Carbon leakage in the nitrogen fertilizer industry

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Executive summary

One of the founding principles in EU climate policy – including the EU Emissions Trading System (ETS) – is the recognition that asymmetric climate ambitions between EU and third countries may put severe strain on the competitiveness of EU industries exposed to foreign competition.[1] The replacement of European-based production and emissions with production and emissions abroad is known as *carbon leakage*. In the ETS, this is addressed through the administration of free ETS allowances, distributed to industries deemed at risk of carbon leakage.

From 2013, the EU-wide cap on ETS emissions is decreasing each year. Both in the current system and with the 2015 proposal of a revised ETS directive,[2] the allowances available for leakage compensation are reduced in line with the reduced overall cap. Reducing leakage compensation at the same time as the ETS becomes more effective through higher allowances prices, and no outlook for equally ambitious international commitment, is a critical cocktail. It begs the important question:

How should anti-carbon leakage measures be designed in order to ensure both an effective and efficient ETS system?

In the European Commissions' Impact Assessment on the revised ETS directive[3] it argues that a new leakage compensation scheme could be significantly more targeted. One reason is the fact that 97 per cent of total industrial emissions under ETS are currently considered at risk of leakage. By differentiating the risk classification of industries currently deemed at risk of carbon leakage into groups from low to high risk, compensation would be more effectively distributed to the sectors needing it the most, it is argued.

However, in its final proposal,[4] the Commission proposes to maintain the current simplistic classification where an industry is either at risk or not at risk. This implies that the envisaged reduction in free allowances over time – both through the cap reduction and through the cross-sectoral correction factor – will be applied equally to all industries on the leakage list. Even though the Impact Assessment analysis speaks in favour of differentiating sectors at risk of leakage, this feature unfortunately falls into the same policy option-bundle as seemingly less attractive policy elements, consequently concealing the inherent attractiveness of the option.[5]

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[1] Leakage provisions are also found in the Energy Tax Directive and in State aid guidelines on compensation for indirect ETS costs through electricity prices
[2] European Commission (2015b)
[3] European Commission (2015a)
[4] European Commission (2015b)
[5] European Commission (2015a), page 52 and 53. The overall assessment of the policy package 'Targeted' is very positive on all criteria except 'incentives to innovate preserved' and 'increased administrative complexity' which is driven by including 'regular updates of benchmarks' in the same policy package.

We argue that the current approach clearly favours the industries on the leakage list facing the lowest risk at the expense of the industries at the highest risk. This risks undermining the effectiveness of EU climate policy by 'under-protecting' high risk industries leading to relocation of production and carbon leakage, and 'over-protecting' low-risk industries leading to windfall profits. Hence, in line with the Commission's Impact Assessment, we suggest that free allowance allocation should depend on a more differentiated risk categorisation.

Undoubtedly, the fertilizer industry is one of the industries at the highest risk of leakage – if not the industry with the highest risk. This is widely recognised, e.g. in the same Impact Assessment where it classifies nitrogen fertilizers in the 'very high risk' group consisting of no more than 4-5 processes out of the more than 170 processes currently treated as being at risk of carbon leakage.[6] This is in line with previous carbon leakage evaluations, where nitrogen fertilizers are found to be the only process that both have a *very high* energy intensity (more than 30 per cent of value added) and a *high* trade intensity (above 10 per cent), thereby simultaneously fulfilling both the combined criteria of high energy and trade intensity *and* the criteria of very high energy intensity.

In this report, we confirm this picture of an industry at high risk of leakage. This is not just based on the 'traditional' leakage criteria of high emission intensity and high trade intensity, but also considering the industry's so-called ability to pass through cost increases to consumers. In the report we demonstrate the following:

The first step in a carbon leakage assessment is whether production costs are significantly affected by carbon prices such as the price of ETS allowances.[7] Based on model simulations of the business outlook for different types of fertilizer plants, we find that increases in ETS prices will substantially increase the production cost of European fertilizer production. Indeed, an ETS price of EUR 30 will increase average production costs for the two main nitrogen fertilizers Urea and AN production by 17-18 per cent, and an additional 12 per cent if the ETS price reaches EUR 50, cf. the Figure below. This estimate might even be on the low side, as it does not include the ETS impact on electricity prices nor the ETS costs for N_2O emissions for AN.[8]

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[6] European Commission (2015a), page 173.
[7] When we use the term 'carbon price' in this report, it will refer to a price on greenhouse gas emissions more broadly.
[8] Most fertilizer producers use a small amount of electricity in production.

Figure ETS price will significantly raise cost of production

EUR/ton
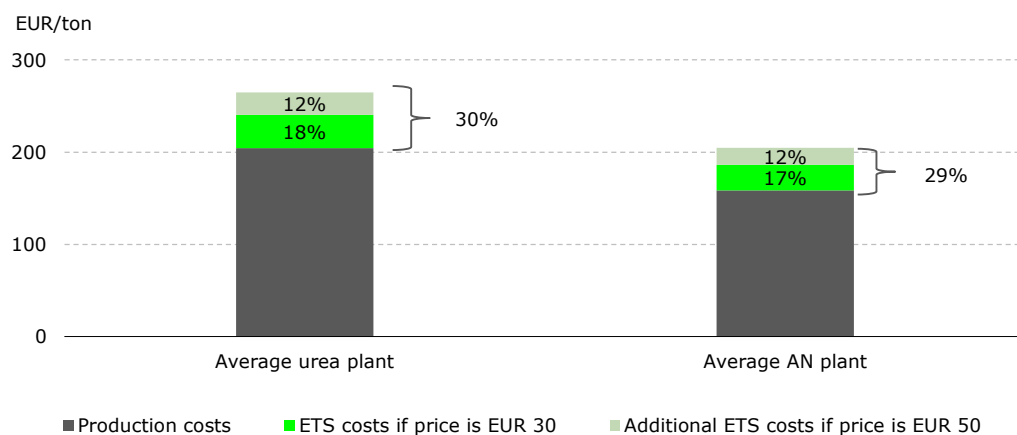
Note: The production cost is based on urea and AN production respectively and is calculated as an average plant. The figure does not include free allowances in order to show the 'raw impact' of the ETS price.

Urea is more costly than AN per ton, as there is a higher nutrient value in one ton of urea than AN

Source: Copenhagen Economics based on Integer Research

This is the 'raw impact' on production cost from ETS prices, not taking into account the potential to reduce emissions through e.g. technological improvements or end-of-pipe technologies such as 'scrubbers'. However, we argue that this potential is very limited in the European fertilizer industry, as significant progress has already been achieved and there is a natural/theoretical limit to emission reductions given the chemical nature of ammonia production.

In order to assess the magnitude of the effect of a stricter ETS system – higher prices and fewer allowances – we have simulated the profitability of EU-based fertilizer plants under different scenarios.[9] With an ETS price of EUR 30, and no possibilities to pass through these costs, the return on capital employed (RoCE) of an average urea plant in the EU will be less than 1.5 per cent without any free allowances, cf. Figure below. This means that the plant is just able to operate at positive margins (price slightly above variable costs), but that there is almost no return on its capital investments. The implication of this is that the plant will be closed down as soon as it faces a need for reinvestment. Also, even small deteriorations in the business case would spur immediate closure, as variable costs (including carbon price) outweigh revenue.

With the current free allowance allocation mechanism,[10] the same urea plant would achieve a RoCE of approx. 8 per cent. This is still significantly below the threshold of 12 per cent, which industry experts assess is necessary in order to sustain industrial produc-

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[9]   Based on model simulations performed by Integer Research.
[10] An industry benchmark of 1,619 allowances per tonne and a cross-sector correction factor of 1.74 per cent. The correction factor's cumulative effect has not been large as we measure the year 2015. We therefore overestimate the profitability, as the amount of free allowances will decrease over time.

tion in the long term. To reach the 12 per cent RoCE, the plant should have additional allowances corresponding to in total 115 per cent of the plant's GHG emissions, compared to the 73 per cent it would receive under current allocation.

Figure Profitability for an average urea plant in EU

Note: The numbers are based on simulations in an industrial model performed by Integer Research. The simulations are performed based on a number of assumptions:
We assume a EUR 30 ETS price.
The simulation is based on a current estimate for 2015, including current natural gas prices as provided by the World Bank. The EU plants are divided into 4 quartiles based on their technological sophistication. The average of the 4 quartiles are used for this calculation.
The above calculation of RoCE assumes a 2015 EXW price of urea in the EU of 299. This price level has been found by Integer Research to correspond with the average price level between 2006 and 2015, and therefore not expected to be due to a short term trend.

Source: Copenhagen Economics based on model simulations by Integer Research

The implication of this is not that producers should obtain more free allowances than they emit. Instead the implication is that the average urea fertilizer plant in EU – in the absence of cost pass-through possibilities – will become unsustainable without leakage compensation as the ETS price increases. Instead, significant compensation is required to offset the ETS impact. Some plants are better suited to deal with foreign competition (inland location and more energy efficient technologies) than the average plants, and some are worse. Moreover, the picture looks somewhat brighter for AN production in EU, as it can sustain a price margin above urea per nutrient. This margin can however be challenged e.g. in an economic environment where consumers of fertilizers, including farmers, are economically strained.

Traditionally, the EU fertilizer industry has been somewhat sheltered from non-EU competition through non-trivial transport costs and import tariffs. This theoretically allows producers to price above foreign markets and pass through further costs to consumers. However, the ability to pass through costs is highly dynamic and depends on the production cost differential inside and outside the EU. Once the EU cost disadvantage becomes large enough, cost pass-through becomes impossible (pass-through rate of zero), and the industry will relocate; as many industries have done in the past.

In this report, we argue that the cost pass-through potential for EU fertilizer production is limited, especially going forward with increasing ETS prices. Fertilizers are both very homogenous and quite transportable products especially at sea. This makes carbon leakage a very tangible risk either through entry of foreign competitors, or – perhaps even more likely – through the relocation of production facilities by European companies outside the EU. We are in fact already seeing this development. Very little capacity is being built in the EU, EU producers are building new capacity outside the EU, and the EU's share of global capacity is declining. As the existing EU fertilizer plants are relatively old, and depend on significant investments to maintain operations, a significant capacity shift could take place rather abruptly.

Such a shift driven by asymmetric climate policy would not just be problematic for European industry, but also for the global climate as European facilities are the most efficient both in terms of energy, CO_2 and N_2O emission. In addition, issues on nitrogen losses to the environment is likely to increase as the relocation of the European AN production will be replaced by the more transportable urea, which is more difficult to proportion with respect to nitrogen content.

In the proposed revised ETS directive, the concept of cost pass-through potential is introduced as a possible element in assessing the risk of carbon leakage. While we agree that pass-through *can* be correlated with the risk of leakage, it should be interpreted with much caution for at least two reasons:

Firstly, cost pass-through rates can capture several different underlying dynamics with very different implications for carbon leakage. For example, a high cost pass-through rate may be the result of a cost increase which affects both EU and non-EU production e.g. increased transport costs within EU or a requirement to label goods sold in the EU. Such pass through-rates are uncorrelated with leakage risk as it also affects production outside EU. Similarly if EU consumers become less price responsive: this will increase pass-through ability, but will not reduce the risk of carbon leakage if non-EU production stand ready to deliver large volumes at slightly higher prices.

It is also important to recognise that leakage not only takes place due to competitive pressure from non-EU producers gaining market shares, but also from relocation of production capacity by EU-producers. In case of a high cost pass-through say due to entry barriers to new competitors, this might limit foreign competition, but does not mitigate the incentive for EU producers to move their production plants to cheaper locations abroad.[11]

Secondly, empirical estimates of cost pass-through face challenges making them unsuitable as direct indications of carbon leakage. A few examples:
- Estimates are typically based on assessment of historical or current abilities to pass through costs. This is misleading, as pass-through potential changes over time as cost differentials between EU and non-EU production change.[12]

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[11] See e.g. Copenhagen Economics (2011)

[12] This is e.g. the methodology used in the only study suggesting a high cost pass-through rate for fertilizers of 75 per cent (Vivid Economics (2014a)).

- Historical assessments are unlikely to capture 'investment leakage' where production remains in Europe until new large investments are due. When new investments are needed, the entire production facility will move out of EU giving rise to substantial leakage.

As we demonstrate in the report, the one study which in particular estimate high cost pass-through rates for EU industry in general – also for the fertilizer industry (app. 75 per cent) – is in fact characterised by these features. This is, therefore, an overestimation of the pass-through rate going forward, and is a poor indicator of the carbon leakage risk, which is also clearly stated by the authors in the report.[13]

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[13] Vivid Economics (2014a), e.g. page 68 and 70.

Chapter 1
Understanding the mineral fertilizer industry

In order to provide an accurate description of the carbon leakage risk in the fertilizer industry, it is important to thoroughly understand the specifics of the industrial economics of an industry. In this chapter, we provide an overview of the mineral fertilizer industry with a particular focus on *nitrogen* fertilizers.

1.1 The production of nitrogen fertilizers

All crops need a combination of different nutrients, including nitrogen (N), phosphorus (P) and potassium (K). These nutrients all have essential and complementary roles for plant growth and are commonly used in European agriculture.

Nitrogen-based fertilizers are by far the largest product group and the most important fertilizer, accounting for almost 67 per cent of total nutrient consumption in the EU[14]. In terms of carbon leakage, nitrogen-based fertilizers are also the most interesting, as the production process is very greenhouse gas (GHG) emission intense.

There are two main types of N fertilizers: nitrates and urea. Both types of fertilizers are made from ammonia, but the production process differs. The ammonia resulting from the first step of the production is mixed with nitric acid – also derived from ammonia – to produce nitrate-based fertilizers such as ammonium nitrate (AN) or with liquid carbon dioxide to create urea, cf. Figure 1.

Figure 1 Production of N-fertilizers
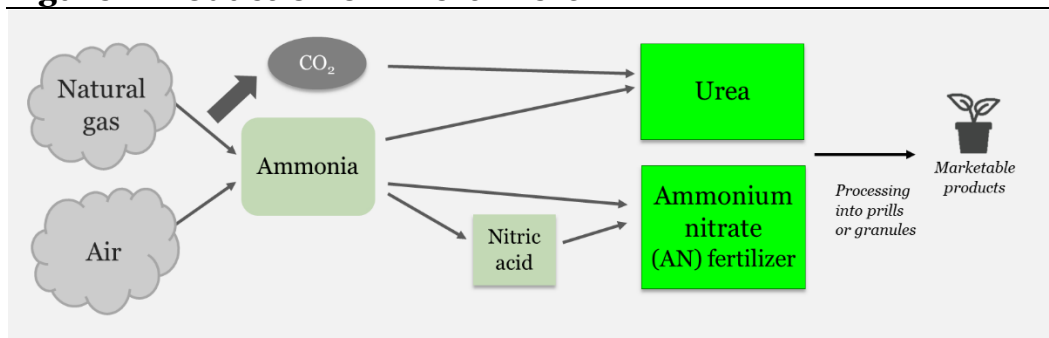
Source: Copenhagen Economics based on Yara (2014) and Fertilizers Europe (2014)

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[14]   Based on data provided by Fertilizers Europe

The two types of N fertilizers have a different content of nitrogen per tonne. Urea has 46 per cent nitrogen content per tonne while AN has 34-35 per cent.[15] This makes urea somewhat more transportable than AN, as it is possible to transport more nutrients per tonne of product.

The production of urea is an integrated process meaning that the production of urea from ammonia is integrated with the production of ammonia. For AN, the process of making fertilizer from nitric acid *can* be geographically separated from the site of the ammonia production – but is typically not. Ammonia production typically takes place at the fertilizer production site.

N fertilizers also have industrial use. For example, urea can be used for glue, pharmaceutical applications, cosmetics etc. Approximately 18 per cent of global urea consumption is for non-fertilizer use.[16]

1.2   Characteristics of different N fertilizers

Nitrate-based fertilizers such as AN, and urea ultimately serve the same purpose, namely to provide nitrogen nutrients for crops. The two types of N fertilizers therefore to a large degree act as substitutes.[17]

However, nitrate-based fertilizers, such as AN, have advantages compared to urea both in terms of uptake of nitrogen and dispensing the optimal amount of nitrogen. Nitrate-based fertilizers is easily absorbed by plants at high rates and, unlike urea, it is immediately and fully available as a nutrient. Urea requires at least 15 per cent higher N application to achieve same yield and quality as AN. Most of this underperformance can be compensated for by a higher nitrogen dosage. However, this comes at a cost of an increased environmental burden. Nitrate-based fertilizers on the contrary allow for a more accurate nitrogen distribution and has for that reason been associated with the term 'precision farming'.

Conversely, urea contains more nutrients per ton compared to AN, which makes it more transportable. Consequently, the main imported fertilizer in the EU is urea, while EU producers to a higher extent produce AN.

The main GHG emission from the production processes is from the production of ammonia. CO_2 emissions are an unavoidable by-product, since the production of ammonia (NH_3) converts carbon based feedstock (typically natural gas) into finished products. This process is the same for production of urea and AN. In production of AN, the step of converting ammonia to nitric acid (HNO_3) further emits nitrous oxide (N_2O) at plant level, which is also a greenhouse gas.

[15]   Yara (2014) and Fertilizers Europe (2014)
[16]   International Fertilizer Industry Association (2015)
[17]   This has also been the view of the Commission in competition cases, where both products were treated as forming a single
        product market, cf. European Commission (2013), European Commission (2004)

European producers surrender allowances for the CO_2 emitted in ammonia production, and for the case of nitrate-based fertilizers also for the N_2O released in nitric acid production. Since production of nitric acid is not required for urea, producers do not surrender allowances for N_2O for the production of urea. The emissions from production of fertilizers covered by the ETS are therefore the same as those emitted during production, which is higher for AN than for urea, cf. Figure 2.

Figure 2 Emissions from production of different fertilizer types

CO$_2$e/ton N
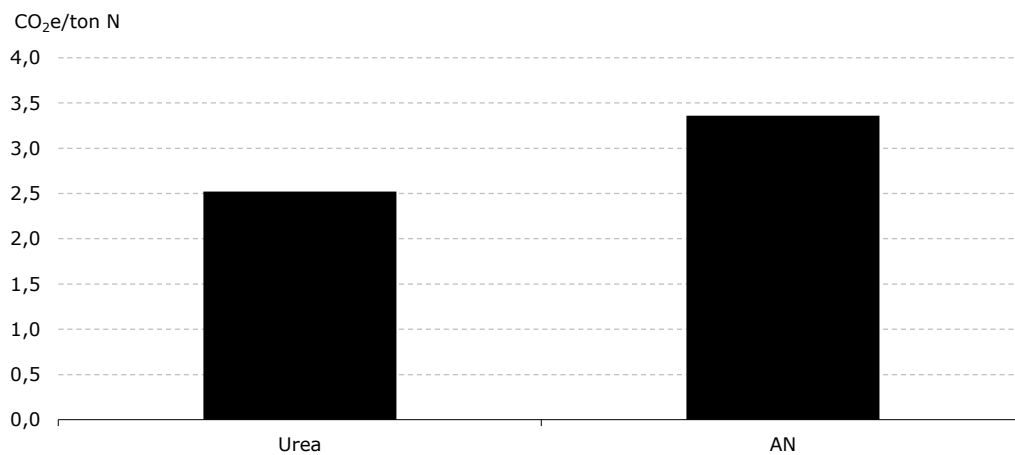
Note: The emissions for AN include CO_2 as well as N_2O measured in CO_2 equivalents

Source: Copenhagen Economics based on Fertilizers Europe

The ETS system does not take emissions taking into account on the field.[18] While emissions from production – the emissions covered by the ETS - are higher for AN than urea, as seen in Figure 2, the overall level of emissions is higher for urea than for nitrate-based fertilizers. While urea is more CO_2 efficient in *production*, CO_2 and N_2O emissions on application more than offset for this, see Figure 3.[19] Total emissions associated with urea increase even further when considering that it typically requires 15 per cent more nitrogen to give the same effective nutrient uptake.

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[18] Primarily due to measurement issues
[19] Yara (2014) and Fertilizers Europe (2014)

Figure 3 GHG emissions from production and application

Kg CO_2-equivalent
per kg N

■ N2O emissions (production and application) ■ CO2 emissions (production, transport and application)
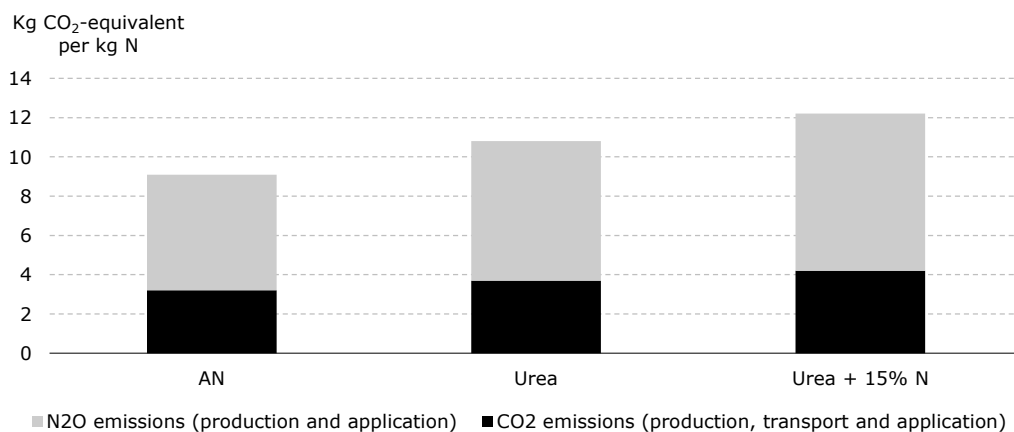
Note: The life-cycle carbon footprint for ammonium nitrate is lower than for urea and UAN. When compen-
          sating for the lower efficiency of urea and UAN with a higher dosage, the difference is even more
          marked

Source: Copenhagen Economics based on Fertilizers Europe

Even though the ETS discriminates against nitrate-based fertilizers such as AN, this is
still the preferred type of fertilizer in Europe today, cf. Figure 4. This is inter alia due to its
ability to dosage nitrogen better than urea, which also has environmental benefits linked
to nitrogen losses to the environment.

Figure 4 Nitrates are the preferred nitrogen fertilizer in Europe
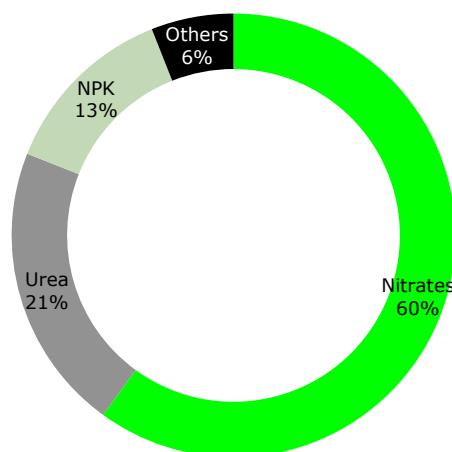
Note: Data for 2014. NPK fertilizers are complex fertilizers containing varying proportions of the three main
          nutrients; nitrogen, phosphate and potash. The N-part of NPK fertilizers is mainly based on nitrates.
          In this graph, nitrates include UAN (Urea Ammonium Nitrate) liquid fertilizers

Source: Fertilizers Europe (2014)

Chapter 2
The fertilizer industry is at significant risk of carbon leakage

In this chapter, we argue that the fertilizer industry is at significant risk of carbon leakage based on a number of objective criteria and a commonly accepted methodology.

2.1 What is carbon leakage and how does it apply to the fertilizer industry?

Carbon leakage is a concept describing the situation where a reduction in greenhouse gas (GHG) emissions in one region is followed by increased emissions in other regions. Carbon leakage can occur when one region implements carbon pricing, and thereby induces higher total costs for industries within the region, than for producers in regions with less strict climate policy. If the asymmetric carbon prices put the domestic producers at such a competitive disadvantage that they will lose market share to foreign competitors – or relocate their entire production facilities abroad – this will reduce the overall effectiveness of the climate policy, as global emissions are not reduced but merely shifted around.[20] Several studies suggest that carbon leakage can indeed be more than 100 per cent, indicating that for each tonne of GHG reduced in the EU for example, global GHG emissions will increase by more than one tonne.

Production of nitrogen fertilizers is widely recognised as an industry at risk of carbon leakage, and both the ammonia production process and the nitric acid process have been on the Commissions' two carbon leakage lists.[21]

When considering the Commission's two traditional criteria for assessing carbon leakage risks, emission intensity and trade intensity, nitrogen fertilizer are among the industries at the absolutely highest risk. In fact, out of more than the 170 industrial processes on the list, nitrogen-fertilizers is *the* only process which simultaneously fulfils both the combined criteria of high emission and trade intensity *and* the criteria of very high emission intensity, cf. Table 1. This means that among the industries with the highest emission intensity, fertilizers are deemed to have the highest trade intensity as well.

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[20] Another source of carbon leakage is the so called rebound leakage, where reduced demand for fossil fuels in one region lowers the global price of these fuels and thereby stimulates increased demand outside the region.

[21] European Commission (2014) and European Commission (2009)

**Table 1 Nitrogen fertilizer production is the most trade intensive
process of all the emission intensive processes**

	Combined criteria and very high emission intensity	Combined criteria and very high trade intensity	Fulfilling just one of the criteria
Number of processes	1	11	159
	(Manufacture of fertilizers and nitrogen compounds)		

Note: The very high emission intensity criteria is defined as when the sum of direct and indirect ETS costs account for more than 30 per cent of GVA. The very high trade intensity criteria is defined as when the trade intensity (measured by exports and imports) to third countries (i.e. non-EU countries) are above 30 per cent of. The combined criteria is when the emission intensity is above 5 per cent and the trade intensity with third countries is above 10 per cent.

Source: European Commission (2014)

Based on the new leakage assessment methodology proposed by the Commission,[22] nitrogen fertilizers are also deemed at significant risk. It is the most emission intense industry of about 35 kg CO_2e/EUR GVA, and combined with a high trade intensity of about 30 per cent, nitrogen fertilizers are among the very few processes in the undesirable category of 'very high' leakage risk, cf. Figure 5.

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[22] European Commission (2015b), page 20.

Figure 5 Nitrogen fertilizers at high risk of carbon leakage
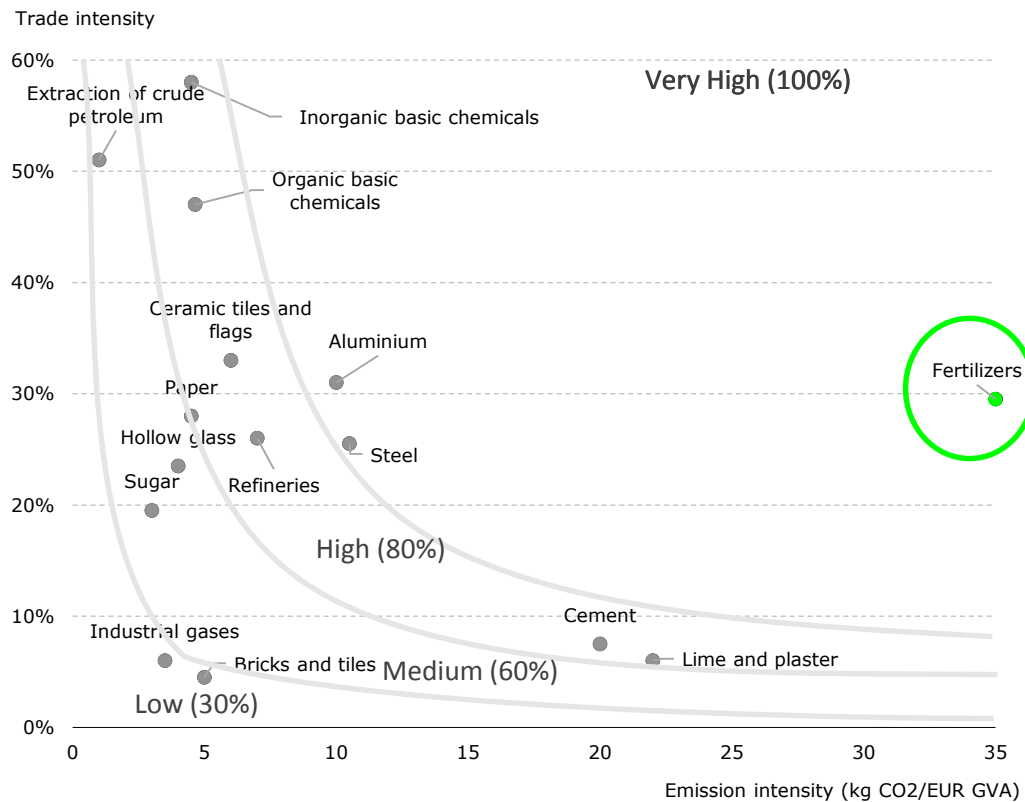
Source: Copenhagen Economics based on figure 13 in European Commission (2015a)

The two criteria, emission and trade intensity are approximations of the underlying economic structures of an industry. For instance, a low existing trade intensity of a product does not imply that this product cannot be traded in the future, e.g. if the carbon prices become high enough. Hence, in order to make a proper assessment of the leakage risk of an industry or a process, one needs to assess the underlying economics of the industry. In order to be deemed at risk of carbon leakage, the following must be true:

Figure 6 The risk of carbon leakage is high when…

1) **Costs are significantly affected by GHG prices**
and there is limited potential to improve carbon efficiency

2) **Costs cannot be passed through to consumers…**
due to:
- Homogeneity
- Transportability
- Resulting trade intensity
- Lack of bargaining power in value chain

3) **Profit loss cannot be absorbed…**
through reduced return on capital

Source: Copenhagen Economics (2011) and Öko-Institut & Ecofys (2013)

In addition, it is very important to assess whether or not there are emission-intensive parts of the value chain of a final product that is easy to split up and move abroad. The case of cement is very illustrative: being a product that is very difficult to transport, cement would be considered at limited risk of carbon leakage. However, the intermediary process of burning clinkers is much easier to transport and is in fact the most energy-intensive process of cement production. Due to this characteristic of the value chain, cement is now considered as highly exposed to carbon leakage. Ammonia production might be such a case. While transportability of pure ammonia has been drawn into question, the reality is that ammonia is already traded today, and increased carbon price differentials might drive this even further.[23]

Given that relocation will take place (sometimes known as output leakage) the size of carbon leakage will depend on the GHG-emission intensity of the foreign produced substitutes.

In the following sections we evaluate how the leakage risk of nitrogen-fertilizers is assessed based on these criteria.

2.2   Fertilizer costs are significantly affected by carbon prices

Whether costs are significantly affected by increased carbon prices depend on two elements. *Firstly*, that GHG emissions per value added are high and *secondly*, that options to mitigate GHG emissions, e.g. through energy efficiency, are limited or very costly. In this section we argue that nitrogen fertilizers is in fact very emission-intensive and that there is limited potential to reduce emission-intensity further.

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[23]   10 percent of ammonia production is internationally traded according to International Fertilizer Industry Association (2015)

ETS prices will significantly increase cost of production
A higher cost of carbon will substantially raise the cost of producing fertilizers in the EU. If the carbon price is EUR 50 the extra cost will amount to a 30 per cent increase, cf. Figure 6.

Figure 6 ETS price will significantly raise cost of production
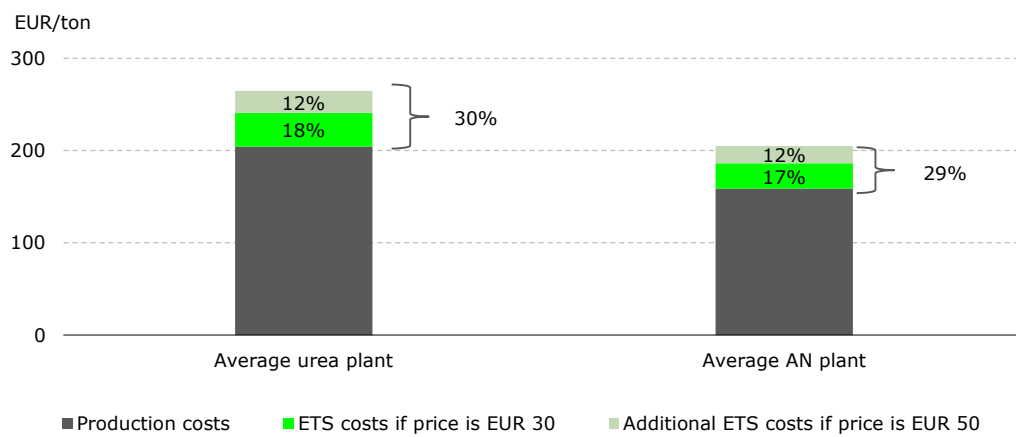
Note: The production cost is based on urea an AN production respectively and is calculated as an average plant. The figure does not include free allowances in order to show the 'raw impact' of the ETS price.

Urea is more expensive than AN per ton, as there is a higher nutrient value in one ton of urea than AN

Source: Copenhagen Economics based on Integer Research

Limited potential to improve emission efficiency in production
As mentioned in Chapter 1, GHG emissions in nitrogen fertilizer production come from three sources:

1. Energy to drive the process (CO_2 emissions)
2. Converting a carbon-based raw material to ammonia (CO_2 emissions)
3. Converting ammonia to nitric acid (N_2O emissions)

The potential to further reduce GHG emissions from these processes is limited, as we will illustrate.

Energy efficiency is already close to the theoretical minimum
Energy is needed to drive the ammonia production process. Energy is typically produced on-site with natural gas. The chemical production process requires a minimum energy inflow. The theoretical minimum for the feedstock is 18.6 GJ/t and when the theoretical minimum for the necessary energy is added, the total absolute theoretical minimum is 23 GJ/t.[24] The potential to reduce emissions is therefore to optimise the inflow of energy to reduce waste. EU fertilizer producers have already reduced their emission level substantially and are currently well below other fertilizer producing countries, cf. Figure 7.

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[24]   Kirova-Yordanova (2012)

Ukrainian is used as a reference benchmark here. A more complete comparison is provided in section 2.6.

Figure 7 Little room for further energy reductions

GJ per tonne
ammonia
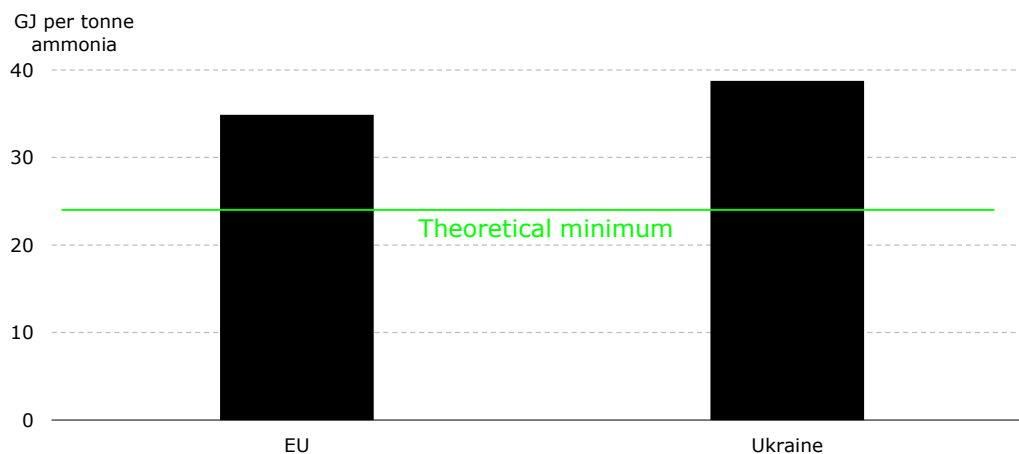
Note: The column show that energy intensity for an average European and Ukrainian plant in 2013. 23 GJ is
         used as the definition of theoretical minimum per tonne of ammonia in line with large parts of the lit-
         erature, among others in de Boer (2000), Kirova-Yordanova (2012) and the references herein.

Source: Copenhagen Economics based on data provided by Fertilizers Europe and de Boer (2000)

GHG emissions are a unavoidable in the chemical process

Production of ammonia will unavoidably emit carbon, as it converts a carbon-based feed-stock such as natural gas. [25] In fact, two thirds of natural gas consumption is as a raw material, and the remaining third is to provide an energy source. The only way to reduce emissions is to change to a less carbon-intensive feedstock. EU producers already use the most carbon efficient feedstock,[26] namely methane, where e.g. Chinese producers typically use coal, which emits significantly more carbon per tonne of ammonia.

The N_2O emissions have almost been eliminated in the EU

Aside from the CO_2 emissions that stem from the production of ammonia, the conversion of raw ammonia into nitric acid leads to N_2O emissions. However, over the last decade, EU producers have proactively invested and have succeeded in substantially reducing N_2O-emissions through end-of-pipe technologies, such that the emissions of N_2O per tonne of nitric acid in 2014 were less than one sixth of the 2005 level, cf. Figure 8.

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[25]   Other carbon feedstock such as biomass could also be used, but this is not deemed a realistic option as it is currently neither
       technically possible, reliable in a sufficient scale nor realistic in terms of costs, cf. Vivid Economics (2014a)
[26]   Not considering biomass

Figure 8 N₂O emissions from AN production have almost been eliminated in the EU

kg N_2O/tonne of
nitric acid
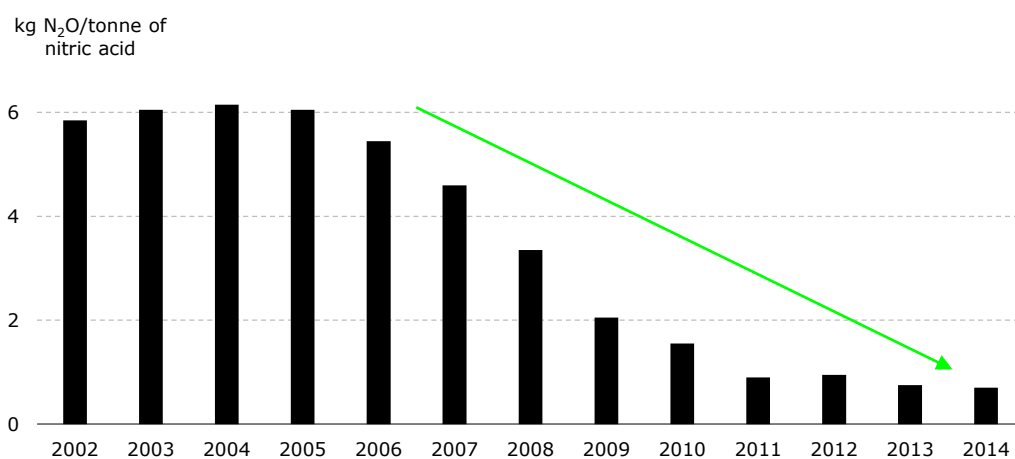
Note: These numbers are based on actual emission collected by Fertilizers Europe based on its member
           companies.
Source: Copenhagen Economics based on data provided by Fertilizers Europe

2.3   Low cost pass-through rates for fertilizers

The ability – or lack hereof – to pass on cost increases to consumers is one element in as-
sessing the risk of carbon leakage. If it is possible for EU producers to pass on costs to
consumers without losing market shares, leakage risk may be lower. Higher prices may
reduce demand, but demand responses to marginal GHG prices is indeed one of the pur-
poses of introducing a carbon price. If, on the other hand, cost increases *cannot* be passed
on to consumers without losing significant market shares to non-EU production facilities,
the ETS system does not work as intended, as final demand remains the same, but is now
being serviced from regions with laxer climate policy.

In consultancy work done for the Commission,[27] the cost pass-through concept takes a
central stage in the evaluation of carbon leakage risk. While we agree that cost pass-
through *may* be correlated with leakage risk, we argue that this is just a single piece of the
puzzle, and should be treated as such.[28] One example is that a high cost pass-through rate
may limit competition from non-EU producers, but does not prevent a European pro-
ducer from relocating its production facility to a non-EU country. Another example is that
the definition and empirical assessments of a pass-through rate has different implications
for leakage depending on the type of cost increase considered. In section 2.4 we elaborate
on this point.

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[27]   Öko-Institut & Ecofys (2013)
[28]   Here we agree with e.g. Vivid Economics (2014a) page 70, stating that: 'the cost pass-through should not be the focus of
         attention of policy makers… It represents an intermediate step to the calculation of the variables that actually reflect the
         impact on the sector'.

In the next sections, we argue that nitrogen fertilizers are homogenous goods and rela-
tively transportable, which are important criteria suggesting a low cost pass-through po-
tential.[29]

**Nitrogen fertilizers are homogenous across regions**
Fertilizers are homogenous goods as the possibilities for differentiation are very limited.
Although there are different types of N fertilizers, all N fertilizers form one single product
market since the products are partly interchangeable from a customer's perspective.[30] For
example, as discussed in Chapter 1, AN and urea are not perfect substitutes, but are still
interchangeable at the right relative prices.

For producers, the consequence of fertilizers being homogenous goods is that these prod-
ucts are very price sensitive as substitution from one producer to another is easier than in
the case of highly differentiated products. Indeed, the substitutability between AN and
urea is can be seen from the high degree of correlation between AN and urea prices, cf.
Figure 9. The development in the AN price lags behind the development in the urea price
by about two weeks, indicating that AN is a urea price follower rather than a leader.

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[29]   In Öko-Institut & Ecofys (2013), 'export specialisation position' is also mentioned as a market characteristic to analyse. Ex-
        port specialisation position is a metric for the robustness of a sector's net export position over time, influencing the ability
        to pass through costs without risking to lose export markets. We believe the exposure to foreign competitors is demon-
        strated by the homogeneity of products in combination with the product's transportability, and therefore does not add new
        information. Bargaining power in the value chain is also a criterion. We expect the fertilizer industry to have very limited
        bargaining power towards its upstream suppliers which are mainly distributors of natural gas.
[30]   European Commission (2013)

Figure 9 AN and urea prices co-vary

USD/tonne
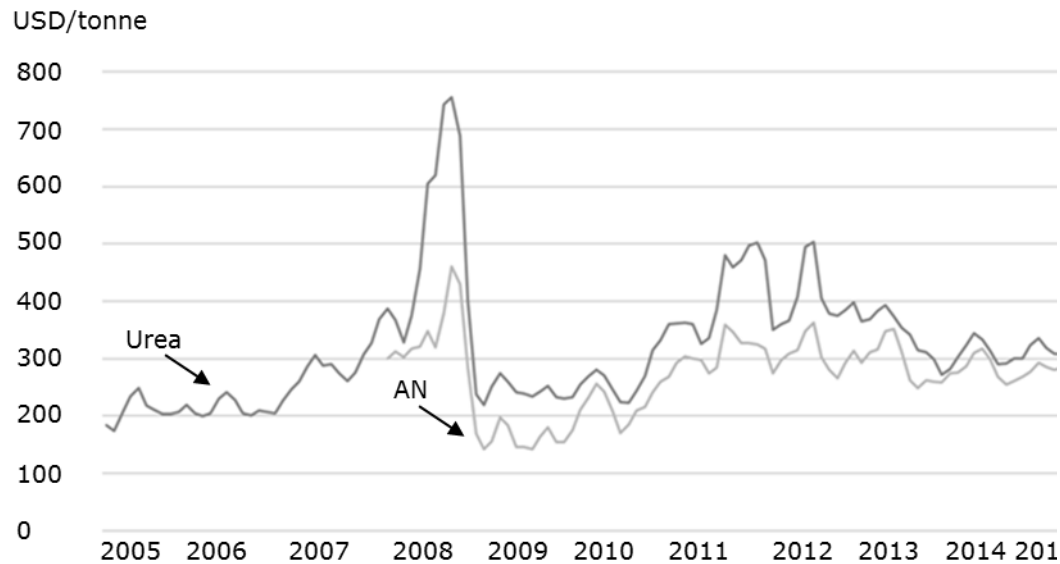
Note: AN FOB Baltic and Urea prilled FOB Baltic

As urea contains more nutrients per tonne, it is priced higher than AN when assessed on its weight.
AN is considered a higher quality product, which is also reflected in a higher price per nutrient than
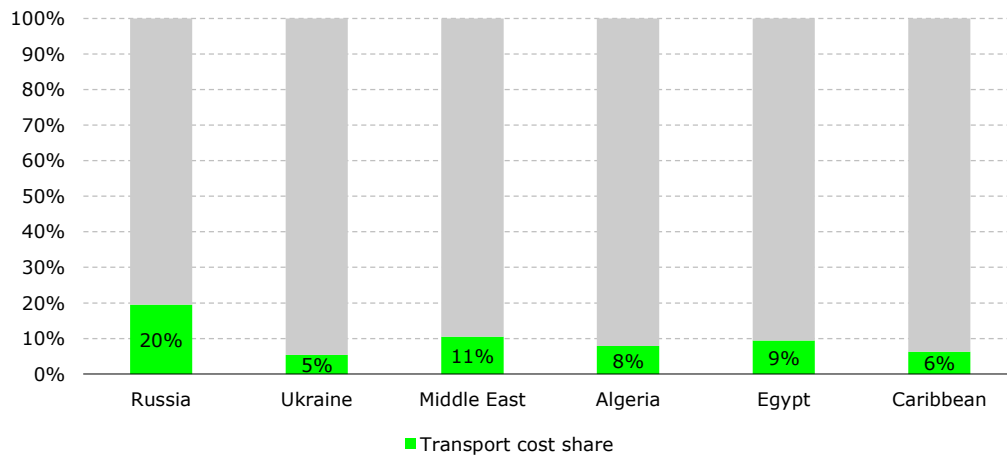urea.

Source: ICIS

When goods are homogenous, consumers will not be willing to pay a premium for one
producer's product over another's. There will still be a nitrate-premium, meaning that
consumers are willing to pay more for higher N-efficiency. Homogeneity means that for a
given product with a given N-efficiency, for example AN, consumers will not be willing to
pay more for one producer's AN over another's. As a result, the pricing power of the indi-
vidual producer is weak, and will not be able to raise prices above the market price with-
out losing market shares.

Nitrogen fertilizers are transportable
When a product is transportable it means that the product in question has low transport
costs relative to the product's value. Goods such as steel or oil have low enough transport
costs making them transportable almost all over the globe. Consequently, producers com-
pete in a global market, making it unlikely to possess local pricing power.

Transportability is a relative term, and it is hard to determine when exactly transport
costs are 'high' or 'low'. For fertilizers, the transport cost as a share of product value
ranges from 20 per cent in Russia to 5 per cent in Ukraine, cf. Figure 10. Notice that the
low relative cost in Ukraine reflects the current very high cost of natural gas in Ukraine.

## Figure 10 Transport costs of nitrogen fertilizers

Note: The calculation is based on urea which is the main import/exported product. The transport cost share
         is calculated as the cost of transporting to Europe relative to the value of the product measured by a
         EXW price of EUR 250 per tonne. Rail to EU border has been used for calculations of transport costs
         from Russia and Ukraine. For the other regions, transport costs have been estimated based on dry
         bulk ocean freight.

Source: Copenhagen Economics based on Integer Research

Transporting nitrogen fertilizers to the European market comes at a cost higher than truly global commodities such as steel. However, relative to the product price, this cost is not substantial. In fact, it is below 10 per cent for most of the regions in question, especially the regions where the goods are transported by sea. This picture suggests that non-European production could be cost-competitive with European production for relatively small cost differentials.

Indeed, nitrogen fertilizers are already significantly traded on the global market. The EU has gone from a position as net exporter of nitrogen fertilizers until the mid-1990s to being a net importer, with a substantial share of consumption now being imported, cf. Figure 11.

Figure 11 EU is now a net importer and imports a significant share of demand

1,000 USD
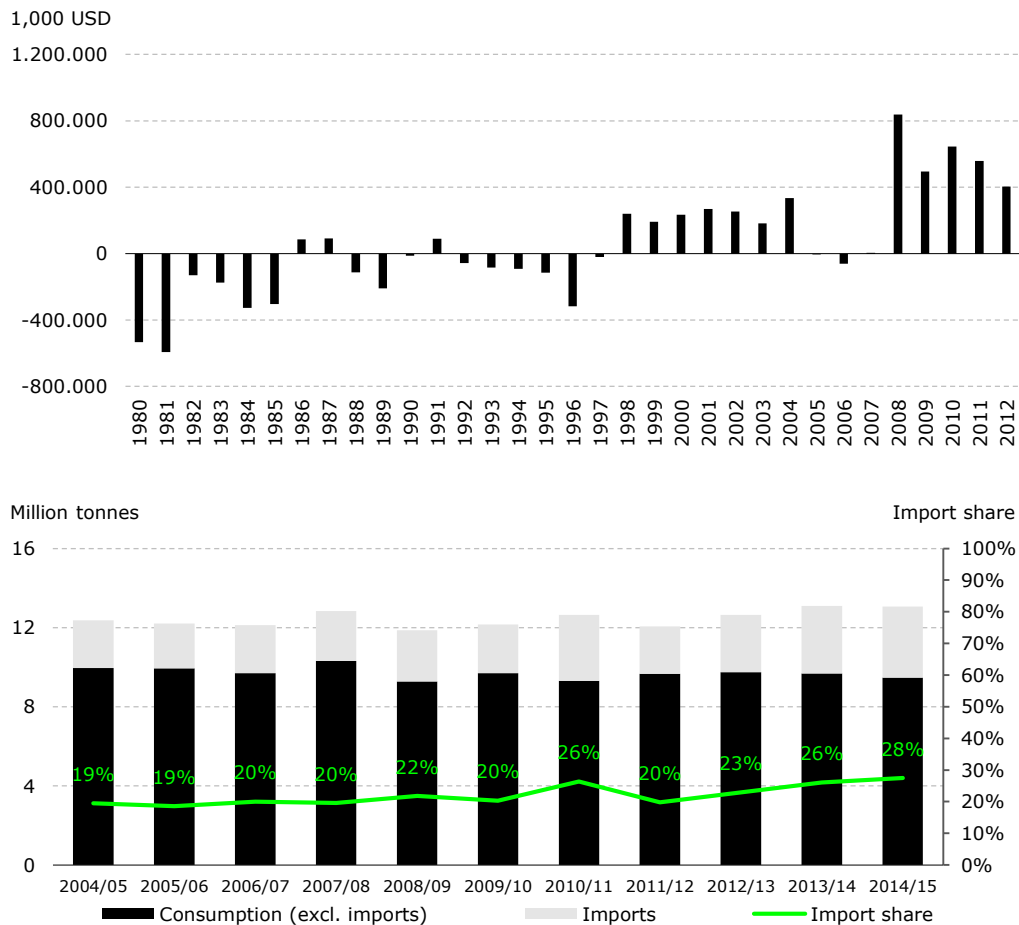
Note: The upper figure shows net imports, which is import less exports in each year

The lower figure shows imports as a share of consumption of nitrogen based fertilizers

Source: Copenhagen Economics based on FAOstat (upper figure) and Fertilizers Europe (2015) (lower figure)

The main sources of import currently is Russia, the Middle East and to some extent non-EU countries in Europe such as Belarus, the Caribbean countries and USA, cf. Figure 12.

Figure 12 Most important sources of import
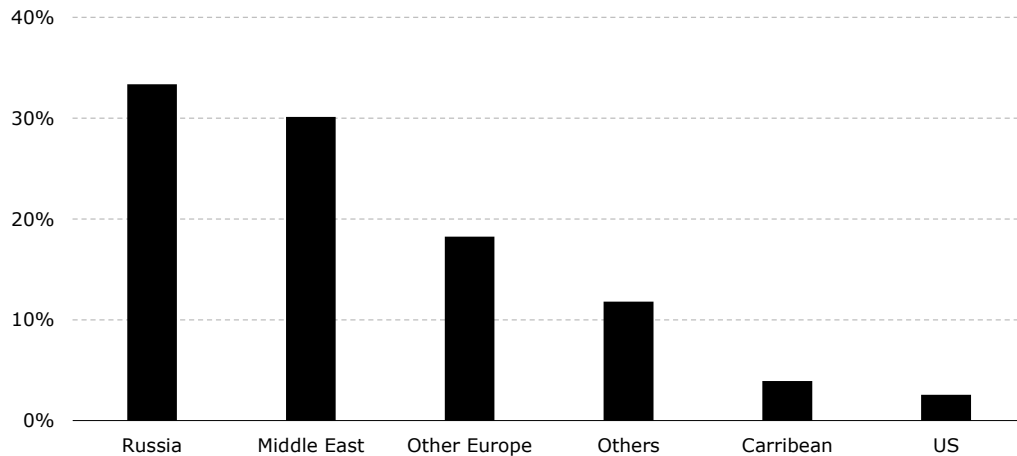
Note: The figures show the imports of N fertilisers to the EU. The shares are calculated based on figures from the exporting country and refers to data from July 2014 to April 2015.

'Other Europe' comprises Norway, Belarus and Ukraine; 'Middle East' comprises Morocco, Tunisia, Libya, Algeria, and Iran, whilst 'Caribbean' refers to Trinidad and Tobago

Source: Copenhagen Economics based on Fertilizers Europe and Eurostat

Pass-through is dynamic and the 'tipping point' has been reached
It is important to recognise that cost pass-through is a dynamic concept, and the ability to pass on to consumers depends strongly on the underlying economics of an industry industry as well as general market conditions. In addition, the concept of a cost pass through rate may indicate leakage risk but in many circumstances it is unrelated to leakage risk.

Traditionally the EU fertilizer industry has been somewhat sheltered from foreign competition through transportation cost and import tariffs. This shelter theoretically allows EU producers to price above foreign markets, cf. Figure 13, and therefore pass on costs to final consumers.

Figure 13 Illustration of ability to pass through costs

Year 1
EU industry is at a cost disadvantage
but competitive due to high transport

Year 2
EU industry's costs have increased,
resulting in competitive disadvantage

Max chargeable price by EU producers before
significant loss of market share

EU
cost dis-
advantage

Transport
cost and
tariffs to
Europe

Increased
costs *can*
be passed
on. Low
carbon
leakage

Production
cost

Increased
costs
cannot be
passed
on.
Carbon
leakage
can be
massive

EU-based
production

Non-EU
production

Non-EU
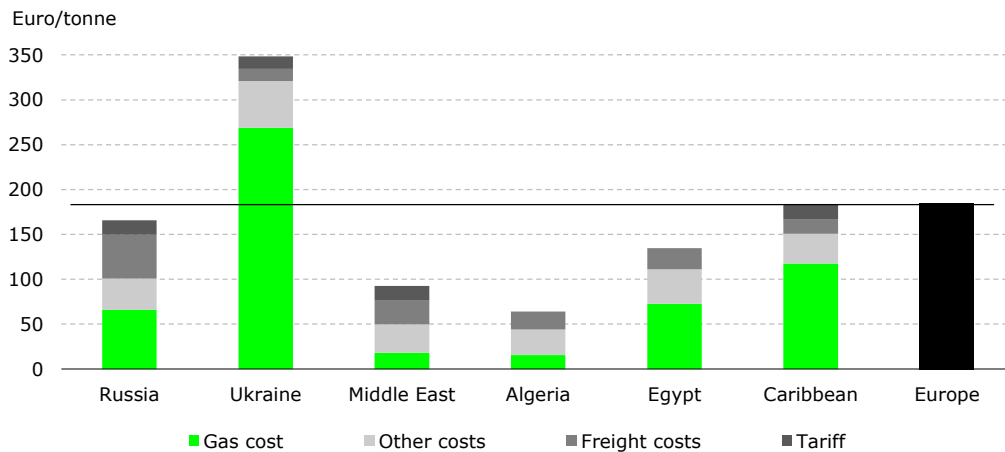production

EU-based
production

Note: The figure is an illustration. Actual relative size of costs may differ from those illustrated

Source: Copenhagen Economics

However, as as European producers' cost disadvantage becomes sufficiently high, the
ability to pass on further costs to final consumers disappears. This is particularly the case
when goods are homogenous and therefore cannot justify a price premium for domestic
production. The level of the cost differential that spurs foreign competition can be la-
belled 'the tipping point'.

The current differential in natural gas prices, cf. Figure 15, in addition to e.g. the cost of
reducing N_2O emissions, contributes towards higher production cost in the EU than in
other regions. Except for Ukraine, this production cost differential is currently larger than
the extra transport costs and tariffs faced by non-EU production, cf. Figure 14. The pic-
ture illustrates that production costs in the EU is relatively high and approaching, or may
have surpassed, the tipping point.

Figure 14 Cost differential with non-EU production currently higher than transport costs

Euro/tonne

Note: The numbers are delivered cost to Europe. The freight costs are calculated based on delivery to the nearest selling-hub, e.g. a harbour. Algeria and Egypt are exempt from import tariffs. The MVN tariff for urea is 6.5%.

Production cost are based on an average plant

Source: Copenhagen Economics based on calculations performed by Integer Research

One reason for the cost disadvantage of the European producers is the current large differential in natural gas prices. Costs in the EU are significantly above those of the main competitors, cf. Figure 15.

Figure 15 High costs of natural gas in Europe

EUR per MBTU
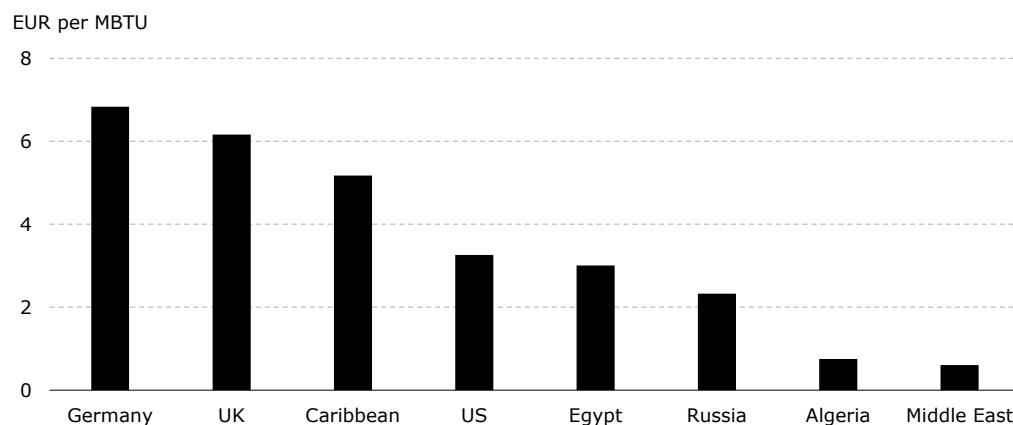
Note: The depicted prices are the average price of natural gas in a given area in 2014. MBTU = Million British thermal units.

Source: BP (2015) and data provided by Integer Research

2.4 What can we learn from estimates of cost pass-through rates?

In recent years, several analyses have attempted to estimate the cost pass-through rate in different industries, including the nitrogen fertilizer industry. Moreover consultancy work has been done suggesting more focus on the issue of pass-through rates in the Commissions' assessment of carbon leakage.[31]

In this section we make two arguments: 1) estimates on pass-through rates are highly uncertain and strongly dependent on uncertain assumptions, and 2) the cost pass-through rate is only a single piece of the puzzle and is not an important metric in itself.

Uncertain estimates and methodologies
Analyses of pass-through rates are often conducted either as a backwards looking econometric exercise, or as a forward looking (partial equilibrium) modelling exercise. Both between the analytical class and within these classes, specific assumptions and parameters can drive large differences in estimates. For nitrogen fertilizers, recent estimates on pass-through rate range from 16 – 75 per cent, even with an analysis suggesting no pass-through potential at all, cf. Table 2. These analyses clearly show that different analytical techniques and assumptions can produce many different estimates on the pass-through rate in the same industry.

Table 2 Cost pass-through rates in the literature

Study	Method	Time scale	Nitrogen fertilizers	Refined products	Paper and paper products	Container and hollow glass	Plastics (petrochemicals)	Iron and steel	Cement, lime and plaster
Alexeeva-Talebi (2010)	Two-stage estimation based on time series econometrics	Short/long	16		0-38	60	42		73
CE Delft (2010)	Econometric time series	Short		100				100	
Oberndorfer et al (2010)	Econometric time series	Short	50-60	50-75		0-25	100		
CE Delft (2008)	Qualitative assessment (not empirical)	N/A	0	75	30		33-100	50	100
Vivid Economics (2014)	Partial equilibrium model	Long	75	65-95	75-95	65		75-85	80-90
Range in all studies (per cent)			**0-75**	**50-100**	**0-95**	**0-65**	**33-100**	**50-100**	**73-100**

Source: Copenhagen Economics based on the sources in the table

While being methodologically advanced, all econometric attempts and most modelling attempts suffer from a variety of problems linked to using present or historic conditions to predict future developments. At least two examples should be highlighted:

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[31]   Öko-Institut & Ecofys (2013)

Using historical estimates to predict future leakage risk is misleading
Econometric models applied to leakage risks can be used to assess whether there has been leakage in the past. However, such results should not be interpreted as the risk of carbon leakage in the future for at least two reasons:

1. ETS prices in the past have been very low compared to the expected increases going forward. The historic and current low ETS prices will only spur leakage in industries with very low profit margins. Due to the tipping-point mechanics of carbon leakage, leakage rates will not be linear in the ETS price. Consequently, such estimates underestimate the real leakage risk at high ETS prices.
2. Historical assessments are unlikely to capture 'investment leakage' where production remains in Europe until new large investments are due. When new investments are needed, the entire production facility will move out of EU giving rise to substantial leakage.

The same methodological problem is relevant in ex ante equilibrium models. Even though they are forward-looking in nature, they are calibrated based on present or historical data. One example is the use of trade elasticities which are estimated based on an economic environment much different from an environment with high ETS prices.

Failure to account for 'tipping points'
Related to the above point, 'tipping points' are often (always) overlooked in analyses, which try to assess an industry's ability to pass on costs to consumers. As discussed in this report, the tipping point is a measure for how much reduction in the profit margin an industry can sustain before relocating production or investments outside EU. For small cost differentials towards non-EU countries, carbon leakage can likely be assessed as marginal changes: a slight increase in the ETS price will give a slight relocation. However, as cost differentials reach the tipping point, leakage will not be marginal; it can potentially be massive.

Most equilibrium models are built as 'marginal models' – using Armington price elasticities – and will therefore, almost by definition, underestimate leakage rates when cost differentials become high enough.

Pass-through is just a single piece of the puzzle
In consultancy work done for the Commission,[32] the cost pass-through concept takes a central stage in the evaluation of carbon leakage risk. While we agree that cost pass-through *may* be correlated with leakage risk, we argue that this is just a single piece of the puzzle.[33] In fact, cost pass-through rates can capture several different dynamics with very different implications for carbon leakage.

It is important to distinguish between cost increases which affect both EU and non-EU production, and cost increases which only affect EU production:

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[32] Öko-Institut & Ecofys (2013)
[33] Here we agree with e.g. Vivid Economics (2014a) page 70, stating that: 'the cost pass-through should not be the focus of attention of policy makers... It represents an intermediate step to the calculation of the variables that actually reflect the impact on the sector'.

First, consider an increase in a cost affecting both EU and non-EU production, e.g. increased transport costs within EU or a requirement to label goods sold in the EU. The cost pass through rate associated with such an increase will depend on especially consumers' price responsiveness and will give rise to an overall reduction in demand for fertilizers. Even if consumers are price responsive and cost pass through is low, the risk of carbon leakage has not increased, as non-EU producers are also facing the increased cost. The same point applies if say EU consumers becomes more price responsive e.g. due to an economic downturn. The associated low cost pass through rate is likely to reduce fertilizer consumption, but will not in itself increase the risk of carbon leakage, as non-EU production will also be affected and vice versa. In this example, leakage might however in fact increase as a change in EU consumers price responsiveness may induce a shift from the more expensive AN to the cheaper – and more transportable – urea.

Second, consider an increase in costs affecting just production within EU such as an ETS price increase. The real cost pass through rate now depends to a lesser extent on consumers' price responsiveness (demand elasticity) and to a much higher extent on the ability of non-EU producers to cater for the European market (trade elasticity, transportability, homogeneity, etc). Even if consumers were not very price responsive (and estimates of pass through therefore could be high), carbon leakage risk can be substantial if non-EU producers stand ready to deliver large volumes at slightly higher prices.

It is also important to recognise that leakage not only takes place due to competitive pressure from non-EU producers gaining market shares, but also from relocation of production by EU-producers. Consequently, if a high cost pass-through rate is due to specific circumstances providing an advantage to EU producers, e.g. entry barriers such as strong local existing customer/supplier relationships or bargaining power, this might limit foreign competition, but does not mitigate the incentive for EU producers to move their production plants abroad.[34]

Consequently, it is very important to acknowledge that the link between cost pass-through and the risk of carbon leakage is not straightforward. Empirical and modelling estimates of pass through rates should therefore be used with caution and with a focus on the specific drivers of cost pass-through in their models.

Applying these points to the Vivid Economics (2014)-study
The Vivid Economics (2014) study has spurred some attention in the leakage-exposed industry as cost pass-through estimates are generally quite high; indeed, significantly higher than other studies, cf. Table 2 above. We argue that their modelling methodology does not in fact properly take into account the above points, and we wish to highlight that the authors are in fact very explicit about the pass-through rate not being an important metric for assessing the carbon leakage risk.

The estimation of cost pass-through in their model is based on three drivers: profit margins, non-EU import shares, and the domestic demand elasticity. We argue that these

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[34] See e.g. Copenhagen Economics (2011)

three drivers cannot be used to predict the carbon leakage risk of a sector going forward,
cf. Figure 16.

Figure 16 Why cost pass-through in Vivid Economics (2014) does not predict carbon leakage risk

| Drivers of pass-through	Copenhagen Economics' assessment of 'drivers'
Profit margins *High margins lead to high pass-through*	While intuitively true, this does not predict leakage risk. High profit margins (e.g. due to entry barriers) for EU producers can still drive leakage if EU producers find it more profitable to relocate production/investments to countries with lower carbon costs
Non-EU import shares *Low import shares lead to high pass-through*	This criterion is an example of using the present competitive environment to indicate the future situation, thus not accounting for tipping points and non-marginal changes
Demand elasticity *Low consumer response to price lead to high pass-through*	A traditional demand elasticity (consumer responsiveness to price) does not say much about leakage risk. Even very inelastic consumers will spur leakage if non-EU countries can cater for demand (homogenous and transportable products)

Source: Copenhagen Economics based on Vivid Economics (2014a)

It is also very clearly highlighted in Vivid Economics (2014)[35] that cost pass-through
should *not* in itself be an important part in assessing the risk of carbon leakage. Instead,
the important metric should be the potential reduction in output (output leakage) and the
associated impact on global emissions (carbon leakage). Here, the nitrogen fertilizer in-
dustry undoubtedly comes out as one of the industries with the absolute highest risk of
carbon leakage. Their analysis suggests that the UK fertilizer industry would contract by
more than 60 per cent for ETS prices of EUR 30 and that there will be no industry for ETS
prices of EUR 50, in the absence of leakage compensation e.g. in the form of free allow-
ances, cf. Figure 17. Taking into account the GHG emission intensity of non-EU produc-
tion facilities, Vivid Economics (2014) estimate the carbon leakage rate of the nitrogen
fertilizer industry to be between 105-118 per cent.[36]

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[35] Vivid Economics (2014a), e.g. page 68 and 70
[36] Vivid Economics (2014b), page 49.

Figure 17 Reduction in sector output for different ETS prices
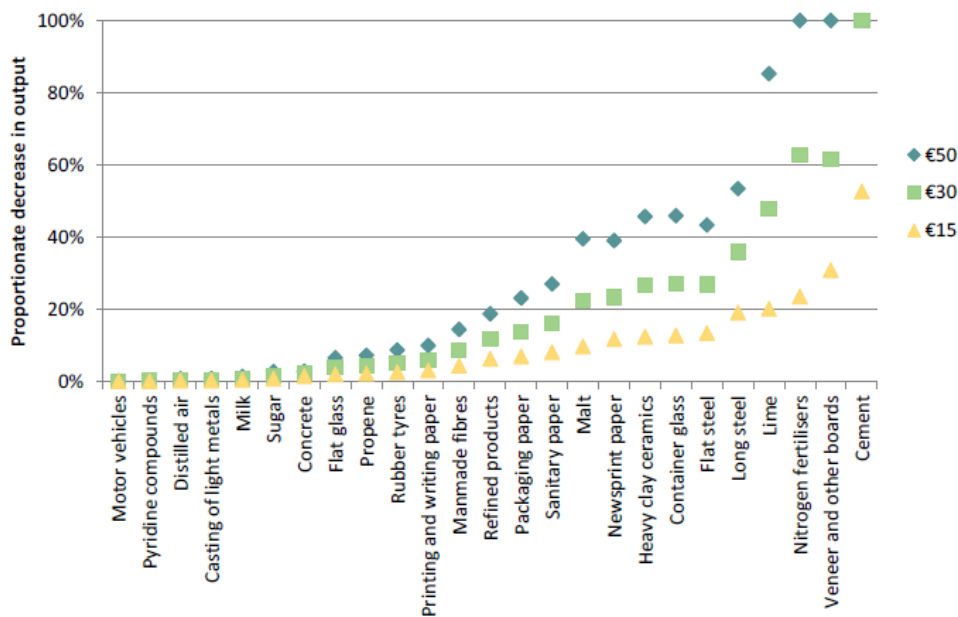
Source: Vivid Economics (2014a)

2.5 Without sufficient anti-carbon leakage compensation, fertilizer production in Europe is facing an uphill battle

An improved ETS system with significantly higher prices will put European fertilizer production under significant pressure. Pressure which is building on top of the deteriorated competitive situation driven by the increased natural gas price differentials.

As the fertilizer industry is capital intensive, it is likely that production in the EU will continue for a number of years, as the capital stock is being deteriorated. However, if the return on capital is too low, new investments will not be undertaken in Europe, and production capacity will deteriorate.

Given the risk profile of fertilizer production, estimates from industry experts suggest that the required return on capital employed (RoCE) to attract capital is 12-15 per cent.[37] In fact, the failure to achieve such returns over the past 15 years has spurred a significant closure of production capacity.[38]

The main reason for a required RoCE around 12 per cent is that the fertilizer industry is very capital intensive and that prices are extremely volatile. To put this number into perspective it can be useful to look at other, comparable industries. PWC[39] has analysed the upstream oil and gas industry, which is also a capital intensive industry facing volatile

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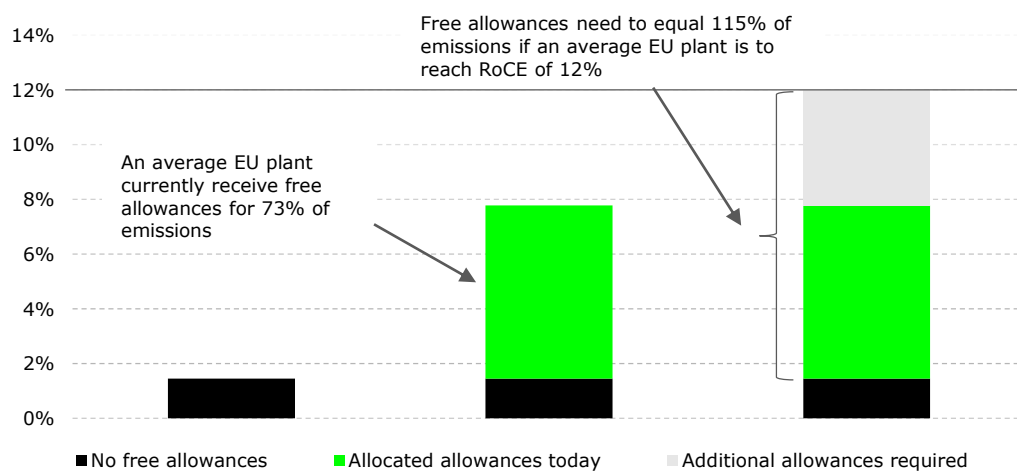[37] See Integer Research (2011) and Z/Yen (2008)
[38] Integer Research (2011)
[39] PWC (2013a)

global market prices. PWC found an average RoCE of 21 per cent from 2006-2012. Companies in the top quartile recorded an average RoCE of more than 32 per cent. In an analysis of the mining industry – another capital intensive industry - PWC found an average RoCE of 14 per cent over the ten year period from 2002-2012[40].

In order to assess the profitability of European-based production with higher ETS prices, we make use of an industrial model run by Integer Research. Concretely, we estimate that with an ETS price of EUR 30 and no free allowances, the RoCE of an average urea fertilizer production facility will fall to app 1.5 per cent, cf. Figure 18. If the current level of free allowances is withheld, the return on capital is app 8 per cent, and therefore still quite below the threshold of 12 per cent. In order for the industry to obtain 12 per cent RoCE, this would require free allowances in the magnitude of 115 per cent of total emissions.

Figure 18 Profitability for an average urea plant in EU

Note: The numbers are based on simulations in an industrial model performed by Integer Research. The
       simulations are performed based on a number of assumptions:
       We assume a EUR 30 ETS price.
       The simulation is based on a current estimate for 2015, including current natural gas prices as pro-
       vided by the World Bank. The EU plants are divided into 4 quartiles based on their technological so-
       phistication. The average of the 4 quartiles are used for this calculation.
       The above calculation of RoCE assumes a 2015 EXW price of urea in the EU of 299. This price level
       has been found by Integer Research to correspond with the average price level between 2006 and
       2015, and therefore not expected to be due to a short term trend.

Source: Copenhagen Economics, based on model simulations performed by Integer Research

2.6   Leakage may be abrupt and problematic for global greenhouse gas emissions reduction ambitions

The fertilizer industry is characterised by large capital investments easily exceeding 1 billion euro. This implies that carbon leakage is likely to happen quite abruptly instead of gradually. *Firstly*, very limited new investments are likely to take place. *Secondly*, once

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[40]   PWC (2013b)

the existing capital stock is sufficiently depreciated it will close down entirely, leading to abrupt relocation.

The European fertilizer facilities are relatively old, where app. 73 per cent of European fertilizer facilities were built before 1990, cf. Figure 19. For such facilities maintenance investments become increasingly important.[41] This implies that there is potentially a large 'chunk' of production facilities which could quite rapidly face the troublesome choice of making a large new investment in expectation of increasing ETS prices and decreasing free allowances.

Figure 19 Relatively old production plants in the EU
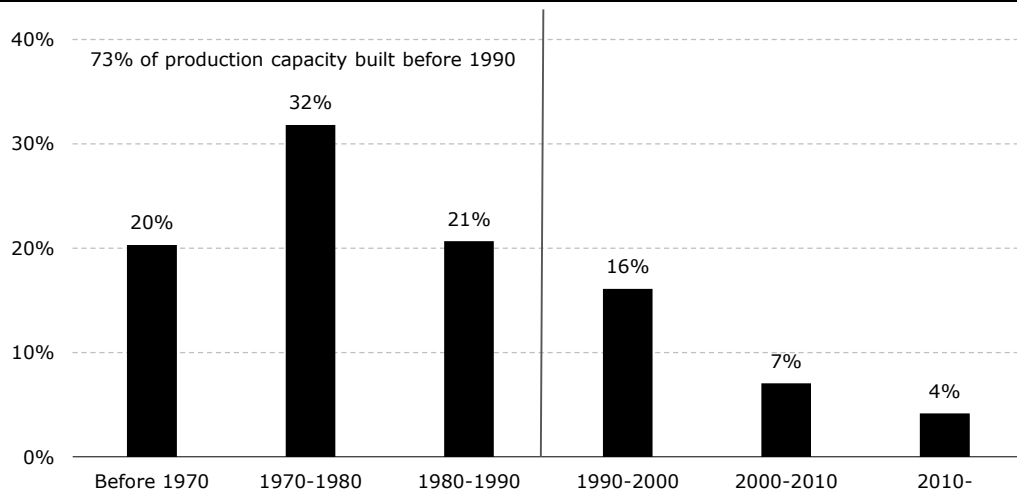
Note: Production lines in the EU for which the dataset does not include date of construction have been excluded
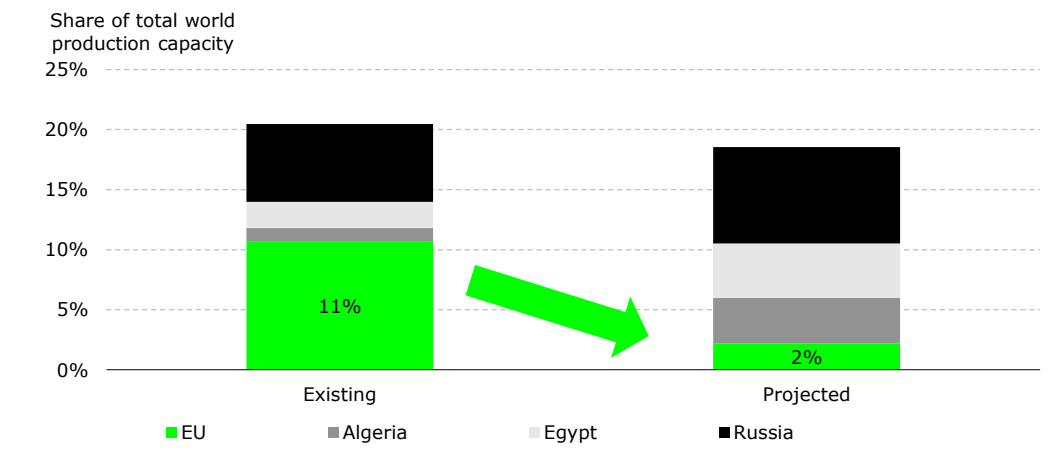
Source: Copenhagen Economics based on data provided by Fertilizers Europe

In fact, we are already witnessing reductions in the European share of global production capacity. From the 1990s to 2006, production capacity in the EU decreased by more than 10 per cent.[42] Looking forward, projected new capacity in EU has stagnating, constituting only 2 per cent of all new planned capacity, against its current 11 per cent, cf. Figure 20. The main expansion is expected to take place in Algeria, Egypt and Russia.

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[41]   As a rule of thumb, the 'technical lifetime' of fertilizer plants is around 30 years
[42]   Pellervon (2008)

Figure 20 Production capacity is already leaving the EU

Share of total world
production capacity

Note: The two columns show the location of existing and planned fertilizer production capacity. The numbers
   are based on N fertilizers only.

Source: Copenhagen Economics based on data provided by Fertilizers Europe

The implication for global greenhouse gas emissions of a reduced European fertilizer in-
dustry is not promising. The European industry is both the most energy efficient, and has
the most effective abatement of N_2O emissions.

EU fertilizer production is the most energy efficient

European ammonia production plants uses less energy on average per tonne of ammonia
than production plants outside the EU, cf. Figure 21. This implies that for each tonne of
production being relocated to non-EU plants, more energy will be used typically giving
rise to higher GHG emissions.

Figure 21 The EU has the highest energy efficiency in ammonia production

GJ per tonne of
ammonia, 2013
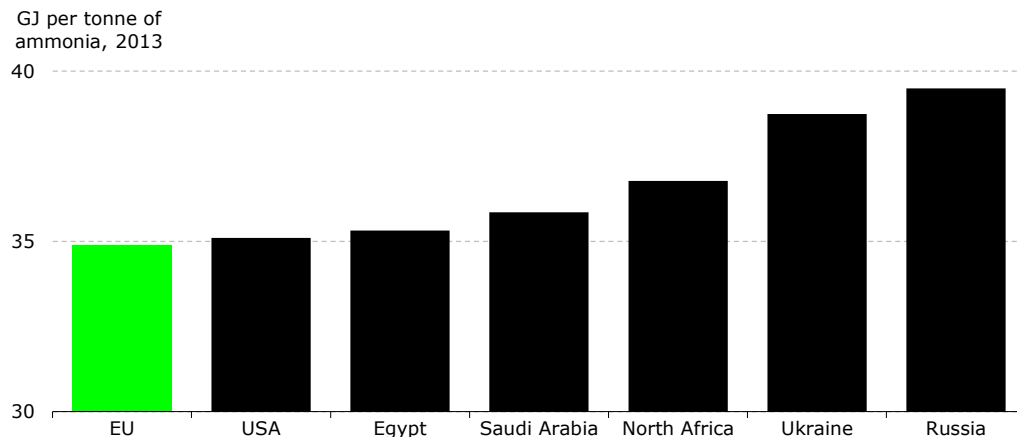
Note: Regional averages

Source: Copenhagen Economics based on data from Fertilizers Europe and Integer Research

European AN plants have already abated most N₂O emissions

As shown in Figure 8 in Section 2.2 above, the vast majority of N_2O emissions from AN production are already being abated in European production through end-of-pipe technologies. As Europe is currently the only region where carbon emissions are priced, other regions face much lower commercial and regulatory incentives to install N_2O abatement technology.[43] Consequently, relocation of production outside the EU will give rise to higher N_2O emissions per tonne of fertilizer.

European cost competitiveness may be improved over time if properly compensated in the meantime

From an economic point of view, it is inefficient to protect an industry that is not cost competitive based on true underlying economic factors. If EU industry cannot compete in the absence of an asymmetric EU climate policy, then free allowances will make no difference in the longer term.

However, the current large differences in natural gas prices, which affect the EU cost disadvantage, will not necessarily persist. In fact, several projections suggest that the cost gap might narrow in the future, cf. Figure 22. This will make EU industry more sustainable, unless insufficient ETS compensation has given rise to massive relocation in the meantime.

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[43]   See e.g. Integer Research (2011)

Figure 22 Natural gas price gap may close

€/MBtu
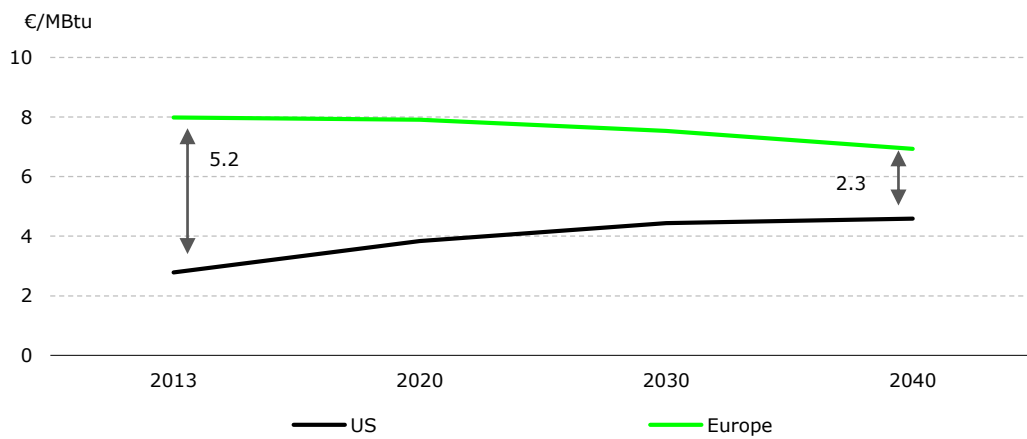
Note: Based on the 450 scenario

Source: Copenhagen Economics based on IEA (2014)

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Economics