# NETL Life Cycle Inventory Data
# Process Documentation File

**Process Name:** Operation of a 250 MW solar thermal power plant

**Reference Flow:** 1 MWh of Solar Thermal Electricity Generation

**Brief Description:** Operation of a 250 MW solar thermal power facility

## Section I: Meta Data

**Geographical Coverage:** US **Region:** U.S. Southwest

**Year Data Best Represents:** 2010

**Process Type:** Energy Conversion (EC)

**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 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:**

| | |
|---|---|
| HTF_total | *[kg/MWh] Mass of heat transfer fluid loaded during construction* |
| HTF_lossrate | *[dimensionless] Annual loss rate of heat transfer fluid* |
| MWH_annual | *[MWh] Annual production rate of electricity* |

**Tracked Input Flows:**

| | |
|---|---|
| Natural gas combusted in an auxiliary boiler | *[kg/MWh] Natural gas combusted in an auxiliary boiler* |
| Diesel combusted in a reciprocating engine | *[kg/MWh] Diesel combusted in a reciprocating engine* |

| | |
|---|---|
| Gasoline combusted by a truck | *[kg/MWh] Gasoline combusted by a maintenance vehicle* |
| Heat transfer fluid | *[kg/MWh] Heat transfer fluid that is circulated through the solar thermal system.* |

**Tracked Output Flows:**

| | |
|---|---|
| Electricity [Valuable Substance] | *Electricity produced by the solar thermal power plant* |

## Section II: Process Description

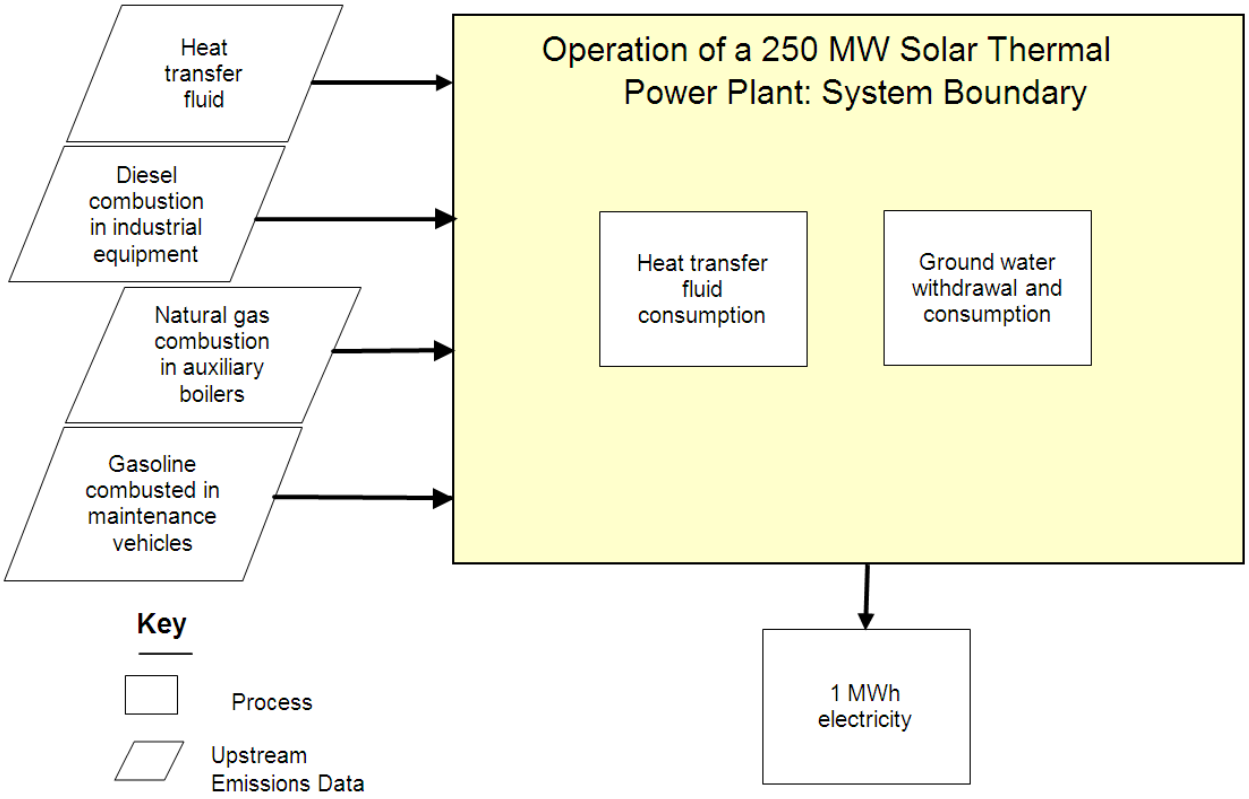
### Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_Solar_Thermal_Operations_2011.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

### Goal and Scope

The scope of this unit process covers the operation of the energy conversion facility (ECF), in this case the solar thermal power plant, as shown in **Figure 1**. The output of this unit process is one MWh of electricity is delivered to the life cycle (LC) Stage #4 (Transmission and Distribution) boundary.

**Figure 1: Unit Process Scope and Boundary**




## Boundary and Description

LC Stage #1 or RMA (raw material acquisition) is not relevant to solar thermal power because solar energy is a natural resource that does not require anthropogenic inputs prior to power generation. LC Stage #2 or RMT (raw material transport) is not relevant to solar thermal power because solar energy is a natural energy source that does not require anthropogenic inputs prior to power generation.

This unit process accounts for the steady state operation of a 250 MW solar thermal facility, an energy conversion facility categorized by LC Stage #3 of NETL's LCA framework.

The LCA model of this analysis uses a screening approach, which means that proxy data were used instead of developing new data specific to geothermal systems. Four key existing unit processes were identified for the operation of a solar thermal power plant:

- Natural gas combusted in an auxiliary boiler
- Diesel combusted in industrial equipment
- Gasoline combusted in a maintenance vehicle
- Heat transfer fluid

The data used for these four processes are described below.

The environmental impact statement (EIS) for the Genesis Solar Energy Project (BLM 2010) specifies two auxiliary boilers that each combust 30 million Btu/hr of natural gas. These boilers operate for 1,000 hr/yr (BLM 2010). Factoring the per boiler energy consumption rate by the number of boilers and annual operating hours results in an annual natural gas consumption rate of 6.00E+10 Btu/yr. The heating value of natural gas is 1,027 Btu/scf and the density of natural gas is 0.042 lb/scf; applying these conversion factors to the above consumption rate (6.00+10 Btu/yr) translates to 1.11E+06 kg natural gas combusted per year. At a nominal capacity factor of 27 percent, the 250 MW solarthermal facility produces 600,000 MWh/yr. Dividing the natural gas consumption rate by the electricity production rate gives 1.855 kg NG/MWh. The emission factors for the combustion of natural gas in an auxiliary boiler are not accounted for in this unit process, but are accounted for by an upstream unit process (*NETL Life Cycle Inventory Data – Unit Process: NG Auxiliary Boiler.*).

The environmental impact statement (EIS) for the Genesis Solar Energy Project (BLM 2010) specifies fire pump engines and emergency generators, both fueled by diesel. The 250 MW facility has two 315 horsepower fire pump engines and two 1,341 horsepower emergency generators, for a total of 3,312 horsepower of diesel-fueled equipment. Using a conversion factor of 2,544 Btu/(horsepower-hr), 3,312 horsepower translates to 8,426,000 Btu/hr. The diesel-fueled equipment run 52 hr/yr (BLM 2010) and is assumed to convert 85 percent of input diesel energy to useful energy. Factoring the above energy rate (8,426,000 Btu/hr) by annual operating hours (52 hr/yr) and the assumed efficiency (85 percent) the rate of diesel consumption is 515,500,000 Btu/yr. Using a conversion factor of 42,560 Btu/kg of diesel, this rate of diesel consumption is equivalent to 12,110 kg of diesel per year. At a nominal capacity factor of 27 percent, the 250 MW solarthermal facility produces 600,000 MWh/yr. Dividing the diesel consumption rate by the electricity production rate gives 0.0202 kg diesel/MWh. The emission factors for the combustion of diesel are not accounted for in this unit process, but are accounted for by third party data provided by PE Americas as part of the GaBi software license (diesel combustion in industrial equipment).

The environmental impact statement (EIS) for the Genesis Solar Energy Project (BLM 2010) specifies a gasoline storage tank used for holding gasoline used by onsite maintenance vehicles (trucks). The inventory around this gasoline storage tank is 21,536 gal/yr (BLM 2010). A gallon of gasoline has a mass of 2.8 kg, and thus the annual gasoline use rate converts to 60,311 kg gasoline per year. The emission factors for the combustion of gasoline are not accounted for in this unit process, but are accounted for by another unit process that was previously developed by NETL (combustion of gasoline in a passenger vehicle).

The solar thermal facility uses heat transfer fluid to carry heat from the collector field to the steam system. The environmental impact statement (EIS) for the Genesis Solar Energy Project (BLM 2010) specifies 2,000,000 gal of heat transfer fluid for the 250 MW facility. Most is this fluid is recirculated, but some degrades to a vapor that is vented from the system. This unit process has a parameter that allows variation of the heat transfer loss rate; the default loss rate is 5 percent per year. The actual heat transfer

fluid is a mix of organic fluids for which no life cycle data are available. This analysis uses benzene as a proxy for the production of the heat transfer fluid. The energy and material flow for the production of benzene are not accounted for in this unit process, but are accounted for by third party data provided by PE Americas as part of the GaBi software license.

The environmental impact statement (EIS) for the Genesis Solar Energy Project (BLM 2010) specifies a water consumption rate of 1,644 acre-feet per year, drawn from a groundwater source. This volume of water is equivalent to an annual water consumption of 2,027 million kg (1 acre-foot of water per 1.233 million kg of water). At a nominal capacity factor of 27 percent, the 250 MW solarthermal facility produces 600,000 MWh/yr. Dividing the water use by the electricity production rate gives 112.7 kg of water per MWh of electricity produced.

**Table 1** shows key parameters for a solar thermal power facility, and **Table 2** shows the input and output flows of this unit process.

**Table 1: Solar Thermal Power Modeling Parameters**

| Parameter | Nominal Value | Units |
|---|---|---|
| Net capacity | 250 | MW |
| Capacity factor | 27 | % |
| Annual electricity production | 600,000 | MWh |
| Auxiliary natural gas boilers | 60 | MMBtu/hr |
| Fire pumps | 630 | hp |
| Emergency generators | 2,682 | hp |
| Gasoline for maintenance vehicles | 21,536 | gal/yr |
| Heat transfer fluid (total amount in system) | 2,000,000 | gal |
| Heat transfer fluid loss rate | 5 | %/yr |

**Table 2: Unit Process Input and Output Flows**

| Flow Name | Value | Units (Per Reference Flow) |
|---|---|---|
| Inputs | | |
| Natural gas combusted in an auxiliary boiler | 1.855E+00 | kg |
| Diesel combusted in industrial equipment | 2.019E-02 | kg |
| Gasoline combusted in a maintenance vehicle | 1.005E-01 | kg |
| Water (ground water) [Water] | 1.127E+02 | kg |
| Heat transfer fluid | 6.342E-01 | kg |
| Outputs | | |
| Solar Thermal Electricity Generation | 1 | MWh |

## Embedded Unit Processes

*NETL Life Cycle Inventory Data – Unit Process: NG Auxiliary Boiler.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: October 2010 (version 01). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses)

*NETL Life Cycle Inventory Data – Unit Process: Wellhead Compressor, Gas-Powered Reciprocating, 200 HP.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: April 2011 (version 01). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses)

## References

BLM 2010 U.S. Bureau of Land Management. (2010). Plan Amendment/Final EIS for the Genesis Solar Energy Project. http://www.blm.gov/ca/st/en/fo/palmsprings/Solar_Projects/Genesis_Ford_Dry_Lake.html (Accessed September 30, 2011)

## Section III: Document Control Information

**Date Created:** October 20, 2011

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**Revision History:**

Original/no revisions

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

NETL (2011). *NETL Life Cycle Inventory Data – Unit Process: Solar Thermal Power Plant, Operation.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: October 2011 (version 01). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses)

## Section IV: Disclaimer

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