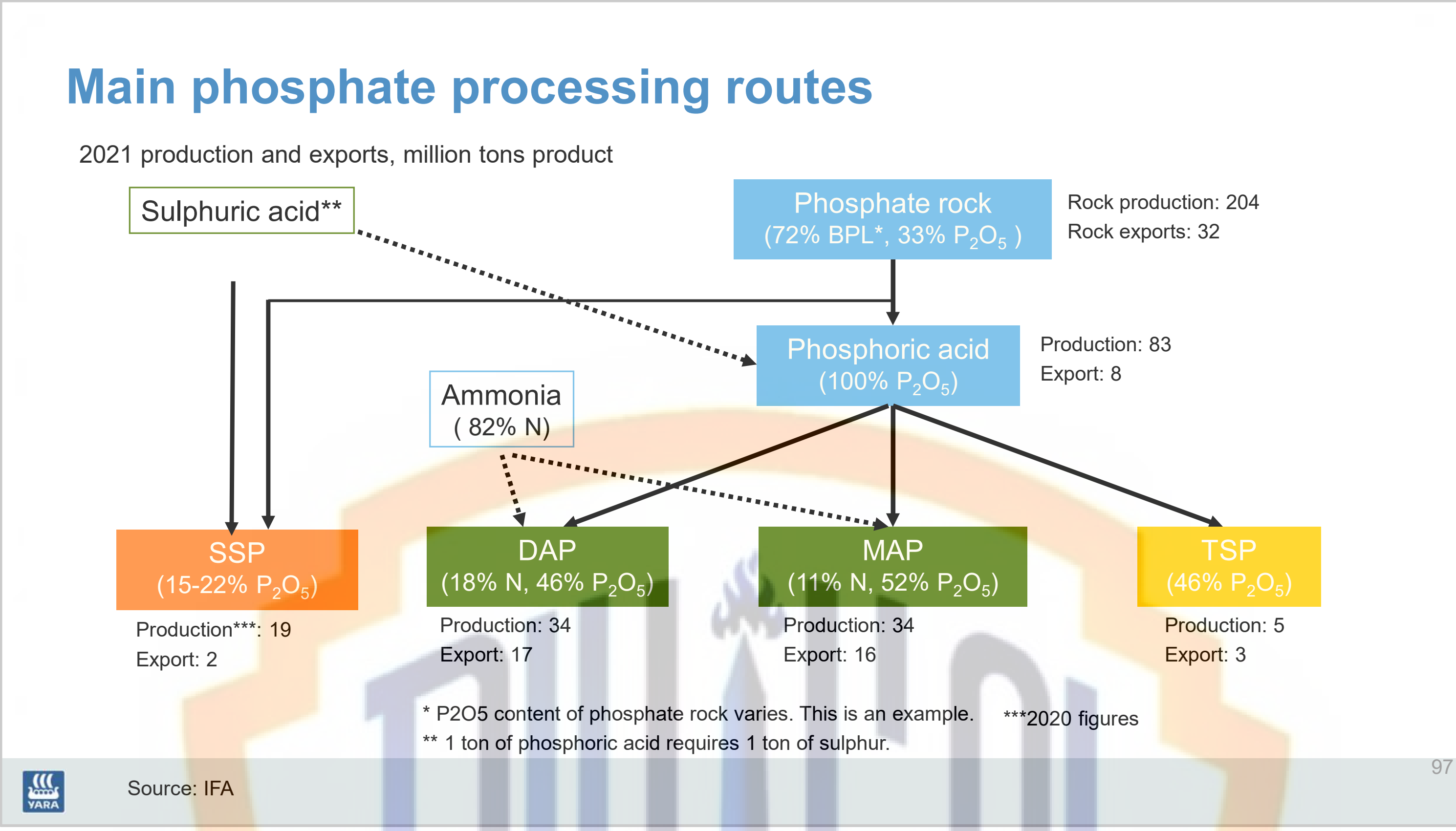
Consumption factors to compare price movements

As shown in the costing example for urea, the real ammonia consumption factor is above the theoretical consumption factor, which is based on nitrogen (N) content. The difference varies between plants according to their energy efficiency. Using the theoretical consumption factors is easier when making calculations. If the N content for a product is known (46% N in urea), the ammonia consumption factor can easily be calculated by dividing the figure with the N content in ammonia (0.46/0.82 = 0.56).

Based on this illustration, it is possible to follow relative variation in the various nitrogen prices. As an example, if ammonia becomes USD10/mt more expensive, the production cost of urea increases by 10 * 0.56 (0.46/0.82) = 5.6USD/mt. Similarly, if the urea price increases by USD10/mt, a price increase of 10 * (0.27/0.46) = USD5.9/mt of CAN would keep the relative pricing at the same level.

CAN production also include a cost for calcium, sourced as dolomite (calcium magnesium carbonate) or limestone (calcium carbonate). However this cost is small and relatively stable compared to nitrogen/ammonia. NPK production require phosphate and potash which account for a significant portion of total cost together with nitrogen/ammonia. The cost depend on the nutrient content of the NPK and on the production process.



Phosphate processing routes

The three main phosphate finished fertilizer products are diammonium phosphate (DAP), monammonium phosphate (MAP) and triple superphosphate (TSP), all of which are based on phosphate rock processed via intermediate production of phosphoric acid. Single superphosphate (SSP) is produced by the reaction of sulphuric acid and phosphate rock. It is an important fertilizer product, despite its relatively low P_2O_5 content (ranging between 15 and 22% P_2O_5) due to its high water-solubility and its effectiveness as a source of secondary nutrients: sulphur (10-12% S in the readily available form of sulphate) and calcium.


Industrial applications
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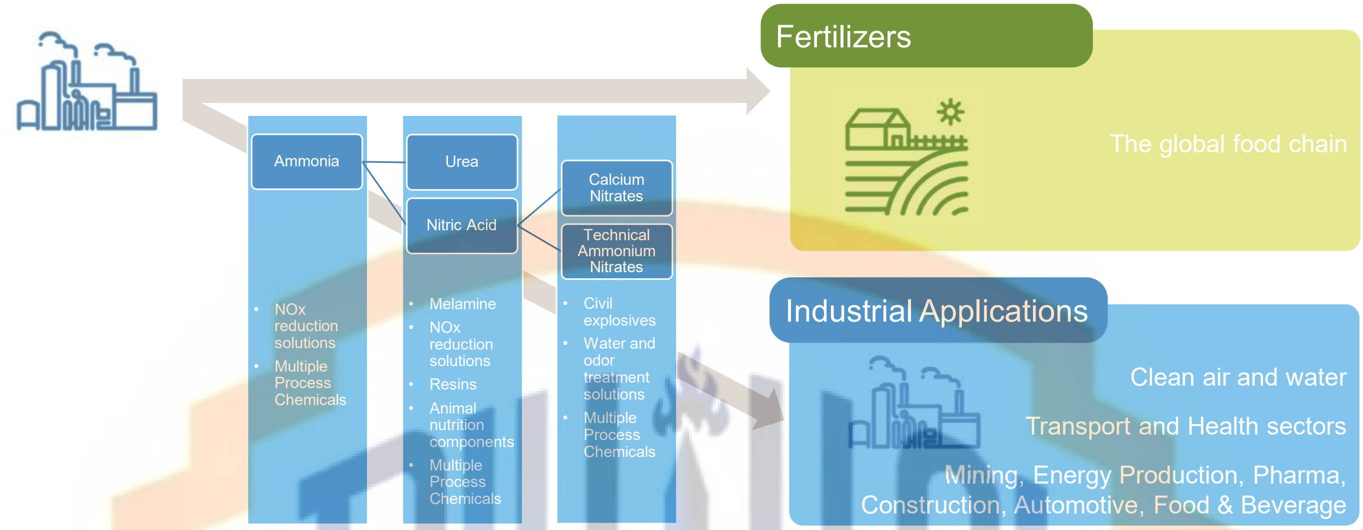
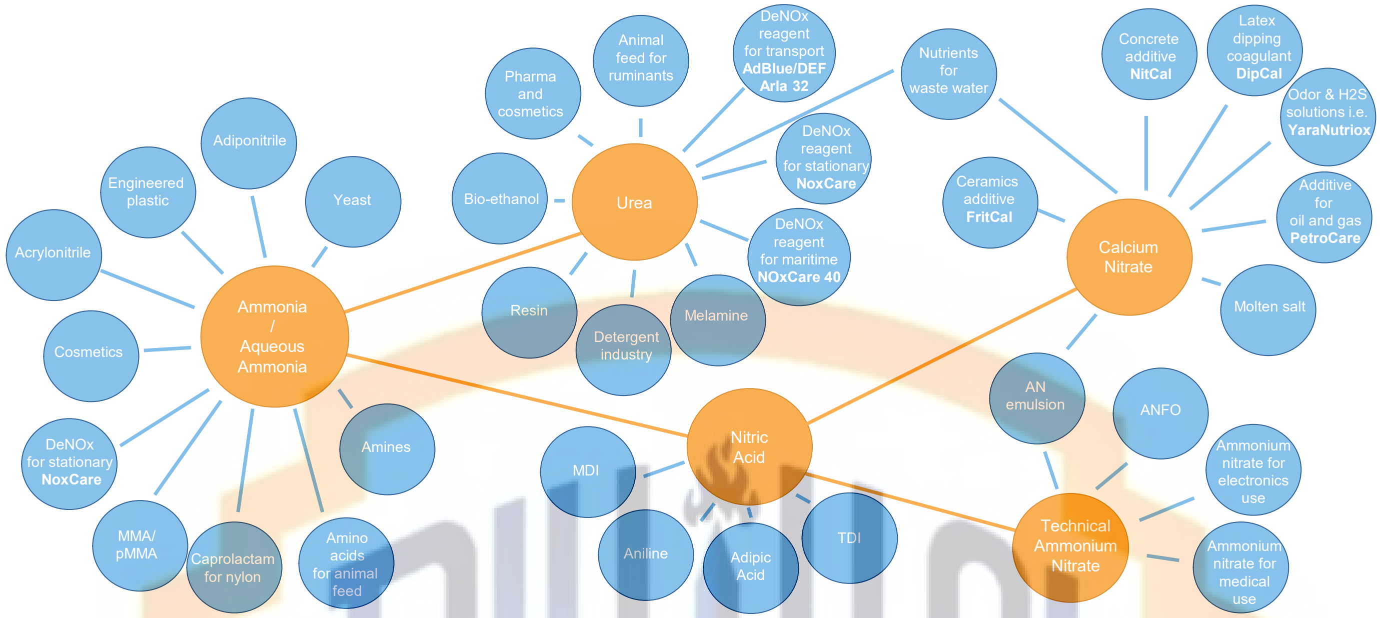
Nitrogen is key for food production and indispensable in numerous industrial applications in addition to fertilizer



Nitrogen has many industrial applications



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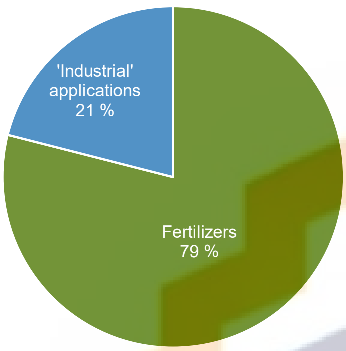
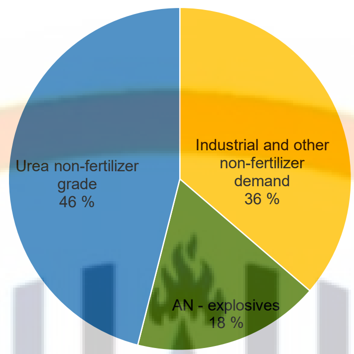
Industrial use accounts for ~21% of global nitrogen consumption

Global ammonia consumption



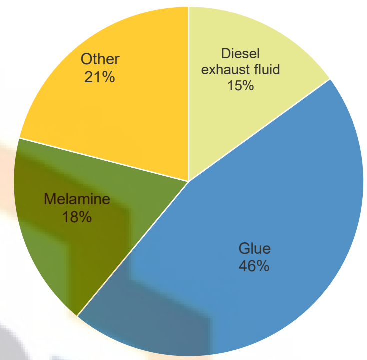
~ 191 mt ammonia

Industrial ammonia consumption



~40 mt ammonia

Technical grade urea consumption



~31 mt urea

* Sources: IHS Markit, Argus, 2021 estimates

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Industrial use accounts for appx 21% of global nitrogen consumption with multiple products and applications

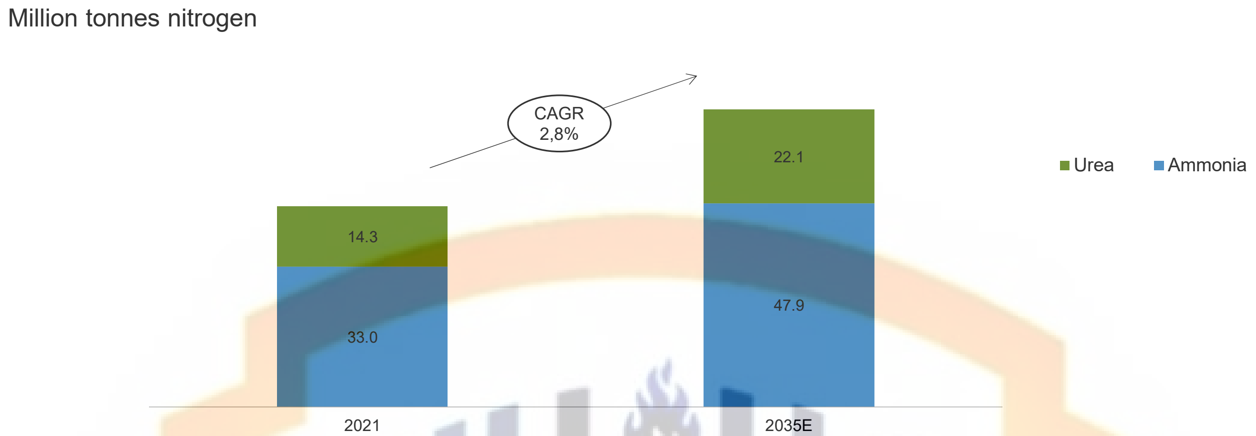
Industrial demand has a lower share (appx 17%) of total urea demand than for nitrogen in total (appx 21%).

Industrial use of urea covers roughly 46% of total industrial nitrogen demand. Around 46%of urea consumption in non-fertilizer application is for the production of urea-formaldehyde resins which are used as binders (glue) in various end uses.

Explosives/Technical ammonium nitrate (TAN) is the most global of all Industrial business units, where Yara already is the world's largest independent supplier of technical nitrates to the civil explosives industry. Asia and Australia are expected to drive growth in this business, with Europe and the US being more mature markets.

Diesel exhaust fluid is a fast-growing segment, as growth is driven by legislation and by the need to treat NOx emissions from heavy-duty trucks and in the power sector.

Global demand development for industrial nitrogen applications is strong



Demand growth for Industrial applications is estimated to ~2.8 % annually

Source: Fertecon

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The pace of growth in nitrogen chemicals for Industrial applications is higher than for N-fertilizer growth

Reagents, technology and services to improve air quality

Nitrogen oxides (NOx) are a major air quality issue causing serious problems mostly in urban centers related to both the environment and human health. Legislation around the world drives the business growth.

- **Air 1™   AdBlue/DEF** is a generic name for urea-based solution (32.5% liquid urea) Air 1 is Yaras brand name for AdBlue that is used with the selective catalytic reduction system (SCR) to reduce emissions of oxides of nitrogen from the exhaust of diesel vehicles such as trucks, passenger cars and off-road vehicles
- **NOxcare™** As a world leader in reagents like urea and ammonia in combination with our experience in abatement systems like SNCR and SCR technology Yara offers its clients one of the most comprehensive and effective solutions to reduce NO_x emissions in industrial power plants and utilities.

Effective abatement of nitrogen oxides

NOx emissions produce smog which is highly toxic to humans. Most national governments have given commitments, and are implementing legislation to reduce NOx emissions and improve the air quality

Yara was at the forefront of product development when we created a new product for an application linked to NOx abatement. This product is now called AdBlue, which is utilized with SCR technology for NOx abatement in heavy-duty trucks, passenger cars and non-road vehicles such as tractors, construction and mining vehicles and trains. Yara is the world's largest producer of AdBlue, and its Air1 brand is the only global brand.

Similar technology, based on ammonia and/or urea, is used to reduce emissions of industrial installations such as power plants, cement factories, waste incinerators etc.

Europe is expected to progressively apply more stringent NOx emission limits. Also in the marine segment legislations on NOx and SOx are being implemented.

Calcium nitrate applications in wastewater treatment, concrete manufacturing, oil fields and latex industries

- **Nutriox™** provides H2S prevention for Corrosion, Odor and Toxicity control of municipal and industrial wastewater systems
- **Nitcal™** is a multifunctional concrete admixture serving concrete admixtures companies around the world
- **PetroCare™** prevents well souring and supports drilling in oilfields around the world, for both the oil majors and the service companies that serve them
- **Dipcal™** is the premier dipping coagulant for the latex industry
- Other important applications are in the ceramics, bio-gas and solar CSP industries

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H2S abatement for waste water

The presence of hydrogen sulphide (H_2S) in waste water and sludge is defined as a septic condition. By preventing septic conditions from arising, negative effects like odors, health hazards, corrosion and reduced efficiency of the treatment plant, can be eliminated or reduced.

Yara's calcium nitrate based septicity control process is a natural biological method of preventing septicity and removing H_2S by controlled dosage of nitrate. It can be used both for municipal sewer systems and industrial wastewater and sludge, and is non-toxic, non-corrosive, pH-neutral and safe-to-handle.

Nitrate-based products are also used to reduce H_2S toxic emissions in oil fields and pipelines.

Technical Nitrates for Civil Explosives

- Various grades of Ammonium Nitrate and Calcium Nitrate for use in the civil explosives and mining industries
- Largest customer segments are civil explosives companies, open-pit coal and iron mining sectors



Technical AN: the main raw material for civil explosives

Technical ammonium nitrate is the main raw material for ANFO (Ammonium Nitrate Fuel Oil) which is the most used and most economical civil explosive currently on the market. The main civil explosive market segments are mining and infrastructure development.

ANFO has grown to be the most widely used industrial blasting agent in the world, due to its excellent manufacturing, handling and storage properties, low cost per energy unit, high safety levels and outstanding performance.

Calcium nitrate is used as a secondary nitrate in emulsion explosives. It extends the shelf life of the emulsion, increases the solubility of the ammonium nitrate and increases the total energy content of the emulsion.

Animal Feed industry with several nutritional products based on core chemicals

- **Feed Phosphates**

  Macro-minerals such as phosphorus and calcium are essential elements to sustain healthy and productive animal growth

- **Feed Acidifiers**

  Antimicrobial effect and lowering pH, replace AGP (antibiotic growth promoter) and effective against salmonella and moulds

- **Feed Urea**

  Source of NPN (non-protein nitrogen) used by rumen micro-organisms forming proteins, replacing part of vegetable protein

- **Ammonia for fermentation**

  Amino acids like lysine, methionine, and threonine are essential to add to lower the total use of protein

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Animal Feed industry with several nutritional products based on core chemicals


Market Data Sources
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Sources of market information

Fertilizer market information

- Argus www.argusmedia.com
- IHS Markit/S&P Global (Fertecon) www.spglobal.com/commodityinsights/en/ci/products/agribusiness-fertilizers.html
- Fertilizer Week www.crugroup.com
- Profercy www.profercy.com
- ICIS/The Market www.icis.com
- Green Markets (USA) www.fertilizerpricing.com
- China Fertilizer Market Week www.fertmarket.com

Fertilizer industry associations

- International Fertilizer Industry Association (IFA) www.fertilizer.org
- Fertilizers Europe (EFMA) www.fertilizerseurope.com

Food and grain market information

- Food and Agriculture Organization of the UN www.fao.org
- International Grain Council www.igc.org.uk
- Chicago Board of Trade www.cmegroup.com
- World Bank commodity prices www.worldbank.org
- US Department of Agriculture (USDA) www.usda.gov


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Knowledge grows