CBAM TRAINING

CASE STUDY – Nitrogen Fertilizers

EGYPT

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EUROPEAN BANK FOR RECONSTRUCTION AND DEVELOPMENT (EBRD)

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CBAM FERTILIZER INDUSTRY

CHARACTERISTICS OF THE FERTILIZER INDUSTRY IN EGYPT

CHARACTERISTICS OF THE FERTILISERS INDUSTRY

Total production

6,178,000 t/y

Types of goods produced

- Ammonia, Urea
- Ammonium Nitrate
- Mixed Fertilizers

Number of plants

9 with 12 production lines

Total production exported to the EU

1,450,000 t/y
(24% of total)

Other characteristics

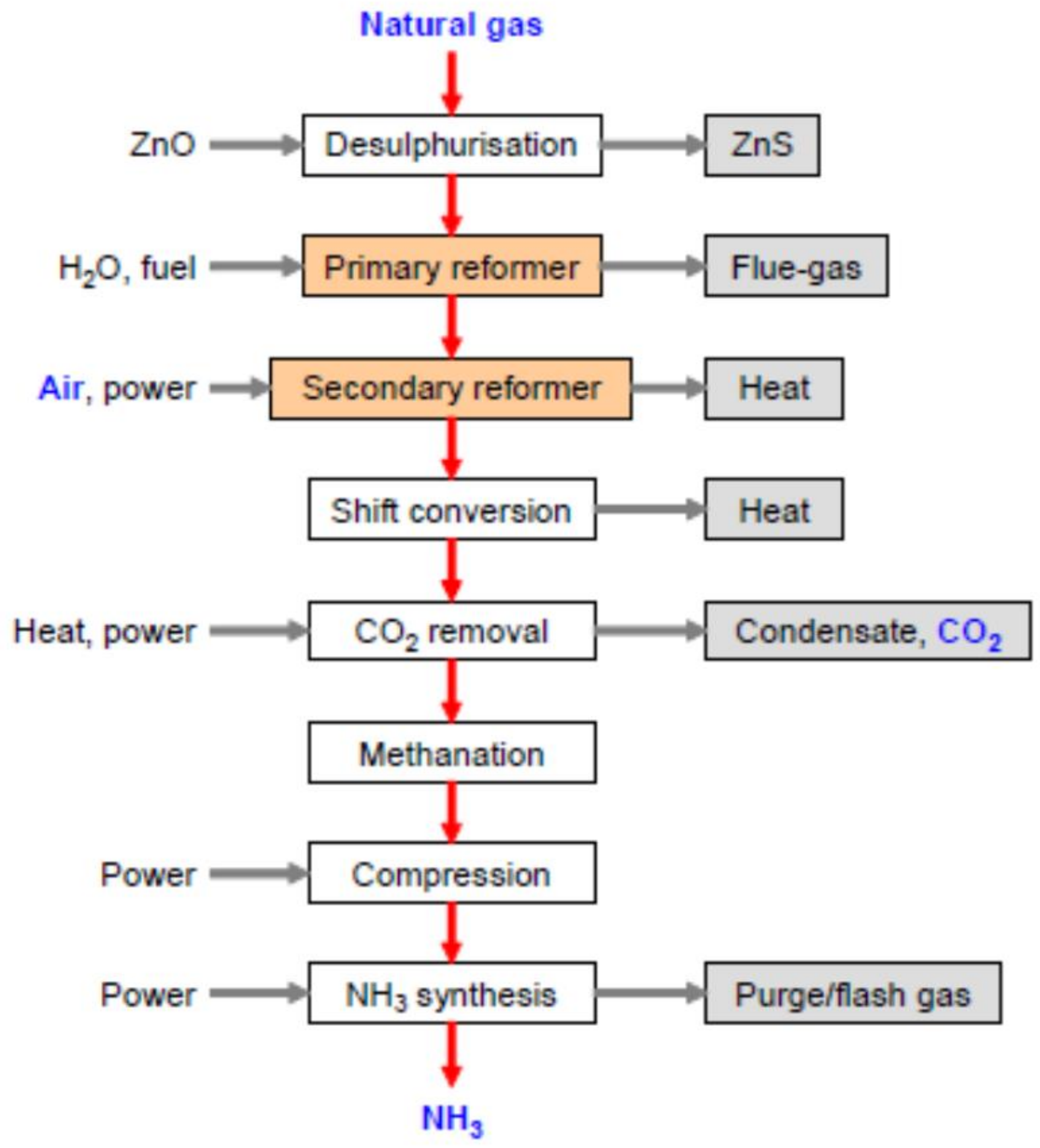
- All plants use Conventional SMR Technology
- There are plans for installation of Green Ammonia lines

Number of plants that export to the EU

40% of total

PRODUCTION PROCESS IN A TYPICAL PLANT IN EGYPT

- All Egyptian N-Fertilizer Plants use the Haber-Bosch conventional Steam Methane Reforming (SMR) technology.
- Lines lifetime > 50 years
- The process generates steam from exothermic reactions and from the NG-fueled reformer furnace and auxiliary boiler.
- Steam is used to provide thermal energy, generate electricity and as a driver for motors, turbines and compressors as it much cheaper than electricity.
- Some of the newer plants operate within the Best Available Techniques Benchmarks.
- CO_2 process emissions vary from 1.24 (EU BAT) – 1.4 tCO_2/t NH3.



IPPC BREF Manual for Fertilizers, 2007

CARBON FOOTPRINT OF A TYPICAL FERTILIZER PLANT IN EGYPT

Production line components	Product	Scope 1	Scope 2	Scope 3	Embedded Emissions	Percent Ammonia
		tCO_2/t product				
Ammonia / Urea	Ammonia	1.57	0.0411	0	1.62	100%
	Urea	0.163	0.018	0.923	1.1	57%
Ammonia / Nitric Acid/ Ammonium Nitrate	Ammonia	2.48	0.0411	0	2.52	100%
	Nitric Acid	0.19	0.0024	0.7	0.89	28%
	Ammonium Nitrate	0	0	1.11	1.11	42%

GOODS IN SCOPE OF CBAM FOR THE FERTILIZERS SECTOR

GOODS IN SCOPE OF CBAM – FERTILIZERS SECTOR

Ammonia

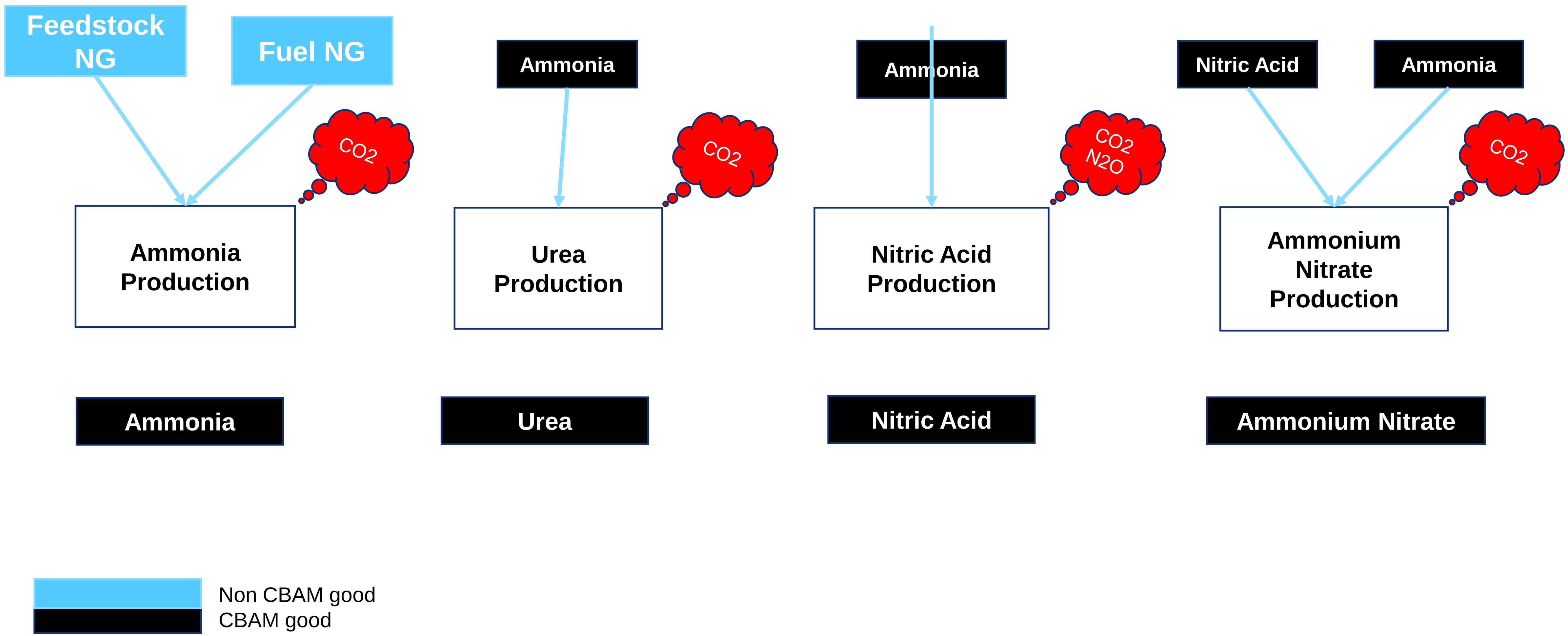
Simple good
Produced from fuels and raw materials considered to have zero embedded emissions under CBAM

Urea, Nitric Acid, Ammonium Nitrate

Complex good
Produced from other CBAM goods (either simple or complex goods)

Aggregated Goods Category	Product CN Code	Description
Nitric Acid	2808 00 00	Nitric acid, Sulpho-nitric acid
Urea	3102 10	Urea
Ammonia	2814	Ammonia
Mixed Fertilizers	2834 21 00	Nitrates of Potassium
	3102	Mineral or Chemical fertilizers, Nitrogenous (except Urea)
	3105	Mineral or Chemical fertilizers containing N, P, K and other fertilizers except those containing P and K.

SIMPLE/ COMPLEX GOODS IN FERTILIZERS SECTOR



DETERMINATION OF EMBEDDED EMISSIONS IN THE FERTILIZER SECTOR

OVERVIEW OF EMBEDDED EMISSIONS IN FERTILIZER

Scope 1 Direct emissions =

Process emissions (CO2 from Feedstock) + fuel emissions + imported CO2 in (steam and waste gases) – exported CO2 in (steam and waste gases)

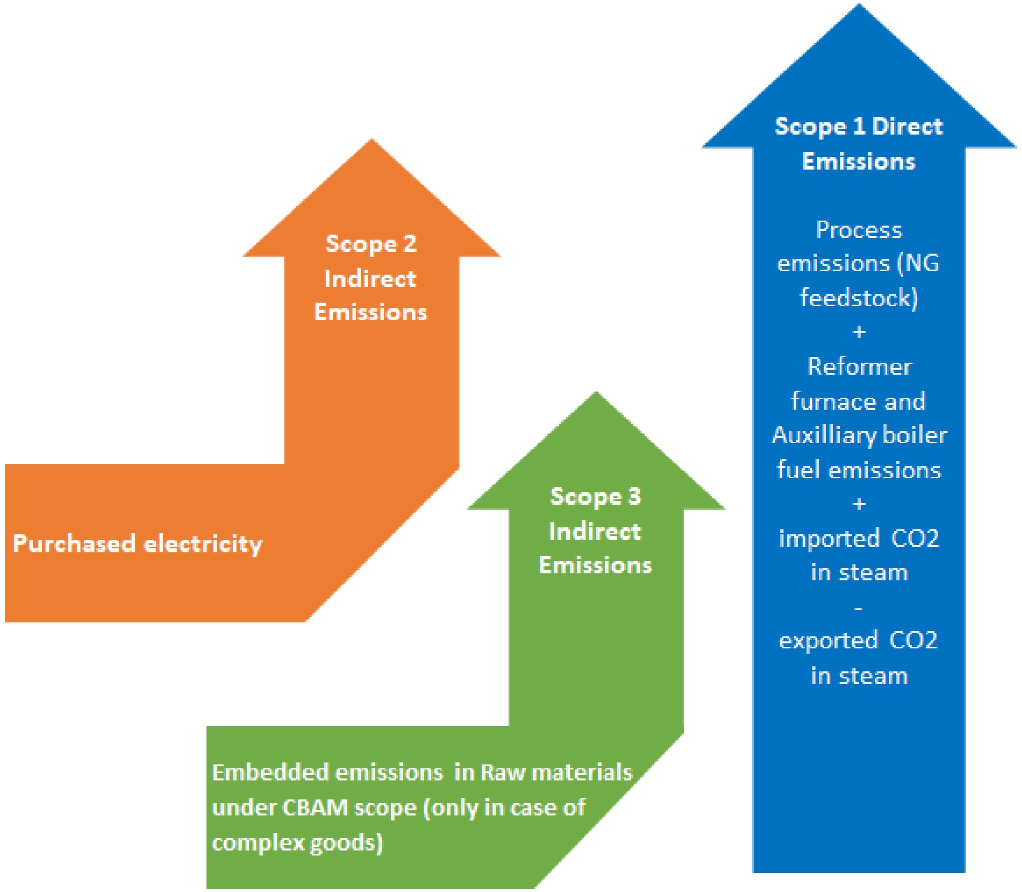
Scope 2 Indirect emissions =

Purchased electricity

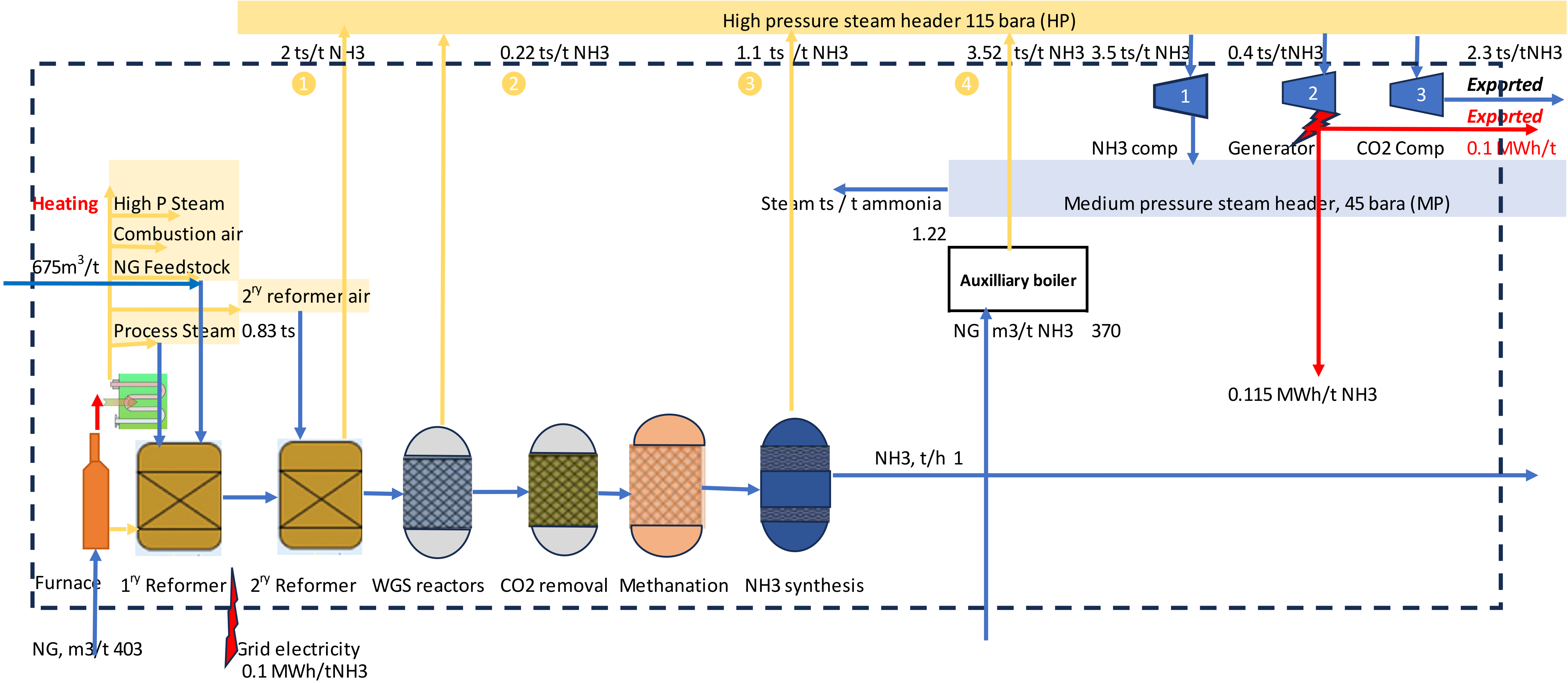
Scope 3 emissions upstream =

Embedded CO2 in raw material under CBAM scope (only in case of complex goods)

Total embedded emissions = **Scope 1 +2 + 3**



Setting the boundary for estimating Embedded Emissions in Ammonia (A/U plant)



Elshishini, S. (2024). Product carbon footprint methodology for ammonia production by conventional steam reforming–A case study. EJSDR, 8(1), em0241.

CO2 ALLOCATION TO HP STEAM

Data used in calculations:

Basis 1 t NH3

EF for Natural gas = 56.1 t CO2/TJ

LHV for NG = 38 MJ/m3

NG feedstock = 675 m3

NG fuel to auxiliary boiler = 370 m3

C-free Steam from 2ry reformer = 2 ts

C-free Steam from Water Gas shift Reactors = 0.22 ts

C-free steam from Ammonia Synthesis = 1.1 ts

Total C- free steam = 3.32 ts

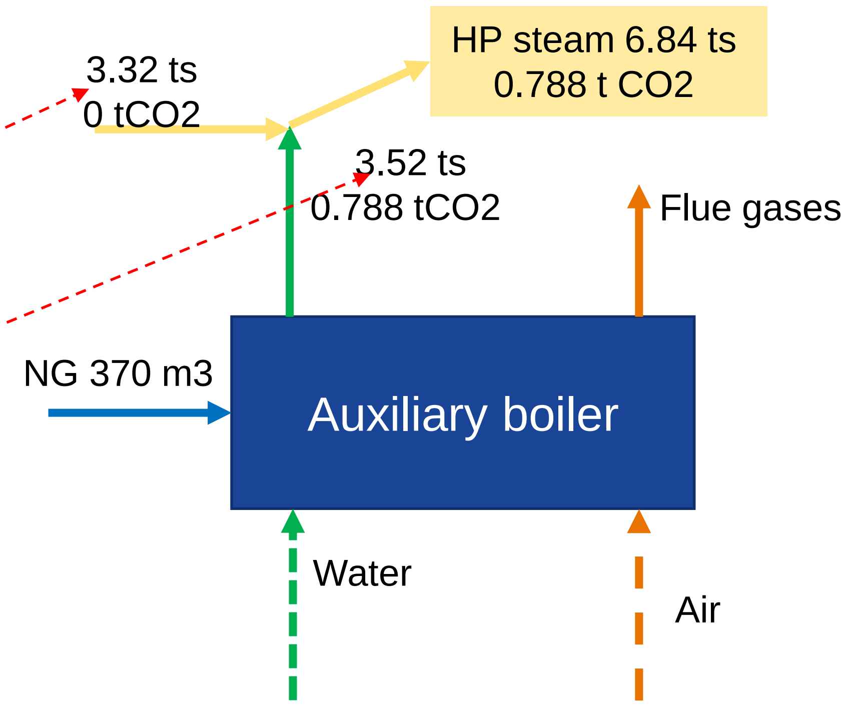
Fossil based Steam from boiler = 3.52 ts

Total steam = 6.84 ts

Allocated emissions to HP steam

CO2 generated from NG combustion = 370 * 38 * 56.1/1,000,000 = 0.788 tCO2

CO2 allocated to 1 ts = 0.788/6.84 = **0.115 t CO2/t HP steam**



Emission factor of HP steam = 0.155 t CO2 /t steam used to estimate embedded emissions in Urea

DATA USED FOR CALCULATING EMBEDDED EMISSIONS IN AMMONIA / UREA PLANTS

Additional Data used in calculations

EF (emission factor) for Egyptian grid electricity = 0.411 tCO_2e /MWh

NG (Natural Gas) feedstock = 675 m3/t NH_3

NG fuel to reformer = 403 m3/t NH_3 product

NG fuel to auxiliary boiler = 370 m3/t NH_3

Grid electricity consumption = 0.1 MWh/ t NH_3

Consumption of steam from HP header = 1.22 t

Consumption of steam for self-generated electricity = 0.21 t

Assumptions

- No embedded emissions in NG under CBAM scope
- Thermal energy generated from reformer is consumed within the boundary of ammonia line
- Part of self-generated electricity is exported to the Urea plant equivalent to = 0.19 t
- Medium pressure steam exported to Urea equivalent to HP steam = 2.3 t
- Process CO_2 exported to Urea plant = 1.24 tCO_2

CALCULATING EMBEDDED EMISSIONS IN AMMONIA

Scope 1 emissions

- Embedded Process emissions = Natural gas feedstock * LHV * Emission factor for NG = 675 * 38 * 56.1 /1,000,000 = 1.44 tCO_2
- CO_2 generated from primary reformer fuel = Amount of fuel * LHV * Emission factor = 403 * 38 * 56.1 /1,000,000 = 0.86 tCO_2
- CO_2 generated auxiliary boiler fuel = 370 * 38 * 56.1 / 1,000,000 = 0.788 t CO_2
- CO_2 exported to Urea = -1.24 tCO_2
- Steam exported to Urea = tons of steam exported to Urea * Emission factor for steam = 2.3 * 0.115 = -0.264 tCO_2
- Steam used for self-generated electricity exported to Urea = amount of steam * EF of steam (slide 13) = 0.19 * 0.115 = - 0.022 tCO_2

Total scope 1 emissions = 1.57 tCO_2

Scope 2 emissions

- CO_2 emissions from grid electricity = Amount of electricity consumed * EF for Egyptian grid = 0.1 * 0.411 = 0.0411 tCO_2

Total scope 2 emissions = 0.0411 tCO_2

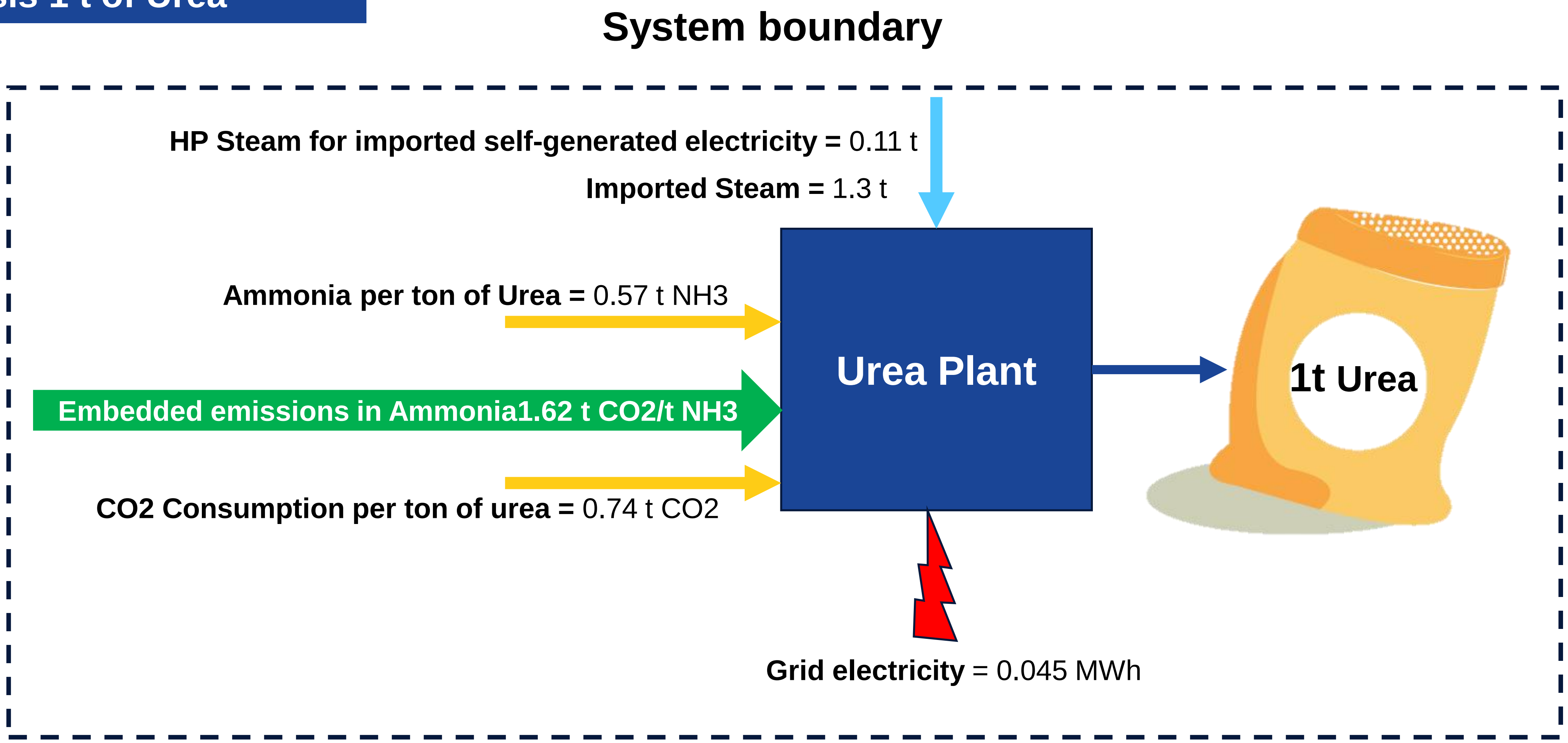
Scope 3 emissions = 0 for CBAM simple goods

Total embedded emissions = Scope 1 + scope 2 = 1.62 (tCO_2)

Ammonia embedded emissions = 1.62 t CO_2/tNH_3

SETTING THE BOUNDARY FOR ESTIMATING EMBEDDED EMISSIONS IN UREA (2)

Basis 1 t of Urea



CALCULATING EMBEDDED EMISSIONS IN UREA

Scope 1 emissions:

- Process emissions = **0 tCO_2**
- CO_2 in imported steam = Amount of steam * EF = 1.3 * 0.115 = 0.15 t CO_2
- CO_2 in steam equivalent to imported electricity = 0.11 * 0.115 = 0.013 t CO_2

Total scope 1 emissions = 0.163 tCO2

Scope 2 emissions

- CO_2 emissions from grid electricity = Consumed electricity * Grid EF = 0.045 * 0.411 = 0.018 tCO_2

Scope 3 emissions

CO_2 form Ammonia precursor = Amount of ammonia consumed per t Urea * Embedded C in ammonia

= 0.57 t NH3 * 1.62 = **0.923 t CO_2**

Total emissions = Scope 1 + Scope 2 + Scope 3 = 0.163 + 0.018 + 0.923

Urea embedded emissions = 1. 1 t CO_2 / t Urea

DATA USED FOR CALCULATING EMBEDDED EMISSIONS IN AMMONIA/ NITRIC ACID PLANTS

Characteristics of Ammonia / Nitric acid plants

- Thermal energy requirements for Nitric acid production is provided by steam obtained from waste heat of the exothermic oxidation reaction. There is no export of steam from SMR.
- Additional electricity is generated from carbon free steam in the nitric used and used within the plant. There is no export of electricity from SMR
- There is no export of CO2 from SMR and therefore no steam required to drive the compressor. Process CO2 discharged to atmosphere.

Data used in calculations:

NG fuel to auxiliary will be reduced from 370 Nm3/t NH3 to 86 Nm3/tNH3 (due to reduced steam requirements)

NG feedstock = 685 m3/t NH3

NG fuel to reformer = 403 m3/t NH3 product

EF for NG (IPCCC default value) = 56.1 tCO2/TJ

Grid Electricity consumption = 0.1 MWh/ t NH3

Consumption of steam from NA header = 1.22 t steam for use within NA plant + 0.211 t steam to generate electricity.

CALCULATING AMMONIA EMBEDDED EMISSIONS IN AMMONIA / NITRIC ACID PLANTS

Scope 1 emissions:

- Process emissions = NG Feedstock * LHV * EF = 685 * 38 * 56.1 /1,000,000 = 1.44 tCO_2
- CO_2 from combustion of reformer fuel = Amount of fuel * LHV * EF = 403 * 38 * 56.1 /1,000,000 = 0.86 tCO_2
- CO_2 from combustion of boiler fuel = 86 * 38 * 56.1 / 1,000,000 = 0.183 t CO_2

Total scope 1 emissions = 2.48 tCO_2

Scope 2 emissions

- CO_2 emissions from grid electricity = 0.1 * 0.411 = 0.0411 tCO_2

Total scope 2 emissions = 0.0411 tCO_2

Scope 3 emissions = 0 for CBAM simple goods

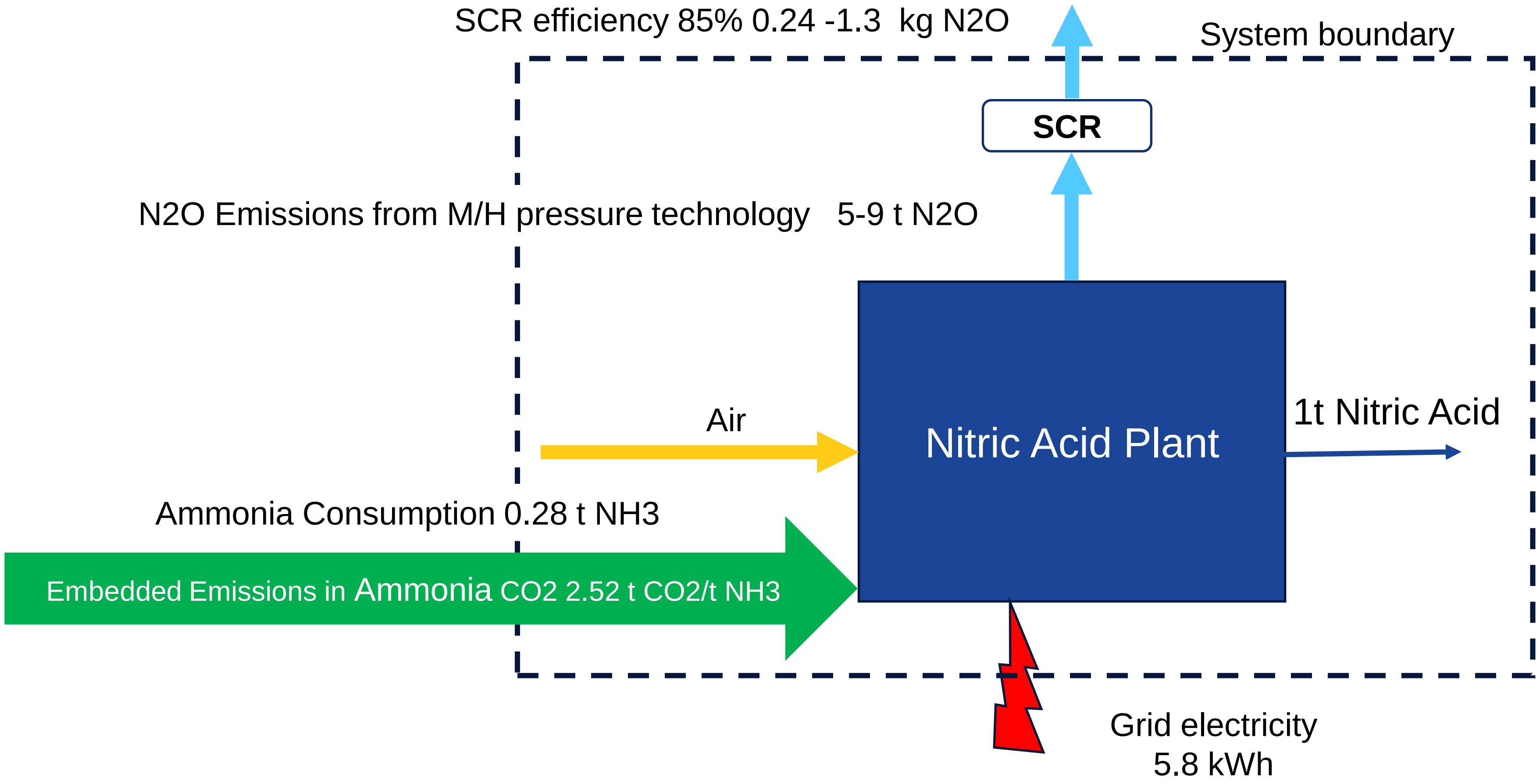
Ammonia embedded emissions = 2.52 t CO2/tNH3

SETTING THE BOUNDARY FOR ESTIMATING EMBEDDED EMISSIONS IN NITRIC ACID

Characteristics of Nitric acid plants

Newer Nitric Acid plants in Egypt use the Medium/High Pressure technology

NA plants are characterized by their large energy generation from exothermic reactions (1.6 - 2.4 GJ/t NA)



CALCULATING NITRIC ACID EMBEDDED EMISSIONS IN AMMONIA /NITRIC ACID PLANTS

Scope 1 emissions:

- Process emissions consist of Nitrous Oxides in tail gases after Selective Catalytic Reduction (SCR) = 0.0007 (av) t N_2O/t NA * 273 tCO_2e/ tN_2O (GWP) = 0.19 tCO_2e

Total scope 1 emissions = 0.19 tCO_2

Scope 2 emissions

- CO_2 emissions from grid electricity = Electricity consumption * EF = 0.0058 * 0.411 = 0.0024 tCO_2

Total scope 2 emissions = 0.0024 tCO_2

Scope 3 emissions

- CO_2 emissions from ammonia = 0.28 * 2.52 = **0.7 t CO_2/t NA**

Embedded emissions in Nitric Acid = 0.89 t CO_2/t HNO_3 (100%)

ESTIMATING EMBEDDED EMISSIONS IN AMMONIUM Nitrate

Emission Estimation

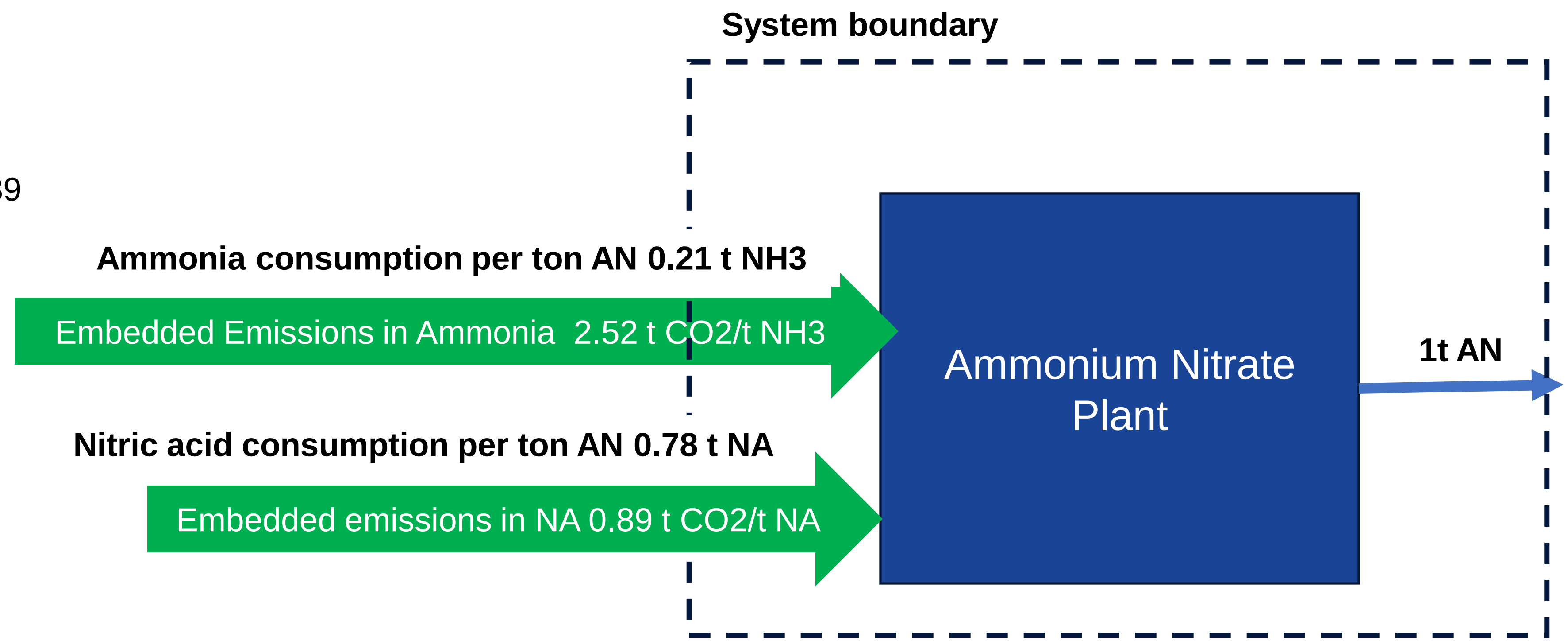
Scope 1 emissions = 0

Scope 2 emissions = 0

Scope 3 emissions

= 0.21 * 2.52 + 0.78 * 0.89

= 1.18 t CO2/t AN



Embedded emissions in Ammonium Nitrate = 1.18 t CO2/t AN

DECARBONISATION OPTIONS AND THEIR IMPACT

REDUCTION OF THERMAL ENERGY CONSUMPTION

Implementing Energy Efficiency projects

- Industry benchmark for CO_2 from fuel consumption is 1.66 tCO_2/t NH3
- There is a potential for reducing Fuel CO_2 by implementing Energy Efficiency projects.
- A maximum of 2-3% reduction can be achieved through the following projects

Potential projects

- Hydrogen recovery from purge gas to use as fuel
- Optimize the steam cycle
- Minimize steam losses
- Increase efficiency of electricity generator
- Improve boiler and furnace efficiency

Impact on CBAM

By decreasing fuel emissions by 0.04 tCO_2/t NH3, embedded emissions in ammonia will become **1.58 tCO_2/t NH3**. CBAM cost reduction = € 3.2 / t NH3 (based on ETS cost of € 80/t CO_2)

IMPLEMENTING MEASURES TO REACH BAT BENCHMARK FOR PROCESS EMISSIONS

Implementing BAT for the SMR (Steam Methane Reforming) plant (Grey Hydrogen)

- BAT benchmark for process emissions is 1.24 tCO2/t NH3
- Current industry benchmark is between 1.24 – 1.48 with an average of **1.44 tCO2/t NH3**
- Potential CO2 reduction is the difference between the Industry benchmark and the BAT
- A maximum of 14% reduction can be achieved by implementing projects that maximize ammonia production and minimize losses, such as:

Potential projects:

Replace catalyst of ammonia synthesis reactor with more efficient catalyst

Ammonia recovery from purge gas

Improve conversion efficiency in primary reformer

Improve maintenance to minimize fugitive ammonia emissions.

Impact on CBAM

By decreasing process emissions by 0.2 tCO2/t NH3, embedded emissions in ammonia will become **1.42 tCO2/t NH3**.
CBAM cost reduction = € 19.2 / t NH3 (based on ETS cost of € 80/t CO2)

REPLACE 15% OF THE HYDROGEN USED IN AMMONIA SYNTHESIS BY GREEN HYDROGEN

Replacement of 15% Grey Hydrogen by Green Hydrogen

- Each kg of Grey Hydrogen produced requires 4.5 kg of NG
- Each t ammonia produced requires 176 kg H2
- A reduction of (176*0.15*4.5) 118.8 m^3 NG can be achieved with corresponding CO_2 reduction of 0.25 t CO_2/t NH3

Applicability

Implementation of this project does not require extensive rehabilitation of the primary reformer

Green electricity can be transported through the national grid

Produces large reductions with minimum cost/t CO_2 abated

Impact on CBAM

By decreasing CO_2 emissions by 0.25 tCO_2/t NH3, embedded emissions in ammonia will become **1.37 tCO_2/t NH3**.

CBAM cost reduction = € 20/ t NH3 (based on ETS cost of € 80/t CO_2)

Associated risks

- High capex although relatively low cost modifications on primary reformer due to reduced Feedstock.
- High Opex due to cost of green electricity.
- Need for large amounts of demineralized water for electrolyzers – city network not allowed as well as irrigation canals.
- Plant location should be next to sea or sewage treatment plants which is used by some plants as a renewable source of water.
- Cost of desalination plant should be accounted for.
- Process CO2 will be reduced – additional cost of capturing CO2 from flue gases to maintain Urea production level.

IMPACT OF DECARBONIZATION ON EMBEDDED EMISSIONS AND DEVIATION FROM FREE ALLOWANCE

Product	Embedded Emissions, tCO2/tNH3					Free allowance	Deviation from free allowance	CBAM Cost $/t NH3
	Current	Energy Efficiency	Reduce Process Emissions	15% green hydrogen	All 3 measures			
Ammonia (A/U plants)	1.62	1.58	1.48	1.37	1.19	1.57	-0.44	0
Ammonia (A/NA plants)	2.52	2.49	2.32	2.27	2.17	1.57	1.6	128

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FREE ALLOWANCE PHASE OUT

FREE ALLOWANCE PHASE OUT FOR FERTILIZER SECTOR

Impact of phase out on deviation from free allowance for the various decarbonization projects, tCO2/t NH3

Case 1: reduction of thermal energy consumption

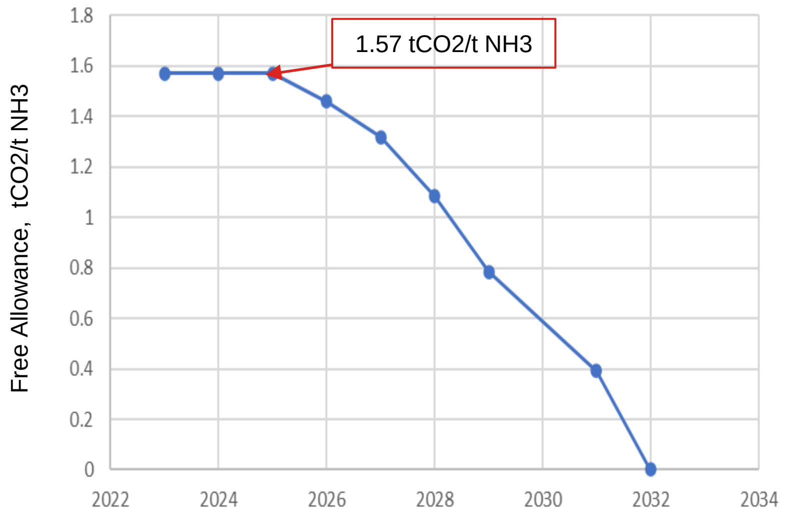
Case 2: reduction in process embedded CO2 to BAT value

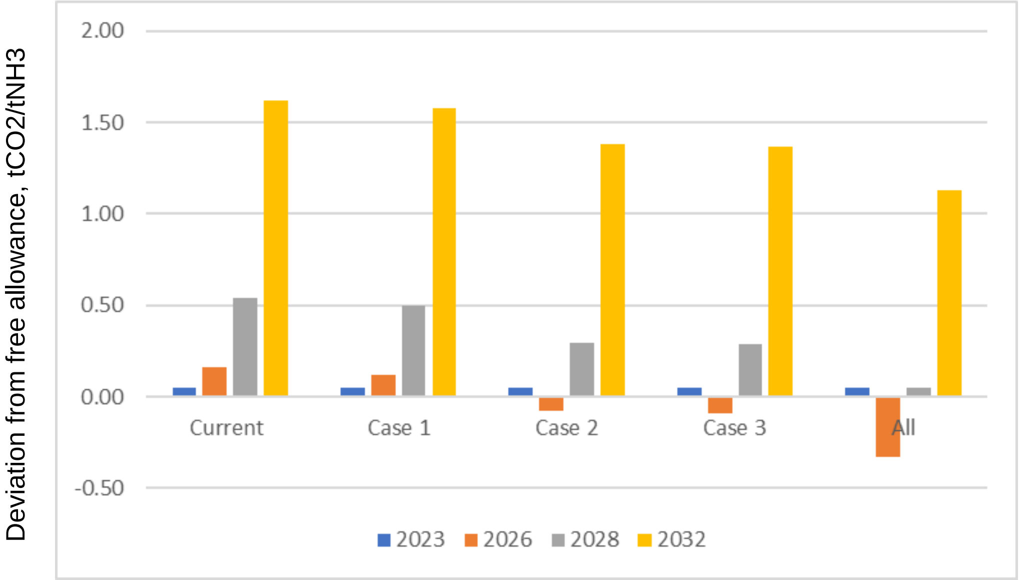
Case 3: 15% replacement of grey hydrogen by green hydrogen

All: all the above

Minus sign means potential for issuance of carbon credits

	Current	Case 1	Case 2	Case 3	All
2023	0.05	0.05	0.05	0.05	0.05
2026	0.16	0.12	-0.08	-0.09	-0.33
2028	0.54	0.50	0.30	0.29	0.05
2032	1.62	1.58	1.38	1.37	1.13





IMPACT OF CBAM AND CONCLUDING REMARKS

IMPACTS OF CBAM - FERTILISERS SECTOR AND CONCLUSION

Only precursors have ETS free allowances.

CBAM cost on a complex good such as Urea will depend on the amount of precursor in the complex good. In the case of The proportion of ammonia in Urea is **0.57** fraction of ammonia in Urea.

CBAM cost in €/ t Urea = deviation from free allowance tCO2/t ammonia * fraction of ammonia * average ETS cost in 2022

= (Embedded emissions – Free allowance) (tCO2/tNH3) * 0.57 * 80 (€/t CO_2) = cost €/t Urea

In 2032, CBAM cost after implementing all proposed projects

= 1.19 (tCO2/tNH3) * 0.57 * 80 €/t CO_2 = € 24.2 /t Urea.

Companies will have to weigh their options based on a financial feasibility that would take into consideration factors such as:

- Investment and operating costs of implemented decarbonization project
- Potential tapping into non-CBAM markets
- Current and future CBAM cost
- Change in ETS cost of CO_2

OFFICIAL USE

REFERENCES

- Guidance Document on CBAM Implementation for importers, Aug 2023
- European Commission webinar takeaway on CBAM for Fertilizer Industry, 2023
- CELEX_32021R0447_EN_TXT CAP
- Assessment of low carbon hydrogen production in Egypt, UNIDO, 2022
- National Greenhouse Gas Inventories on N2O, USEPA, 1999
- Studie Ammoniak, DECHEMA,2022
- IPPC-BREF manual for fertilizers, 2007
- Benchmarking Egyptian Fertilizer Industry, UNIDO, 2014

THANK YOU!

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