NETL Life Cycle Inventory Data
Process Documentation File

Process Name: CO2 Sequestration Saline Aquifer Well, Construction

Reference Flow: 1 piece of CO2 Sequestration Well Construction and Installation

Brief Description: Materials of construction and installation fuels and emissions for a well for underground storage of CO2

Section I: Meta Data

Geographical Coverage: United States **Region:**

Year Data Best Represents: 2012

Process Type: Installation Process (IP)

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	☐ 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:

Drill_speed	*[m/h] Drilling rate, estimated from anecdotal account of the number of days to drill a well of 7000 feet.*
Drill_depth	*[m] Well depth is highly variable, depending on reservoir*
Drill_power	*[MW] Power of drilling equipment; brake specific power. See "Fuel and*

	emissions" worksheet for power ratings for different wells.
Prod_Case_dens	*[kg/m] Linear density of production casing - carbon steel*
Prod_Conc_dens	*[kg/m] Linear density of production casing - concrete*

Tracked Input Flows:

Steel, pipe welded, BF (85% Recovery Rate) [Metals]	*[Technosphere] Welded steel pipe used for well casing*
Concrete, ready mix, R-5-0 [Concrete_Cement]	*[Technosphere] Concrete used for well casing*
Diesel [Crude oil products]	*[Technosphere] Diesel used for powering drilling equipment*

Tracked Output Flows:

CO2 Sequestration Well Construction and Installation	*[well] Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_C_Well_Construction_CO2_Seq_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 and installation of a well for underground storage of carbon dioxide (CO_2). There are eight different well types included in this unit process: stratigraphic (strat) test, injection, reservoir monitoring, above seal monitoring, groundwater monitoring, vadose zone monitoring, water production, and water disposal. Steel and concrete are used for the construction of the well casing; these materials enter the boundaries of this unit process in the form of prefabricated steel pipe and ready-mix concrete. Diesel is used for the internal combustion engines powering the rotary drilling equipment. The air emissions from diesel combustion include greenhouse gases and criteria air pollutants. The energy and material flows for the upstream production and delivery of steel, concrete, and diesel are not included in this unit process but are accounted for by other unit processes. Water use and water quality are not included in this unit process. The reference flow of this unit process is 1 piece (well) of CO_2 Sequestration Well Construction and Installation. The relevant flows of this unit process are described below and shown in **Figure 1.** This unit process is an input to the saline aquifer well construction assembly process, which is a modeling tool

for tying together the eight different well types required for a saline aquifer that is being utilized to sequester CO_2.

Boundary and Description

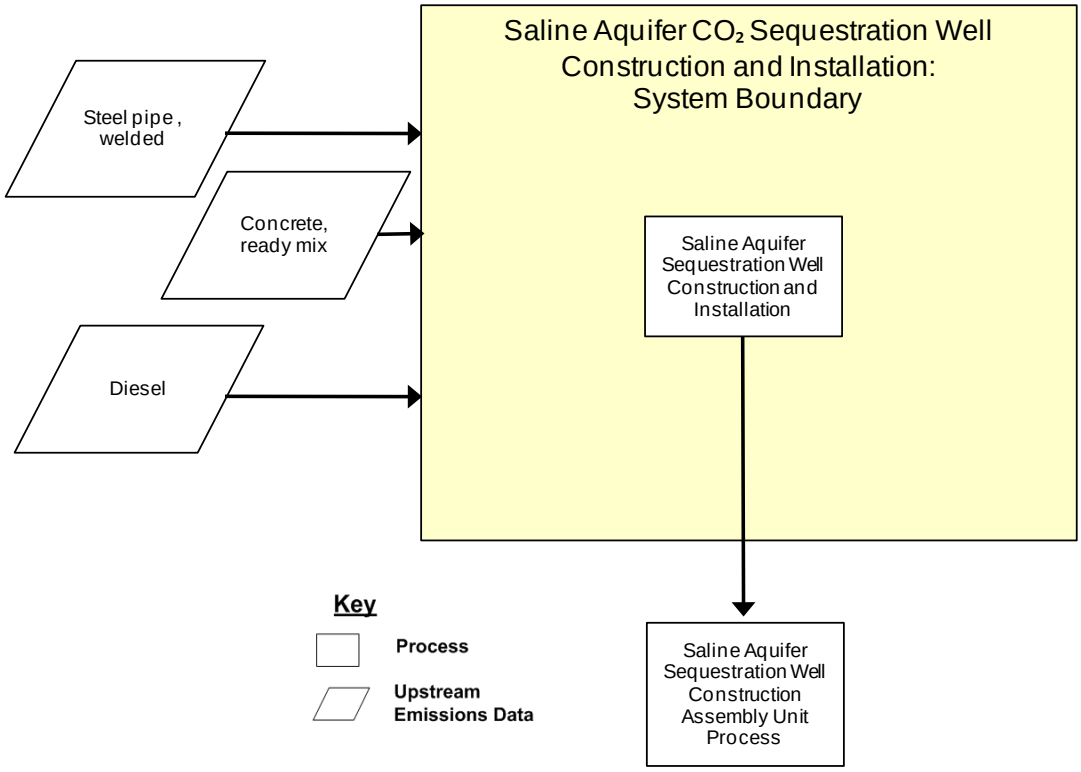
The construction and installation of wells includes the drilling of the well, followed by the installation of a well casing that provides strength to the well bore and prevents contamination of the geological formations and groundwater that surround the well.

There are eight different well types, of varying depths, that are required for CO_2 sequestration in a saline aquifer: strat test, injection, reservoir monitoring, above seal monitoring, groundwater monitoring, vadose zone monitoring, water production, and water disposal. The NETL saline aquifer storage cost model (internal) contains a representative list of possible storage formations in the United States. For each formation, the cost model calculates the depth of each well type based on the individual geologic formation characteristics. This unit process uses the average well depths from the selected list of storage formations for the calculation of drilling and casing requirements.

Vertical drilling is used for the wells required for saline aquifer sequestration. An advanced drilling rig has a drilling speed of 17.8 meters per hour (Reum, Dahlem, & Pollock, 2008). A typical diesel engine used for oil and gas exploration has a power of 600 horsepower and a heat rate of 7,000 Btu/hp-hr (EPA, 1995). The diesel consumption per hour of drilling was calculated from the above horsepower and heat rate and was applied to AP-42 emission factors for diesel combustion in stationary industrial engines (EPA, 1995) in order to determine the emissions from the installation of a well.

A well is lined with a carbon steel casing that is held in place with concrete. Each well, with the exception of the groundwater and vadose zone monitoring wells, is assumed to have three concentric casing sections of varying diameters and depths (API, n.d.). The top layer of casing, known as the conductor casing, has a 16-inch pipe set in a 26-inch hole to a depth of 40 feet (12.2 m). The next casing section, known as the surface casing, consists of an 8 5/8-inch diameter pipe set in a 12 1/4-inch hole extending from the surface to a depth of 2,167 feet (660.5 m). The final casing section in the series, known as the production casing, consists of a 5 1/2-inch pipe set in a 7 7/8-inch hole extending from the surface down to the depth determined from the NETL saline storage cost model for each well type. The total amount of carbon steel is determined by adding the various casing sections together with linear densities based on standard API casing dimensions (Halliburton, 2009). The casing diameter is assumed to be the same for all eight well types in the model. The void between the outer diameter of the carbon steel casing pipe and the drilled hole is filled with concrete. The amount of concrete required for each well section is a function of the annulus volume and depth for each casing section.

Figure 1: Unit Process Scope and Boundary



Key properties of the well construction and installation process are summarized in **Table 1.** The inputs and outputs of this unit process are summarized in **Table 2** for the eight different well types required for saline aquifer CO_2 sequestration.

Table 1: Properties of Saline Aquifer Well Construction and Installation

Property	Value	Source
Conductor and Surface Casing Mass – Carbon Steel, kg/well	24,770	Calculated based on API, n.d. and Halliburton, 2009
Conductor and Surface Casing Mass – Concrete, kg/well	51,321	Calculated based on API, n.d.
Production Casing Mass – Carbon Steel, kg/m	20.8	Calculated based on API, n.d. and Halliburton, 2009
Production Casing Mass – Concrete, kg/m	30.6	Calculated based on API, n.d.
Well Depths, m	Strat Test – 2,619; Injection – 2,519 In-Reservoir Monitor – 2,419; Above Seal Monitor – 2,358 Groundwater – 152; Vadose Zone – 12 Water Production – 2,519; Water Disposal – 2,519	NETL – Saline Storage Cost Model (Internal)

Table 2: Unit Process Input and Output Flows for Various Well Types

Flow Name	Strat Test	Injection	In-Reservoir Monitoring	Above Seal Monitoring
Inputs				
Steel, pipe welded, BF (85% Recovery Rate) [Metals]	7.93E+04	7.72E+04	7.52E+04	7.39E+04
Concrete, ready mix, R-5-0 [Concrete_Cement]	1.31E+05	1.28E+05	1.25E+05	1.23E+05
Diesel [Crude oil products]	1.45E+04	1.40E+04	1.34E+04	1.31E+04
Outputs				
CO_2 Sequestration Well Construction and Installation	1.00	1.00	1.00	1.00
Carbon dioxide [Inorganic emissions to air]	4.65E+04	4.47E+04	4.29E+04	4.19E+04
Methane [Organic emissions to air (group VOC)]	2.54E+00	2.45E+00	2.35E+00	2.29E+00
Nitrogen oxides [Inorganic emissions to air]	9.62E+02	9.25E+02	8.89E+02	8.66E+02
Sulphur oxides [Inorganic emissions to air]	1.62E+01	1.56E+01	1.50E+01	1.46E+01
Carbon monoxide [Inorganic emissions to air]	2.20E+02	2.12E+02	2.04E+02	1.98E+02
NMVOC (unspecified) [Group NMVOC to air]	2.57E+01	2.47E+01	2.38E+01	2.32E+01
Dust (PM10) [Particles to air]	2.80E+01	2.70E+01	2.59E+01	2.53E+01
Flow Name	Groundwater	Vadose Zone	Water Production	Water Disposal
Inputs				
Steel, pipe welded, BF (85% Recovery Rate) [Metals]	3.17E+03	2.54E+02	7.72E+04	7.72E+04
Concrete, ready mix, R-5-0 [Concrete_Cement]	4.66E+03	3.73E+02	1.28E+05	1.28E+05
Diesel [Crude oil products]	8.46E+02	6.77E+01	1.40E+04	1.40E+04
Outputs				
CO_2 Sequestration Well Construction and Installation	1.00	1.00	1.00	1.00
Carbon dioxide [Inorganic emissions to air]	2.71E+03	2.16E+02	4.47E+04	4.47E+04
Methane [Organic emissions to air (group VOC)]	1.48E-01	1.18E-02	2.45E+00	2.45E+00
Nitrogen oxides [Inorganic emissions to air]	5.60E+01	4.48E+00	9.25E+02	9.25E+02
Sulphur oxides [Inorganic emissions to air]	9.43E-01	7.55E-02	1.56E+01	1.56E+01
Carbon monoxide [Inorganic emissions to air]	1.28E+01	1.03E+00	2.12E+02	2.12E+02
NMVOC (unspecified) [Group NMVOC to air]	1.50E+00	1.20E-01	2.47E+01	2.47E+01
Dust (PM10) [Particles to air]	1.63E+00	1.31E-01	2.70E+01	2.70E+01

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

Embedded Unit Processes

None.

References

API. (n.d.). *Summary of Carbon Dioxide Enhanced Oil Recovery (CO2 EOR) Injection Well Technology*. API Retrieved August 28, 2012, from http://www.api.org/environment-health-and-safety/environmental-performance/~/media/d68de1954b8e4905a961572b3d7a967a.ashx

EPA. (1995). *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*. (AP-42.). Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, from http://www.epa.gov/ttnchie1/ap42

Halliburton. (2009). API Casing Chart Retrieved August 29, 2012, from http://www.halliburton.com/public/sdbs/sdbs_contents/Data_Sheets/H03038.pdf

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Section III: Document Control Information

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