TNO

PBL Netherlands Environmental Assessment Agency

UPDATE REPORT:

DECARBONISATION OPTIONS FOR THE DUTCH FERTILISER INDUSTRY

Update based on original MIDDEN report published by M. Batool and W. Wetzels on 03 October 2019

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MIDDEN

Manufacturing Industry Decarbonisation Data Exchange Network

Colophon

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MIDDEN project coordination and responsibility

The MIDDEN project (Manufacturing Industry Decarbonisation Data Exchange Network) was initiated and is also coordinated and funded by PBL and TNO. The project aims to support industry, policymakers, analysts, and the energy sector in their common efforts to achieve deep decarbonisation. Correspondence regarding the project may be addressed to: D. van Dam (PBL), Dick.vanDam@pbl.nl or S. Lamboo (TNO), Sam.Lamboo@tno.nl.
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This report has been reviewed by Dick van Dam (PBL) and Marcel Weeda (TNO). PBL and TNO are responsible for the content of the report. The decarbonisation options and parameters are explicitly not verified by the company.

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1 Introduction

This report update refers to the MIDDEN report 'Decarbonisation options for the Dutch fertilizer industry', published on 03 October 2019. This report update only discusses significant changes that have occurred since the research leading to the aforementioned report, particularly changes in market, production output, production process, decarbonisation options and circumstances.

2 Production in the Netherlands

Based on Yara's own reporting, the ammonia production capacity at Yara Sluiskil is higher than reported in the previous MIDDEN report on the Dutch fertiliser industry (see Table 1). The liquid CO_2 capacity is owned and operated by Nippon Gases (Yara Sluiskil B.V., 2022). Another 50 kton CO_2 per year is sold to nearby horticulture as part of the WarmCO_2 project (Yara Sluiskil B.V., 2022). From the urea approximately 1 Mton of Adblue is produced per year (Yara Sluiskil B.V., 2022).

Table 1
Production capacity Yara Sluiskil in 2020

	Estimated production capacity [Mt/year]	**Source**	**Comments**
Ammonia (total)	1.9	(Yara International, 2020)	Total of 3 plants. Total is higher than in previous report (1.82 Mt/year)
Nitric Acid	1.4	(Yara International, 2020)	Lower than in previous report (1.5 Mt/year)
Urea	1.3	(Yara International, 2020)	Same as in previous report
Nitrates	1.9	(Yara International, 2020)	Higher than in previous report (1.8 Mt/year)
UAN (Urea Ammonium Nitrate)	0.6	(Yara International, 2020)	Lower than in previous report (913 kton/year)
Liquid CO_2	0.42	(Gedeputeerde Staten van Zeeland, 1998)	Has not been updated

OCI N.V. is also planning to produce Adblue from urea in the Netherlands (Gedeputeerde Staten van Limburg, 2021), with expected start of production in Q1 2024 (OCI Global, 2023). OCI is also working on increasing the ammonia import capacity in the Rotterdam harbour from a capacity of 400 kton per year to 1.2 Mton per year (OCI Global, 2022).

Table 2
Production capacity OCI N.V. in 2017

	Estimated production capacity [kt/year]	Source	Comments
Ammonia (total)	1,184	(OCI N.V., 2018)	Total of 2 plants
Nitric Acid	965	(Ecofys; Fraunhofer Institute for Systems and Innovation Research; öko-Institut, 2009)	Same as previous report
Ammonium nitrate	923	Own estimate	Required capacity for UAN and CAN production. Expected to be an overestimate as full UAN capacity cannot be achieved when producing max. CAN capacity
Urea	525	(European Commission, 2007)	Same as in previous report
UAN (Urea Ammonium Nitrate)	730	(OCI N.V., 2018)	Same as in previous report
CAN (Calcium Ammonium Nitrate)	1,542	(OCI N.V., 2018)	Same as in previous report
Melamine	164	(OCI N.V., 2018)	Same as in previous report. OCI's melamine production capacity in China is not included

Table 3 shows the EU ETS emissions of Yara Sluiskil B.V. and Chemelot in the period 2017-2022. The reduction in CO_2 emissions in 2022 is expected to be the consequence of the scaling down of production due to the increased natural gas prices (CBS, 2023) (CBS, 2023). At certain times during the year only one ammonia plant was operational at both Yara Sluiskil B.V. and OCI N.V. (interviews Yara Sluiskil B.V. and OCI N.V.).

Table 3
EU ETS emissions of Yara Sluiskil B.V. and Chemelot in kt CO_2eq per year, for the 2017-2022 period. Source: Dutch Emissions Authority (NEa)

Year	2017	2018	2019	2020	2021	2022
Yara Sluiskil B.V.	3,828	3,607	3,447	3,298	3,190	2,750
Chemelot	4,749	4,643	4,650	4,652	4,502	3,870

Table 4 shows the CO_2 and N_2O emissions at Yara Sluiskil B.V. from the European Pollutant Release and Transfer register. In 2020 N_2O emissions reduced by 40% and reduced emissions by over 100 kt CO_2e. Another 110 kton CO_2e emissions reduction is expected in 2022 based on the replacement of the burners for one of the nitric acid plants (Yara Sluiskil B.V., 2022).

Table 4
Emissions of CO_2 and N_2O by Yara Sluiskil B.V., for the 2015-2020 period. Source: European Pollutant Release and Transfer Register (PRTR)

Year	2015	2016	2017	2018	2019	2020	2021
Carbon dioxide [kt CO_2/yr]	3,550	3,500	3,580	3,350	3,170	3,130	3,050
Nitrous oxide [kt N_2O/yr]	0.74	0.78	0.82	0.85	0.87	0.52	0.53
Nitrous oxide [kt CO_2eq/yr]	220	231	245	253	259	155	158
Total [kt CO_2eq/yr]	2,770	3,731	3,825	3,603	3,429	3,285	3,208

Table 5 shows the CO_2 and N_2O emissions at Chemelot from the European Pollutant Release and Transfer register. A significant reduction in N_2O emissions was realized in 2021 at Fibrant (Chemelot, 2021). The reduction is not related to activities at OCI in Geleen.

Table 5
Emissions of CO_2 and N_2O by Chemelot, for the 2015-2020 period. Source: European Pollutant Release and Transfer Register (PRTR)

Year	2017	2018	2019	2020	2021
Carbon dioxide [kt CO_2/yr]	4,750	4,640	4,090	4,150	3,960
Nitrous oxide [kt N_2O/yr]	4.17	3.71	3.67	3.58	2.89
Nitrous oxide [kt CO_2eq/yr]	1,224	1,106	1,094	1,067	861
Total [kt CO_2eq/yr]	5,974	5,746	5,184	5,217	4,821

3 Processes

The processes have not significantly changed since the previous report. Below are updated calculations for the nitrous oxide emissions.

Nitrous oxide emissions

The nitrous oxide emissions from nitric acid production in Europe have reduced since the 1990s due to the implementation of various abatement technologies (IPCC, 2021). The EU ETS benchmark for nitric acid is 230 kg CO_2e per ton nitric acid, which is equal to 0.77 kg N_2O per ton nitric acid (European Commission, 2021).

Yara Sluiskil B.V. emitted 530 ton N_2O in 2021 (See Table 3) and assuming a nitric acid production capacity of 1500 kton per year and 8000 full load hours, relative emissions have decreased to 0.4 kg N_2O per ton nitric acid. There is no recent publicly available data for N_2O emissions by OCI N.V., but considering NEa emissions data from 2017 the relative emissions can be estimated. Emissions from nitric acid production in 2017 were 61 kton CO_2e (see Table 7 from (Batool & Wetzels, 2019)), which corresponds to 205 kg N_2O emissions. With an estimated nitric acid production capacity of 965 kt per year, the yearly estimated production of nitric acid is 881 kt per year at 8000 full load hours (see Table 13 of (Batool & Wetzels, 2019)). This results in an estimated N_2O emission of 0.23 kg per ton nitric acid.

4 Products and application

The prices of ammonia and fertilizers have gone up significantly in 2021 and 2022. Benchmark prices presented by OCI N.V. (OCI N.V., 2023) are a factor 3-4 higher compared to 2018. Table 6 captures the large uncertainty in current fertilizer product market prices.

Table 6
Benchmark prices for several main fertilizer products. All in USD/tonne product. Based on (Batool & Wetzels, 2019), (OCI N.V., 2023) and (IEA, 2023).

Product	2018 (OCI N.V., 2018)	2021 (OCI N.V., 2023)	2022 (OCI N.V., 2023)	2023 (IEA, 2023)
Ammonia (NW Europe)	278	623	1221	
Ammonia (US)	267	595	1161	
Ammonia (Global)	-	-	-	216-1049
Granular Urea (Egypt)	244	529	756	
CAN (Germany)	175	338	717	
UAN (France)	153	340	669	
UAN (US)	231	413	631	

Both Yara Sluiskil B.V. and OCI N.V. produce more products than just fertilizers. As indicated in Chapter 2, Adblue is an increasingly important product for both Yara Sluiskil B.V. and OCI N.V. Adblue is water-diluted urea and is used as an additive for diesel cars for the reduction of NOx and CO_2 emissions.

The Chemelot cluster is highly integrated and OCI N.V. supplies various products to other companies on-site. Ammonia is delivered to Fibrant and AnQore for the production of caprolactam, ammonium sulfate and other products. Hydrogen is sold to Envalior and Fibrant (interview OCI N.V.). CO_2 from OCI N.V. is also used by various parties at Chemelot (interview OCI N.V.). Carbolim, a joint venture between Air Liquide and Air Products, purifies and conditions CO_2 at the Chemelot cluster and distributes the CO_2 to end users such as Coca Cola (Chemelot, 2023).

5 Options for decarbonisation

In 2023 both Yara Sluiskil B.V. and OCI N.V. signed Expressions of Principles with the Dutch government, which provide insight into the preferred decarbonization options for the short term. Yara Sluiskil's Expression of Principles (Minister of Economic Affairs and Climate Policy; State Secretary of Infrastructure and Water Management; Provincial Executive of the Province of Zeeland; Yara Sluiskil B.V., 2023) aligns well with their Climate Roadmap for 2030 (Yara Sluiskil B.V., 2022). A mix of options are mentioned, most prominently Carbon Capture and Storage (CCS), energy efficiency, the use of renewable hydrogen and nitrous oxide emission reduction. For the longer term, the import of renewable hydrogen is also mentioned as a part of Yara Sluiskil's aspirations.

In November 2023 Yara International signed a binding commercial agreement with Northern Lights for the liquefaction and transport of 800 kton of CO_2 per year from Sluiskil to Norway, where it will be stored (Yara International, 2023). The project will start in 2025 and run for 15 years. The investment decision followed the announcement from the Dutch government to support the project with a maximum of €30 million in subsidies, out of a total investment of €194 million (Ministerie van Economische Zaken en Klimaat, 2023).

OCI N.V. mention a similar mix of decarbonization options in their Expression of Principles (Minister of Economic Affairs and Climate Policy; State Secretary of Infrastructure and Water Management; OCI N.V., 2023). The focus is more heavily on producing ammonia from low carbon, circular and renewable hydrogen and/or through the import of low-carbon, circular[1] and renewable ammonia through their terminal in the Port of Rotterdam. CCS is mentioned as a possible transition technology.

RWE's FUREC project at Chemelot is a potential source of hydrogen and CO_2 for OCI N.V., produced from the gasification of non-recyclable solid waste streams (RWE, 2023)(European Commission, 2023).

A portion of external hydrogen can be blended in the current ammonia production. According to Yara Sluiskil B.V. and OCI N.V., this is possible up to approximately 20% of the hydrogen use (interviews Yara Sluiskil B.V. and OCI N.V.). At higher percentages of external hydrogen, an Air Separation Unit is required to supplement the missing amount of nitrogen that would otherwise be introduced into the process via conventional hydrogen production. The ammonia synthesis plant also needs to be updated, which requires significant investments. Costs for a greenfield ammonia synthesis island for a power-to-ammonia design are approximately 400 USD_{2020} higher per ton of ammonia production capacity than the natural gas production route (Zhang, Wang, Van Herle, Maréchal, & Desideri, 2020). In a CE Delft and TNO study the cost for the refurbishment of the existing ammonia plants are estimated at 150 million $Euro_{2023}$ for a 600 kton ammonia plant, including a 25% increase for refurbishment instead of a new plant (Leguijt, et al., 2023). This would imply additional costs of 450 million $Euro_{2023}$ for Yara Sluiskil B.V. and 300 million $Euro_{2023}$ for OCI N.V. for the refurbishment of the ammonia synthesis islands. The additional investment in Air

[1] Refers to ammonia made from hydrogen from circular waste-gasification. See also the FUREC project.

Separation Units is estimated at 125 million $Euro_{2023}$ for the required 2200 kton nitrogen per year (Leguijt, et al., 2023).

For complete decarbonization of the fertilizer production, a CO_2-neutral solution also needs to be implemented for urea production. There are two main options:

1. Producing urea with CO_2 from e.g. biomass or direct air capture
2. Shifting production away from urea-based fertilizers to nitrogen-based fertilizers such as Calcium Ammonium Nitrate (CAN)

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