NETL Life Cycle Inventory Data
Process Documentation File

Process Name: CO_2 Captured from Ammonia Production

Reference Flow: 1 kg of CO_2

Brief Description: Fuel, feedstock, and emissions associated with 1 kg of CO_2 captured from an ammonia plant.

Section I: Meta Data

Geographical Coverage: US **Region:** Not Applicable

Year Data Best Represents: 2010

Process Type: Manufacturing Process (MP)

Process Scope: Gate-to-Gate Process (GG)

Allocation Applied: No

Completeness: Individual Relevant Flows Captured

Flows Aggregated in Data Set:

☑ Process ☑ Energy Use ☐ Energy P&D ☐ Material P&D

Relevant Output Flows Included in Data Set:

Releases to Air:	☑ Greenhouse Gases	☑ Criteria Air	☐ Other
Releases to Water:	☐ Inorganic	☐ Organic Emissions	☐ Other
Water Usage:	☑ Water Consumption	☐ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

NG_in	*[kg/kg] Natural gas input (feedstock and fuel) per unit of CO_2 captured*
Water_in	*[kg/kg] Water input per unit of CO_2 captured*
Fuel_fraction	*[dimensionless] Fraction of natural gas input used as fuel instead of feedstock*

Tracked Input Flows:

Natural gas	*[Technosphere] Natural gas used as feedstock*
Natural gas combustion in auxiliary boiler	*[Technosphere] Natural gas used as fuel for steam generation*
Surface water	*[Technosphere] Water input to ammonia plant*

Tracked Output Flows:

Carbon dioxide (captured)	*Reference flow*
Ammonia	*Ammonia (co-product)*
Carbon dioxide [Inorganic emissions to air]	*Emission to air*
Carbon monoxide [Inorganic emissions to air]	*Emission to air*
Sulphur dioxide [Inorganic emissions to air]	*Emission to air*
NMVOC (unspecified) [Group NMVOC to air]	*Emission to air*
Ammonia [Inorganic emisisons to air]	*Emission to air*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_CO2_from_Ammonia_Production_2012.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant input and output flows associated with ammonia production. The reference flow is CO_2 output, captured from a stripper column, that can be used as an alternative source of CO_2. The reference flow of this unit process is: 1 kg of CO_2

Boundary and Description

Figure 1 provides an overview of the boundary of this unit process. The boundaries of this unit process start with the delivery of natural gas feedstock and water. The boundaries end with the outputs of ammonia, pipeline CO_2, and emissions. The reference flow of this unit process is the production of one kg of pipeline CO_2.

CO_2 is a co-product of synthetic ammonia, which is used as fertilizer. Ammonia plants use natural gas as a fuel and feedstock (EPA, 2009). As a fuel, natural gas is used to generate steam that is used to reform methane, air, and water (Energetics, 2000; Strait and Nagvakar, 2010; USDA, 2007). As a feedstock, ammonia is combusted in the presence of air and water to form H_2, CO, and CO_2. Unconverted CO is then shifted to produce more H_2 and CO_2. Ammonia is then produced using the Haber process, a high-pressure, catalyzed reaction between N_2 and H_2.

An ammonia plant has two key sources of CO_2, emissions from the reformer unit and emissions from the stripper unit that removes CO_2 from the ammonia product stream. The conditions of the reformer emission stream are not suitable for CO_2 recovery, but the acid gas stream that exits the stripper unit is 99 percent CO_2 and can be easily captured. The CO_2 capture stream of this unit process is representative of the CO_2 exiting the stripper; the CO_2 emissions from this unit process are representative of the emissions from the reformer.

Many ammonia plants use a portion of captured CO_2 and produced ammonia to make urea. This unit process does not include urea production. The flow rates of the captured CO_2 and produced ammonia streams represent an ammonia plant with no intermediate products being sent to urea production.

The CO_2 emissions from this unit process are representative of the CO_2 in the reformer flue gas (Strait and Nagvakar, 2010). Other air emissions include carbon monoxide, sulfur dioxide, ammonia, and volatile organic compounds. These other air emissions were calculated using EPA AP42 emission factors for a typical ammonia plant in the U.S. (EPA, 1993)

The steam used in the reformer is generated in a separate process, so the emissions from steam generation are not included in this unit process. This unit process calculates the portion of natural gas used for steam generation (Worrel et al, 2000). The portion of natural gas used for steam generation is a tracked input to this unit process, which allows the modeling of the combustion of natural gas for steam generation in a separate unit process outside the boundary of this unit process.

Water is consumed by the ammonia plant. This water is converted to steam used in the reforming process. The flow rate of water depends on the efficiency of the reformer. Water is also used by other systems in an ammonia plant, but the loss rate of water for these other systems is negligible compared to the water consumed by the reformer. (EFMA, 2000)

According to Haldor Topsoe, a supplier for the ammonia industry, many ammonia plants have catalysts that have lasted 20 years. Haldor Topsoe also notes that the catalyst is usually replaced only during plant modifications (Haldor Topsoe, 2011). Therefore, it is assumed that the amount of catalyst used during ammonia production is negligible with respect to this unit process.

Figure 1: Unit Process Scope and Boundary

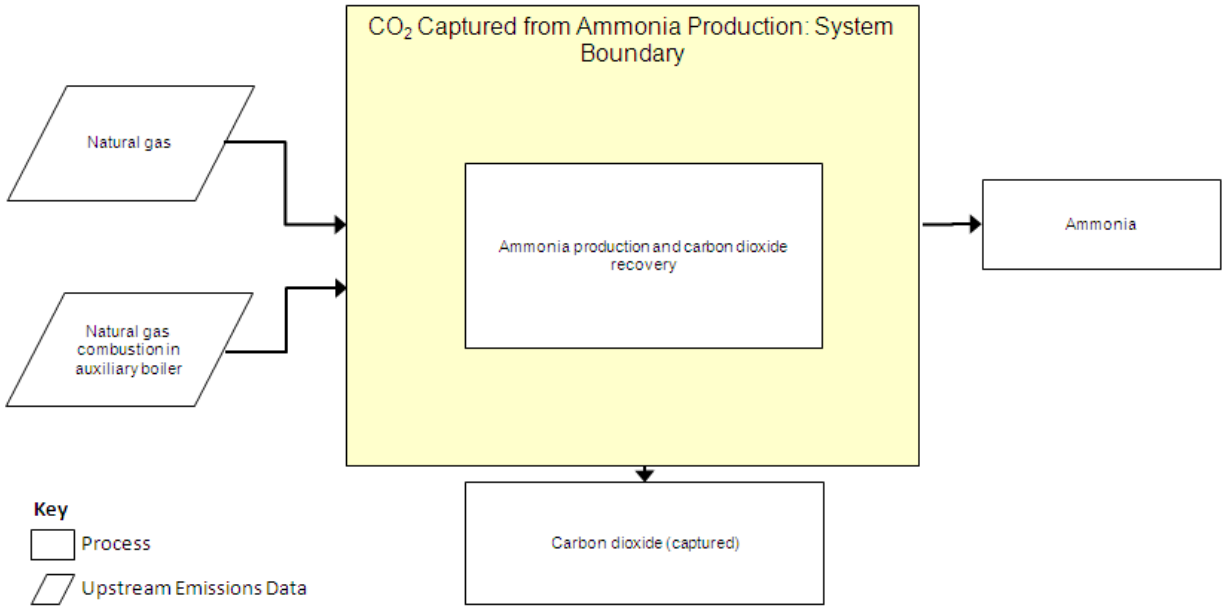

Table 1: Characteristics of a Typical Ammonia Plant

Characteristic	Value
Capacity	1,000,000 tons/year
Actual Production Rate	720,000 tons/year
Pipeline CO_2 Temperature	69° F
Pipeline CO_2 Pressure	23.52 psia

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Natural gas	0.538	kg
Natural gas combustion in auxiliary boiler	0.392	kg
Surface water	1.72	kg
Outputs		
Carbon dioxide (captured)	1.00	kg
Ammonia	1.57	kg
Carbon dioxide [Inorganic emissions to air]	1.93	kg
Carbon monoxide [Inorganic emissions to air]	1.24E-02	kg
Sulphur dioxide [Inorganic emissions to air]	4.51E-05	kg
NMVOC (unspecified) [Group NMVOC to air]	7.39E-03	kg
Ammonia [Inorganic emissions to air]	3.29E-03	kg

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows.

Embedded Unit Processes

None.

References

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Section III: Document Control Information

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