NETL Life Cycle Inventory Data
Process Documentation File

Process Name: CO_2 Pipeline Construction

Reference Flow: 1 piece of CO_2 pipeline

Brief Description: The construction requirements for a CO_2 pipeline.

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:

Pipe_L	*Pipeline length (miles)*
CO2_rate	*Flow rate of CO_2 through pipeline (ton/day)*
Tortuosity	*Tortuosity factor of pipeline*
Valves	*Fraction of total pipeline mass added by valves and other pipeline equipment*

Tracked Input Flows:

Steel	*Steel used for pipeline construction*

Tracked Output Flows:

CO2 Pipeline Construction	*1 piece of CO_2 pipeline construction*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_C_CO2_Pipeline_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 the construction of a CO_2 pipeline. It includes scaling equations based on the relationships between distance, flow rate, and pipeline diameter. It includes parameters for pipeline tortuosity and extra materials for valves and other pipeline equipment.

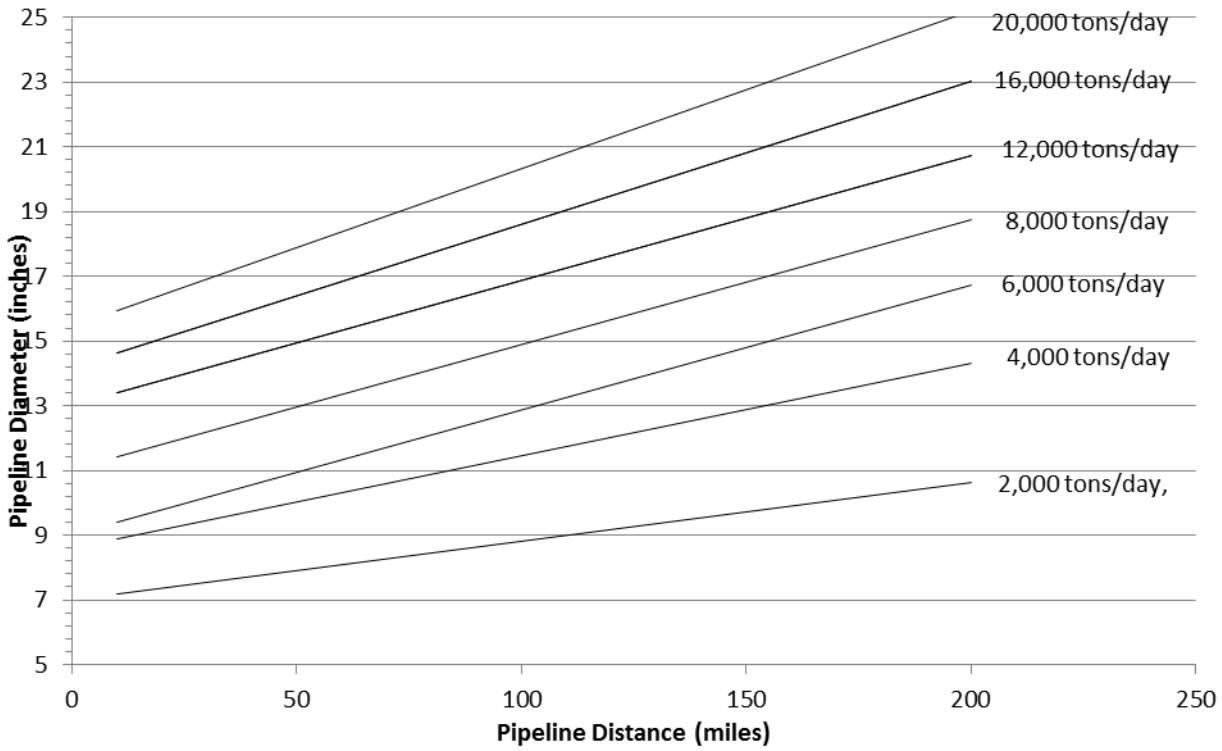
The tracked input is steel used for pipeline construction. The reference flow of this unit process is the construction of a CO_2 pipeline as described below and shown in **Figure 1**. This unit process is used within Life Cycle (LC) Stage #3 of NETL's energy conversion models.

Boundary and Description

This unit process provides a summary of relevant input and output flows associated with the construction of a CO_2 pipeline. It includes scaling equations based on the relationships between distance, flow rate, and pipeline diameter. It includes parameters for pipeline tortuosity and extra materials for valves and other pipeline equipment. The reference flow of this unit process is the construction of a CO_2 pipeline.

CO_2 pipelines are sized to achieve a desired pressure drop for a given flow rate of CO_2. The calculation of pipeline diameter is an iterative process. Instead of iteratively converging on a solution for diameter each time the parameters are revised, this unit process has a set of 7 ranges for flow rates, with 0 to 2,000 ton/day as the lowest range and 18,000 to 20,000 ton/day as the highest range. For each flow rate range, a unique equation is used to calculate pipeline diameter as a function of pipeline length. These equations are based on the outputs of NETL cost model for CO_2 transport (NETL, 2010). Each equation was derived by plotting a trendline for a set flow rate over a range of pipeline distances. Linear relationships were assumed when deriving general equations for pipeline diameter as a function of flow rate. At pipeline distances less than 200 miles, these linear relationships correlate strongly with the data points. Examples of these trendlines are shown in **Figure 1** below.

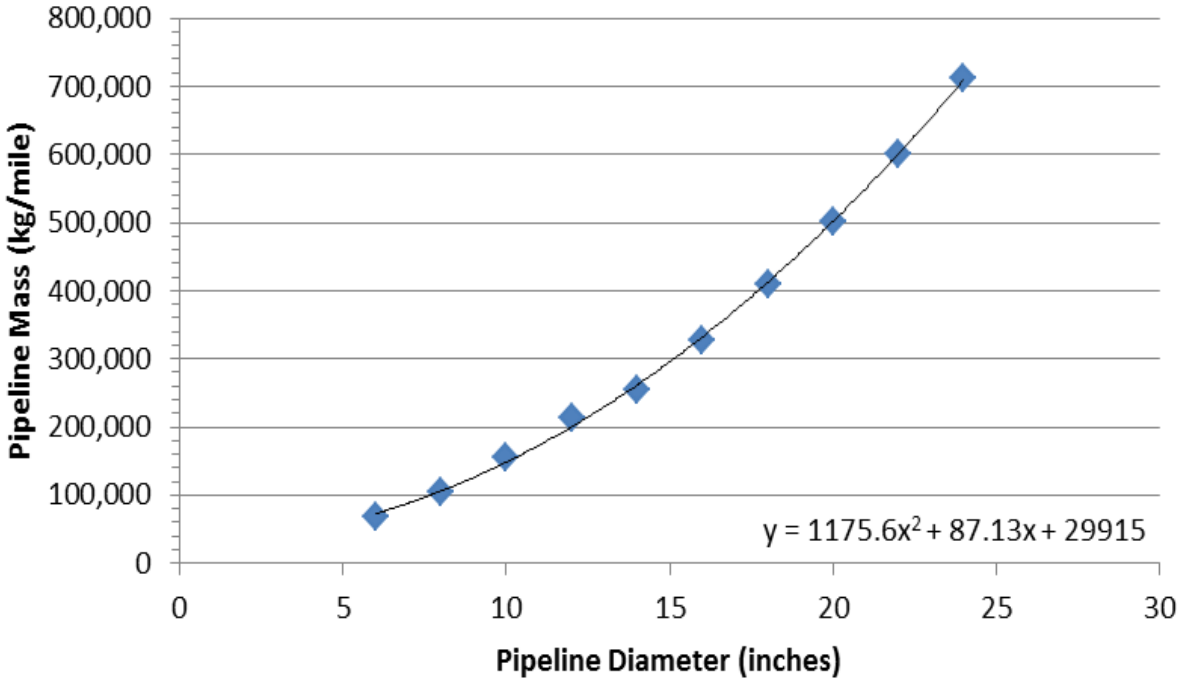
Figure 1: Pipeline Diameter vs. Mileage for Various Flow Rates



A CO_2 pipeline is made of carbon steel and has a minimum yield rate of 60,000 to 80,000 psi. Steel pipes that meet the American Petroleum Institute (API) 5L specifications for X60 and X80 pipes meet the strength requirements for CO2 pipelines (WRI, 2008). API's 5L specifications provide standards for "line pipe" used by gas and liquid transport systems (API, 2008).

Pipe diameter for steel pipe was plotted versus the weight per unit length. The resulting curve is shown in **Figure 2** below.

Figure 2: Pipeline Mass vs. Pipeline Diameter



Based on the curve shown in **Figure 2**, this unit process calculates pipeline weight (in kg/mi) using the following equation:

$$\textit{Pipeline density (kg/mi)} = 1{,}175.6 * \textit{Diameter}^2 + 87.13 * \textit{Diameter} + 29{,}915$$

Figure 3 illustrates the boundaries of this unit process and shows the tracked inputs and outputs of the unit process.

Figure 3: Unit Process Scope and Boundary

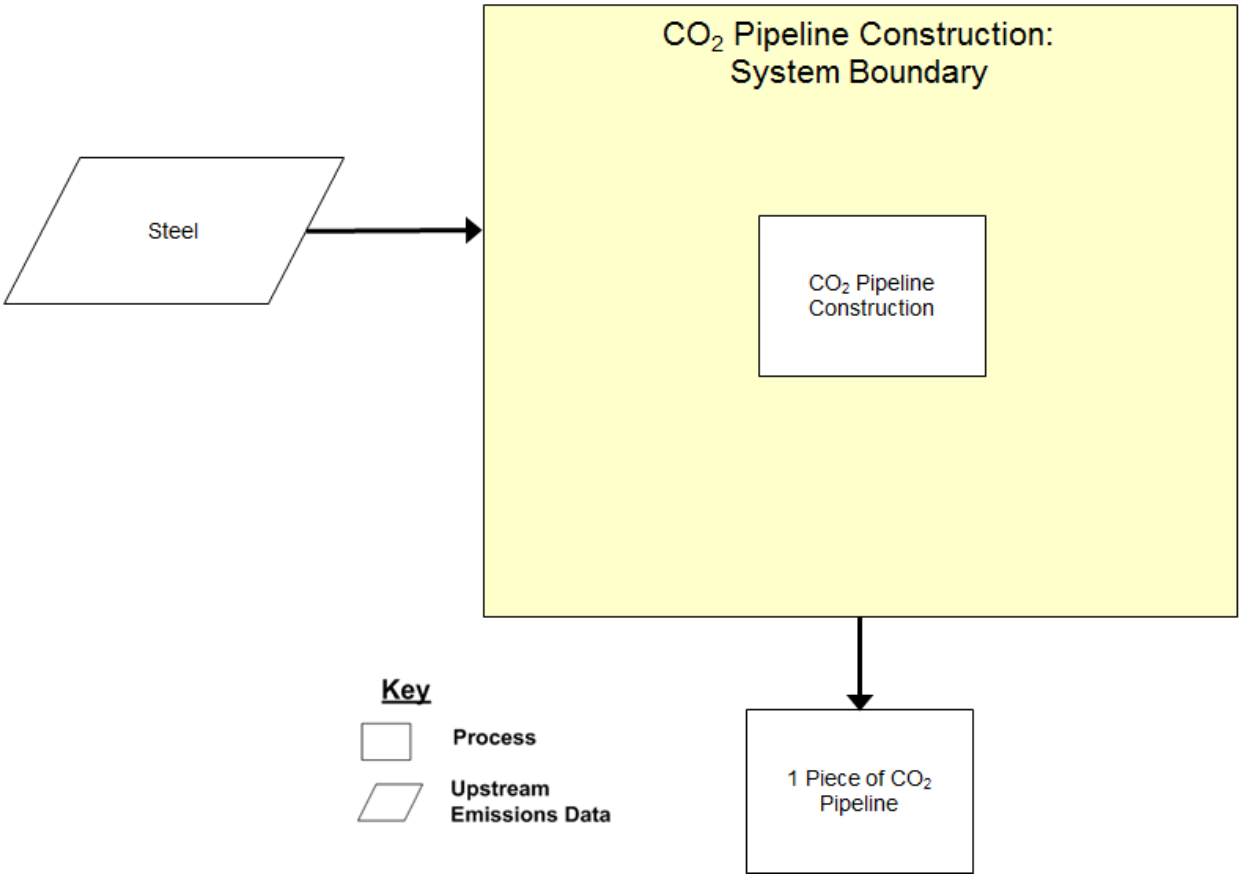


Table 1 shows key equations used by the parameters of this unit process. **Table 2** provides a summary of modeled input and output flows and shows all inputs and outputs on the basis of the reference flow (the construction of one CO_2 pipeline). Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Table 1: Emission Factors and Other Relevant Parameters

Flow Name	Equation, where *Pipeline Length* is in miles	Units
Pipeline diameter for flow rates less than or equal to 2,000 short tons/day	0.0103**Pipeline Length*+7.54	Inches
Pipeline diameter for flow rates greater than 2,000 and less than or equal to 4,000 short tons/day	0.0151* *Pipeline Length* +9.51	Inches
Pipeline diameter for flow rates greater than 4,000 and less than or equal to 6,000 short tons/day	0.0209* *Pipeline Length* +10.2	Inches
Pipeline diameter for flow rates greater than 6,000 and less than or equal to 8,000 short tons/day	0.0209* *Pipeline Length* +12.2	Inches
Pipeline diameter for flow rates greater than 8,000 and less than or equal to 10,000 short tons/day	0.0210* *Pipeline Length* +13.3	Inches
Pipeline diameter for flow rates greater than 10,000 and less than or equal to 12,000 short tons/day	0.0228* *Pipeline Length* +14.1	Inches
Pipeline diameter for flow rates greater than 12,000 and less than or equal to 14,000 short tons/day	0.0222* *Pipeline Length* +14.8	Inches
Pipeline diameter for flow rates greater than 14,000 and less than or equal to 16,000 short tons/day	0.0250* *Pipeline Length* +15.4	Inches
Pipeline diameter for flow rates greater than 16,000 and less than or equal to 18,000 short tons/day	0.0510* *Pipeline Length* +14.9	Inches
Pipeline diameter for flow rates greater than 18,000 and less than or equal to 20,000 short tons/day	0.0487* *Pipeline Length* +15.5	Inches

Table 2: Unit Process Input and Output Flows (based on a pipeline length of 100 miles and a flow rate of 10,000 tons/day)

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Steel	3.42E+07	kg
Outputs		
CO2 Pipeline [Construction]	1	pcs

* **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

API, 2007	API, 2007. Specification for Line Pipe: ANSI/API Specification 5L. American Petroleum Instititute. Washington, DC.
NETL, 2010.	NETL, 2010. Quality Guidelines for Energy System Studies: Estimating Carbon Dioxide Transport and Storage Costs. NETL/DOE. Accessed at http://www.netl.doe.gov/energy-analyses/pubs/QGESStransport.pdf on September 19, 2012.
WRI, 2008	WRI, 2008. Guidelines for Carbon Dioxide Capture, Transport, and Storage. WRI. Washington, DC. Accessed September 19, 2012 at http://pdf.wri.org/ccs_guidelines.pdf.

Section III: Document Control Information

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