NETL Life Cycle Inventory Data
Process Documentation File

Process Name: CO_2 Recovery

Reference Flow: 1 kg of carbon dioxide

Brief Description: Operation of an amine-based CO_2 recovery system

Section I: Meta Data

Geographical Coverage: United States **Region:** N/A

Year Data Best Represents: 2012

Process Type: Transport Process

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

Allocation Applied: No

Completeness: All 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 Pollutants	☐ Other
Releases to Water:	☐ Inorganic Emissions	☐ Organic Emissions	☐ Other
Water Usage:	☒ Water Consumption	☒ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

Solvent	*Makeup rate of amine solvent for CO_2 recovery*
Steam	*Steam input per unit of CO_2 captured*
Water_in	*Water withdrawal per unit of CO_2 captured*
Swater_share	*Share of water withdrawn from surface water sources*
CO2_caprate	*CO_2 capture rate*

Tracked Input Flows:

Steam	*Steam used for reboiler heating*

Carbon dioxide	*CO_2 from flue gas or other process*
Monoethanolamine	*Amine solvent used for CO_2 recovery*

Tracked Output Flows:

Recovered CO2	*CO_2 captured from a flue gas stream or other process*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_CO2_Recovery_2012.01.doc*, 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 the operation of an amine-based CO_2 (carbon dioxide) capture system at an energy conversion facility or other process. The key emissions of this unit process are CO_2 that is not captured by the process and amine solvent that is released during solvent regeneration.

The tracked inputs into this unit process include steam, CO_2, and solvent (monoethanolamine [MEA]). Key outputs are CO_2 and amine released to air. The reference flow of this unit process is the capture of one kilogram of CO_2 as described below and shown in **Figure 1**. This unit process is used within Life Cycle (LC) Stage #3 of NETL's energy conversion models.

Boundary and Description

This unit process provides a summary of relevant input and output flows associated with the operation of an amine-based CO_2 capture system at an energy conversion facility or other process. The key emissions of this unit process are CO_2 that is not captured by the process and amine solvent that is released during solvent regeneration. The tracked inputs into this unit process include steam, CO_2, and solvent (MEA). Key outputs are CO_2 and amine released to air. The reference flow of this unit process is the capture of one kilogram of CO_2.

The CO_2 recovery facility in NETL's bituminous baseline (NETL, 2010) has a steam requirement of 3,556 kilojoules per kilogram (kJ/kg) of captured CO_2. If more controls are used for optimizing solvent consumption and waste, the steam requirement is lower

(3,242 kJ/kg CO_2) (NETL, 2010). Another report by NETL on advanced CO_2 recovery technologies (NETL, 2011) shows a steam consumption rate of 3,559 kJ/kg CO_2. Data published by Fluor Corporation, which owns the service mark for the Econamine FG Plus CO_2 recovery technology, shows steam consumption of 3,245 kJ/kg CO_2 (FLUOR, 2003). The low and high values within this set of data points are 3,242 kJ/kg CO_2 and 3,559 kg kJ/kg CO_2, respectively (the high value is 9.8 percent higher than the low value). The midpoint of these two values is 3,400 kJ/kg CO_2 and is used as the expected value. This unit process accounts for energy on a megajoule (MJ) basis, so these steam consumption rates are converted from kJ to MJ using a conversion factor of 1,000 kJ per MJ.

NETL's bituminous baseline (NETL, 2010) includes water balances for the operation of CO_2 recovery systems for natural gas combined cycle (NGCC), SCPC (supercritical pulverized coal), and subcritical PC (pulverized coal). The water withdrawn by the CO_2 recovery systems of these power technologies range from 12 to 39 gallons per minute. This unit process uses the net power output of each case to translate the water withdrawal to a basis of kg of water/kg of CO_2 captured. The water withdrawal calculations for the NGCC case are described below:

1. Conversion of water withdrawal rate from gal/min to kg/hr:
    - The CO_2 capture system of an NGCC facility withdraws water at a rate of 12 gal/min.
    - One gallon of water has a mass of 3.786 kg (at standard conditions), so 12 gal/min is equal to 45.4 kg/min.
    - There are 60 minutes per hour, so 45.5 kg/min is equal to **2,726 kg water withdrawal/hr**.
2. Calculation of hourly CO_2 capture rate:
    - The NGCC facility with carbon capture captures 90 percent of total CO_2 and releases 94 lb of CO_2 per MWh of net production
    - Dividing 94 by 10 percent (100 percent minus 90 percent) gives total CO_2 produced (940 lb CO_2/MWh)
    - Subtracting released CO_2 (94 lb CO_2/MWh) from total CO_2 (940 lb CO_2/MWh) gives a CO_2 capture rate of 846 lb CO_2/MWh. This is equivalent to 384 kg CO_2/MWh (using a conversion factor of 2.205 lb/kg).
    - Multiplying the CO_2 capture rate (384 kg CO_2/MWh) by hourly electricity production (474 MWh/hr) gives a CO2 capture rate of **182,000 kg CO_2 captured/hr**.
3. Divide the hourly water withdrawal rate by the hourly CO2 capture rate: 2,726 kg water withdrawal/182,000 kg CO_2 captured = **0.0150 kg water withdrawal/kg CO_2 captured.**

Using the above method, the average water withdrawn by the CO_2 recovery systems for NGCC, SCPC, and subcritical PC is 0.0184 kg water/kg CO_2 captured, with a range of 0.0149 to 0.0219 kg water/kg CO_2 captured.

No water is discharged by the CO_2 recovery system; all water is lost through the vent of the CO_2 absorption vessel.

Water flows are usually expressed on a volumetric (e.g., liters) basis, but this unit process accounts for water flows on a mass basis (kg). One kilogram of water has a volume of 1 liter.

The balance sheet for NGCC with CO_2 captured in NETL's bituminous baseline shows a MEA solvent replacement rate of 0.48 ton/day. The same plant captures 5,342 ton/day of CO_2, which was calculated by converting the CO_2 capture rate (940 lb/MWh_{net}) to the basis of tons (1 ton = 2,000 lbs), and multiplying by the electricity production rate at a 100 percent capacity factor (11,366 MWh_{net}/day). Dividing the solvent replacement rate (0.48 ton/day) by the CO_2 capture rate (5,342 ton/day) gives a solvent replacement rate of 8.985E-05 kg solvent per kg CO_2 captured. The same method was applied to the MEA solvent replacement rates for subcritical PC and SCPC. When expressed on the basis of mass of solvent per mass of CO_2 captured, the MEA replacement rates for the three technologies vary by less than 0.8 percent.

CO_2 capture rate is an adjustable parameter in this unit process. The reference flow of this unit process is the capture of 1 kg of CO_2. Since the amount of captured CO_2 is held constant by the reference flow, as the parameter for CO_2 capture rate increases, there is a decrease in both the CO_2 input to the unit process and the emission of CO_2 from the unit process. Similarly, since the reference flow of this unit process is the capture of 1 kg of CO_2, the steam inputs and water consumption are not affected by the CO_2 capture rate. The steam and water requirements for CO_2 capture are a function of total captured CO_2, not the capture rate of CO_2.

Figure 1 provides an overview of the boundary of this unit process. There are three tracked inputs to this unit process: steam, CO_2, and solvent (MEA). Captured CO_2 is the only tracked output from this unit process.

Figure 1: Unit Process Scope and Boundary

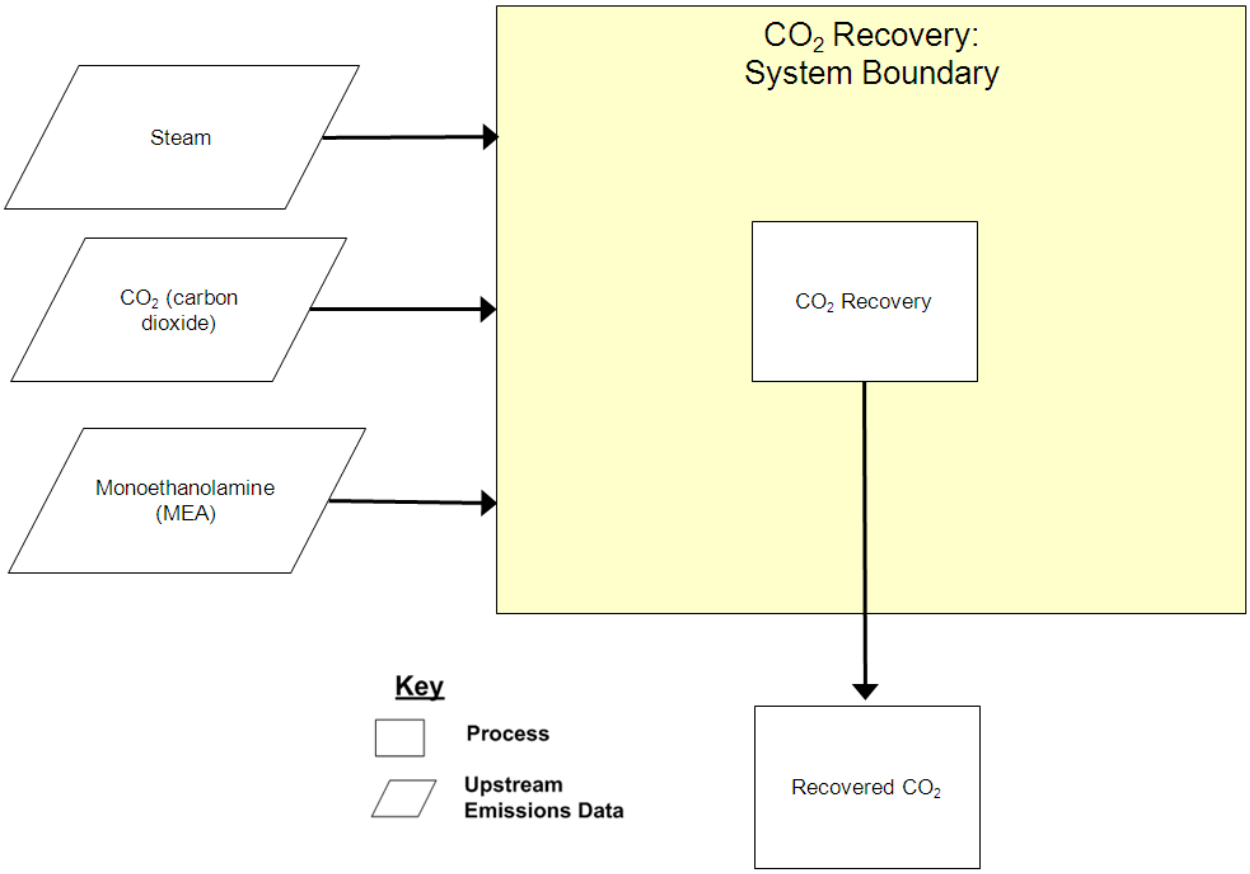

Table 1 summarizes the emission factors and other parameters that are relevant to this unit process. **Table 2** provides a summary of modeled input and output flows and shows all inputs and outputs on the basis of the reference flow (the capture of one kilogram of CO_2). Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Table 1: Emission Factors and Other Relevant Parameters

Flow Name	Value	Units
Makeup rate of amine solvent	1.00E-04	kg solvent/kg captured CO_2
Steam input	3.4	MJ/kg captured CO_2
CO_2 capture rate	90	percent
Share of input water that is surface water	50	percent

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Steam	3.400	MJ
Water (ground water) [Water]	7.46E-03	kg
Water (surface water) [Water]	7.46E-03	kg
Carbon dioxide	1.111	kg
Monoethanolamine	1.00E-04	kg
Outputs		
Carbon dioxide	1.000	kg
Carbon dioxide [Inorganic emissions to air]	0.1111	kg
NMVOC (unspecified) [Group NMVOC to air]	1.00E-04	kg

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows. Upstream environmental flows were added during the modeling process using GaBi modeling software, as shown in Figure 1.

Embedded Unit Processes

None.

References

FLUOR, 2003. Fluor's Econamine FG Plus Technology: An Enhanced Amine-Based CO2 Capture Process, FLUOR Corporation. Accessed on July 30, 2012 at http://www.fluor.com/SiteCollectionDocuments/FluorEconamineFGPlusTechnology-NETLConf_May2003.pdf.

NETL, 2010 NETL, 2010. Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity, National Energy Technology Laboratory, Pittsburgh, PA. Accessed on July 30, 2012 at http://www.netl.doe.gov/energy-analyses/pubs/BitBase_FinRep_Rev2.pdf.

NETL, 2011 NETL, 2011. DOE/NETL Advanced Carbon Dioxide Capture R&D Program: Technology Update, National Energy Technology Laboratory, Pittsburgh, PA. Accessed on July 30, 2012 at http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/CO2Handbook/CO2-Capture-Tech-Update-2011_Front-End%20Report.pdf.

Section III: Document Control Information

Date Created: July 30, 2012

Point of Contact: Timothy Skone (NETL), Timothy.Skone@NETL.DOE.GOV

Revision History:

Original/no revisions

How to Cite This Document: This document should be cited as:

NETL (2012). *NETL Life Cycle Inventory Data – Unit Process: CO2 Recovery.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: July 2012 (version 01). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses)

Section IV: Disclaimer

Neither the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) nor any person acting on behalf of these organizations:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information, apparatus, method, or process disclosed in this document may not infringe on privately owned rights; or

B. Assumes any liability with this report as to its use, or damages resulting from the use of any information, apparatus, method, or process disclosed in this document.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by NETL. The views and opinions of the authors expressed herein do not necessarily state or reflect those of NETL.