NETL Life Cycle Inventory Data
Process Documentation File

Process Name: LNG Liquefaction, Operation

Reference Flow: 1 kg of LNG

Brief Description: Natural gas liquefaction, storage, and ship loading. Process data is derived from a specific facility in Australia and adapted to represent Atlantic LNG near Trinidad and Tobago.

Section I: Meta Data

Geographical Coverage: Trinidad & Tobago **Region:** N/A

Year Data Best Represents: 2005

Process Type: Basic Process (BP)

Process Scope: Gate-to-Gate (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:

None.

Tracked Input Flows:

Natural gas	*Raw natural gas received from offshore extraction*
Water (municipal)	*Potable water from a municipal source*

Tracked Output Flows:

LNG	*Reference flow; 1 kg of liquefied natural gas (LNG)*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_LNG_Liquefaction_2010.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process encompasses the energy inputs and material outputs for the liquefaction of natural gas. The unit process is based on the reference flow of 1 kg of liquefied natural gas (LNG). The relevant flows of this unit process are described below and shown in **Figure 1.**

The inputs to this unit process are natural gas (received from an offshore well) and municipal water; the energy and material flows of these two inputs are not included in this unit process but are accounted for by other unit process. The output of this unit process is liquefied natural gas that is suitable for cross-ocean transport in a tanker. This unit process also accounts for environmental emissions that are directly released by the liquefaction operations.

Boundary and Description

This unit process characterizes the liquefaction of natural gas. The boundaries of this unit process start with the receipt of natural gas extracted from a foreign, offshore natural gas extraction site and ends with liquefied natural gas (LNG) ready for shipment to the U.S. This unit process assumes that Atlantic LNG (ALNG) in Trinidad and Tobago is the foreign source of natural gas.

Trinidad and Tobago is currently the biggest supplier of LNG to the US. Approximately 70% of US-imported LNG comes from Trinidad (EIA). Trinidad and Tobago has only one LNG production facility (Atlantic LNG), which currently has four liquefaction trains (the largest, Train 4, has only recently come online). Trains 1, 2, and 3 are designed to produce 3.3 MTPA of LNG. They all use the Phillips Optimized Cascade Liquefaction technology with slight modifications between the original Train 1 and the subsequently added Trains 2, 3 and 4, which improve operability and reduce energy consumption as well as greenhouse gas emissions. Trains 1, 2, and 3 were all designed to liquefy 3.3 MTPA.

The process and technology used by the Atlantic LNG facility has most recently been licensed for the Darwin LNG Plant in Australia. The Darwin plant was designed to have a capacity of 3.24 MTPA. The Darwin LNG facility utilizes the same technology and processing scheme, but different equipment. For example, the Darwin facility uses six GE LM-2500 turbines rather than six GE Frame 5C/5D models. The process design is the same generation as Atlantic LNG Trains 2 and 3 and approximately the same scale (ALNG had an original design capacity of 3.3 MTPA and ALNG has been undergoing upgrades to increase capacity to 3.3 MTPA while Darwin has a design capacity of 3.24 MTPA).

The amount of natural gas input per production of one kilogram of LNG (the reference flow of this unit process) was calculated from a performance test (Richardson 1999) for Atlantic LNG Train 1 (1.13 kg raw natural gas/kg LNG).

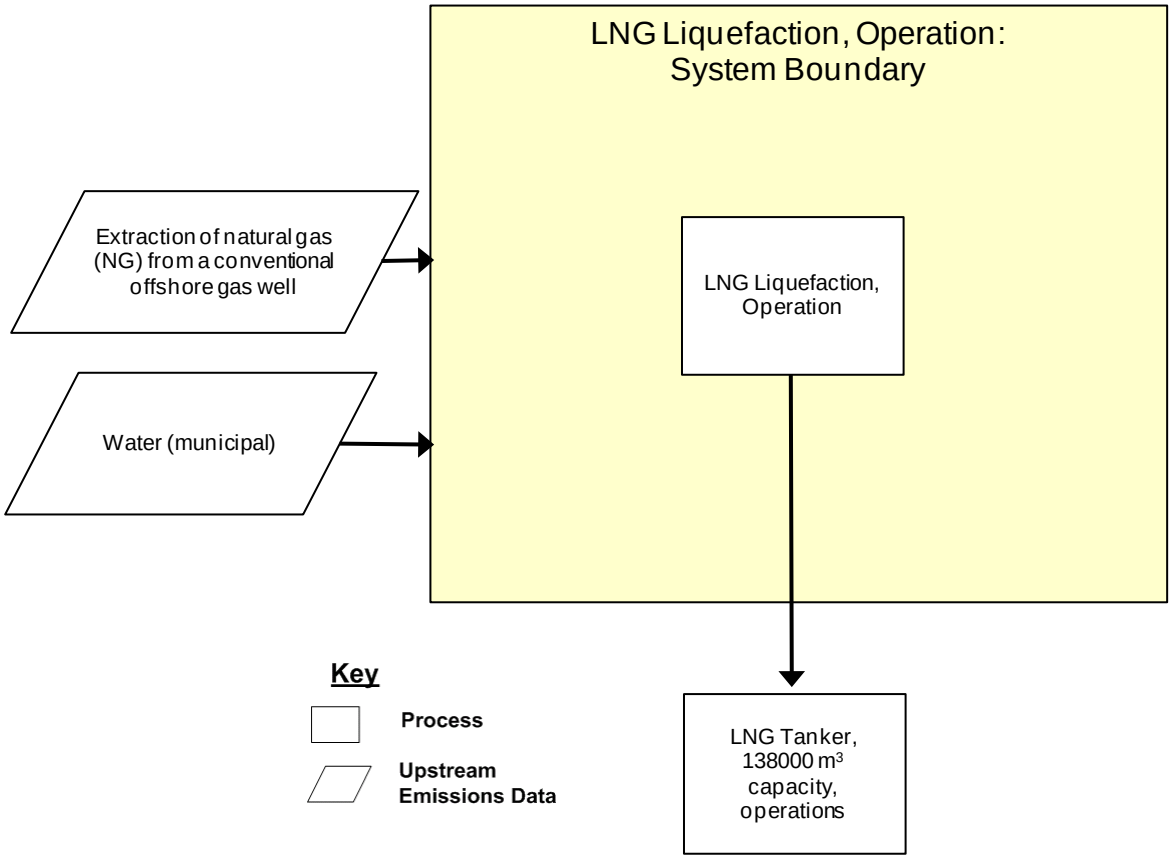
The CO_2 emissions reported for the 3.24 MTPA Darwin LNG Plant are 0.418 kg of CO_2 per kg of LNG (ConocoPhillips 2005). For criteria air pollutants, this unit process uses data reported for the Darwin LNG project (ConocoPhillips 2005), which includes emissions of total particulate matter (PM), SO_2, NO_x, CO, VOC, and N_2O. The emissions data for Darwin LNG include an aggregated category of emissions for TOC and methane (labeled as "TOC/CH4" in the Darwin LNG data). No data are available to specify methane and TOC emissions separately, and thus this unit process specifies these emissions as VOCs, which is a generic emission category that includes TOC and methane.

Mercury and lead emissions were not included in the data obtained and is noted as a data limitation. Ammonia emissions were estimated using emissions data from the Kenai, Alaska terminal (EPA 2005). Ammonia emissions were divided by terminal LNG production (EIA 2009) to arrive at a discharge rate of 0.00063 kg NH3/kg LNG.

Water intake and discharge data were obtained from an environmental management report for the Darwin plant (URS 2005). Inputs and outputs for the unit process are shown below in Table 1.

Darwin LNG's utility usage is also assumed to be similar to the utilities of Atlantic LNG. Electricity is generated onsite by the gas turbines and any emergency power generation is assumed to be provided by diesel generators located onsite. It is assumed that no electricity is produced for external consumption; all electricity generation and consumption occurs within the boundaries of this unit process and thus does not need to be accounted for in any input or output flows of the unit process.

Figure 1: Unit Process Scope and Boundary



Key properties of the liquefaction process are summarized in **Table 1.** The values for these variables are expressed on the same bases as reported in literature and do not necessarily match the bases as described above.

The inputs and outputs of this unit process are summarized in **Table 2.**

Table 1: Properties of Natural Gas Liquefaction Operations

Property	Value	Source
LNG facility design capacity	3.3 million tonnes per year	ConocoPhillips 2005
Electricity source	Onsite natural gas turbines	URS 2005
Location	Trinidad and Tobago	EIA 2009

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
Natural gas	1.13	kg
Water (municipal) [Water]	0.169	kg
Outputs		
LNG [product]	1.00	kg
Carbon dioxide [Inorganic emissions to air]	0.42	kg
Methane [Organic emissions to air (group VOC)]	6.71E-04	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	5.01E-07	kg
Nitrogen oxides [Inorganic emissions to air]	4.68E-04	kg
Sulphur dioxide [Inorganic emissions to air]	1.33E-05	kg
Carbon monoxide [Inorganic emissions to air]	6.70E-05	kg
Dust (unspecified) [Particles to air]	1.35E-05	kg
Ammonia [Inorganic emissions to air]	6.88E-06	kg
Water (municipal) [Water]	3.94E-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 2.

Embedded Unit Processes

None.

References

ConocoPhillips. 2005. *Operations Environmental Management Plan - Section 5*. ConocoPhillips. http://www.conocophillips.com.au/NR/rdonlyres/79B19009-8E3F-44A1-81A0-7E78F7227888/0/DLNGHSEPLN001_s05_r1.pdf (accessed April 29, 2009).

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Section III: Document Control Information

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