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FINAL REPORT

FOR A STUDY ON COMPOSITION AND DRIVERS OF ENERGY PRICES AND COSTS IN ENERGY INTENSIVE INDUSTRIES: THE CASE OF THE CHEMICAL INDUSTRY - AMMONIA

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1. Ammonia

1.1 Chemical description and uses

Ammonia (NH3) is a compound composed of one nitrogen (N) and three hydrogen (H) atoms. It is usually found as a gas.

In the environment, ammonia is produced naturally through the breakdown of organic waste matter. Although intensive agricultural practices may increase the local production of ammonia (e.g. from large amounts of animal waste), this substance occurs naturally at very low levels (Health Protection Agency, 2007). Ammonia is also one of the most commonly produced industrial chemicals and is used in a diversified set of industrial sectors (see Table 1). About 80% of the global ammonia production is consumed by the fertiliser industry; specifically, 48% of the ammonia produced is deployed in the production of urea (the most commonly used nitrogen fertiliser and basic feedstock for industrial products like plastics, resins and adhesive), 11% is employed in the production of ammonium nitrate, 20% for the production of other fertilisers like ammonium sulfate, ammonium phosphate, diammonium phosphate and monoammonium phosphate and 3% is directly used as fertiliser (Potashcorp, 2013).

Table 1. Uses of Ammonia

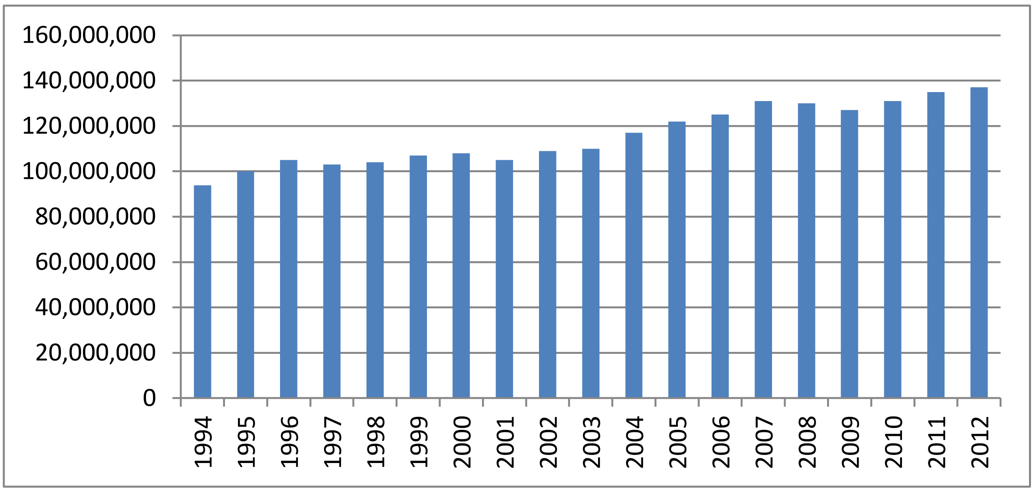
Industry	Use
Fertiliser	production of: • urea, $(NH_2)_2CO$ • ammonium nitrate, NH_4NO_3 • other fertilisers; ammonium sulfate, ammonium phosphate, diammonium phosphate, monoammonium phosphate • direct application
Chemicals	synthesis of: • nitric acid, HNO_3, which is used in making explosives such as TNT (2,4,6-trinitrotoluene), nitroglycerine which is also used as a vasodilator (a substance that dilates blood vessels) and PETN (pentaerythritol nitrate). • sodium hydrogen carbonate (sodium bicarbonate), $NaHCO_3$ • sodium carbonate, Na_2CO_3 • hydrogen cyanide (hydrocyanic acid), HCN • hydrazine, N_2H_4 (used in rocket propulsion systems)
Explosives	ammonium nitrate, NH_4NO_3
Fibres and Plastics	nylon, $-[(CH_2)_4$-CO-NH-$(CH_2)_6$-NH-CO]-,and other polyamides
Refrigeration	used for making ice, large scale refrigeration plants, air-conditioning units in buildings and plants
Pharmaceuticals	used in the manufacture of drugs such as sulfonamide which inhibit the growth and multiplication of bacteria that require *p*-aminobenzoic acid (PABA) for the biosynthesis of folic acids, anti-malarials and vitamins such as the B vitamins nicotinamide (niacinamide) and thiamine.
Pulp and Paper	ammonium hydrogen sulfite, NH_4HSO_3, enables some hardwoods to be used
Mining and Metallurgy	used in nitriding (bright annealing) steel, used in zinc and nickel extraction
Cleaning	ammonia in solution is used as a cleaning agent such as in 'cloudy ammonia'

Source: Potashcorp (2013).

1.2 Ammonia market features

Global ammonia production has been constantly growing in the last decades, peaking at 137 million tonnes in 2012 (see Figure 1).

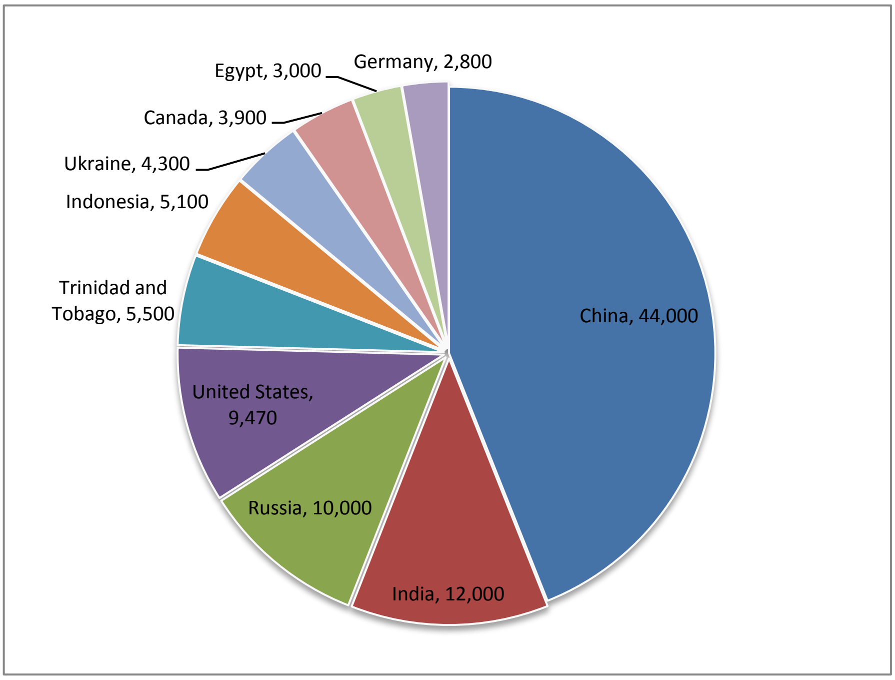
Figure 1. Global ammonia production (tonnes)



Source: Authors' elaboration on USGS (2013).

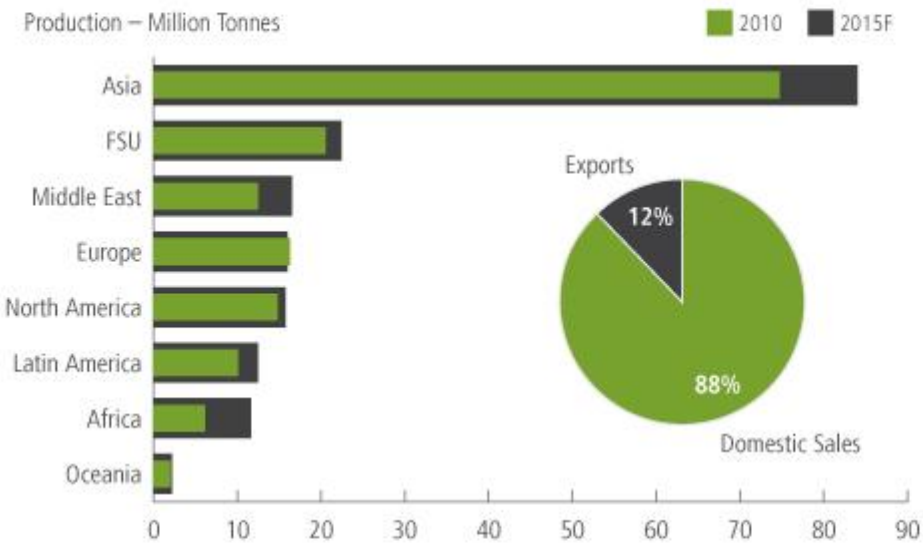
The global production of ammonia is dominated by China which was responsible for 32% of the total global production in 2012; the other major producers are India (9%), US (7%) and Russia (7%) (USGS, 2013). Figure 2 illustrates the ammonia production of the top ten global producers.

Figure 2. Top ten global ammonia producers, 2012 (k tonnes)



Source: Authors' elaboration on USGS (2013).

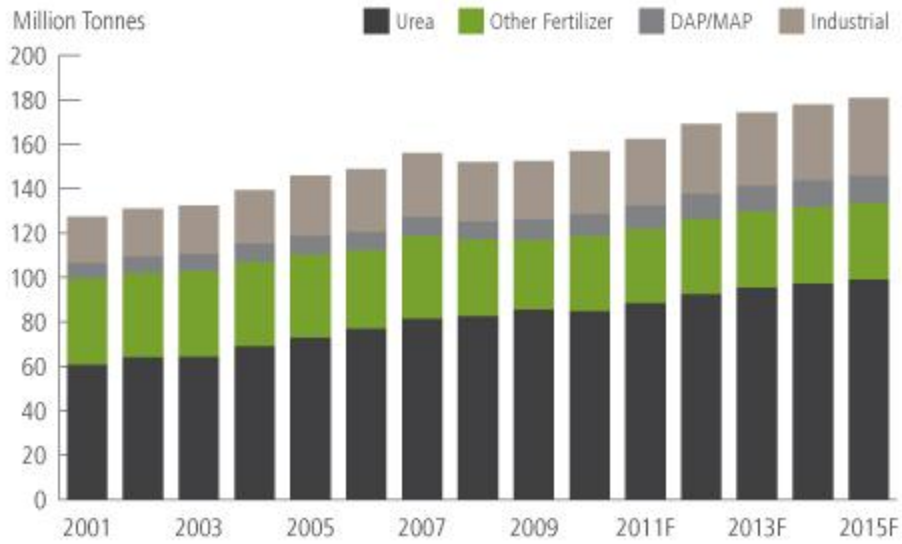
Figure 3. Ammonia sales profile



Source: Potashcorp (2013).

The two main drivers of ammonia consumption are the use in the agricultural sector and the development of applications for industrial purposes; both have determined the increase of consumption of ammonia in the last decade. Interestingly, as shown in Figure 4, the moderate drop in consumption during the recent global economic downturn (2008-2009) has been mostly triggered by a decline in the demand for industrial applications; this can be explained by the strong agricultural fundamentals in developing countries that managed to limit the fall in consumption.

Figure 4. Global ammonia consumption (mln tonnes)



Source: Potashcorp (2013).

In the EU virtually all ammonia is produced by using natural gas as a feedstock; however this is not the case in some major producers of ammonia. In particular, in China coal is still the most commonly used feedstock, while in India a mix of natural gas and naphtha is used (IEA, 2009). Natural gas is generally favoured over other feedstocks for different reasons:

its availability and ease of delivery as an inexpensive feedstock, its high hydrogen content and the relative simplicity and relative low operating costs of plants designed for natural gas (ChemSystems, 2007). Table 2 below compares the efficiency of different types of feedstock used for ammonia production.

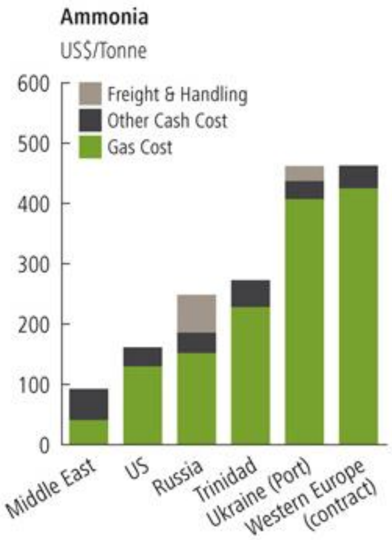
Natural gas is usually employed both as feedstock, in order to obtain the necessary hydrogen to form the chemical compound NH_3 (non-energy use of natural gas), and as fuel to provide the required energy. According to gross estimations, approximately 2/3 of consumed natural gas is used as a feedstock, while around 1/3 is used for energy purposes. Natural gas is the key cost driver for the ammonia industry as, depending on its price, it makes up approximately 70-85% of the ammonia production costs (see Figure 5).

Table 2. Feedstock comparison in ammonia production

	Natural Gas	Heavy Oil	Coal
Energy Consumption	1	1.3	1.7
Investment Cost	1	1.4	2.4
Production Cost	1	1.2	1.7

Source: EFMA (2000).

Figure 5. Ammonia production costs by geographical region



Source: Potashcorp (2013).

1.3 The ammonia production process

Large scale industrial production of ammonia has been performed since the beginning of the 20th century. The industrial process through which nitrogen gas and hydrogen gas are reacted together is called the Haber-Bosch process[1].

[1] The origin of the name comes from the German chemists Fritz Haber who discovered the process and Carl Bocsh who scaled-up the process for industrial applications. Ammonia was synthesised on an industrial scale with the Haber-Bosch process for the first time in 1913 in the BASF's Oppau plant located in Germany.

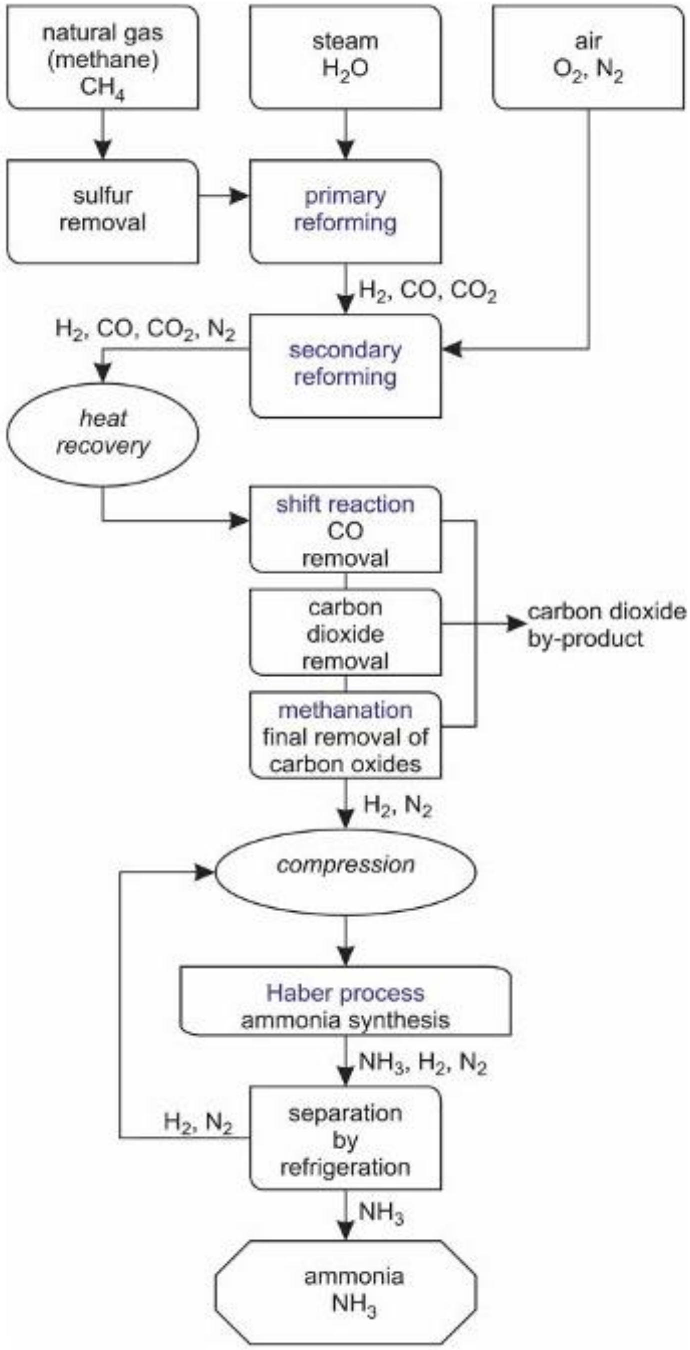
The industrial production of ammonia can be divided into two major stages: the manufacture of hydrogen and the synthesis of ammonia. The whole process requires the use of a feed stock, mainly natural gas, coal or naphtha. When coal or naphtha is used, it is first converted into methane, hydrogen and oxides of carbon.

The first stage involves the manufacture of synthesis gas as well as the removal of the carbon monoxide and production of a mixture of hydrogen and nitrogen. The latter is called *the shift reaction* and involves the release of carbon monoxide which is often liquefied and sold as coolant for nuclear power stations or for carbonated drinks (University of York, 2013).

During the second stage, the synthesis gas[2] is introduced in a so-called fixed bed reactor, at certain conditions of pressure and temperature which vary from reactor to reactor. Temperatures range from 600 to 700k, while pressures can reach up to 100 atmospheres. The reactant passes through several layers or beds of catalyst, usually potassium hydroxide, undergoing the fundamental chemical reaction of the process: $N_2 + 3H_2 <==> 2NH_3 + Heat$. Part of the synthesis gas is then converted into ammonia (NH_3) and stored, while the remaining mix of hydrogen and nitrogen is returned again into the reactor (New Zealand Institute of Chemistry, 2008).

[2] This is a mixture of nitrogen and hydrogen.

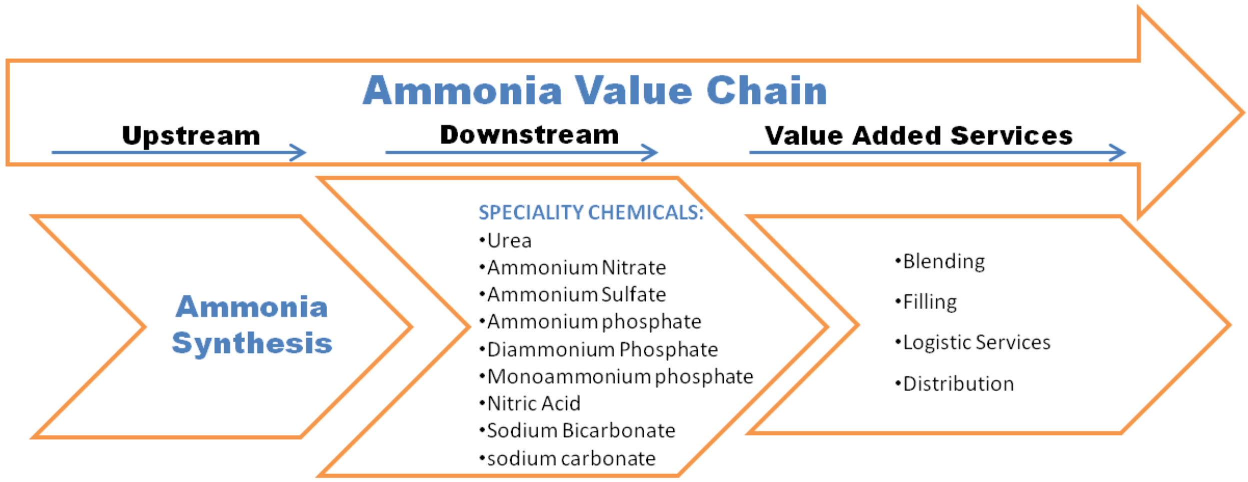
Figure 6. The Ammonia production process



Source: University of York (2013).

1.4 The ammonia value chain

Figure 7. Ammonia value chain



Source: Authors elaboration.

The ammonia value chain is highly vertically integrated. The possibility to exploit substantial economies of *scale* and *scope* determines that the largest majority of fertilisers producers synthesise "in-house" the ammonia they use as input for the following stages of production. The option of sharing production facilities for the synthesis of different types of fertilisers creates the incentive for the industry to integrate horizontally.

1.5 The EU ammonia market

The EU-27 has a total capacity for the industrial production of ammonia equal to about 21 million tonnes. The EU production is spread over 17 different member states and over a total number of 42 plants (see Table 3). Note that different ammonia production lines operating at the same site are considered to be part of the same facility[3]. The member state with the highest capacity is Germany with a total capacity of around 3.4 million tonnes per year (5 plants, 17% of EU capacity) followed by Poland with about 3.2 million tonnes (5 plants, 16 % of EU capacity), the Netherlands with 2.7 million tonnes (2 plants 13% of EU capacity), Romania with 2.1 million tonnes (6 plants, 11% of EU capacity) and France with 1.5 million tonnes (4 plants, 7% of EU capacity). The remaining ammonia production facilities are located in Lithuania, Bulgaria, UK, Belgium, Spain, Italy, Austria, Slovakia, Hungary, Czech Republic, Estonia and Greece.

[3] See section 1.6.1 for more details

Table 3. EU-27 capacity and number of plants per country, 2013

COUNTRIES	CAPACITY (k tonnes)	NUMBER OF PLANTS PER COUNTRY	% EU-27
GERMANY	3,438	5	17%
POLAND	3,210	5	16%
NETHERLANDS	2,717	2	13%
ROMANIA	2,176	6	11%
FRANCE	1,495	4	7%
LITHUANIA	1,118	1	5%
BULGARIA	1,118	3	5%
UK	1,100	3	5%
BELGIUM	1,020	2	5%
SPAIN	609	3	3%
ITALY	600	1	3%
AUSTRIA	485	1	2%
SLOVAKIA	429	1	2%
HUNGARY	383	2	2%
CZECH REP.	350	1	2%
ESTONIA	200	1	1%
GREECE	165	1	1%
TOTAL EU-27	20,613	42	100.00%

Source: Authors' elaboration on list of plants provided by Fertilizers Europe.

Table 4. EU-27 statistics on plants capacity, 2013

EU-27 statistics	
Average plants capacity (kt)	490
Median capacity (kt)	405
Highest (kt)	1700
Lowest(kt)	9
Standard deviation	326

Source: Authors' elaboration on list of plants provided by Fertilizers Europe.

1.6 Sample selection

1.6.1 Sample selection criteria

Considering that about 80% of the global ammonia production is used for the production of fertilisers (see section 1.1), this study focuses on ammonia plants that in the vast majority of cases are integrated in large installations that subsequently produce fertilisers.

During the early stages of the project the consultant acquired from the European Fertilizer Manufacturers Association (Fertilizers Europe) a list[4] including all ammonia production lines across the EU, displayed by country, location, capacity and type of feedstock. The list was compiled through data from public sources such as company websites and trade magazines. To double-check the validity of this information, plants included in the final sample were asked to provide data on exact location, capacity and production[5]. Different ammonia production lines located at the same site are treated in this study as part of the same plant. This decision was taken following consultations with the industry.

The criteria for establishing the final sample are presented below. It should be noted that before selecting the sample, a number of European ammonia producers expressed their interest in participating in the study, in collaboration with Fertilizers Europe. The research team duly took into account these expressions of interest when selecting the final sample so as to enable both an authoritative analysis and limit the risk of receiving too few questionnaires.

Geographical coverage

The geographical criterion was chosen to ensure that different EU regions are represented in the analysis and to reflect the relative weight of the member states' ammonia capacity.

Capacity of plants

To reflect different capacities, the consultant divided the total set of EU-27 plants into 3 sub-groups: those plants with a capacity equal or higher than 600.000 tonnes per year were defined as *large size*; those with a capacity higher than 400.000 t/y but strictly lower than 600.000 t/y were included in the *medium size* set; those with a capacity lower than 400.000 t/y were included in the *small size* set. According to these criteria, in the EU there are 10 large plants, 15 medium-size plants and 17 small plants.

1.6.2 Sample statistics

Based on the above criteria, out of the 42 plants located at 17 different member states, the final sample includes 10 plants from 10 different member states[6]. Concerning the size of the selected plants, 4 are defined in this study as large-size plants, 4 as medium and 2 as small. The plants selected in the sample represent altogether around 27% of the total EU-27 capacity (Table 6).

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[4] The list is not publicly available.

[5] Production data were provided for the period between 2010 and 2012 (three years).

[6] Please note that two companies which initially committed to participate in the study decided to withdraw their participation. This happened before the final version of the sample was established and has thus no impact on the validity of the results presented in this study. One of the two companies claimed that it encountered technical difficulties in completing the questionnaire due to the integration of the ammonia plant with other facilities, while the other did not provide any justification for its withdrawal.

Table 5. EU-27 statistics on plant size, 2013

EU-27 plants size	N plants	% total
Large (>600 kt)	10	24%
Medium (>=400<=600 kt)	15	36%
Small (<400 kt)	17	40%
Total	42	100%
Number of member states	17	63%

Source: Authors' elaboration on the list of plants provided by Fertilizers Europe.

Table 6. Sample statistics

		% EU-27 total
Total Capacity (kt)	5,500	27%
Sample average capacity (kt)	554	
Sample standard deviation	307	

Source: Authors' elaboration on the list of plants provided by Fertilizers Europe.

1.7 Methodology

1.7.1 Data collection

The analysis of the energy prices and costs for the ammonia sector was based on questionnaires sent to all plants included in the sample. The content of the questionnaire was discussed with ammonia industry experts to ensure that the technical specifications of the ammonia sector are properly reflected. In addition and with the help of the Chemical Industry Association (Cefic), the questionnaire was tested by one pilot plant. Strict confidentiality agreements were also signed with the companies participating in the study.

All 10 participants provided detailed figures on the level and structure of energy prices as well as on energy consumption. The data underwent a validation process e.g. through a plausibility check, and then evaluated (see section 1.7.4 below). Additionally, 7 out of the 10 sampled plants provided further data on production costs. Table 7 below presents an overview of the number of questionnaires received and used in the analysis of each section.

Table 7. Number of questionnaires received and used in each section

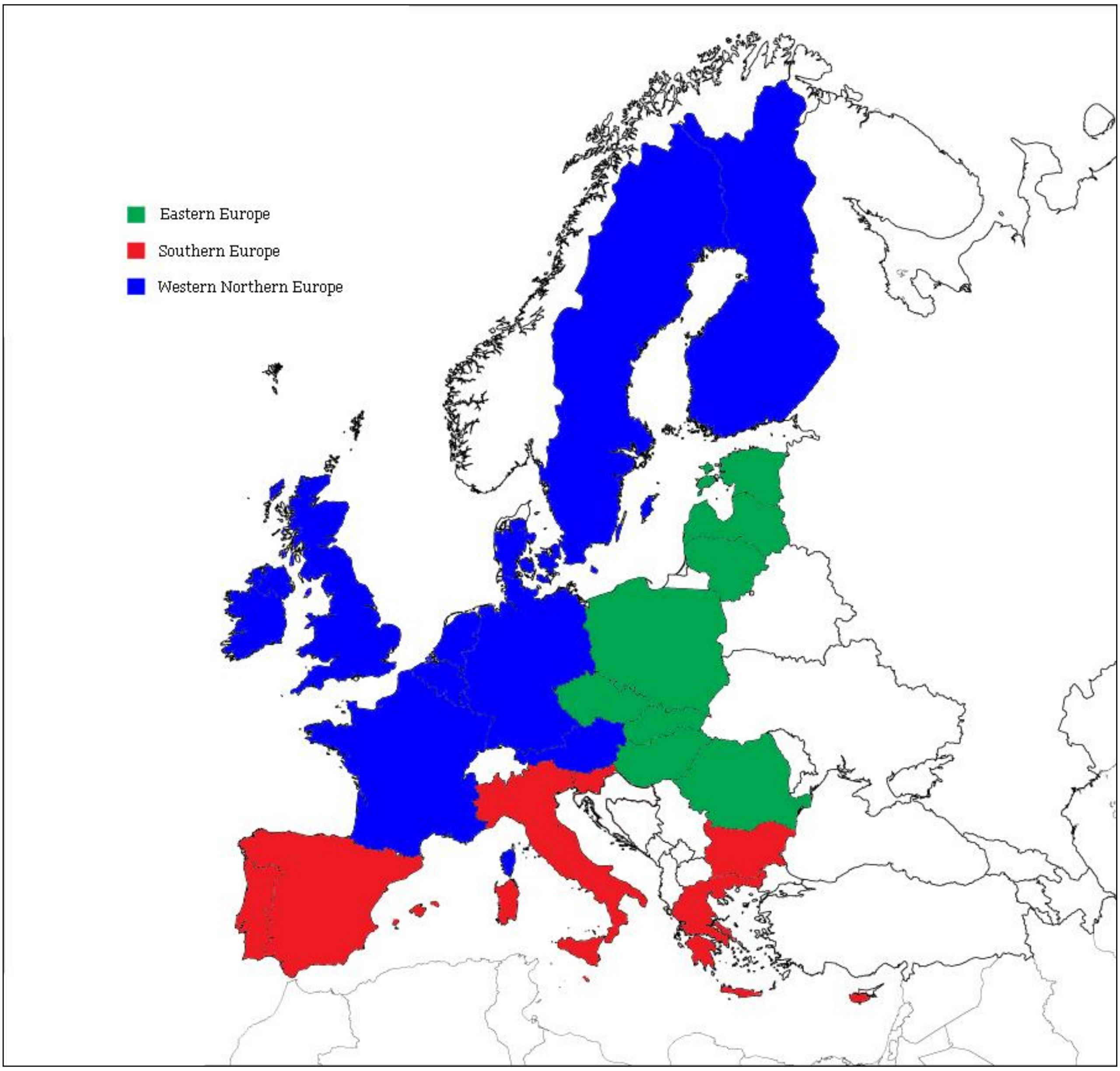
Number included in the sample	10
Energy prices trends	10
Energy bill components	10
Energy intensity	10
Indirect ETS costs	10
Production costs	7

1.7.2 Data analysis and presentation

To ensure that no information can be attributed to any specific plant, data have been aggregated together per three major EU geographical regions. As already recalled, the sample covers 10 different member states; however, the number of ammonia plants per region/country is not included in the report for confidentiality reasons and in order to avoid any risk of identifying the plants included in the study:

a. **Southern Europe** (Italy, Malta, Portugal, Greece, Slovenia, Cyprus, Spain and Bulgaria) is responsible for 12% of total EU ammonia production capacity.
b. **Western Northern Europe** (UK, France, Belgium, Ireland, Luxemburg, Sweden, Germany, the Netherlands, Finland, Denmark and Austria) is responsible 65% of total EU ammonia production capacity.
c. **Eastern Europe** (Lithuania, Romania, Czech Republic, Hungary, Estonia, Latvia, Slovakia and Poland) is responsible for 23% of total EU ammonia production capacity.

Figure 8. **EU division in major geographical regions**



Source: Own illustration.

Based on the geographical division explained above, section 1.8 presents the average energy prices paid by EU ammonia producers as well as the differences among the major EU regions. Importantly, prices represent average values of the price paid by each plant included in the sample within the region considered (Southern Europe, Eastern Europe, Western Northern Europe or EU-27). Each plant price has been weighted by a coefficient representing the specific year contribution of that plant to the total actual production of the region considered (Western Northern Europe, Southern Europe, Eastern Europe or EU-27). Section 1.9 focuses on the analysis of the energy bill components, while section 1.10 addresses the energy intensity of ammonia producers. The indirect ETS costs for ammonia producers are presented in section 1.11, while section 1.12 analyses the production costs for 7 sampled plants. Finally, section 1.13 reflects the general impressions of the participants on the current state of energy policy and markets.

1.7.3 Calculation of indirect ETS costs

The objective of the ETS cost calculations per sector in this study is to provide an estimation of the indirect ETS cost for the sub-sector between 2010 and 2012. The level of information is aggregated on a regional level, although the definition of those regions differs between cases studies.

The model for the indirect cost of EU ETS, per plant, is defined as:

Indirect costs

Indirect cost (€/Tonne of product) = Electricity intensity (kWh/Tonne of product)

** Carbon intensity of electricity (Tonne of CO_2/kWh)*

** CO_2 Price (€/Tonne of CO_2) * Pass-on rate*

Where:

- Electricity intensity of production: the amount of electricity used to produce one tonne of product. This amount is sector, plant and process specific;
- Carbon intensity of electricity generation indicates the amount of tonnes of CO2 emitted by utilities to generate one kWh;
- CO2 Price: is the average yearly market-price of CO2.
- Pass-on rate: the proportion of direct costs faced by utilities (disregarding any mitigating effects from free allocation) that they pass on to electricity consumers.

Sources:

- Electricity intensity of production; this was acquired from interviews with and questionnaires answered by industry members.
- Carbon intensity of electricity generation: the maximum regional carbon intensity of electricity is utilised, provided by the Commission's Guidelines on State aid

measures[7]. Note that these figures are not national. Member States who are highly interconnected or have electricity prices with very low divergences are regarded as being part of a wider electricity market and are deemed to have the same maximum intensity of generation (for example, Spain and Portugal).

- CO2 Price: Yearly averages of the daily settlement prices for Dec Future contracts for delivery in that year. The daily settlement prices were reported by the European Energy Exchange.

Table 8. Average yearly prices per tonne of CO2 (€)

Year	2010	2011	2012
CO_2 Price	14.48	13.77	7.56

1.7.4 Validation of information

The research team has used a combination of an internal cross-sectoral comparison of energy prices reported by all participant sectors and sub-sectors[8] and a validation through EU energy statistics publications[9]. To test consistency, the research team conducted targeted interviews with ammonia producers included in the sample. No secondary sources could be retrieved on plant-specific energy costs of ammonia producers.

The validation of the production costs for the EU ammonia industry is a complex task. Ammonia is an intermediate product which companies usually use as an input for their downstream activities. As a result, it is not possible to retrieve meaningful information from companies' balance sheet data as regards this specific product line. Nonetheless, data consistency for production costs was ensured by comparing data submitted by different producers and data submitted by the same producer for different years and asking for clarification and integrations whenever inconsistency was detected. This verification process improved the quality of the analysis and led to the exclusion of data submitted by one of the sampled companies for 2010, taking into account that the observed plant was undergoing a restructuring process and cost figures were not representative for the business as usual.

[7] Communication from the Commission: Guidelines on certain State aid measures in the context of the greenhouse gas emission allowance trading scheme post-2012 (2012/C 158/04).

[8] This refers to all 5 sub-sectors included in the study i.e. the float glass sector, the wall and floor tiles/bricks and roof tiles (ceramics sector) and the two chemicals sub-sectors (ammonia and chlorine).

[9] Validation was conducted through the EU Statistical Pocketbook for 2012 (European Commission, 2013; available at: http://tinyurl.com/latgngh; accessed: 27 October 2013) and the EU Market observatory & Statistics (available at: http://ec.europa.eu/energy/observatory/gas/gas_en.htm; accessed: 15 September 2013).

1.8 Energy prices trends

1.8.1 Introduction

This section will focus on the energy prices for the ammonia industry, namely natural gas and electricity prices. Table 9 below summarises the share of natural gas and electricity costs in total energy costs and total production costs, respectively. As shown in the table, natural gas dominates the total production costs and is thus a key cost driver for the sampled ammonia producers. Natural gas and electricity collectively account for the vast majority of total energy costs. Note that the energy prices presented in this section are delivered at plant excluding VAT; hence include possible exemptions[10] from taxes, levies or transmission costs. All values presented in this section are weighted averages that have been calculated on the basis of actual production.

Table 9. Share of natural gas and electricity in total energy costs and total production costs[11]

	Share in total energy costs, %	Share in total production costs, %
Natural gas	90-94%	80-88%
Electricity	4-8%	3-6%

Source: Author's elaboration based on data from questionnaires.

1.8.2 Natural gas

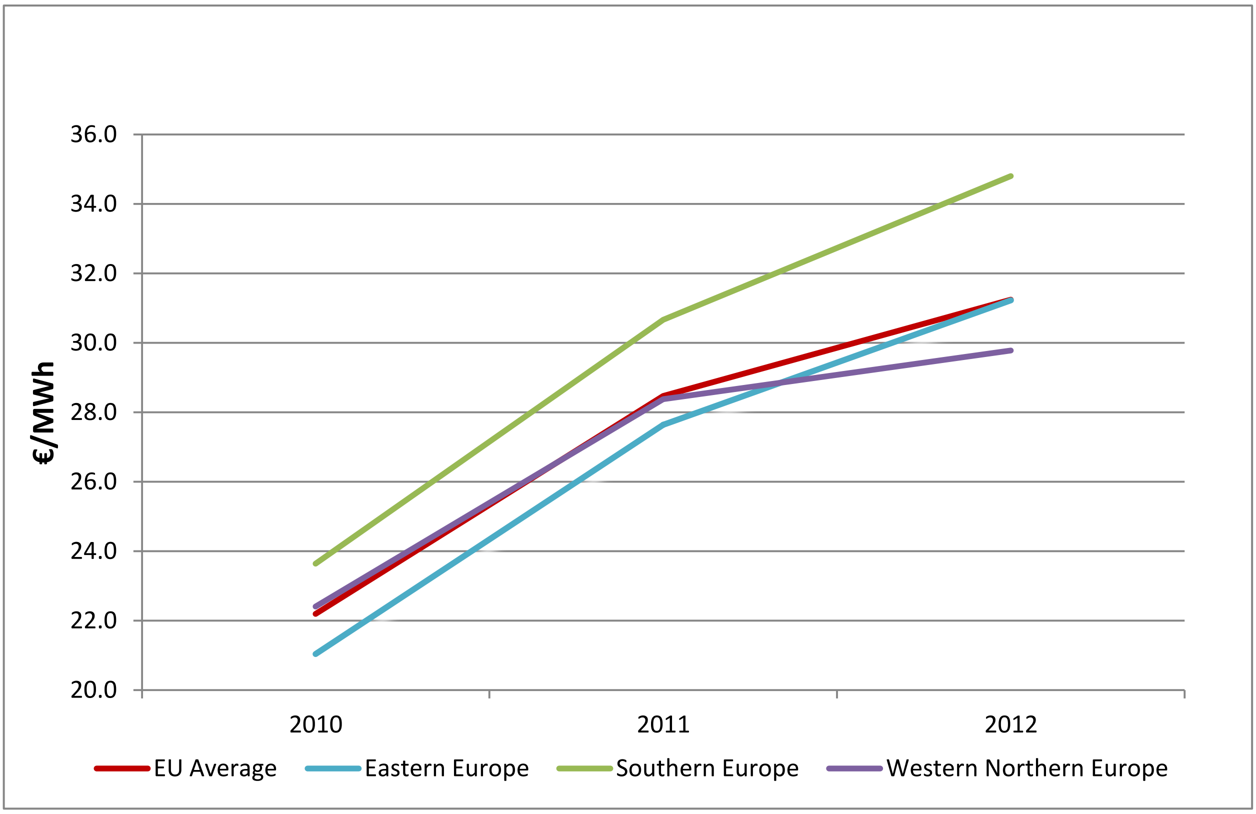
1.8.2.1 General trends

There is an upward trend in the prices of natural gas paid by EU ammonia producers (Figure 9). The EU average price rose by about 28% between 2010 and 2011 and by 9.5% between 2011 and 2012. Between 2010 and 2012, the average EU price for the ammonia industry rose by 40.5%, i.e. from 22.2 €/MWh to 31.2 €/MWh. Table 10 provides an overview of the natural gas prices for the sampled EU producers.

[10] Notably, five out of 10 participants mentioned that they are entitled to reductions/exemptions from network tariffs, taxes or levies.

[11] The figures on the share of natural gas and electricity costs in total energy costs represent averages for the full sample (ten plants). The figures on the share of natural gas and electricity costs in total production costs represent averages for the seven plants (see section 1.12 for more details) that provided data on production costs and thus have a lower representativeness.

Figure 9. Natural gas prices paid by EU ammonia producers, (€/MWh)



Source: Author's elaboration based on data from questionnaires.

Table 10. Descriptive statistics for natural gas prices paid by sampled EU ammonia producers (€/MWh)

	2010	2011	2012
EU (average)	22.2	28.5	31.2
Eastern Europe (average)	21	27.6	31.2
Southern Europe (average)	23.6	30.7	34.8
Western Northern Europe (average)	22.4	28.4	29.8

Source: Author's calculation based on data from questionnaires.

Figure 10. Natural gas prices paid by EU ammonia producers (box plots), (€/MWh) [Confidential]

1.8.2.2 Regional differences

Southern Europe

For the whole period - 2010 to 2012 - ammonia plants in Southern Europe were exposed to the highest average natural gas price among the three addressed regions. The average price rose by 47%, i.e. from 23.6 €/MWh in 2010 to 34.8 €/MWh in 2012.

Eastern Europe

From 2010 to 2012, natural gas prices rose from 21 €/MWh in 2010 to 31.2 €/MWh representing an increase of around 49%, the sharpest increase across the three sub-regions considered in this study. In the period 2010-2011, they rose by 31% and between 2011-2012 by 13%.

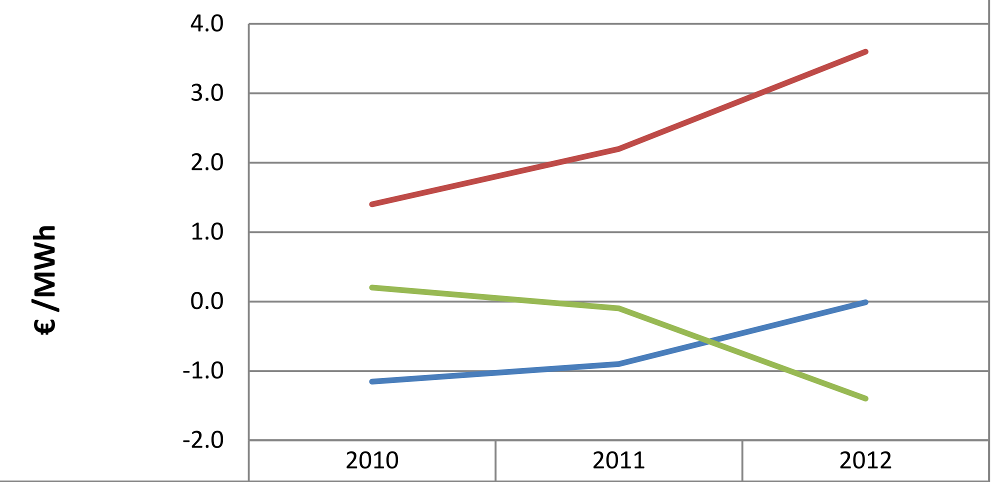
Western Northern Europe

In 2012, the average natural gas price in Western Northern Europe was lower than the EU average and the two other regional average prices. During the whole period - 2010 to 2012 - the average price increased by 33% with an increase of approximately 27% from 2010 to 2011 and 5% during the following year.

Regional gaps

Figure 11 below provides a graphical representation of the evolution of the gaps between the EU average price and the three regional average prices. The gap between the EU average and Southern Europe has consistently been the largest, while ammonia producers in Southern Europe have constantly paid a higher average price than the EU average: in 2010, producers were paying on average 1.4 €/MWh more than the EU average price; in 2012 this gap more than doubled reaching the value of 3.6 €/MWh. This is different when comparing the EU average with Western Northern Europe: while in 2010 the gap between the average natural gas price in this region and the EU average was +0.2 €/MWh, in 2012 this value reached -1.4 €/MWh. As for Eastern Europe, the gap between the average natural gas price in this region and the EU average steadily diminished between 2010 and 2012.

Figure 11. Regional gaps of natural gas price with EU average, (€/MWh)



	2010	2011	2012
Eastern Europe	-1.2	-0.9	0.0
Southern Europe	1.4	2.2	3.6
Western Northern Europe	0.2	-0.1	-1.4

Source: Author's elaboration based on data from questionnaires.

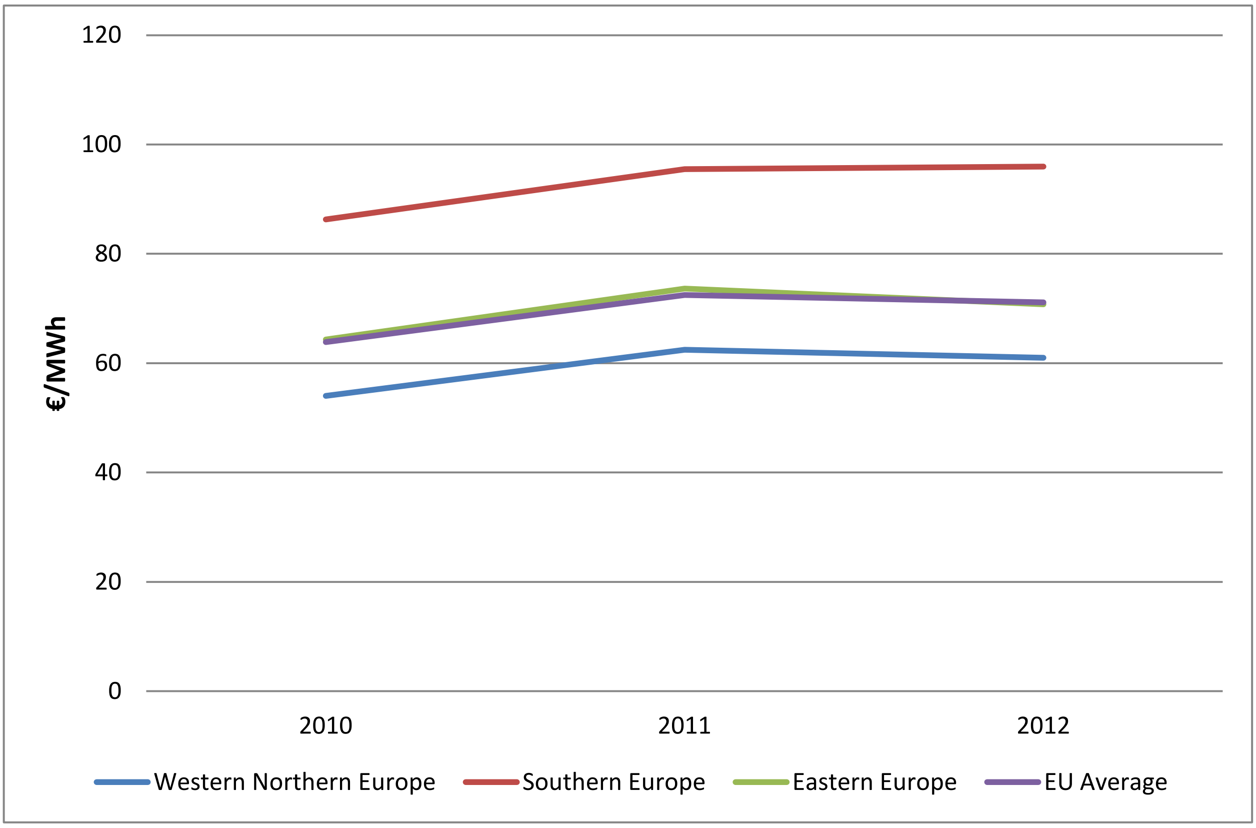
1.8.3 Electricity

1.8.3.1 General trends

Between 2010 and 2012 prices increased from 63.9 €/MWh to 71.1€/MWh; this represents an increase of approximately 11%. In more detail, the EU average electricity price paid by ammonia producers increased by about 13.5% between 2010 and 2011, while it decreased by 1.9% during the following year. Table 11 provides an overview of the electricity prices for the sampled EU ammonia producers[12].

[12] Please note that for 2012 the sample has been reduced to 9 plants, after the validation of all data points.

Figure 12. Electricity prices paid by EU ammonia producers, (€/MWh)



Source: Author's elaboration based on data from questionnaires.

Table 11. Descriptive statistics for electricity prices paid by sampled EU ammonia producers (€/MWh)

	2010	2011	2012
EU (average)	63.9	72.5	71.1
Eastern Europe (average)	64.3	73.6	70.7
Southern Europe (average)	86.3	95.5	96
Western Northern Europe (average)	54	62.4	61

Source: Author's calculation based on data from questionnaires.

Figure 13. Electricity prices paid by EU ammonia producers (box plots), (€/MWh) [Confidential]

1.8.3.2 Regional differences

Southern Europe

Similar to natural gas, ammonia plants in Southern Europe were exposed to the highest average electricity price among the three regions during the whole period of observation. Between 2010 and 2012 the prices increased from 86.3 €/MWh to 96 €/MWh (+11%).

Eastern Europe

Electricity prices in Eastern Europe are almost coincident with average EU prices. For the whole period - 2010 to 2012 - they rose by around 10%, i.e. from 64.3 €/MWh to 70.7 €/MWh. Between 2010 and 2011 they increased by 14.5%, while from 2011 to 2012 they decreased by 3.9%.

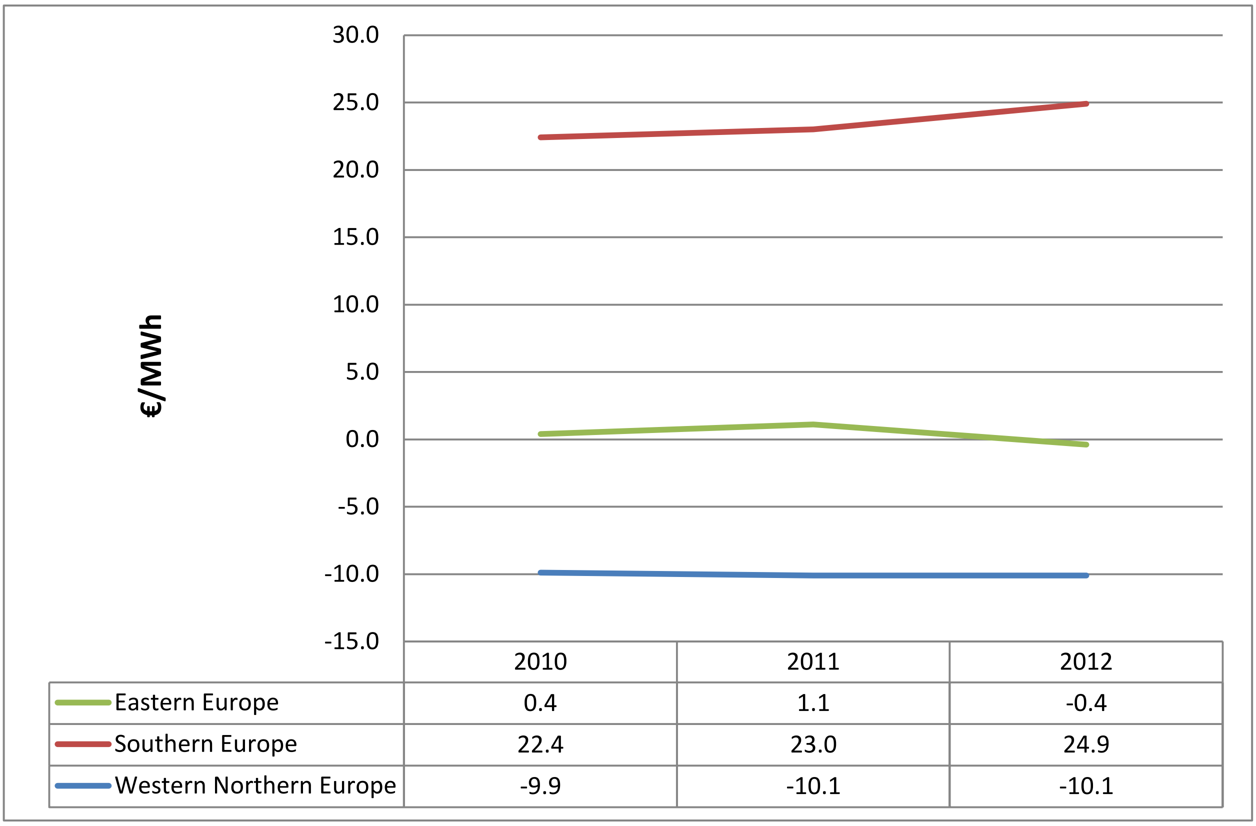
Western Northern Europe

Ammonia producers in Western Northern Europe paid lower electricity prices than the EU average during all the three years covered by this study. Prices in this region increased by about 13% between 2010 and 2012, from 54 €/MWh to 61 €/MWh; specifically, they increased by 15.5% between 2010 to 2011, while during the following year they decreased by 2.2%.

Regional gaps

Figure 14 below provides a graphical representation of the evolution of the gaps between the EU average electricity price paid by ammonia producers and the three regional average prices. Similar to natural gas, the difference between the EU average and Southern Europe has consistently been the largest: in 2010, Southern European producers were paying on average 22.4 €/MWh more than the EU average price; in 2012 this gap reached the value of 24.9 €/MWh. In contrast, ammonia producers from Western Northern Europe paid in 2010 9.9 €/MWh less than the EU average, and this value remained almost stable between 2010 and 2012. As for the Eastern European producers, they paid prices that were very close to the EU average, except for the year 2011 when the prices were slightly higher (+1.1 €/MWh).

Figure 14. Regional gaps of electricity price with EU average, (€/MWh)



	2010	2011	2012
Eastern Europe	0.4	1.1	-0.4
Southern Europe	22.4	23.0	24.9
Western Northern Europe	-9.9	-10.1	-10.1

Source: Author's elaboration based on data from questionnaires.

1.9 Analysis of energy bills components

1.9.1 Introduction

In order to better understand the price developments, sections 1.9.2 and 1.9.3 present the breakdown (in €/MWh and percentages, respectively) of the different components of the natural gas and electricity bills for the sampled EU ammonia producers: i) energy component, ii) grid fees, iii) RES levy and iv) other non-recoverable taxes.

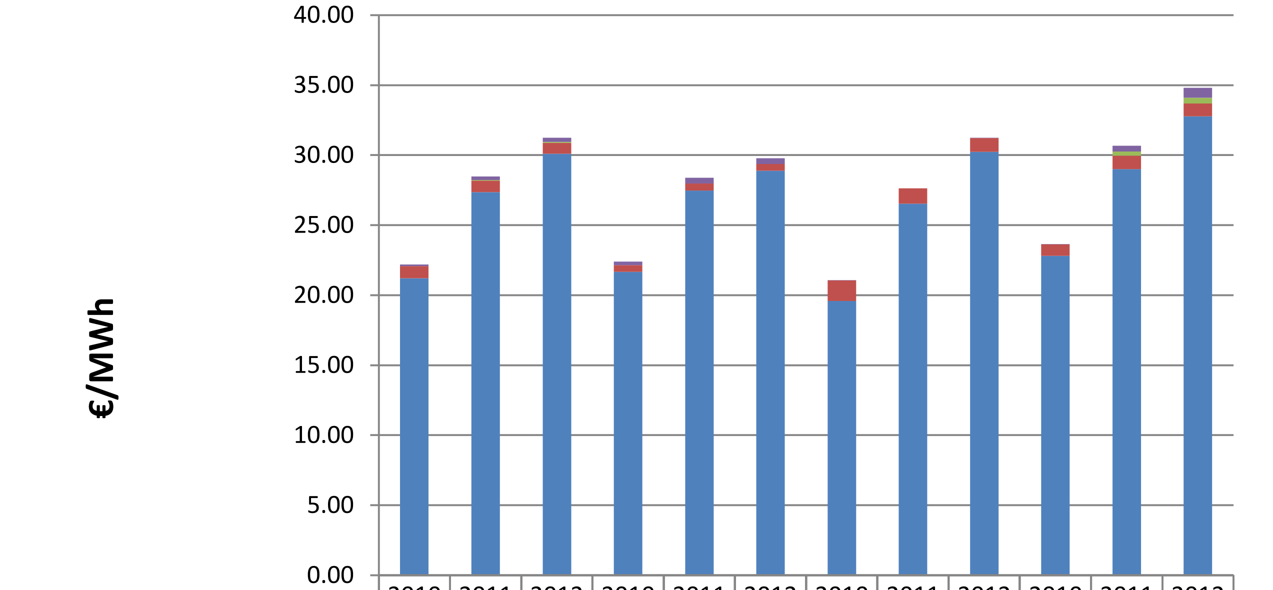
1.9.2 Natural gas

1.9.2.1 General trends

As shown in Figure 15, the natural gas bill[13] is dominated by far by the energy component, which makes up more than 90% of the total bill. In 2010, the energy component accounted for 95.5% of natural gas bill; this figure increased to 96.1% in 2011 and to 96.4% in 2012. Note that between 2010 and 2012, the absolute value of the energy component increased by about 42% (from 21.2 to 30.1 €/MWh).

[13] Please note that in some of the legal systems covered by the sample, gas consumption is subject to a RES levy.

Figure 15. Components of the natural gas bill paid by EU ammonia producers (€/MWh)

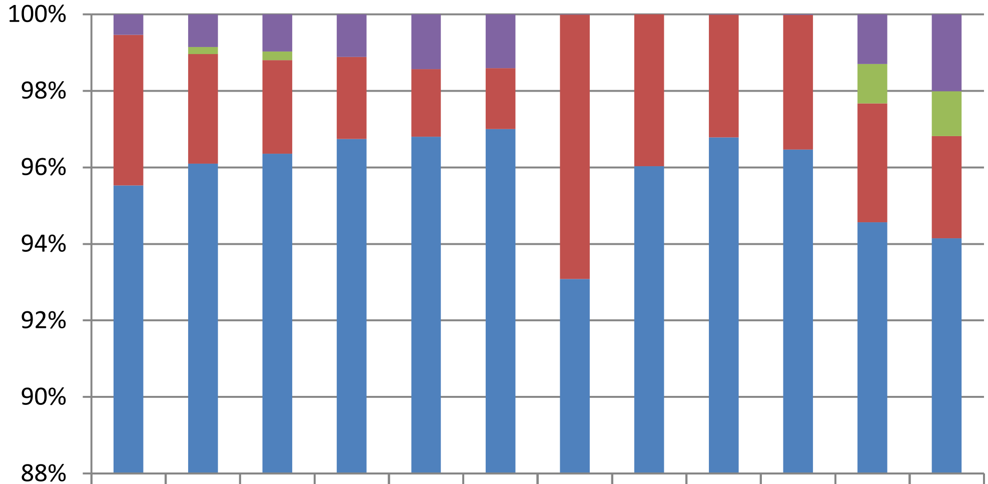


	EU average			Western Northen Europe			Eastern Europe			Southern Europe		
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
Other non-recoverable taxes	0.12	0.24	0.30	0.25	0.41	0.42	0.00	0.00	0.00	0.00	0.40	0.70
RES levy	0.00	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.41
Grid fees	0.87	0.82	0.76	0.48	0.50	0.47	1.45	1.10	1.00	0.83	0.95	0.93
Energy component	21.20	27.36	30.10	21.67	27.47	28.89	19.58	26.54	30.23	22.81	29.00	32.76

Source: Data from questionnaires.

Other price components accordingly represent a small part of the overall bill. Starting with the category of other non-recoverable taxes, their share in the total natural gas bill increased from 0.5% in 2010 to 0.9% in 2011 and to 1% in 2012. This represents an increase in absolute values between 2010 and 2012 from 0.12 to 0.3 €/MWh. On the contrary, the impact of grid fees on the total bill decreased from 3.9% in 2010 to 2.9% in 2010 and to 2.4% in 2012. This represents a decrease in absolute values from 0.87 €/MWh in 2010 to 0.76 €/MWh in 2012. RES levies were introduced in 2011; however, their share in the total bill is small (0.2% in both 2011 and 2012).

Figure 16. Components of the natural gas bill paid by EU ammonia producers (in %)



	EU average			Western Northen Europe			Eastern Europe			Southern Europe		
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
Other non-recoverable taxes	0.5%	0.9%	1.0%	1.1%	1.4%	1.4%	0.0%	0.0%	0.0%	0.0%	1.3%	2.0%
RES levy	0.0%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.2%
Grid fees	3.9%	2.9%	2.4%	2.1%	1.8%	1.6%	6.9%	4.0%	3.2%	3.5%	3.1%	2.7%
Energy component	95.5%	96.1%	96.4%	96.7%	96.8%	97.0%	93.1%	96.0%	96.8%	96.5%	94.6%	94.1%

Source: Data from questionnaires.

1.9.2.2 Regional differences

Southern Europe

In Southern Europe the energy component increased in absolute terms from 22.81€/MWh in 2010 to 29€/MWh in 2011 and to 32.76 €/MWh in 2012. However, the share of the energy component in the total bill decreased somewhat from 96.5% in 2010 to 94.6% in 2011 and to 94.1% in 2012. This small decrease in the share of energy component and grid fees in the total bill is owed to the introduction of non-recoverable taxes and RES levies. In 2011, other non-recoverable taxes for ammonia producers were introduced and rose from 1.3% in 2011 to 2%[14] in 2012. RES levies were also introduced in this region in 2011; however, compared to non-recoverable taxes, their contribution in the total bill remains small (1% in 2011 and 1.2% in 2012). Southern Europe is the only region where ammonia producers pay RES levies in the gas bill.

The share of grid fees in the total natural gas prices decreased from 3.5% in 2010 to 3.1% in 2011 and to 2.75% in 2012. In absolute terms their value however increased by around 12% between 2010 and 2012 (from 0.83 to 0.93 €/MWh).

[14] The absolute value on other non-recoverable taxes increased from 0.4 to 0.7 €/MWh between 2011 and 2012.

Eastern Europe

Compared to the other two regions, Eastern Europe has seen the most significant increase in the cost level of energy component. Specifically, the energy component increased from 19.58 €/MWh (93.1% of total bill) in 2010 to 26.54 €/MWh (96% of total bill) in 2011 and to 30.23 €/MWh (96.8% of total bill) in 2012. In parallel, the grid fees decreased from 1.45 €/MWh (6.9% of total bill) in 2010 to 1.1 €/MWh (4% of total bill) in 2011 and to 1 €/MWh (3.2% of total bill) in 2012. Ammonia producers in this region pay neither non-recoverable taxes nor RES levies.

Western Northern Europe

Ranging from 96.7% in 2010 to 97% in 2012, the share of the energy component in the total natural gas bill remained almost stable in Western Northern Europe. Although in absolute terms grid fees were rather stable[15], the contribution of grid fees in the total bill decreased from 2.1% in 2010 to 1.8% in 2011 and to 1.6% in 2012. The share of non-recoverable taxes increased from 1.1% in 2010 to 1.4% in 2011 and remained stable between 2011 and 2012. There were no RES levies.

1.9.3 Electricity

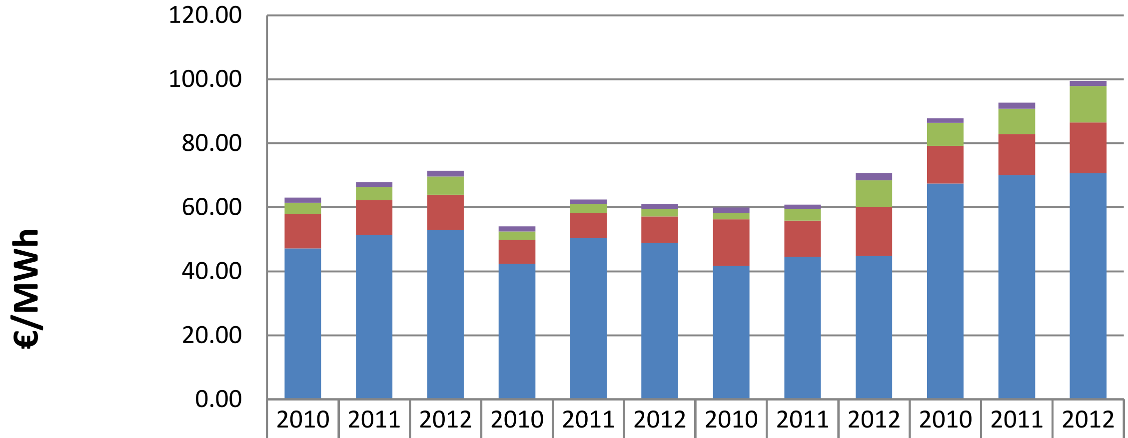
1.9.3.1 General trends

Although the energy component represents the dominant component of the electricity bill, its share in the total electricity price is less significant compared to natural gas. In 2010, the energy component amounted for 74.8% of the electricity price; this figure increased to about 75.8% in 2011 and then decreased to 74.1% in 2012. However, in absolute terms the energy component has steadily increased: from 47.1 €/MWh in 2010 to 51.36 €/MWh in 2011 and to 52.91 €/MWh in 2012[16].

[15] Specifically, their value was 0.48 €/MWh in 2010, 0.5 €/MWh in 2011 and 0.47 €/MWh in 2012.

[16] Please note that for one plant the energy component also includes network costs; however, this has a negligible impact on the various averages herein reported. Please also note that for one plant the electricity price (thus also the various components) for 2012 as well as the values of RES levy for 2010-2012 are missing. For another plant, the RES levy could be disentangled from network costs based on public sources. In view of the aforementioned, there are some divergences between the average electricity prices reported in section 1.8.3.1 and the total values of all components of the electricity bill presented in this section.

Figure 17. Components of the electricity bill paid by EU ammonia producers (€/MWh)

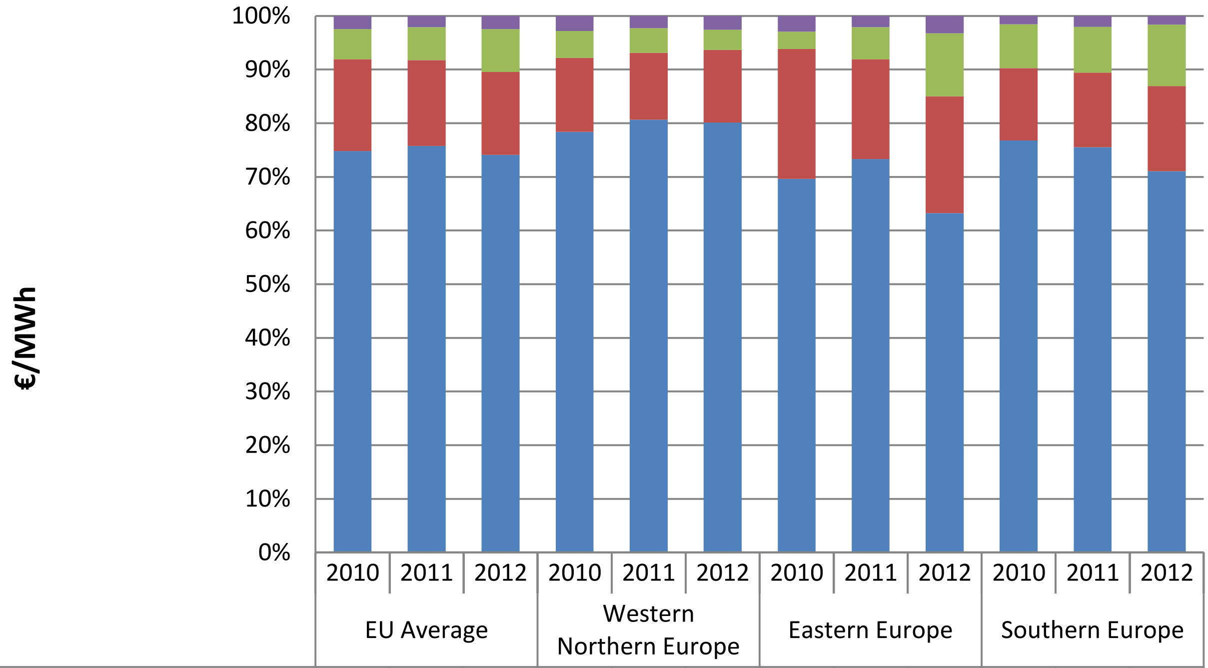


	EU Average			Western Northern Europe			Eastern Europe			Southern Europe		
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
Other non-recoverable taxes	1.58	1.45	1.75	1.54	1.43	1.57	1.75	1.28	2.30	1.37	1.92	1.64
RES Levy	3.53	4.13	5.70	2.68	2.87	2.29	1.95	3.63	8.33	7.17	7.91	11.37
Grid Fees	10.78	10.84	11.05	7.44	7.80	8.29	14.51	11.32	15.38	11.83	12.87	15.82
Energy component	47.10	51.36	52.91	42.37	50.36	48.86	41.69	44.56	44.73	67.40	70.01	70.65

Source: Data from questionnaires.

Regarding the other price components, the share of other non-recoverable taxes in the total bill remained stable between 2010 and 2012. Their value was also rather stable in absolute terms, as it moved between 1.58 €/MWh and 1.75 €/MWh. The contribution of RES levies in the total bill has steadily increased: from 5.6% in 2010 to 6.1% in 2011 and to 8% in 2012. In absolute terms, their value also increased from 3.53 €/MWh in 2010 to 4.13 €/MWh in 2011 and to 5.7 €/MWh in 2012. As for the grid fees, their impact on the total bill decreased from 17.1% in 2010 to 15.5% in 2012. Their absolute value remained almost stable between 2010 and 2012.

Figure 18. Components of the electricity bill paid by EU ammonia producers (in %)



	EU Average 2010	EU Average 2011	EU Average 2012	Western Northern Europe 2010	Western Northern Europe 2011	Western Northern Europe 2012	Eastern Europe 2010	Eastern Europe 2011	Eastern Europe 2012	Southern Europe 2010	Southern Europe 2011	Southern Europe 2012
Other non-recoverable taxes	2.5%	2.1%	2.5%	2.9%	2.3%	2.6%	2.9%	2.1%	3.2%	1.6%	2.1%	1.7%
RES Levy	5.6%	6.1%	8.0%	5.0%	4.6%	3.8%	3.2%	6.0%	11.8%	8.2%	8.5%	11.4%
Grid Fees	17.1%	16.0%	15.5%	13.8%	12.5%	13.6%	24.2%	18.6%	21.7%	13.5%	13.9%	15.9%
Energy component	74.8%	75.8%	74.1%	78.4%	80.6%	80.1%	69.6%	73.3%	63.2%	76.8%	75.5%	71.0%

Source: Own calculation based on questionnaires.

1.9.3.2 Regional differences

Southern Europe

Southern Europe is the region with the highest impact of RES levies on the total energy bill, except for the year 2012 when the share of RES levies in the total bill in Eastern Europe was slightly higher (11.8% vs 11.4%). The absolute value of RES levies in Southern Europe increased from 7.17 €/MWh in 2010 to 11.37 €/MWh in 2012. The level of the energy component also increased from 67.4 €/MWh in 2010 to 70.65 €/MWh in 2012; however, during the same period its impact on the bill decreased from 76.8% to 71%. As for the grid fees, their value increased from 11.83 €/MWh to 15.82 €/MWh, while their contribution to the bill also rose from 13.5% in 2010 to 15.9% in 2012. The contribution of other non-recoverable taxes to the total bill remained rather stable from 2010 to 2012.

Eastern Europe

As shown in Figures 17 and 18, the impact of the energy component on the total bill in Eastern Europe is the lowest among the three addressed regions during the three year-period studied, while its value increased from 41.69 €/MWh in 2010 to 44.73 €/MWh (+7.3%) in 2012. In contrast, the share of the grid fees in the total bill in Eastern Europe is the highest among the three regions. The value of RES levies in this region has increased substantially from 1.95 €/MWh in 2010 to 8.33 €/MWh in 2012, while their contribution to the bill also increased from 3.2% in 2010 to 11.8% in 2012. The absolute value of other non-recoverable taxes increased from 1.75 €/MWh in 2010 to 2.3 €/MWh in 2012, while their impact on the bill increased from 2.9% to 3.2%.

Western Northern Europe

Augmenting from 78.4% in 2010 to 80.1% in 2012, the share of the energy component in the total bill in Western Northern Europe is the highest among all three regions during the three-year period covered by this study. Although in absolute terms grid fees increased from 7.44 €/MWh in 2010 to 8.29 €/MWh in 2012, their impact on the total bill remained almost stable. The contribution of RES levies to the total bill decreased from 5% in 2010 to 3.8% in 2012; in absolute terms they also decreased from 2.68 €/MWh to 2.29 €/MWh. The absolute value of non-recoverable taxes increased from 1.54 €/MWh in 2010 to 1.57 €/MWh in 2012, while their contribution to the electricity price decreased from 2.9% to 2.6%.

1.10 Energy intensity

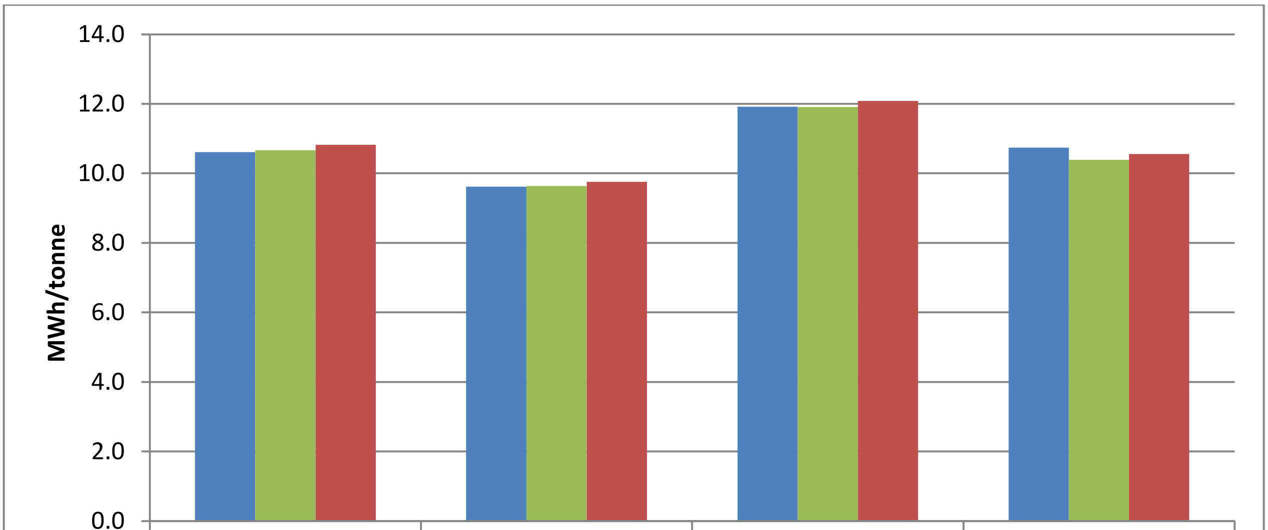
This section addresses the energy intensity of sampled ammonia plants in terms of physical output (unit: MWh/tonne). The analysis focuses on natural gas which dominates the energy consumption of the sampled producers; specifically, the average share of natural gas consumption in total energy consumption was about 94%[17] during all three years considered in the study. The figures presented below are based on the natural gas consumption data and ammonia production levels provided by all 10 sampled ammonia producers.

1.10.1 General trends

Figure 19 below illustrates the energy intensity per tonne of ammonia product of the sampled EU ammonia plants. All presented figures are weighted averages that have been calculated on the basis of actual production. Ranging from 10.6 MWh/tonne in 2010 to 10.8 MWh/tonne in 2012, the average intensity of EU natural gas consumption has increased moderately (+1.9%). It should be noted that 6 out of 10 participants reported that they have made energy efficiency investments in recent years, mainly triggered by energy cost savings considerations; however, this is not reflected in the energy efficiency data for the addressed period (2010-2012).

[17] Ranging from 94.1% in 2010 to 94.2% in 2012. Regarding the remaining energy sources, all participants used electricity in addition to natural gas, while four producers also used steam.

Figure 19. Natural gas intensity of EU ammonia producers (MWh/tonne)



	EU average	Western Northern Europe	Eastern Europe	Southern Europe
2010	10.6	9.61	11.92	10.74
2011	10.7	9.64	11.91	10.39
2012	10.8	9.75	12.08	10.56

Source: Author's elaboration based on data from questionnaire

1.10.2 Regional differences

Eastern Europe

Eastern Europe has the highest average natural gas intensity (i.e. lowest average energy efficiency) among all three regions considered in this study. This is the only region where average natural gas intensity is higher than the EU average. The average natural gas intensity increased from 11.92 MWh/tonne in 2010 to 12.08 MWh/tonne in 2012 (+1.3%). For the whole period - 2010 to 2012 - the average natural gas prices in Eastern Europe were close to the EU average.

Western Northern Europe

Western Northern Europe had the lowest average natural gas intensity (i.e. highest average energy efficiency) during the three-year period covered by this study; however the average intensity increased from 9.61 MWh/tonne tonne in 2011 to 9.75 MWh/tonne in 2012 (+1.5%). As described in section 1.8.2, the average natural gas price paid by ammonia producers in this region was lower than the EU average.

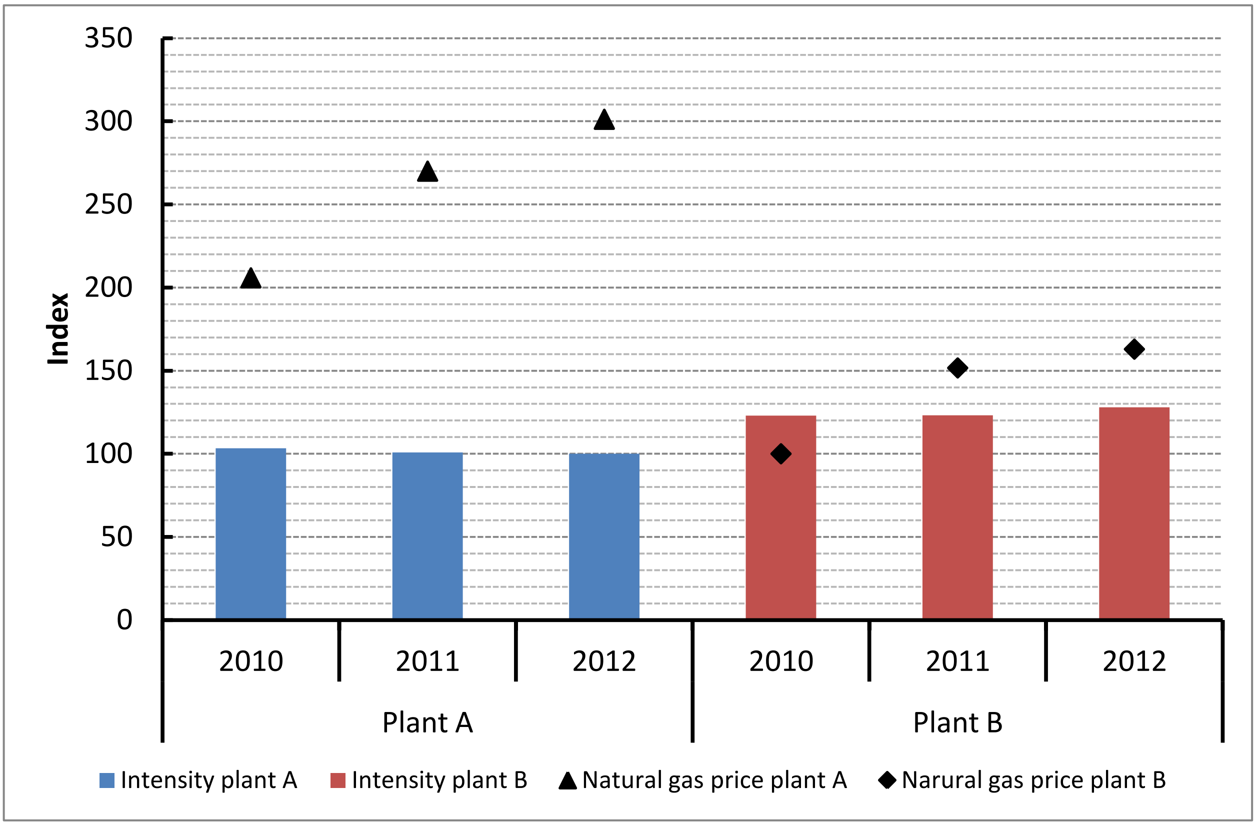
Southern Europe

Compared to the other two regions, the average energy intensity in Southern Europe is closest to the EU average. Between 2010 and 2012, the average intensity decreased from 10.74 MWh/tonne to 10.56 MWh/tonne (-1.7%). Notably, ammonia producers in Southern Europe faced the highest natural gas price among the three addressed regions.

1.10.3 Plant case study

Figure 20 below illustrates the different natural gas intensities of two sampled plants of comparable capacity. Plant A has a lower natural gas intensity (i.e. higher energy efficiency) which decreased by approximately 3.3% between 2010 and 2012. Plant B has a higher natural gas intensity (i.e. lower energy efficiency), which increased by 4% between 2010 and 2012. As shown in the figure, Plant A, which has a higher energy efficiency, pays significantly higher natural gas prices[18] during all three years addressed in this study than Plant B, which has a lower energy efficiency[19].

Figure 20. Natural gas intensity and natural gas prices of two EU plants (indexed values, lowest value = 100)



Source: Author's elaboration based on data from questionnaire

1.11 Indirect ETS costs

1.11.1 Results

The calculation of indirect ETS costs for the ammonia industry was based on the electricity consumption and total production figures provided by the sampled EU ammonia producers as well as on the maximum regional CO2 emission factors of electricity

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[18] Figure 20 presents the natural gas intensity and natural gas prices of the two plants in relative (indexed) terms.

[19] Please note that no general conclusions can be drawn from this comparison of two individual plants.

generation and price of emission allowances (see also 1.7.3). Tables 12, 13 and 14 summarise the indirect costs borne by EU ammonia producers, using different pass-on rates.

Table 12. Ammonia indirect costs, averages per region (Euro/tonne of ammonia)

	Western Northern Europe	Eastern Europe	Southern Europe
2010	1.46	1.58	0.77
2011	1.59	1.61	0.72
2012	0.70	0.85	0.39

Pass-on rate: 0.6

Table 13. Ammonia indirect costs, averages per region (Euro/tonne of ammonia)

	Western Northern Europe	Eastern Europe	Southern Europe
2010	1.94	2.11	1.02
2011	2.12	2.15	0.97
2012	0.94	1.13	0.52

Pass-on rate: 0.8

Table 14. Ammonia indirect costs, averages per region (Euro/tonne of ammonia)

	Western Northern Europe	Eastern Europe	Southern Europe
2010	2.43	2.64	1.28
2011	2.66	2.68	1.21
2012	1.17	1.41	0.65

Pass-on rate: 1

Three plants in this sample used long term electricity contracts to acquire electricity; one from Eastern Europe and one from Southern Europe acquired 100% of their electricity via a long term contract, while one Western Northern European plant still relied on the wholesale market for 25% of its electricity. In addition one Eastern European plant covered around 10% of their electricity consumption with self-generated power.

Electricity that is acquired via a contract pre-dating the establishment of the EU ETS or is self-generated is not taken into account for the calculation of indirect ETS costs.

The drop in indirect-ETS costs across all regions between 2011 and 2012 can be largely attributed to a sharp decrease in EUA prices (from a yearly average of 13.77 Euros per EUA in 2011 to a yearly average of 7.56 Euros per EUA in 2012).

There are large inter-regional differences in indirect costs, caused by two distinct factors:

- the maximum regional CO_2 emissions factor[20], which is lowest in Southern Europe and highest in Eastern Europe and
- differences in electricity intensities between plants. Ammonia plants in Eastern Europe consume on average circa 0.33 MWh/tonne of ammonia, compared with circa 0.20 in Western Northern Europe and circa 0.18 in Southern Europe.

1.11.2 Key findings

1) The inter-regional differences are relatively large.

   Indirect ETS costs in Eastern Europe are higher than those in the other regions, caused largely by significantly higher electricity intensity of production for two out of three plants in the Eastern European region.

   The difference between Eastern Europe and Western Northern Europe is relatively limited because the number of plants shielded from indirect costs differs while the sample-size is limited. Two out of three Eastern European plants face partial or no indirect ETS costs, while only one out of four Western Northern European plants is partially shielded from indirect costs.

   In Southern Europe these costs are lower than the other regions due to a combination of lower electricity intensity of production and lower maximum regional CO2 emissions factors.

2) Electricity intensity of production differs significantly between plants within the same region.

3) The ETS indirect cost was significantly lower in 2012 compared to the previous years, because the price of EUAs was significantly lower in 2012.

[20] As defined and listed in Annex IV of the 'Guidelines on certain State aid measures in the context of the greenhouse gas emission allowance trading scheme post-2012' (2012/C 158/04).

1.12 Production costs

This section presents an analysis of the production costs for EU producers of ammonia. Due to the intermediate nature of the good, it is not possible to retrieve meaningful data from publicly available sources – including companies' balance sheets. Therefore, to estimate production costs of ammonia it is necessary to rely on information provided directly by companies that can extract relevant data from their analytical accounting. The research team ensured the consistency of those cost figures by comparing data submitted by different producers and data submitted by the same producer for different years and asking for clarification and integrations whenever inconsistency was detected.

As explained in section 1.7.1, a questionnaire to collect data on production costs was sent to all the companies included in the sample. Data over the period 2010-2012 were provided by only seven out of ten plants. Thus, due to the lower response rate, the representativeness of the following figures is lower than of the figures presented in the other sections of this report. Furthermore, one of these plants underwent a restructuring process in 2010 so that information for that year is not representative for the business as usual and is not included in the analysis presented in this section.

All figures presented in this section are indexed for confidentiality reasons. For the responding plants, the following elements are estimated for the years 2010, 2011, and 2012:

- Total production costs, whose estimate has been provided by companies and includes all production costs, *i.e.* cost of finished ammonia, other operating expenses, depreciation, amortization, and financial expenses referred to the product line[21]; for confidentiality reasons, production costs have been indexed, with 2010 as the base year;
- Natural gas costs, provided by companies in terms of €/MWh and converted into €/tonne using the corresponding energy intensities of the production process; for confidentiality reasons, natural gas costs have been indexed, with 2010 as the base year;
- Electricity costs, computed adopting the same methodology as natural gas costs.

[21] Although the research team provided this explicit definition of total production costs to the participants, it is possible that due to the intermediate nature of the good in some cases depreciation and amortization were not included in the calculation of total production costs.

Table 15. Production costs of EU ammonia producers

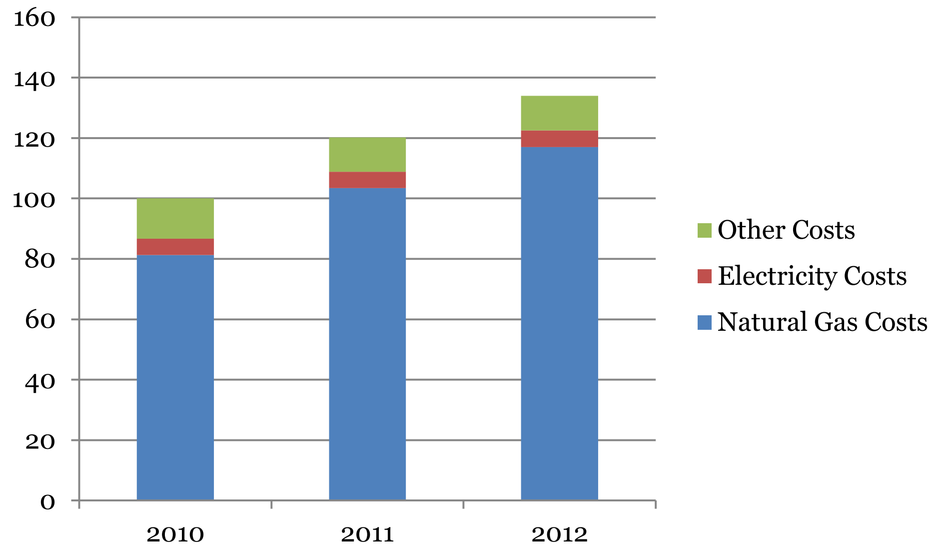
	2010	2011	2012
Number of plants	6	7	7
Total production costs, Index 2010=100	100	120.2	134.0
Natural gas costs, Index 2010=100	100	127.3	144.0
Electricity costs, Index 2010=100	100	99.1	101.2

Source: Author's calculation based on companies' data.

Total production costs experienced a steep increase over the observation period (+34%). This trend reflects the parallel growth of natural gas costs, that increased by 44% between 2010 and 2012. As for electricity costs, they remained almost stable over the entire period (+1%), with a cost reduction between 2010 and 2011 (-1%) and a growth between 2011 and 2012 (+2%).

As shown in Figure 21, natural gas costs were responsible for the lion's share of total production costs, i.e. about 80-88%. Electricity costs accounted for around 3-6% of total production costs.

Figure 21. Total production costs of EU ammonia producers (€/tonne)



Source: Authors' elaboration on companies' data.

1.13 General impressions

The consultant used the questionnaires to (*inter alia*) ask EU ammonia producers about their impressions of the effects of liberalisation. The respondents had divergent views on the impact of liberalisation on the energy markets. Some participants, mainly from Western Northern Europe, emphasised the benefits of liberalisation and claimed that it has opened the door to more suppliers and has helped them to move away from oil-indexed contracts. However, one producer also noted that oil-related gas prices are still the long term proxy. On the contrary, producers from Southern and Eastern Europe generally claimed that the market is still not liberised or partially liberised in their countries with a negative impact on their energy costs. Some participants also mentioned that they face monopoly situations. Finally, one producer from this region claimed that oil remains the underlying driver of the market.

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