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Preliminary communication

Determination of FreeCarbon Dioxide Emissions in Mineral Fertilizers Production

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Abstract: Food, energy and water are the welfare of the whole mankind, but unfortunately they are often used to blackmail those who suffer from their lack. In this light the influence of the European Union Trading System in the field of mineral fertilizer production is analysed. Based on the available data for mineral fertilizer plant free allocation for the emission of greenhouse gases, predominantly carbon dioxide and in smaller part nitric oxide, is calculated. Determining of the internal mass and energy fluxes is very challenging due to the fact that required pieces of information are not publicly available. Thus, the volume of ammonia and natural gas used in the energy balance is assumed to allow the calculation of preliminary free emissions in the production of ammonia and nitric acid subsection and for heat and fuel. Also, benchmarks and carbon leakage exposure factors are set by the European Commission and taken for the fourth trading period. Historic activity level is calculated from available data. The discussion is aimed at assessing the impact of allotted and measured emissions and their financial impact to agricultural activity.

Keywords: CO_2 free preliminary emissions; mineral fertilizer production

1 INTRODUCTION

Modern agriculture is inconceivable without mineral fertilizers which are produced from raw materials, chemical products and industrial minerals. The statistics of the world production of mineral fertilizers is monitored through three basic chemicals: ammonia, phosphoric acid and potash which represent the basic components of mineral fertilizers, but also can be used as raw material for other purposes. In summary, the global supply of the mentioned components in 2016 was 244 131 thousand tons with constant growth in the following years reaching 269 482 thousand tons in 2022. In the same period, the demand for fertilizer production and for other uses grew constantly from 234 009 thousand tons in 2016 to 255 676 thousand tons in 2022 [1]. In this paper the focus will be put onto ammonia with the following statistics: the supply grew from 153 646 thousand tons in 2016 to 163 219 thousand tons in 2022 while the total demand followed the same trend from 142 078 thousand tons in 2016 to 152 251 in 2022 [1]. It is worth mentioning that the cited source presented actual numbers up to 2019 and predicted trends until 2022 in which period two global crises occurred, SARS-Cov 2 pandemic and the Russian invasion to Ukraine, both strongly affecting the global balance in all supply chains. However, opposite to expectations neither of these crises caused any serious disturbance in the trends of supply and demand of ammonia shown before. As mentioned in reference [2]: "Global phosphorus fertilizer production actually increased from 2021 to 2022. And while nitrogen and potash production were curtailed somewhat during this time, the large drop-off in production was never seen". The same source pointed out something else: "Fertilizer producers are in the midst of decarbonizing, and this will have a huge effect on how nutrients are produced in the future". One of the measures for the decrease of industrial carbon dioxide emissions is that charging the company for every emitted ton of carbon dioxide exceeds the allotted amount. In ten years period the price of emitted carbon dioxide rose dramatically from 2,47 USD per ton in January 2013 to the current 88,13 USD per ton and reached its historical maximum of 104,65 USD per ton [3] in February this year. Even though it seemed an effective mechanism to the lower emissions it became the subject of stock trading and lost its original purpose enabling extra profit to traders and at causing extra costs to mineral fertilizer producers at the same time, as well as the increase of food price.

2 MINERAL FERTILIZER PRODUCTION

In this paper, a case of selected mineral fertilizer producer is investigated, for which the scheme of the technological chain is shown in Fig. 1 [4].

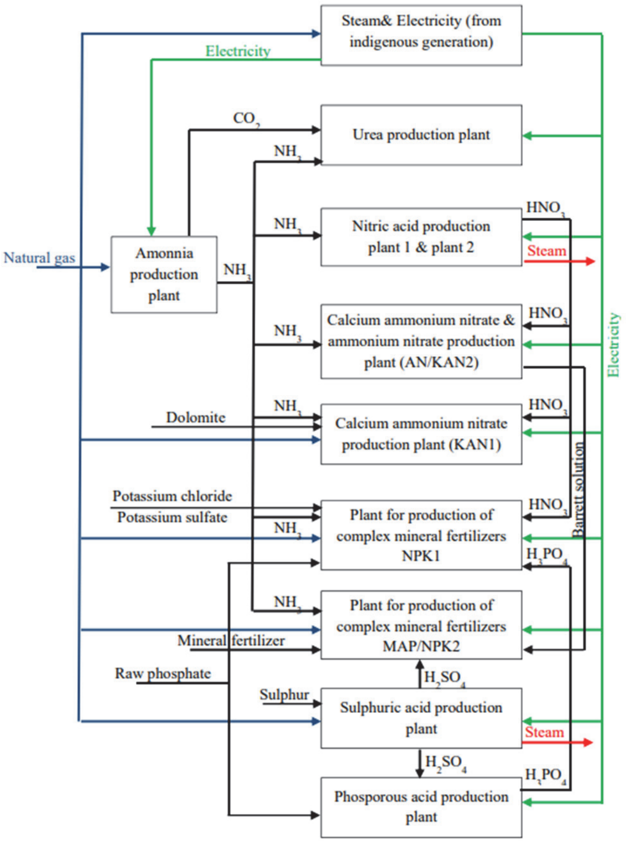

Figure 1 Scheme of mineral fertilizer production

Although the scheme is simplified the significant mass and energy fluxes are clearly depicted. Natural gas enters the process in a twofold way, as fuel and as a raw material for synthesis of gas production which is then used as the basic compound for ammonia production. Gas synthesis is a mixture of carbon monoxide and hydrogen ($CO + H_2$) from which hydrogen combined with nitrogen from air is used for ammonia production.

Ammonia is produced in a middle pressure process, with operating pressures between 200 and 500 bar, also known as the Kellog's process [5]. After that ammonia is introduced in the urea production process together with CO_2 produced from CO and oxygen from the air. Also ammonia is used for nitric acid production which is then used together with ammonia, in ammonium nitrate, calcium ammonium nitrate and complex mineral fertilizers NPK1 production. For the production of complex mineral fertilizers NPK and MAP sulphuric and phosphorous acid are used, both of which are produced in a single process. The described components of mineral fertilizer production shown in Fig. 1 are also accompanied by natural gas, process steam and electricity, all produced in separate facilities.

3 CARBON DIOXIDE AND NITRIC OXID EMISSION SOURCES

The inevitable byproducts of chemical processes for mineral fertilizer production are the emissions of carbon dioxide (CO_2) and nitric oxide (N_2O). These emissions of previously mentioned greenhouse gases are subjected to legislative regulating fees to be paid when the gases are emitted to atmosphere according to the Regulation on the scheme for greenhouse gas emission allowance trading set by the Government of the Republic of Croatia and published in the Official Gazette of the Republic of Croatia [6]. This document gives the definition of the activities involved in mineral fertilizers production and the resulting greenhouse gases (GHG) emissions from those activities as shown in Tab. 1.

Table 1 Activities and resulting GHG emissions in mineral fertilizers production

Activity	GHG
Fuel combustion in facilities of total input thermal power over 20MW (excluding incineration of hazardous or municipal solid waste)	CO_2
Nitric acid production	CO_2, N_2O
Ammonia production	CO_2

The activities and their related GHG emissions presented in Tab. 1 combined with the data on production of the facility will be used in the analysis. The objective of the analysis is to determine free emissions of GHG (tons/year).

3.1 Cap and Trade Principle

"Cap and trade" principle is established as financial tool for mitigation of the GHG emissions: As can be seen from its name it consists of two parts. First is the "cap" referring to allowed i.e. allotted emissions expressed as tones of CO_2 equivalent (CO_{2eq}) in tones CO_{2eq}/year set by European Commission and then allocated to member countries of the EU and then imposed to those who emit GHG under certain criteria as seen in Tab. 1, including mineral fertilizer producers. This represents the upper limit of the quantities to be emitted free of charge. These quantities are expressed in a unit which equals 1 tone of CO_{2eq} and is called a permit or allowance i.e. European Union Allowance (EUA). When the quantity of emissions is lower than the assigned cap the producer can sell the remainder, and if the emitted quantity exceeds the cap this overlap can be bought on market from producers who have a surplus. Thus, the emitted quantities are subjected to "trade". The trading can be direct between two parties, or market based, done on the bid and demand principle. The idea of this concept is to enable financial benefit to those emitting less than the allotted quantities which can be realized by selling the remainder of unused permits; while producers which emit GHG quantities above the allowed limit will have additional costs, which will be reflected in a more expensive final product which should motivate the producers to invest in technological improvements of the plants and that way lower emission. This is especially important for mineral fertilizer industry keeping in mind the facts mentioned in Introduction.

4 FREE ALLOWANCES FOR SUBSECTIONS IN MINERAL FERTLIZER PRODUCTION

In this section, free allowances will be calculated for four subsections from Fig. 1, and according to the activities given in Tab. 1. These subsections are as follows: ammonia and nitric acid production, heat energy production and fuel used in subsections of the process.

4.1 Ammonia Production

The free allowances of emitted quantities for ammonia production (first subsection) are calculated as [4, 7, 8]:

$$F_{p,k} = \frac{Em_d + Em_{nih}}{Em_d + Em_{nih} + Em_{ind}} \times BM_p \times HAL_p \times CLEF_{p,k} \quad (1)$$

where are: $F_{p,k}$ - annual preliminary allocation for ammonia production subsection in year k (EUA), BM_p - benchmark for ammonia (EUA/unit of product), HAL_p - historical activity level i.e. arithmetic mean annual production in the reference period as determined and verified in the reference data collection (units of product p), $CLEF_{p,k}$ - carbon leakage exposure factor for product p in year k, Em_d - direct emissions (tons) within the system boundaries for ammonia production during the reference period, Em_{nih} - emissions (tons) from any net measurable heat import by subsection from any other installation and Em_{ind} - indirect emissions (tons) from electricity consumption inside ammonia subsection during reference period regardless of where and how it is produced. This value is calculated as follows.

$$Em_{ind} = elctricity\ consumption \times 0,376 \quad (2)$$

where is: *electricity consumption* - total electricity utilized inside the subsection for ammonia production (MWh).

4.2 Nitric Acid Production

Free allowances for nitric acid production subsection are:

$$F_{p,k} = BM_p \times HAL_p \times CLEF_{p,k} \quad (3)$$

where are: $F_{p,k}$ - annual preliminary allocation of free emission for nitric acid subsection in year *k* (EUA), BM_p - benchmark for nitric acid (EUA/unit of product), HAL_p - historical activity level i.e. arithmetic mean annual production in the reference period based and verified by collected referent data (units of product), $CLEF_{p,k}$ - carbon leakage exposure factor for product *p* in year *k*.

The chemical reaction of nitric acid production is exothermic i.e. it provides extra heat to the subsection. This amount of delivered heat reduces the free emissions from Eq. (3):

$$RPA = BMH \times HAL_{h,nitricacidheat} \quad (4)$$

where are: *RPA* - reduction of preliminary emission, *BMH* - benchmark for heat (EUA/TJ) and $HAL_{h,\ nitricacid\ heat}$ - annual historic import of heat from the subsection for nitric acid production during reference period.

4.3 Heat Generation

Heat generation analysed in the scope of the paper is for steam process of 122 bar produced in three boilers, steam process of 40 bar produced in combined heat and power plant, steam process of 12 bar produced in three boilers, and finally the steam produced in a recovery boiler using the waste heat from exothermic reaction in the sulphuric acid production. Preliminary free allowances are calculated from:

$$F_{h,k} = BM_h \times HAL_h \times CLEF_{h,k} \quad (5)$$

where are: $F_{h,k}$ - annual preliminary allocation of free emission for heat generation in year *k* (EUA), BM_h - benchmark for heat (EUA/unit of product), HAL_h - historical activity level i.e. arithmetic mean value of acceptable yearly heat consumption during reference period based and confirmed by collected referent data (TJ/year). Acceptable heat energy consumption is calculated as sum of measured produced heat energy import from plants covered by the EUETS (European emission trading system), $CLEF_{h,k}$ - carbon leakage exposure factor for heat in year *k*.

4.4 Fuel

This subsection covers the fuel in the form of natural gas, acetylene and propane-butane for combustion. The free allowances in this case are:

$$F_{f,k} = BM_f \times HAL_f \times CLEF_{f,k} \quad (6)$$

where are: $F_{f,k}$ - annual preliminary allocation of free emission for fuel in year *k* (EUA), BM_f - benchmark for heat (EUA/unit of product), HAL_f - historical activity level i.e. arithmetic mean value of fuel consumed by subsections (TJ/year)., $CLEF_{f,k}$ - carbon leakage exposure factor for fuel in year *k*.

4.5 Values of Coefficients

Values of coefficients $BM_{p,k}$, BM_h, BM_f, $CLEF_{p,k}$, $CLEF_{h,k}$, $CLEF_{f,k}$, required in Eq. (1) to (5) are given in Tab. 2 [9] and their values are set by the European Commission for certain trading phase of the European Union Emissions Trading System (EU ETS). In this case values are related to phase 4 of trading. It should be noted that the values of $BM_{p,k}$, BM_h, BM_f are being lowered with the objective to reach minimal levels in each subsequent period which is achieved through prescribing lower and lower amounts of total free emissions on EU level until 2030.

Table 2 Values of coefficients used in calculation of free emissions

	$BM_{p,k}$	$CLEF_{p,k}$
Ammonia	1,57	1
Nitric acid	0,23	1
	BM_h	$CLEF_{h,k}$
heat	47,3	0,3
	BM_f	$CLEF_{f,k}$
fuel	42,6	0,3

4.6 Historic Activity Level

The values of coefficients are set by the European Commission as a part of proscribed climate policies while the values of Historic Activity Level are the result of process data belonging to the analyzed facility. Natural gas is a basic compound in the mineral fertilizer production both as a raw material and as fuel. The annual consumption of natural gas from 2017 to 2022 is given [10] in Tab. 3. This is the relevance period taken into consideration.

Table 3 Natural gas consumption in mineral fertilizer production plant

	Annual natural gas consumption, 10^6 m^3					
	2017	2018	2019	2020	2021	2022
Total	641,8	546,6	627,9	620,6	410,9	78,1
For ammonia production	299,72	255,26	293,23	289,82	191,89	36,47
For energy transformation	342,08	291,34	334,67	330,78	219,01	41,63

From these quantities average, 46,7% of natural gas is used for ammonia production and the remainder of 53,3% is used for energy transformation which includes heat energy and electricity generation [11] to cover the demand of the whole plant. The amounts for these purposes are also given in Tab. 3 while ammonia production volumes are given in Tab. 4.

To produce 1 tonne of ammonia 970 Nm^3 of natural gas is needed [4] and from that 64% of natural gas is used as raw material, while 34% is used for heat generation inside the subsection for ammonia production. Ammonia is a basic product which is used in subsequent technological operation as shown in Fig. 1 including nitric acid production.

While ammonia production is a continuous process, nitric acid is being produced discontinuously depending on the demand for KAN and AN production (see Fig. 1). For one tonne of nitric acid 0,29 tonne of ammonia is needed [4]. The amount or percentage of ammonia to be used in nitric acid is unknown, since many pieces of data about internal energy and mass fluxes are classified and limited to company personnel. Thus, for the calculation it is assumed that 40% of ammonia is used in nitric acid production. As already mentioned, the reaction of nitric acid is exothermic and the quantity of heat released during the reaction is taken as 18746kJ/t of nitric acid [4]. In real conditions this heat energy is utilized for steam generation and therefore its content can be precisely measured. These values are presented in Tab. 4.

Table 4 Ammonia and nitric acid production, exothermic heat from nitric acid reaction

Year	Ammonia production / t	Nitric acid production / t	Heat from exothermic reaction / TJ
2017	482797,4	56004,49	1,04986
2018	411182,7	47697,19	0,894132
2019	472341,0	54791,56	1,027123
2020	466849,5	54154,55	1,015181
2021	309101,6	35855,79	0,672153
2022	58751,1	6815,13	0,127756

The remaining values to be taken into consideration for emissions calculation are those of heat energy and fuel and these values will be determined by the "rule of thumb" as for the nitric acid, since exact measured data are unavailable. It is assumed that 50% of natural gas consumption for energy transformation (the last row of Tab. 3) can be accounted for emissions resulting from natural gas combustion employed in the heat energy generation in the form of steam i.e. using some intermediator. At the same time 10% of natural gas in the energy transformation (last row of Tab. 3) is used for direct heat generation which is used eg. for drying. The remainder of 40% of natural gas used in energy transformation is not a subject of emissions legislative. In both cases for heat and fuel, the values are calculated as a product of the lower heating value ($H_d = 34{,}3\ \mathrm{MJ/m^3}$), the volume of natural gas consumed (last row in Tab. 3) and efficiency ($\eta = 0{,}9$). The values listed in brackets are assumed and should be measured in real conditions.

Results for the heat and fuel are shown in the Tab. 5 using the same unit i.e. TJ.

Table 5 Heat and fuel intensity

Year	2017	2018	2019	2020	2021	2022
Heat / TJ	5280,0	4496,8	5165,6	5105,6	3380,4	642,54
Fuel / TJ	34,21	29,13	33,47	33,08	21,907	4,16

Finally, historic activity level (HAL) can be determined based on previously presented data. It is calculated as an arithmetic mean value of the defined activities in five year period preceding the year in which free emissions are calculated. Hence, HAL is calculated for the period from 2017 to 2021 and then for the period from 2018 to 2022. which enables determining free emissions for years 2022 and 2023. The values of historic activity level based on previously presented data are given in Tab. 6.

Table 6 Historic activity levels of products, heat and fuel

	Year	
Historic activity level	2022	2023
Ammonia, HAL_p / t	428454,40	343645,20
Nitric acid, $HALp$ / t	18372,06	39862,84
Nitric acid heat, $HAL_{h,nitricacid}$ / TJ	0,93169	0,747268858
Heat, HAL_h / TJ	4685,688	3758,192
Fuel, HAL_f / TJ	937,1375	751,6384

5 FREE ALLOWANCES

Now, when values of coefficients are defined free preliminary emissions or allowances can be calculated following the equations given in section 4.

5.1 Free Allowances for Ammonia Production

Prior to inserting the previously shown values in Eq. (1), additional calculation has to be done. As seen in Eq. (1), there are three more quantities not mentioned in the previous analysis and those are values characteristic for the subsection for ammonia production [8]. The values are Em_d, Em_{nih} and Em_{ind} given in Tab. 7.

Table 7 Direct and indirect emissions and netto imported heat in ammonia production

Year	2022	2023
Em_d	690563,2917	24538,2
Em_{nih}	41350,02231	24538,2
Em_{in}	2416,483075	530,0853

Direct emissions Em_d are derived by multiplying the quantity of ammonia produced in one year (see second column in Tab. 4) by the emission of carbon dioxide emitted per one tonne of ammonia produced in the amount of $1{,}2\ \mathrm{tCO_2/1tNH_3}$ [4]. Emission from the net imported heat Em_{nih} is estimated to be 20% of emission of the natural gas burned for energy transformation purpose (see last row of Tab. 3). The emission of carbon dioxide which arises from combustion of 1 $\mathrm{m^3}$ of natural gas with 94% of methane as the major constituent is $1{,}842\ \mathrm{kgCO_2}$ per $1\mathrm{m^3}$ of natural gas. The calculation is based on the generally known combustion relations, while the density of carbon dioxide is taken as $\rho = 1{,}96\ \mathrm{kg/m^3}$. Finally, indirect emission Em_{ind} is calculated from Eq. (2).

Electricity consumption (*electricity consumption*) in the equation represents the product of the amount of produced ammonia (see second column in Tab. 3) and the electricity consumption of 15 kWh per one tonne of ammonia [4]. This value is then inserted in Eq. (2). The calculation of all three items follows the same logic of historic activity level calculation. The values in Tab.7 represent the arithmetic mean values for the five year period reference preceding the actual year (k).

Free emissions in the subsection for ammonia production are the result of inserting values from Tabs. 2, 6 and 7 into Eq. (1) for years 2022 and 2023 and are given in Tab. 8.

Table 8 Free preliminary emissions for ammonia production subsection in 2022 and 2023

Year (k)	Free emission $F_{p,k}$ / t
2022	667237,6629
2023	533757,7245

5.2 Free Allowances for Nitric Acid Production

Free allowances for nitric acid production are the result of inserting data from Tab. 2 and the third column from Tab. 3 into Eq. (3). These values have to be reduced by the amount of heat released due to the exothermic reaction of nitric acid production. The amount of reduced preliminary emission is derived from Eq. (4). The amounts of free emissions $F_{p,k}$ and the reduction of emission RPA for 2022 and 2023 are shown in Tab. 9. In the last row of the same table, the final amount of free preliminary emission is given as a result of RPA being subtracted from $F_{p,k}$.

Table 9 Free preliminary emissions for nitric acid production subsection in 2022 and 2023

	Year (*k*)	
	2022	2023
Free emission $F_{p,k}$ / t	4225,573	2507,567
Reduction of preliminary emission *RPA* / t	770,5284	457,2519
$F_{p,k}$-*RPA* / t	3455,045	2050,315

5.3 Free Allowances for Heat

By inserting the values from Tab. 2 and 5 into Eq. (5), the values of free preliminary emissions for heat are calculated and shown in Tab.10.

Table 10 Free preliminary emissions for heat in 2022 and 2023

Year (*k*)	Free emission $F_{h,k}$ / t
2022	66489,91
2023	53328,74

5.4 Free Allowances for Fuel

Inserting values from Tab. 2 and 5 into Eq. (6), the values of the preliminary emissions for fuel are derived and shown in Tab. 11.

Table 11 Free preliminary emissions for fuel in 2022 and 2023

Year (*k*)	Free emission $F_{f,k}$ / t
2022	11976,62
2023	9605,94

6 FREE ALLOWANCES FOR MINERAL FERTILIZER PRODUCTION PLANT

After the calculation of free preliminary emissions, given in Tab. 8 to 11, the final free preliminary emissions can be calculated. As shown before, free preliminary allowances or emissions shown in Tab. 12 are based on two five year periods first from 2017 to 2021 and second from 2018 to 2022. The first period provides data for historic activity level to be used for calculating free emissions for year 2022, and the second period for year 2023. Free preliminary emissions for year *k* $F_{prel,k}$ are calculated according to the following equation:

$$F_{prel,k} = F_{ammonia,k} + \left(F_{nitricacid,k} - RPA\right) + F_{h,k} + F_{f,k} \quad (7)$$

Indices *k* from Eq. (2) and (3) are replaced with the name of the corresponding products, ammonia and nitric acid respectively.

Table 12 Free preliminary allowances for years 2022 and 2023

	Year (k)	
	2022	2023
Free preliminary allowances / t	749159,23	598742,72

7 DISCUSSION

From mathematical point view, the equations used in this work are very. However, careful analysis of equations reveals a complex problem. Technically, in the previous analysis, a "rule of thumb" had to be applied, while the real scheme of a mineral fertilizer plant is immeasurably more elaborate than the maximally simplified version from Fig. 1. Since the data on mass and energy fluxes is not publicly known or available, the key pieces of data had to be estimated and assumed. This inevitably led to a possible significant deviation from the correct values. In our calculation only the consumption of natural gas given in Tab. 3 is exact. According to the annual nonfinancial reports [11], the fraction of natural gas consumed for ammonia production might vary slightly; however the distribution of ammonia for various products and natural gas used in energy transformations had to be estimated. The calculated and real emission results would be closer if reliable data about various plant operations existed. The results of preliminary emissions differ as a result of rapid fall of production rates which started in 2021 and followed in 2022 and 2023 caused by external risks, dominantly volatile and high growth of natural gas prices which started in the first half of 2021. The measured quantity of the emissions in 2022 was 169000 tons of CO_{2eq}, in 2021 832650 tons of CO_{2eq}, and in the previous period the average value was 1,26 million tonnes of CO_{2eq} [11]. Thus, this constant lowering of emissions is not a result of implemented improvements in production technology, but a decrease of production. The focus of this paper was on carbon dioxide; however this is not the only greenhouse gas emitted from the plant. The second one is nitric oxide N_2O, from the nitric acid production and its share in the total GHG emission is approximately 4,5%, expressed as CO_2 equivalent. The global warming potential (GWP) denotes that 1 ton of N_2O equals 265 tons of CO_2 [13]. If the value of free emissions for year 2022 is subtracted from the measured emissions, a negative result is obtained - 580159 EUA (or tons of CO_2) which can be sold in EUETS. Can this be considered as a positive effect? Perhaps it brought extra profit for the company. For 2023, the amount of measured emissions is not known yet, however an even higher negative value can be expected. Once, the production rates of mineral fertilizers are increased, the preliminary emissions will be lower due to lower historic activity level, which will cause additional expenses for buying extra allowances on the EUETS market. In reference [15] the amounts of free emissions allocated to analyzed facility can be found. For year 2023 the coincidence between real value and calculated in the previously presented way is very high, 778 266 tons as given in the given reference and 749 159 tons as shown in Tab. 12. For year 2023 there are still no official data. In this reference decreasing of the allocated free emissions can be also seen as a result of the trends in mineral fertilizer production in the last few years which is presented earlier in this paper.

The main objective of this paper was to show the methodology and approach for the calculation of free preliminary allowances or emissions as set by the European Commission that from the outside the algorithm appears to be very complicated as already mentioned. After the analysis the authors had that impression stemming from a research conducted in master degree thesis [14]. Preliminary emissions are calculated by the emitters which are subject of EUETS, however their values must be verified by certified verifiers and authorities. Here is a translation of direct quote, originally in Croatian from a presentation on 7th Verification Forum held in Zagreb at the end of 2021 [16]: "Growth of prices, a wider range of verification in the field of free emissions allocation and complexity of the methodology create an additional pressure on verifiers …". The same source lists other obstacles in the verification, adding to an impression of a very demanding process of determining and verifying free emissions.

8 CONCLUSION

In this paper, the methodology for free emissions calculation based on a real mineral fertilizer plant is given. General ambiguities encountered in the calculation as well as in verification process are discussed. The concept of EU ETS was started with benevolent objectives of stimulating the subjects of the system emitted by GHG to decrease their emission, overall to achieve the obligatory climate goals set by the European Union authorities. The concept is based on trading with EUAs on a stock exchange, whether a producer buys the permits in the case of exceeding the allotted free allowances, or sells a surplus of free emissions. However, turning EUAs into financial commodity made the permits very attractive to the financial sector which caused a constant growth of their prices on stock market. This is a second financial shock to the industry, along with volatile increase of natural gas prices, reflecting the market price of mineral fertilizers. These issues are also related to all industries which emit GHGs i.e. use fossil fuels. There are two possibilities for decreasing emission expenses: investing in a more efficient technology, or relocating the industrial facilities to countries or regions with no such legislative constraints. The plants which invested in technological improvements and increased the efficiency of the production process became the benchmark facilities for future emission standards and free allotments. The question is: are the capacities of these "low emission" mineral fertilizer producers sufficient for the European agriculture? If not, the European Union is in a vulnerable exposed state, similar to what has already happened with the natural gas supply. Since many industries are endangered by the GHG emission directives, most notably the food supply chain, European policy makers should quickly make their move.

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