NETL Life Cycle Inventory Data
Process Documentation File

Process Name: CO2 Compression

Reference Flow: 1 kg of carbon dioxide, compressed to 2,200 PSI

Brief Description: The operating requirements for compression of CO_2 from atmospheric pressure to pipeline pressure.

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:

CO2_flow	*Flow rate of CO_2 through compressor*
EF_CO2	*CO_2 emissions per compression of 1 kg of CO_2*
Water_w	*Water withdrawal*
Water_d	*Water discharge*

Tracked Input Flows:

Carbon Dioxide	*Captured CO_2 from an energy conversion facility*
Electricity	*Electricity used for powering a CO_2 compression system*

Tracked Output Flows:

Carbon dioxide	*Compressed CO_2 ready for pipeline transport*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_CO2_Compression_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 a carbon dioxide compression system that compresses CO_2 recovered at an energy conversion facility from atmospheric pressure to pipeline pressure. The key emission of this unit process is CO_2 that leaks from compressors.

The tracked inputs are electricity and CO_2, and the key outputs are compressed CO_2 and CO_2 emissions to air. The reference flow of this unit process is the compression 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 a carbon dioxide compression system that compresses CO_2 recovered at an energy conversion facility from atmospheric pressure to pipeline pressure. The tracked inputs are electricity and CO_2, and the key output is compressed CO_2 and CO_2 emissions to air. The reference flow of this unit process is the compression of one kilogram of CO_2.

To prepare captured CO_2 for pipeline transport, it must be compressed from atmospheric pressure (14.7 pounds per square inch (psi) or 0.1 megapascals [MPa]) to a supercritical pressure (2,200 psi or 15.2 MPa). At pipeline conditions, liquid carbon dioxide forms at a pressure of 7.38 MPa. The pipeline pressure is maintained above this critical point to ensure that all CO_2 remains in the liquid state. A five-stage compression system is required to meet these compression requirements. Once the CO_2 is compressed to a liquid, further pressurization is provided by pumps. Most energy is expended compressing the CO_2 from gas to liquid, while less energy is required to further pressurize the supercritical CO_2 liquid. (McCollum, 2006).

The power to compress CO_2 from atmospheric pressure to a liquid is described by **Equation 1**, which is based on a performance curve for CO_2 compression and is a function of CO_2 flow rate.

*Power (MW) = 0.004182*x, Where x = CO_2 flow rate (tonnes/day)* **(Equation 1)**

The power to further pressurize supercritical CO_2 is described by **Equation 2**, which is also based on a performance curve for CO_2 compression and is a function of CO_2 flow rate.

*Power (MW) = 0.0001867*x , where x = CO_2 flow rate (tonnes/day)* **(Equation 2)**

This unit process models all CO_2 compression and pumping using electric power. The power requirements calculated by the above equations represent compressors and pumps with an efficiency of 75 percent (McCollum, 2006).

To convert to a basis of CO_2 compressed, the power input (MW) is multiplied by the operating time at full capacity (24 hours/day) and divided by CO_2 throughput at full capacity (in tonnes/day). At a CO_2 flow rate of 10,000 tonnes/day, the electricity requirements for CO_2 compression are 1.05E-04 MWh/kg of CO_2.

The operation of CO_2 compressors results in fugitive emissions of CO_2. The low, mid-range, and high emission factors for CO_2 from compressors are 6,972, 23,240, and 116,200 kg of CO_2 per megawatt-year (MW-yr). These factors are based on natural gas pipeline data that the Intergovernmental Panel on Climate Change (IPCC) collected and adapted to CO_2 pipelines using the relative densities of natural gas and CO_2 (Holloway, 2006). On a daily basis, this is equivalent to 19.1, 64.0, and 318 kg CO_2/MW-day. This unit process applies these emission factors to the calculated compressor power output to determine the fugitive CO_2 emissions from CO_2 compressors.

Water is required for interstage cooling of compressors. NETL's characterization of advanced power plant technologies includes the water balance for subcritical PC, SCPC, and NGCC power plants with CCS. These data were the focus of a 2008 NETL document focusing on the water requirements for thermoelectric power plant technologies (NETL, 2008). This unit process converts the water data to a basis of compressed CO_2. Approximately 0.15 liters of water are withdrawn per kg of compressed CO_2; approximately 0.04 liters of water are discharged per kg of compressed CO_2. This unit process models water withdrawal using a 50/50 split between surface and ground water sources.

Figure 1 provides an overview of the boundary of this unit process. There are two inputs to this unit process: electricity used for powering compressors and CO_2 that has been captured at an energy conversion facility. The capture of CO_2 is not included in this unit process. The fugitive emission of CO_2 is accounted for in this unit process. There is one tracked output for this unit process: 1 kg of CO_2.

Figure 1: Unit Process Scope and Boundary

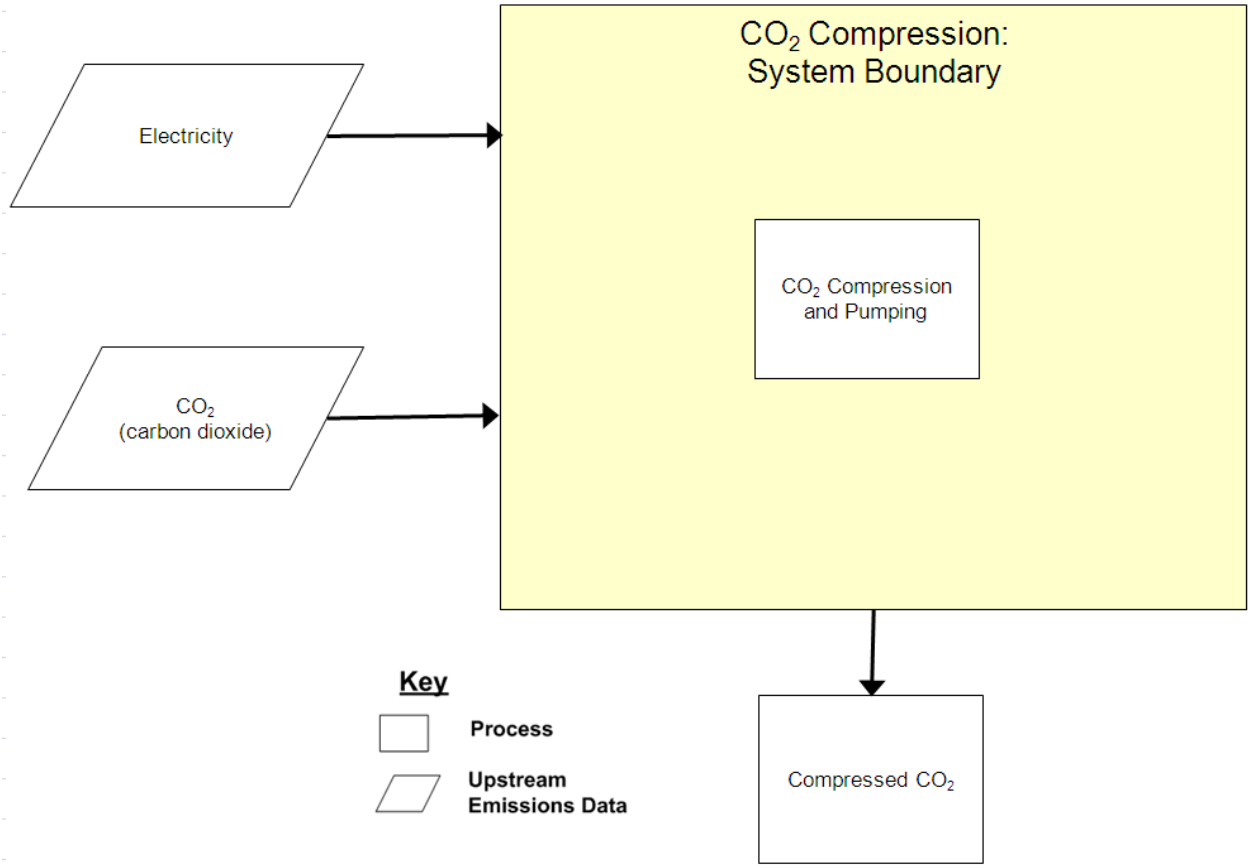

Table 1 summarizes emission factors and other parameters that are relevant to this unit process. **Table 2** provides a summary of modeled input and output flows and shows all inputs and outputs on the basis of the reference flow (the compression of one kilogram of CO_2). Additional detail regarding 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
CO_2 emission factor	64	kg/(MW-day)
CO_2 flow	10,000	tonne/day

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Carbon dioxide	1.000278	kg
Electricity	1.05E-04	MWh
Surface Water	7.31E-02	kg
Ground Water	7.31E-02	kg
Outputs		
Carbon dioxide	1.000	kg
Carbon dioxide [Inorganic emissions to air]	2.78E-04	kg
Water discharged	4.01E-02	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

Holloway, 2006 — Holloway, S., 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Chapter 5: Carbon Dioxide Transport, Injection, and Geological Storage, Intergovernmental Panel on Climate Change (IPCC). Accessed on July 25, 2012 at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_5_Ch5_CCS.pdf.

McCollum, 2006. — McCollum, D.L, 2006. Techno-Economic Models for Carbon Dioxide Compression, Transport, and Storage & Correlations for Estimating Carbon Dioxide Density and Viscosity, Institute of Transportation Studies, University of California, Davis, Davis, California. Accessed on July 26, 2012 at http://pubs.its.ucdavis.edu/publication_detail.php?id=1047.

NETL, 2008 — NETL, 2008. Water Requirements for Existing and Emerging Thermoelectric Plant Technologies. National Energy Technology Laboratory. August 2008 (Revised April 2009). DOE/NETL-402/080108.

Section III: Document Control Information

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