NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Water Tanker Transport, LNG, Operation

Reference Flow: 1 kg of liquified natural gas (LNG)

Brief Description: Operation of a waterborne tanker for transport of LNG. Fueled primarily from boil-off with supplemental power from diesel fuel. Fuel requirements and select emissions determined from Wartsila 50DF engine specs.

Section I: Meta Data

Geographical Coverage: World **Region:** Not Applicable

Year Data Best Represents: 2005

Process Type: Transport Process (TP)

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:

Distance of Travel (Dist_Naut_miles)	*Transport distance from foreign LNG facility port to domestic port*
LNG Carrier Usable Volume (Per_Vol)	*Portion of LNG volume capacity that is usable*
Boil-Off Rate (Boil_Off_Rate)	*The rate at which the LNG transforms into a gaseous form in the tanker and is therefore used for combustion in the engine for propulsion*

Tracked Input Flows:

Diesel [Crude Oil Products]	*Diesel use for propulsion of the tanker*
LNG	*Total LNG input to the transport process. Accounts for both LNG delivered and boil-off energy used for tanker operation*

Tracked Output Flows:

LNG	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage_4_O_Water_Tanker_Transport_LNG_2010.01.xls*, which provides additional details regarding relevant, calculations, data quality, and references.

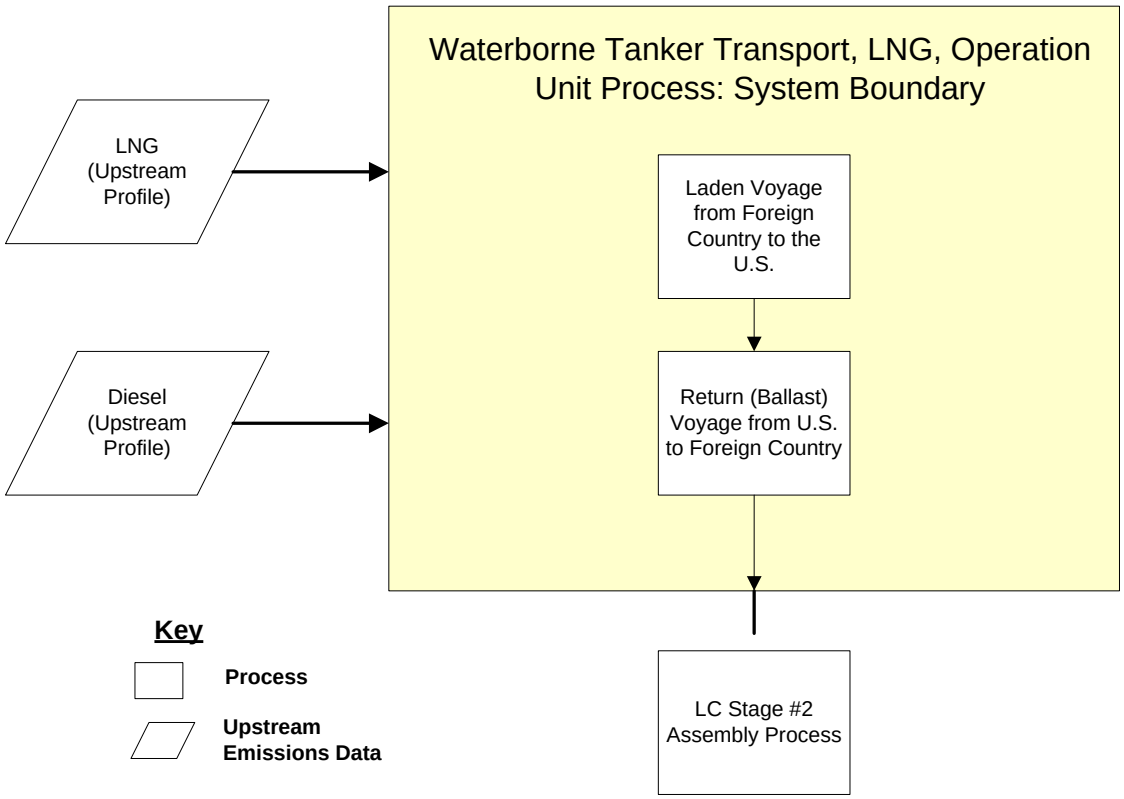
Goal and Scope

The scope of this process covers transport of LNG from foreign LNG facilities to the United States as part of the LNG distribution network during Life Cycle (LC) Stage #2. The water tanker operation process includes a laden voyage and return trip (ballast voyage) for transport an adjustable distance. This unit process is combined with a water-tanker construction process in an assembly process for transport of LNG.

Boundary and Description

Figure 1 provides an overview of the boundary of this unit process. Roundtrip at-sea operations are accounted for; near-shore, security, escort-related operation emissions are calculated outside the boundary of this unit process.

Figure 1: Unit Process Inputs, Outputs, and Boundaries



This module determines the amount of natural gas and diesel fuel used for combustion in transport of LNG from a foreign source to the United States. Optimally, this design scenario has LNG being transported from Atlantic LNG in Trinidad/Tobago to Trunkline LNG in Lake Charles, Lousiana (Panhandle Energy 2006). This unit process can, however, be modified by adjusting the distance between the source and destination. The LNG tanker is a 138,000-cubic-meter (Colton Company 2006, Namba 2006) tanker. Propulsion is fueled by cargo boil-off and then supplemented with diesel fuel, burned in Wartsila (Wärtsilä Corporation 2005) dual-fuel engines. The amount of boil-off is variable for both the laden and ballast voyages (current values are industry average (Hasan. 2009)). The percent usable cargo volume and heel (quantity in percent of initial volume remaining for fuel for return trip) quantity are also variable. After accounting for the quantity of LNG used for fuel and heel (Colton Company 2006, DOE 2005, Hasan. 2009, Namba 2006, Panhandle Energy 2006), the actual delivered quantity of LNG by a single loaded tanker is 127,498 cubic meters. This value forms the basis for the emissions from the tanker. Emissions from operation of a single loaded tanker are divided by this value to calculate emissions for the reference flow of one kg of LNG delivered.

Emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_x) are calculated from engine manufacturer specifications (Wärtsilä Corporation 2005), assuming that the engines are running at 75 percent load (higher emissions than for 100 percent load). Remaining air pollutant emissions are estimated by applying the EPA AP-42 emission factors for Large Stationary Diesel and All Stationary Dual-Fuel Engines (EPA 1996). Emission factors were not

available for ammonia, mercury, or lead, and this is noted as an insignificant data limitation. Emissions are for the roundtrip voyage.

Table 1 provides a summary of modeled input and output flows. Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Table 1: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
LNG	**1.000003E+00**	**kg**
Diesel	**4.702982E-06**	**kg**
Outputs		
LNG	1	kg
Carbon dioxide [Inorganic emissions to air]	2.825748E-05	kg
Methane [Organic emissions to air (group VOC)]	6.327911E-08	kg
Nitrogen oxides [Inorganic emissions to air]	3.688164E-07	kg
Sulphur dioxide [Inorganic emissions to air]	2.797394E-10	kg
Particulate Matter, unspecified [Other emissions to air]	1.125705E-08	kg
Carbon monoxide [Inorganic emissions to air]	2.060655E-07	kg
NMVOC (unspecified) [Group NMVOC to air]	3.101773E-08	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

Colton Company 2009 — Colton Company. 2009. *The World Fleet of LNG Carriers*. Colton Company, ShipbuildingHistory.com. November 26, 2009. http://www.shipbuildinghistory.com/world/highvalueships/lngactivefleet.htm (Accessed December 18, 2009).

DOE 2005 — DOE. 2005. *Liquified Natural Gas: Understanding the Basic Facts*. U.S. Department of Energy. http://www.fossil.energy.gov/programs/oilgas/publications/lng/LNG_primerupd.pdf (Accessed December 18, 2009).

EPA 1996 — EPA. 1996. *AP-42, Chapter 3.4: Large Stationary Diesel and All Stationary Dual-Fuel Engines*. U.S. Environmental Protection Agency. http://www.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf (Accessed December 18, 2009).

Hasan et al 2009	Hasan, M.M.F., Zheng, A.M., Karimi, I.A. 2009. "Minimizing Boil-Off Losses in Liquefied Natural Gas Transportation: Abstract." *Industrial & Engineering Chemical Research* 48(21): 9571-9580. American Chemical Society. http://pubs.acs.org/doi/abs/10.1021/ie801975q (Accessed December 18, 2009).
Namba et al 2006	Namba, N., Shuku, M., Yuasa, K., Ishimaru, J. 2006. "Transportation of clean energy at sea - Mitsubishi LNG carrier, at present and in future." Mitsubishi Heavy Industries, Ltd. *Mitsubishi Heavy Industries, Ltd. Technical Review* 40(1). http://www.mhi.co.jp/technology/review/pdf/e401/e401032.pdf (Accessed December 18, 2009).
Panhandle Energy 2006	Panhandle Energy. 2006. *Flexible LNG Services*. Panhandle Energy. http://www.panhandleenergy.com/serv_lng.asp (Accessed December 18, 2009).
Wärtsilä Corporation 2005	Wärtsilä Corporation. 2005. *Wärtsilä 50DF*. Wärtsilä Corporation. http://www.wartsila.com/Wartsila/global/docs/en/ship_power/media_publications/brochures/product/engines/w50df_ds.pdf (Accessed December 18, 2009).

Section III: Document Control Information

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