# Proposed Tacoma Liquefied Natural Gas Project

## Final Supplemental Environmental Impact Statement


March 29, 2019

Prepared for:


**Puget Sound Clean Air Agency**

1904 Third Avenue, Suite 105
Seattle, Washington 98101

pscleanair.org
Puget Sound Clean Air Agency


Prepared by:


**ecology and environment, inc.**
Global Environmental Specialists
720 Third Avenue, Suite 1700
Seattle, Washington 98104

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# SEPA Fact Sheet

**Name of Proposal**

Tacoma Liquefied Natural Gas (LNG) Facility.

**Description of Proposal**

The Proposed Action is to construct and operate an LNG liquefaction, storage, and marine bunkering facility. The Proposed Action would include construction and operation of an LNG facility to fuel marine vessels and provide LNG fuel to various customers in the Puget Sound area. The liquefaction facility would cool natural gas into a liquid state at -260 degrees Fahrenheit (cryogenic) for on-site storage. The facility would also have the capability to vaporize LNG back to its gaseous state for injection into the Puget Sound Energy (PSE) Natural Gas Distribution System during periods of high demand (referred to as peak shaving). The Proposed Action would consist of the following main components:

- *Tacoma LNG Facility*: Liquefies natural gas, stores LNG, and includes facilities to transfer LNG to the adjacent Totem Ocean Trailer Express (TOTE) Marine Vessel LNG Fueling System, bunkering barges in the Blair Waterway, or tanker trucks on site. It also includes facilities to re-gasify stored LNG and inject natural gas into the PSE Natural Gas Distribution System.
- *TOTE Marine Vessel LNG Fueling System:* Conveys LNG by cryogenic pipeline from the Tacoma LNG Facility to the TOTE site. Includes transfer facilities and an in-water trestle and loading platform in the Blair Waterway to fuel vessels or load bunker barges.
- *PSE Natural Gas Distribution System*: Conveys natural gas to and from the Tacoma LNG Facility. However, this system will require upgrades, including two new distribution pipeline segments with a total length of 5.0 miles, a new limit station (Golden Given Limit Station), and an upgrade to the existing Frederickson Gate Station.

The Tacoma LNG Facility and TOTE Marine Vessel LNG Fueling System would be located in the Port of Tacoma within the City of Tacoma. Two new distribution pipeline segments would be constructed in the City of Tacoma, and the City of Fife (Pipeline Segment A) and unincorporated Pierce County (Pipeline Segment B). The new pipeline segments would be constructed within the dedicated road rights-of-way currently used for vehicular traffic. In addition, the Golden Given Limit Station would be constructed on a developed parcel owned by PSE in unincorporated Pierce County, and modifications to the Frederickson Gate Station would also be located in unincorporated Pierce County.

| | |
|---|---|
| **Location** | The Tacoma LNG Facility would be generally located north of East 11th Street, east of Alexander Avenue, south of Commencement Bay, and on the west shoreline of the Hylebos Waterway. The site is in an area zoned as Port Maritime Industrial. The site is composed of four separate parcels owned by the Port of Tacoma: Pierce County tax parcels 2275200502, 2275200532, 5000350021, and 5000350040.<br><br>The boundaries for these parcels comprise a total area of approximately 30 acres. |
| **Alternatives** | The *No Action Alternative* and the *Proposed Action* are evaluated in this Final Supplemental Environmental Impact Statement (FSEIS); the analysis herein is focused exclusively on life-cycle GHG emissions. Key elements of each alternative include the following:<br><br>*No Action Alternative:* Construction of the Tacoma LNG Facility, including upgrading of the natural gas distribution system, would not occur. Existing levels of maritime petroleum fuels use would continue.<br><br>*Proposed Action:* The Tacoma LNG Facility would be constructed and produce between approximately 250,000 and 500,000 gallons of LNG per day, for use by marine customers, including TOTE, as well as regasification into the PSE natural gas distribution system for peak-shaving purposes. Additional uses would include providing LNG to other industries or merchants, such as fuel for high-horsepower trucks used in long-haul trucking or other marine transportation uses. The Tacoma LNG Facility would operate and be staffed with approximately 16 to 18 full-time employees 24 hours per day, 365 days a year.<br><br>The *Proposed Action* would also include the construction of segments of the PSE natural gas distribution system in the City of Tacoma, the City of Fife, and unincorporated Pierce County. This would include the installation of new pipe, a new limit station, and modifications to the Fredrickson Gate Station. |
| **Proponent** | Puget Sound Energy<br>10885 NE 4$^{TH}$ Street PSE-095<br>Bellevue, WA 98009-9734 |
| **SEPA Lead Agency** | Puget Sound Clean Air Agency<br>1904 Third Avenue, Suite 105<br>Seattle WA 98101<br>Telephone: (800) 552-3565 |

**SEPA Responsible Official**[1] Carole J. Cenci

**FSEIS Contact Person**

Betsy Wheelock
(206) 689-4080
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**Required Approvals and/or Permits**

The federal, state, and local approvals, licenses, and permits required for construction and operation of the Proposed Action are listed in the table below. The approval associated with the analysis in this FSEIS is Puget Sound Clean Air Agency's (PSCAA's) Order of Approval.

| AGENCIES | APPROVAL, LICENSE, or PERMIT |
|---|---|
| **FEDERAL** | |
| United States Department of Transportation/Pipeline and Hazardous Materials Safety Administration | Delegated to Washington Utilities and Transportation Commission for approval of design elements consistent with federal standards |
| United States Department of the Army Corps of Engineers (USACE), Seattle District | Section 10 Permit (Rivers and Harbors Act) |
| | Section 404 Permit (Clean Water Act [CWA]) |
| | Section 106 Consultation (National Historic Preservation Act) with applicable tribes (Puyallup Tribe of Indians and the Muckleshoot Tribe). |
| United States Coast Guard | Waterway Suitability Analysis Addresses requirements of 33 Code of Federal Regulations (CFR) Part 127: Coast Guard assessment of LNG Marine Operations |
| | Permission to establish Aids to Navigation required under 33 CFR Part 66 |
| | Letter of Intent (33 CFR Part 127) recommendation to operator and develops operation plans (OPLAN) at sea ports. |
| National Marine Fisheries Service (NMFS) | Section 7 of Endangered Species Act |
| | Essential Fish Habitat (EFH), Magnuson-Stevens Fishery Management and Conservation Act |

[1] The Responsible Official is the designated person that is responsible for compliance with the SEPA lead agency procedural responsibilities.

| AGENCIES | APPROVAL, LICENSE, or PERMIT |
|---|---|
| | Marine Mammal Protection Act Level B harassment authorization |
| **STATE** | |
| Washington State Department of Ecology (WDOE) | National Pollutant Discharge Elimination System (NPDES) – Construction Stormwater General Permit |
| | NPDES Industrial Stormwater General Permit |
| | Coastal Zone Consistency Determination |
| | 401 Water Quality Certification (CWA) |
| | Spill Prevention and Spill Response Plan (CWA) |
| | Hazardous Chemical Inventory Reporting Requirements |
| Washington Department of Fish and Wildlife (WDFW) | Hydraulic Project Approval |
| Washington State Department of Transportation (WSDOT) | State Highway Crossing Permit |
| Washington Department of Archaeology and Historic Preservation (DAHP) | Section 106 Consultation (NHPA) in coordination with lead federal agency (USACE) |
| **LOCAL JURISDICTIONS** | |
| City of Tacoma | Shoreline Substantial Development Permit |
| | Wetland/Stream/Fish and Wildlife Habitat Area Permit |
| | Floodplain Development Permit |
| | Clear and Grade Permit/Demolition Permit |
| | Building Permit |
| | Street Use or Right-of-Way Use Permit |
| Pierce County | Street use or Right-of-Way Use Permit<br>Conditional Use Permit |
| | Construction (Clear & Grade) Permit |
| | Building Permit |
| | Critical Areas Review |
| City of Fife | Right-of-Way permit Utility permit |
| | Flood permit |
| | Critical Areas Review |
| Port of Tacoma | Tenant Improvement Procedure |

| AGENCIES | APPROVAL, LICENSE, or PERMIT |
|---|---|
| **TRIBAL** | |
| Puyallup Tribe of Indians | Section 106 Consultation in coordination with USACE |
| Muckleshoot Tribe | Section 106 Consultation in coordination with USACE |
| **REGIONAL AGENCIES** | |
| Puget Sound Clean Air Agency | Order of Approval |

**Authors and Principal Contributors**

This FSEIS has been prepared under the direction of PSCAA. Research and analysis associated with this FSEIS were provided by the following consulting firms:

- **Ecology and Environment, Inc.** – FSEIS research, analysis, and document preparation
- **Life Cycle Associates, LLC** – GHG life-cycle analysis for the Proposed Action and No Action alternatives

For a complete list of individual contributors, see Appendix A of the FSEIS.

**Date of Issuance of the DSEIS**

October 8, 2018

**DSEIS Comment Period**

October 8, 2018 through November 21, 2018

**DSEIS Public Hearing**

- Date of the public hearing: October 30, 2018
- Time of the public hearing: 2:00 to 5:00 p.m. and 6:30 to 10:00 p.m.
- Hearing location: Rialto Theater, 310 South 9th Street, Tacoma, Washington 98402

The purpose of the public hearing was to provide an opportunity for agencies, organizations, and individuals to present comments regarding the DSEIS—in addition to submittal of written comments.

Comments were submitted in writing to PSCAA using the address above, by facsimile to (206) 343-7522, or to the following email address: publiccomment@pscleanair.org.

**PSCAA Final Actions**

- Approval of the FSEIS for the Tacoma LNG Facility as a document that is adequate for Washington State Environmental Policy Act (SEPA) compliance, including any proposed mitigation;
- Decision regarding a final Order of Approval for the Proposed Action.

| | |
|---|---|
| **Type of Supplemental Environmental Impact Statement** | This document supplements the Final Environmental Impact Statement (FEIS) for the Tacoma LNG Facility issued by the City of Tacoma in November 2015. This FSEIS evaluates greenhouse gas (GHG) emissions impacts associated with the construction and operation of an LNG liquefaction and marine bunkering facility within the City of Tacoma on land leased from the Port of Tacoma, and construction of segments of a natural gas pipeline in the City of Fife and unincorporated areas of Pierce County. This FSEIS fulfills the need for PSCAA to evaluate the life-cycle GHG emissions from the Proposed Action. |
| **Phased Environmental Review** | No additional SEPA review will be required for site-specific development that is proposed to PSCAA within the scope of the Proposed Action described in this FSEIS. |
| **Location of Background Data** | Puget Sound Clean Air Agency<br>1904 Third Avenue, Suite 105<br>Seattle WA 98101<br>Telephone: (800) 552-3565 |
| **Availability of this FSEIS** | Hard copies of the FSEIS can be viewed at the PSCAA office and at the following locations:<br>• Any Tacoma Public Library<br>• Center at Norpoint, 4818 Nassau Avenue Northeast, Tacoma, Washington 98422<br>The FSEIS can also be reviewed online at: www.pscleanair.org/PSELNGPermit. In addition, a limited number of complimentary hardcopies or electronic media of the FSEIS will be made available (while the supply lasts) at the PSCAA office.<br>PSCAA is open 8 a.m. to 4:30 p.m. Monday through Friday. |

# Table of Contents

**Appendices**

# List of Tables

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# Acronyms and Abbreviations

| Term | Definition |
| --- | --- |
| API | American Petroleum Institute |
| BOG | boil-off gas |
| CFR | Code of Federal Regulations |
| CI | carbon intensity |
| $CO_2$ | carbon dioxide |
| $CO_2e$ | carbon dioxide equivalent |
| CWA | Clean Water Act |
| DEIS | Draft Environmental Impact Statement |
| DSEIS | Draft Supplemental Environmental Impact Statement |
| ECA | (North American) Emission Control Area |
| Ecology | Washington State Department of Ecology |
| EIS | environmental impact statement |
| EPA | United States Environmental Protection Agency |
| FEIS | Final Environmental Impact Statement |
| FSEIS | Final Supplemental Environmental Impact Statement |
| GHG | greenhouse gas |
| gpd | gallons per day |
| gpm | gallons per minute |
| GREET | Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation |
| GWP | global warming potential |
| $H_2S$ | hydrogen sulfide |
| kWh | kilowatt hours |
| LNG | liquefied natural gas |
| MGO | marine gas oil |
| MMBtu | million British thermal units |
| MVFS | marine vessel LNG fueling system |
| NOC | Notice of Construction |
| NPDES | National Pollutant Discharge Elimination System |
| OPGEE | Oil Production Greenhouse Gas Emission Estimator |
| Proposed Action | Construction, operation, and decommissioning of the Tacoma LNG Project |
| PSCAA | Puget Sound Clean Air Agency |
| PSD | Prevention of Significant Deterioration |
| PSE | Puget Sound Energy |
| psig | pounds per square inch gauge |

| | |
|---|---|
| RCW | Revised Code of Washington |
| SEIS | Supplemental Environmental Impact Statement |
| SEPA | Washington State Environmental Policy Act |
| TOTE | Totem Ocean Trailer Express |
| tpy | tons per year |
| USACE | United States Department of the Army Corps of Engineers |
| WAC | Washington Administrative Code |

# Executive Summary

## ES.1 Introduction and Background

The City of Tacoma initiated an environmental review of the Tacoma Liquefied Natural Gas (LNG) Project (referred to herein as the Proposed Action) proposed by Puget Sound Energy (PSE) at the Port of Tacoma in September 2014. The Proposed Action would include on-site LNG liquefaction, storage for bunkering marine fuel, a truck loading facility, and the capability to re-gasify to meet peak natural gas demand. To supply the LNG facility, the Proposed Action also includes the construction of two new segments of pipeline connecting the LNG facility to PSE's existing natural gas distribution system. The construction, operation, and decommissioning of the Proposed Action is referred to herein as the Proposed Action.

This environmental review process, performed under the authority of Revised Code of Washington chapter 43.21C (Washington State Environmental Policy Act [SEPA]), was triggered when PSE formally applied for a Shoreline Substantial Development Permit with the City of Tacoma. On September 12, 2014, the City of Tacoma issued a SEPA Determination of Significance, indicating the City's intention to require an Environmental Impact Statement (EIS) to assess the environmental impacts of the Proposed Action at the Port of Tacoma and the surrounding area.

On September 12, 2014, the City of Tacoma began a SEPA scoping process to solicit input from the public on the issues to address in the environmental review. The City issued a Draft EIS (DEIS) on July 7, 2015. The City accepted comments on the DEIS through August 6, 2015. After consideration of comments on the DEIS and making appropriate changes, the City issued a Final EIS (FEIS) on November 9, 2015.

Following issuance of the FEIS, PSE submitted a Notice of Construction (NOC) permit application to Puget Sound Clean Air Agency (PSCAA) for the Tacoma LNG Facility. During PSCAA's review of the NOC permit application, the agency determined that an analysis of greenhouse gas (GHG) emissions and impacts in the FEIS included quantitative emissions for the Tacoma LNG Facility site, but did not account for "upstream" GHG emissions associated with natural gas extraction and transmission. In addition, PSCAA determined that the Washington State Department of Ecology guidance document for identification and evaluation of GHGs, which the FEIS analysis relied upon, had been withdrawn for revision after completion of the FEIS.

Accordingly, PSCAA initiated this Supplemental EIS (SEIS) to address Sections 3.2 and 3.13 of the FEIS. Specifically, PSCAA concluded that a "life-cycle" approach to characterizing GHG emissions and impacts was needed in the SEIS. The life-cycle analysis identifies and quantifies all GHG emissions associated with natural gas extraction and transmission, on-site LNG production and storage, and "downstream" end-uses of the LNG. To contrast the GHG emissions and impacts from the Proposed Action, a life-cycle analysis was performed for the No Action Alternative (i.e., the current situation) for this SEIS. The life-cycle analysis and SEIS will inform PSCAA's decision-making process for processing the NOC permit application for the facility. The life-cycle analysis forms the basis for the analysis and conclusions in this SEIS. The methodology used and results of the life-cycle analysis are documented in the report contained in Appendix B of this document.

PSCAA initiated a public comment period on the Draft Supplemental Environmental Impact Statement (DSEIS) on October 8, 2018, that extended for 45 days, ending on November 21, 2018. Comments on the DSEIS received by PSCAA included letters, emails, postcards, petitions, and other miscellaneous media, including faxes.

In addition, PSCAA captured public comments from oral testimony at the public hearings held on October 30, 2018. A total of approximately 14,820 comment submittals were received by PSCAA. The comments were categorized into the following broad issue categories:

- General opposition to the project;
- General support for the project;

- Comments outside of the scope of the SEIS;
- Determination of the SEIS scope;
- Language used in the SEIS;
- GHG life-cycle methodology;
- GHG life-cycle calculations;
- GHG life-cycle inputs and assumptions;
- SEIS purpose and need;
- Regulatory framework; and
- SEPA alternatives analyzed.

PSCAA carefully considered all comments submitted, developed responses to the comments, and included changes to the DSEIS and supporting documents based upon some of the comments received. Appendix C of this Final Supplemental Environmental Impact Statement (FSEIS) presents the comments received on the DSEIS and PSCAA's responses to the comments.

This FSEIS is an informational and evaluative tool. It does not mandate approval or disapproval of the Proposed Action, but informs the public and decision-makers of the potential impacts related to the emission of GHGs and, as appropriate, mitigation measures to avoid or reduce potential significant impacts.

This FSEIS is organized as follows:

- **Chapter 1** describes the purpose and need of the Proposed Action in the context of the analysis conducted by PSCAA to comply with SEPA.
- **Chapter 2** describes the Proposed Action components and construction procedures.
- **Chapter 3** describes the No Action Alternative and related assumptions.
- **Chapter 4** evaluates the affected environment, and the Proposed Action's potential environmental consequences associated with GHG emissions on the surrounding region.

# ES.2 SEIS Objectives, Purpose, and Need

The purpose of the Proposed Action is to receive natural gas from PSE's distribution system, chill natural gas to produce approximately 250,000 to 500,000 gallons of LNG daily, and store up to 8 million gallons of LNG on site. LNG would be distributed for use as marine transportation fuel by Totem Ocean Trailer Express (TOTE) at its Port of Tacoma facility, along with other potential future regional LNG marine vessel customers. During times of peak gas demand, 66,000 dekatherms of LNG would be re-gasified and re-injected into PSE's distribution system. In addition, PSE is also proposing to load LNG onto trucks or barges for use by other regional markets seeking an alternative fuel source.

The Proposed Action would address a need for new peak-day resources as identified through PSE's 2013 biennial integrated resource plan. PSE determined that the most cost effective way of meeting its resource needs would be the combination of additional regional underground storage; the Tacoma LNG Facility; and refurbishment of an existing, on-system, peak-day resource.

In addition to meeting long-term resource needs, the Proposed Action would enable TOTE to meet new fuel standards for maritime vessels in response to the North American Emission Control Area (ECA), which established more stringent emission standards within 200 miles of the United States and Canadian coasts. A significant portion of the LNG to be produced at the Tacoma LNG Facility would be consumed by TOTE. However, additional fuel switching by other companies from petroleum products to LNG would provide further demand for LNG in the region.

# ES.3 SEIS Alternatives and Review

This document evaluates two alternatives: the Proposed Alternative and the No Action Alternative, consistent with alternatives evaluated in the City of Tacoma's DEIS and FEIS.

This SEIS addresses direct and indirect Proposed Action GHG emissions impacts, as well as supplements the analysis of cumulative impacts of GHGs evaluated in the FEIS. It also evaluates potential GHG emissions impacts of the Proposed Action that would result from its construction, operation and maintenance, and decommissioning at the end of its design life.

# ES.4 Major Conclusions

Based on the analysis presented in this SEIS, the following major conclusions have been drawn:

- The use of LNG produced by the Proposed Action, instead of petroleum-based fuels for marine vessels, trucks, and peak shaving is predicted to result in an overall decrease in GHG emissions, a net beneficial impact compared to the No Action Alternative. As demonstrated by the range of potential impacts from the Proposed Action and No Action alternatives based on an LNG capacity of 250,000 to 500,000 gallons per day, the greater the replacement of other petroleum-based fuels with LNG, the greater the overall reductions in GHG emissions.
- The conclusion regarding the overall reductions in GHG emissions stated above is dependent upon the assumption that the sole source of natural gas supply to the facility is from British Columbia or Alberta, but entering Washington through British Columbia. The SEIS analysis supports the recommendation that the facility's air permit, if approved, include the condition regarding the sole source of the natural gas through British Columbia as a requirement so the analysis and this conclusion is consistent with the proponent's project description.
- The SEIS analysis demonstrates that GHG emissions are predicted to result in an overall decrease with the completion of the Proposed Action as conditioned above. This means that the Proposed Action will not cause a significant adverse impact from GHG emissions. In addition, if the different assumptions in the life-cycle analysis were to change the final comparative amounts of emissions (e.g., to go from a small decrease to a small increase in GHG emissions as described in Sections 4.5 and 4.8 of the SEIS), the small increase in GHG emissions, between the Proposed Action in comparison to the No Action Alternative, would still not be considered a significant adverse impact because the increase would be small compared to the total GHG emission identified in the life-cycle analysis. Under this latter scenario, the Proposed Action would still need the condition that the sole source of the natural gas supplied to the facility be through British Columbia.

# 1 Purpose, Need, and Alternatives Considered

This chapter presents the purpose of the Proposed Action set forth by the proponent, Puget Sound Energy (PSE), the need for the Proposed Action, and the alternatives considered, consisting of the Proposed Action and the No Action Alternative. Throughout this Final Supplemental Environmental Impact Statement (FSEIS), the term "Proposed Action" refers to the construction, operation, and decommissioning of the Tacoma Liquefied Natural Gas (LNG) Project.

The focus of this SEIS is on impacts associated with air quality, specifically emissions of greenhouse gases (GHGs) from the alternatives. This SEIS does not address the other Washington State Environmental Policy Act (SEPA) elements of the environment (e.g., environmental health/public safety, shoreline use, etc.) as these topics were addressed in the Final EIS (FEIS).

## 1.1 Purpose and Need

The purpose of the Proposed Action as described in the FEIS is to produce LNG for use as a maritime fuel for Totem Ocean Trailer Express (TOTE) vessels and other future regional LNG marine fuel customers, to re-gasify the LNG to meet peak-shaving needs, and for loading on trucks or barges for other regional markets seeking an alternative fuel. Some of the LNG loaded on trucks is proposed to resupply the proponent's LNG storage facility in Gig Harbor.

The stated need for the Proposed Action has two categories: fuel for maritime or other transportation uses and peak-day resource support for natural gas customers. The fuel need for maritime use includes the contract PSE has with TOTE to provide LNG to TOTE at the Port of Tacoma for TOTE's vessels that operate between Tacoma and Anchorage, Alaska. This PSE contract with TOTE was reached, in part, to meet the International Convention for the Prevention of Pollution from Ship emissions limits for nitrogen oxide and sulfur oxide in the Emission Control Areas along the United States and Canadian coasts. In addition to TOTE, the proposed facility would be able to support other transportation fuel needs, not limited solely to maritime use. A second stated need is during peak-energy demand periods, PSE would be able to meet that demand through the use of the LNG as an alternative to other market driven alternatives to meeting customer supply requirements.

## 1.2 Alternatives Considered

Under Washington Administrative Code (WAC) 197-11-620(1) SEISs are to be prepared in the same way and format as the draft and final EISs. The SEIS is intended to evaluate the same alternatives as the FEIS—new alternatives are not required. Therefore, this SEIS analyzes the Proposed Action and the No Action alternatives, which are summarized below.

### 1.2.1 Proposed Action

The Proposed Action for the purposes of the SEIS is to construct the Tacoma LNG Facility to produce 250,000 to 500,000 gallons per day (gpd) of LNG to be used as a marine fuel and provide LNG to various customers in the Puget Sound area via LNG bunkering barges and tanker trucks, replacing the use of marine gas oil (MGO) and diesel fuel. The Tacoma LNG Facility would also have the capability of vaporizing LNG back to its gaseous state for injection into the PSE natural gas distribution system during periods of high demand, referred to as "peak shaving." The area of the Proposed Action is shown in Figure 1-1. The Proposed Action would consist of the following main components:

- **Tacoma LNG Facility**: Would liquefy natural gas, store up to 8 million gallons of LNG, and include facilities to transfer LNG to the TOTE Marine Vessel LNG Fueling System (described below), bunkering barges in the Blair Waterway, or tanker trucks on site. It would also would include facilities to re-gasify stored LNG and inject natural gas into the PSE Natural Gas Distribution System. This facility would be located in the Port of Tacoma within the City of Tacoma.

- **TOTE Marine Vessel LNG Fueling System:** Would convey LNG by cryogenic pipeline from the Tacoma LNG Facility to the TOTE site and include transfer facilities and an in-water trestle and loading platform over the Blair Waterway to fuel vessels or load bunker barges. The proposed locations of these components are shown in Figure 1-2.
- **PSE Natural Gas Distribution System**: Would convey natural gas to and from the Tacoma LNG Facility. It would include two new distribution pipeline segments (Pipeline Segment A and Pipeline Segment B), a new limit station (Golden Given Limit Station), and an upgrade to the existing Frederickson Gate Station. Pipeline Segment A would be located in the City of Tacoma and the City of Fife. Pipeline Segment B would be located in unincorporated Pierce County. In addition, the Golden Given Limit Station and Fredrickson Gate Station would be located in unincorporated Pierce County.

### 1.2.2 No Action Alternative

Under the No Action Alternative, the historic land uses would continue at the proposed Tacoma LNG Facility site, which is zoned Port Maritime Industrial. LNG would not be produced or stored at the Tacoma LNG Facility site and would not be available to replace MGO for fuel marine vessels or other customers in the Puget Sound area. To assess the potential changes from the Proposed Action's operation and supplying LNG, it is assumed that the equivalent amount of MGO and diesel fuel would continue to be used. Additionally, some LNG would be re-gasified and injected into the PSE natural gas pipeline system during periods of peak demand. The Gig Harbor LNG storage facility would continue to be supplied by truck from Canada. Under the No Action Alternative, the economic and employment impacts of the Proposed Action would not occur. However, the No Action Alternative would require TOTE to seek another source of LNG or other means to reduce their emissions to meet International Maritime Organization requirements.

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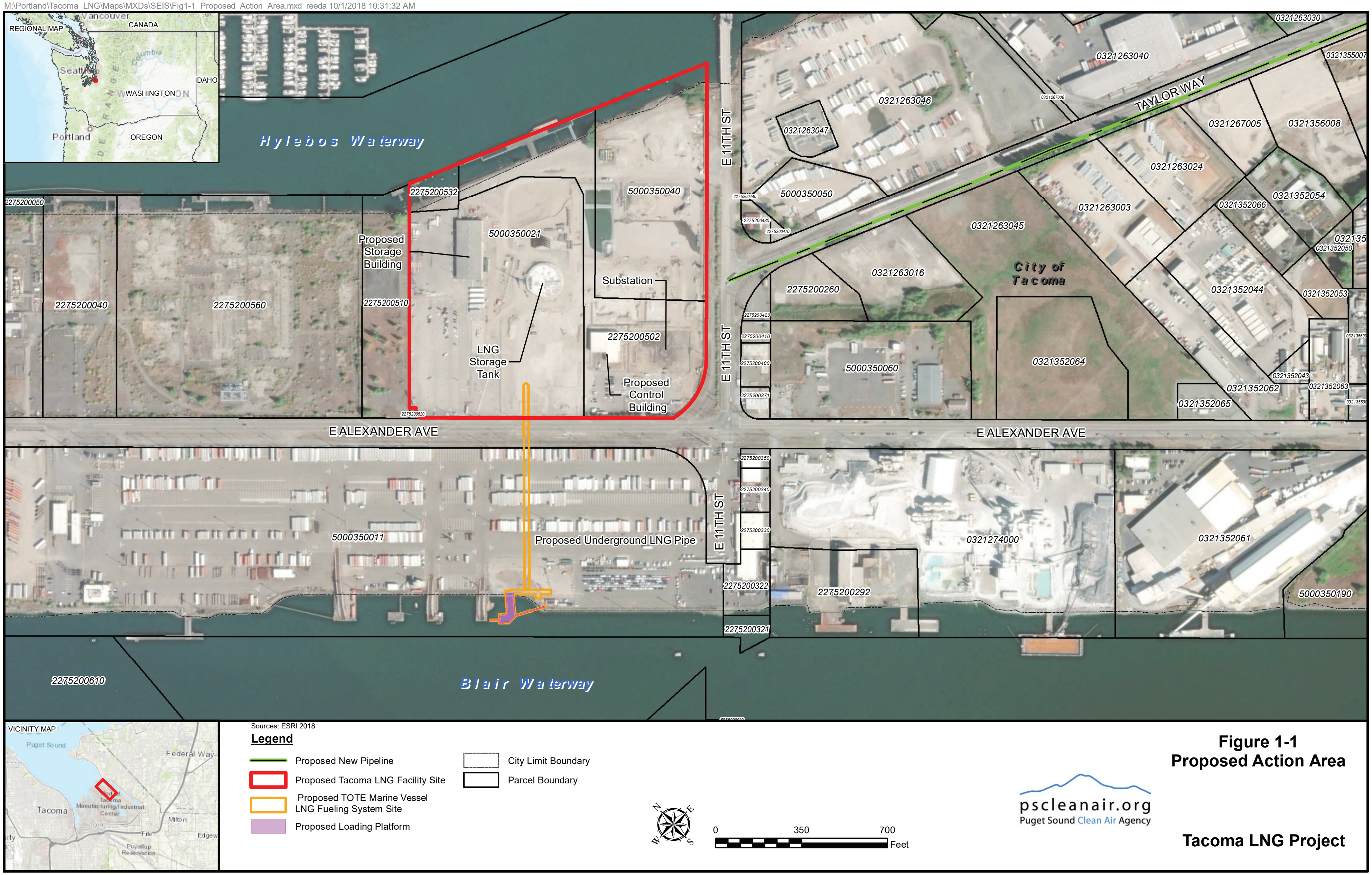


**Figure 1-1**
**Proposed Action Area**

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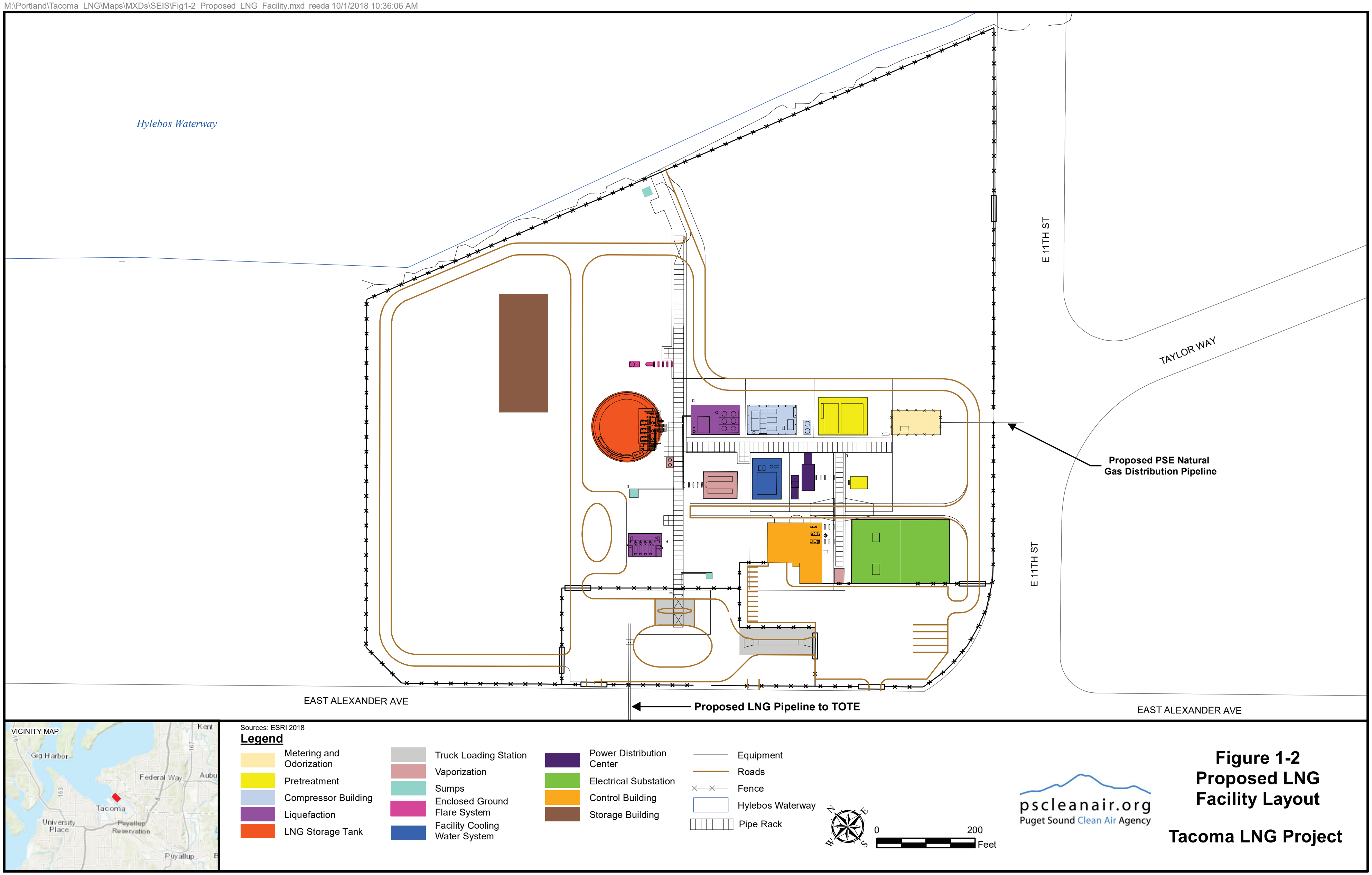



**Figure 1-2**
**Proposed LNG Facility Layout**

**Tacoma LNG Project**

# 2 Description of the Proposed Action

## 2.1 Introduction

The Tacoma LNG Facility components and operational details are fully described in the FEIS. As summarized in Chapter 1 (Purpose, Need, and Alternatives Considered), the Proposed Action for the purposes of the FSEIS is to construct the Tacoma LNG Facility to produce 250,000 to 500,000 gpd of LNG to be used as a marine fuel and provide LNG to various customers in the Puget Sound area via LNG bunkering barges and tanker trucks, replacing the use of MGO and diesel fuel. The Tacoma LNG Facility would also have the capability of vaporizing LNG back to its gaseous state for injection into the PSE Natural Gas Distribution System during periods of high demand, referred to as “peak shaving.”

As the nature of the Tacoma LNG Facility or its intended uses has not changed since the FEIS, and pursuant to the Notice of SEIS issued by the Puget Sound Clean Air Agency (PSCAA) on January 24, 2018, this chapter only examines the components relevant to the GHG life-cycle analysis.

Life-cycle emissions include not only the direct emissions associated with production of LNG, but also include emissions associated with extraction, refining, and transport of each fuel used in production and emissions associated with end use (combustion in marine engines and heavy duty trucks and peak shaving). Upstream life-cycle or well to tank emissions are the emissions associated with production and transport of fuel used at the LNG production plant: natural gas feedstock, natural gas fuel, diesel fuel, and electricity. For natural gas, upstream life-cycle emissions include emissions due to natural gas extraction and transport to the facility. For on-site diesel, upstream life-cycle emissions are those associated with crude oil recovery, transport to the refinery, refining, and finished product transport to end use. For electricity, upstream life-cycle emissions include recovery, and processing and transport of each fuel type to the electricity generating plants (generally a mix of coal, nuclear, natural gas, oil, hydro and other renewables). Direct emissions from the Proposed Action include all fuel combustion emissions, as well as fugitive emissions at the plant. End use emissions refer to the final combustion of LNG for vessel/truck transportation and peak shaving applications.

Appendix B provides the detailed results of the GHG life-cycle analysis.

In the life-cycle analysis, there are references to a “Scenario A” and “Scenario B.” The Scenario A analysis is based on a facility LNG production rate of 250,000 gpd. The Scenario B analysis is based on a production rate of 500,000 gpd. The FEIS stated the facility would produce between 250,000 and 500,000 gpd. The information originally provided by PSE for this life-cycle analysis reflected a facility design for 250,000 gpd production, which also matches the capacity of the facility described in the Notice of Construction (NOC) application. That air permit action is still pending, waiting for the completion of this SEIS review. Both scenarios have been evaluated and included in these analyses to reflect the Proposed Action that PSE is currently seeking and the full capacity of the facility that was referenced in the FEIS.

## 2.2 Upstream (Well to Tank)

### 2.2.1 Natural Gas Extraction and Transportation

The gas supply for the LNG facility would come exclusively from British Columbia or Alberta, but entering Washington through British Columbia. No natural gas would be obtained from other regions for the Tacoma LNG Facility (PSE 2018). British Columbia has adopted comprehensive drilling and production regulations that are intended to reduce methane emissions. The Canadian national government has recently adopted new regulations that require companies to control methane leaks from equipment and the release of methane from compressors starting on January 1, 2020.These regulations are discussed in more detail in the Life Cycle Associates, LLC report (Appendix B of this FSEIS), but no adjustments to the emission factors used in the life-cycle analysis were made in anticipation of these regulatory effects.

The gas supply for the LNG facility would be transported from British Columbia and Alberta by way of Westcoast Pipeline (Duke Energy) to the Huntingdon/Sumas export/import point located near the United States and Canadian border. Gas received at the Huntingdon/Sumas export/import point would be transported approximately 145 miles on Northwest Pipeline (Williams Company) to the Frederickson Meter Station, Southeast of Tacoma. PSE has acquired pipeline capacity on the Northwest Pipeline that would be dedicated to this purpose. (PSE 2018)

The bulk of gas receipts into the PSE system for the LNG facility are anticipated at Frederickson. Under certain conditions, some gas may enter the PSE system at the North Tacoma Meter Station, approximately 131 miles from the Huntingdon/Sumas hub. However, the longer transmission distance of 145 miles is assumed for all gas transmission between the Huntingdon/Sumas hub and the PSE's pipeline system. (PSE 2018)

### 2.2.2 Petroleum Upstream

Under the Proposed Action, diesel fuel would continue to be used in small quantities. See Section 3.2 (Upstream Emissions) for further discussion of petroleum related upstream emissions.

### 2.2.3 Electric Power Generation

For each gallon of LNG produced, the LNG facility would consume 1.35 kilowatt hours (kWh) of grid power to meet its electricity requirements.

The electric power generation mix affects the GHG emissions associated with purchased power. Power would be delivered to the Tacoma LNG Facility through the Tacoma Power electrical system. Although the majority of electricity is generated by hydro-electric, nuclear, and non-hydroelectric renewables, some is generated using natural gas (US EIA 2018a). The Washington State Average Mix, which is a similar mix to Tacoma Power that would supply the Tacoma LNG Facility, with an average emission rate of 18 g/kWh carbon dioxide equivalent ($CO_2e$), was used to estimate upstream electricity emissions (State Energy Office at the Washington Department of Commerce 2017). GHG emissions are calculated with the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) (ANL 2015) model upstream emission factors. Refer to Appendix B for more information on emissions assumptions for electric power generation.

## 2.3 LNG Processing Facility

Direct GHG emissions from the Proposed Action include combustion and fugitive emissions from various processing operations. Natural gas would enter the LNG facility through a metering station connected to a new underground pipeline and upgrades to the existing distribution system originating at Frederickson. Natural gas entering the LNG facility would be routed to an inlet filter separator to remove small particles and liquid droplets to protect the downstream boost compression and the pre-treatment systems. In order to convert the natural gas to a liquid, the feed gas would be boosted in pressure to approximately 525 pounds per square inch gauge (psig) by an electric motor-driven, two-stage, integrally-geared centrifugal compressor. Once cooled to a temperature of -260 degrees Fahrenheit, the pressure is decreased to approximately 3 psig. Fugitive leakage from the feed gas compressor's seals would be captured and sent to the enclosed ground flare. The LNG would then be pumped into an 8 million gallon double-walled storage tank.

LNG would be pumped out from the storage tank for either vaporization and reintroduction into the local distribution system, or use as a marine vessel or surface vehicle fuel. LNG would be removed from the storage tank by way of submerged motor in-tank pumps. The submerged motor LNG pumps would be contained within the enclosed LNG tank and therefore are not a source of fugitive emissions.

## 2.3.1 Natural Gas Pretreatment Systems

### 2.3.1.1 Amine Pretreatment System

Natural gas entering the Tacoma LNG Facility through the dedicated pipeline would be composed primarily of methane, but would also contain other non-methane hydrocarbons. In addition, quantities of nitrogen, carbon dioxide ($CO_2$), sulfur compounds (hydrogen sulfide [$H_2S$] and odorants), and water would be present in the feed gas stream entering the plant. (PSE 2018)

$CO_2$ and water would freeze within the liquefaction process and must be removed to sufficient levels to allow optimal performance of the heat exchangers. $CO_2$, water, some sulfur-based components, and trace contaminants would be removed from the feed gas by an Amine Pretreatment System designed to treat up to 26 million standard cubic feet per day of inlet gas with an average of 2 percent $CO_2$ concentration so as not to limit the capacity of the liquefaction system. (PSE 2018)

For purposes of determining GHG emissions from the Tacoma LNG Facility, the amine pretreatment system generates GHGs from two components of the process. First, there is an 18.0 million British thermal units (MMBtu) per hour natural gas fired water propylene glycol heater that would generate combustion emissions. Second, an aqueous amine solution would absorb $CO_2$ and $H_2S$ from the natural gas through a chemical reaction, resulting in a “sweet” gas with less than 50 parts per million of $CO_2$ and a “rich” amine solution that contains the $CO_2$ and $H_2S$. The “rich” aqueous amine solution would then be heated in a 3.2 MMBtu/hour regenerator to remove the $CO_2$ and $H_2S$, resulting in a “lean” amine solution that would be reused in the process. The exhaust from the amine regenerator would be routed to the enclosed ground flare, which would oxidize $H_2S$, odorants and volatile organic compounds at high temperature into water, $CO_2$, and $SO_2$. (PSE 2018)

### 2.3.1.2 Non-methane Hydrocarbon Removal

After pretreatment, but prior to liquefaction of the natural gas, non-methane hydrocarbons that may freeze at the cryogenic temperatures encountered downstream would be removed by partial refrigeration. The remainder of the removed hydrocarbons would be disposed of via the enclosed ground flare. Flash gases from the non-methane hydrocarbon storage vessel would be sent to the enclosed ground flare. These uses are taken into account in the life-cycle analysis. (PSE 2018)

## 2.3.2 Liquefaction

After the non-methane hydrocarbon removal process, the natural gas would be mixed with compressed boil-off gas (BOG) from the storage tank and condensed to a liquid by cooling the gas to approximately -260 degrees Fahrenheit using a mixed refrigerant (composed of methane, ethylene, propane, isopentane, and nitrogen). Seal leakage from the compressor would be captured and sent to an enclosed ground flare. Liquefaction is expected to typically occur during 51 weeks of the year. Up to 10 days per year, the Tacoma LNG Facility is expected to operate in a holding mode while LNG is vaporized. (PSE 2018)

## 2.3.3 LNG Storage

The LNG would be stored in an 8-million-gallon, low-pressure LNG storage tank at less than 3 psig. The LNG storage tank would be a full containment structure consisting of a steel inner tank and a pre-stressed concrete outer tank. The storage tank would be vapor- and liquid-tight without losses to the environment. Insulating material would be placed between the inner and outer tanks to minimize heat gain and boil-off. (PSE 2018)

To maintain the natural gas in a liquid state, an auto-refrigeration process would be used to keep the temperature of the LNG below -260 degrees Fahrenheit (PSE 2018). Inside the tank, vapor pressure above the liquid is kept constant so the temperature is maintained. When LNG temperature increases, vapors, referred to as BOG, are created. In order to avoid pressure build-up within the tank, BOG is collected in a recovery system (PSE 2018). The BOG recovery system warms the gas and boosts the pressure for either re-liquefaction and return to the storage tank or reinjection into the distribution system as natural gas (PSE 2018). In a situation where the process is disrupted, excess LNG vapors would vent to the enclosed ground flare (PSE 2018). GHG emissions would also occur from fugitive losses that occur from valves associated with the LNG storage tank.

### 2.3.4 LNG Vaporization for Peak Shaving

The LNG vaporization system consists of a pump and vaporizer. The vaporization pump would be external to the LNG storage tank and would boost the pressure to a sufficient level for vaporization and reinjection into the PSE Natural Gas Distribution System pipeline. The vaporizer would consist of a warm water bath that heats the LNG to a gaseous state suitable for use in the pipeline. The vaporization system would have the capacity to deliver 66 million standard cubic feet per day of natural gas at the standard distribution pipeline pressure. The gas sent out to the natural gas pipeline would be metered and odorized. Only one pipeline would convey natural gas to and from the Tacoma LNG Facility. Thus, when the vaporization and reinjection system is operating, the LNG liquefaction system would not operate. (PSE 2018)

Fugitive GHG emissions would occur during the regasification process for peak shaving, and would primarily originate from valves and associated piping connections. PSE is not proposing to generate electricity with natural gas from the LNG facility. The vaporized natural gas from the LNG facility would replace natural gas that, in the No Action Alternative, is supplied by additional purchase contracts, use of other natural gas storage resources, or other measures PSE could identify to meet its supply obligations. The emissions from the revaporizing of natural gas are accounted for in the GHG analysis.

### 2.3.5 LNG Delivery to TOTE and Other Vessels

LNG would be conveyed via cryogenic pipeline to the TOTE marine vessel LNG fueling system (MVFS). The LNG pipeline would extend 1,200 feet from the Tacoma LNG Facility storage tank, pass through a tunnel below the Alexander Avenue right-of-way, then above ground near the Blair Waterway shoreline and extend through a below ground trench to the TOTE terminal access trestle, ending at a loading arm on a bunkering platform. Ship bunkering would typically occur twice per week, for a period of 4 hours each, or a total of 8 hours per week. (PSE 2018)

Marine vessels would be bunkered with LNG for fuel using a dedicated marine bunkering arm equipped with a piggyback vapor return line. The arm is hydraulically maneuvered and includes swivel joints that would be swept with nitrogen to prevent ingress of moisture that could freeze and impede arm movement. When connected to the receiving vessel, the LNG bunkering arm and connected piping would be purged with nitrogen, which would be routed back to the enclosed ground flare. Once the system is purged, LNG would be bunkered onto the receiving vessel at a maximum design rate of 2,640 gpm. Once bunkering is complete, the liquid in the bunkering arm and in the adjacent piping would be drained back to the LNG storage tank. After draining, the arm and connected piping would be purged with nitrogen again. The nitrogen purge would be routed back to the enclosed ground flare and the arm piping depressurized prior to disconnection (PSE 2018).

Fugitive GHG emissions would occur from valves and piping associated with transfer of LNG to TOTE's ships, and from LNG loading to other marine vessels. During bunkering transfer operations, GHG emissions would occur from BOGs.

LNG may also be supplied to bunker vessels for subsequent transfer to ships. In this process, the bunker vessel would load LNG via the MVFS. The bunker vessel would then transit to the LNG-fueled marine vessel, anchor alongside the vessel, and conduct ship-to-ship transfer of the LNG. This is the process typically used for fuel oil. Because the current situation (i.e., the No Action Alternative) involves bunker barge operations using fuel oil, no additional LNG emissions were evaluated for LNG bunker barge operations beyond methane emissions associated with the ship-to-ship transfer process. (PSE 2018)

## 2.3.6 LNG Truck Loading Facilities

Two loading bays on the west side of the Tacoma LNG Facility would have the capacity to load LNG into 10,000-gallon capacity tanker trucks. The loading bays would be designed to fill a tanker truck at a rate of 300 gpm. Truck loading can be functionally undertaken concurrently with liquefaction, marine loading, or to the pipeline (PSE 2018).

Each truck bay would have an LNG supply and vapor return hose. The hoses would be 3 inches in diameter and 20 feet long and made from corrugated braided stainless steel with connections designed for LNG trailers. After truck loading, the LNG hose would be drained to a common, closed truck station sump connected to the Tacoma LNG Facility vapor handling system where it would be allowed to boil off and be re-liquefied or sent to the pipeline. Nitrogen would be used to purge the hoses and facilitate liquid draining and then routed to the enclosed ground flare. (PSE 2018)

Fugitive GHG emissions would occur from valves associated with truck transfer activities.

## 2.3.7 TOTE Marine Vessel LNG Fueling System

The TOTE MVFS would be located on the TOTE site on the Blair Waterway. The TOTE site is primarily a paved parking area for trailers, other vehicles, and equipment and includes some small buildings and structures.

The TOTE MVFS would consist of an access trestle and LNG loading platform with the LNG pipeline ending at a loading arm or hose on the loading platform that would transfer LNG to the TOTE vessel, or other barges and bunker ships. The loading arm or hose would have emergency release couplings at the outboard of the arm or hose.

The shoreline along the Blair Waterway is developed with berths and armored slopes containing riprap, concrete and asphalt pieces. The slope and armoring of the section of shoreline for the MVFS would remain unchanged. In-water structures in the Blair Waterway associated with existing TOTE operations include a timber T-pier, three concrete piers, and one concrete breasting dolphin.

New construction would include a concrete, steel pile-supported access trestle extending from shore to the LNG loading platform. This 81-foot-long by 33-foot-wide (2,673 square feet) trestle would be constructed adjacent to the existing aft loading platform for the TOTE vessels. It would provide a roadway section for fire truck access to the loading platform, a pipeway, a utility corridor for all required piping and utilities, and a walkway for personnel. Twelve 30-inch-diameter steel pipe piles would support the trestle. A concrete spillway installed along the trestle below the LNG pipeline would convey any accidental release of LNG into a purpose-built containment sump located onshore.

PSE's LNG delivery system would terminate at the loading flange on TOTE's ship.

## 2.3.8 Other Process Facilities

The process facilities would include other specific components, such as a meter station, odorizor, BOG recovery system, and flare system. The life-cycle analysis assumed that GHG fugitive emissions would be occur from several of these facility components (see Section 2.3.9 [Fugitive Emissions]).

## 2.3.9 Fugitive Emissions

Fugitive methane emissions can occur from leaks in valves, pump seals, flanges, connectors, and compressor seals. There are multiple fugitive minimization features inherent in the Tacoma LNG Facility design. For example, all of the proposed pumps, with the exception of the hydrocarbon liquid pump, would be submerged inside enclosed liquid storage tanks. In addition, leaks from the feed gas compressor seals would also be captured and vented to the enclosed ground flare. However, the BOG would have fugitive methane emissions. In addition, there are several valves, relief valves, and flanged connectors for conveyance of various process fluids that have the potential for fugitive methane leaks. LNG bunkering of ships at the TOTE terminal would not produce any fugitive emissions. However, there are four swivel joints that have seals with the potential to leak methane. The analysis assumes that the leak rate of the swivel joints would be similar to that of the pump seals. (PSE 2018)

## 2.4 End Use Emissions

The life-cycle analysis assumes that all fuel distributed from the facility would be combusted to power on-road trucking, TOTE marine vessels, other marine vessels by truck-to-ship bunkering, or other marine vessels by bunker barge. The volume and type of use vary slightly depending on the daily capacity (see Table 2-1). TOTE marine vessel fuel use is estimated to remain the same for both the 250,000 gpd and 500,000 gpd production level scenarios. The balance of the 500,000 gallons of LNG per day has been attributed to supply fuel to the Gig Harbor LNG facility, on road trucking, truck-to-ship bunkering, and other marine vessels by bunker barge.

**Table 2-1 LNG End Use Volume, Proposed Action**

| | Scenario A | | | Scenario B | | |
|---|---|---|---|---|---|---|
| **LNG Production** | **End Use Share** | **gallons/ day** | **MGal/ year** | **End Use Share** | **gallons/ day** | **MGal/ year** |
| **Total** | **100.0%** | **250,000** | **88.75** | **100.00%** | **500,000** | **177.50** |
| Peak Shaving | 2.2% | 5,511 | 1.96 | 1.1% | 5,511 | 1.96 |
| Gig Harbor LNG Supply | 0.0% | 0 | - | 1.00% | 5,000 | 1.78 |
| On-road Trucking | 0.0% | 0 | - | 2.00% | 10,000 | 3.55 |
| TOTE Marine | 42.7% | 106,849 | 37.93 | 21.4% | 106,849 | 37.93 |
| Truck-to-Ship Bunkering | 0.0% | 0 | - | 1.00% | 5,000 | 1.78 |
| Other Marine (by Bunker Barge) | 55.06% | 137,640 | 48.86 | 73.5% | 367,639 | 130.51 |

Key:
LNG = liquefied natural gas
MGal = million gallons
TOTE = Totem Ocean Trailer Express

## 2.5 Construction Emissions

Direct construction GHG emissions result from the combustion of fuel in construction equipment. Upstream emissions consist of electric power for construction as well as those emissions generated in the production of gasoline and diesel fuel. Construction equipment emissions correspond to the fuel use combined with emission factors for diesel and gasoline during the construction time of about three and a half years. Another portion of construction emissions consists of vehicle trips (workers and heavy-duty trucks). Equipment use was estimated based on construction activities defined in the FEIS (see Section 2.3 [Construction Procedures] of the FEIS). Material manufacturing emissions include the energy inputs and associated GHG emissions in the production of raw materials, and manufacturing processes to produce building materials for the LNG facility, such as steel and concrete.

GHG emissions were calculated for the following:

- Construction equipment fuel use
- Construction equipment power
- Material delivery
- Material manufacturing for the Tacoma LNG Facility

### 2.5.1 Upstream Construction

Upstream emissions for construction activity include the production of diesel and gasoline for construction equipment, generation of power and upstream fuel production for construction equipment, and manufacturing of materials.

### 2.5.2 Direct Construction Emissions

Direct GHG emissions from construction correspond to the fuel combusted from cranes, dozers, compressors, and other construction equipment, and employee vehicle (i.e., commuter) trips.

# 3 Description of the No Action Alternative

## 3.1 Introduction

Under the No Action Alternative, the Proposed Action would not be implemented. It is assumed that existing historic land uses would continue at the proposed Tacoma LNG Facility site, which is zoned for maritime industrial operations. Table 3-1 shows the activities and fuel types that occur in the No Action Alternative that would be displaced in the Proposed Action.

**Table 3-1 Key Parameters Affecting Life-Cycle Greenhouse Gas Emissions**

| Displaced Activity | Fuel | Equipment Type |
|---|---|---|
| NG Peak Shaving | NG | NG Heater/Boiler |
| Gig Harbor Peak Shaving | LNG | LNG for NG Peak Shaving |
| On-road Trucking | Diesel | Diesel Truck |
| TOTE Marine | MGO | Marine Engine |
| Truck-to-Ship Bunkering | MGO | Marine Engine |
| Other Marine by Bunker Barge | MGO | Marine Engine |

Key:
LNG = liquefied natural gas
MGO = marine gas oil
NG = natural gas
TOTE = Totem Ocean Trailer Express

Absent the Tacoma LNG Facility, MGO and diesel fuels would continue to provide the source of energy for the fuel use applications targeted by the Proposed Action. LNG would not be produced or stored at the Tacoma LNG Facility site and would not replace MGO for fuel marine vessels or other users in the Puget Sound area. To assess the potential changes from the Proposed Action's operation and supply LNG, it is assumed that the equivalent amount of MGO and diesel fuel would continue to be used.

Additionally, LNG would not be stored on site for regasification and injected into the PSE natural gas pipeline system during periods of peak demand. During peak demand, natural gas would be diverted to use for industrial and residential customers. The Gig Harbor LNG storage facility would continue to be supplied by truck from Canada.

Life-cycle GHG emissions from the No Action Alternative consist of upstream and end use activities only. No direct emissions have been included in the No Action Alternative analysis. Upstream life-cycle emissions under the No Action Alternative are associated with extraction, refining, and transport of natural gas fuel, MGO, diesel fuel, and electricity. Natural gas and electricity upstream life-cycle activities are described in Chapter 2 (Description of the Proposed Action). For MGO and diesel fuel, upstream life-cycle emissions are those associated with crude oil recovery, transport of crude oil to the refinery, refining, and finished product transport to end use. End use emissions include peak shaving and transportation related combustion activities. Values from the combustion of MGO and diesel fuel have been estimated based on baseline uses for the TOTE marine vessels and truck transportation. In addition, the analysis of the No Action Alternative quantifies the emissions from MGO combustion that is projected to be replaced in other vessels with the balance of the 250,000 or 500,000 gpd LNG capacity that would be created by the Proposed Action.

# 3.2 Upstream Emissions

Upstream life-cycle GHG emissions for petroleum fuels including diesel, bunker fuel, and gasoline, were calculated based on the regional resource mix for Washington. Inputs for the life-cycle of petroleum fuels include the location of crude oil resources and how it is extracted, Transportation distance and mode, and the American Petroleum Institute (API) gravity of the crude oil and the carbon intensity (CI) of the final products. These inputs were applied to the GREET analysis of crude oil refining. GHG emissions were based on the more detailed regionally specific Oil Production Greenhouse Gas Emission Estimator (OPGEE) analysis published by the California Air Resources Board (California ARB 2018; El-Houjeiri et al. 2018).

## 3.2.1 Crude Oil Extraction

Crude oil is produced and transported from a variety of resources and regions in the world. GHG emissions from petroleum production depend on the crude oil type and the extraction method, as well as oil refinery configuration, with about a 10 percent range in life-cycle emissions from different crude oil types (Gordon et al. 2015; Keesom, Blieszner, & Unnasch 2012) The life-cycle analysis of petroleum production in the GREET model takes into account the upstream emissions for crude oil production as well as the energy intensity to refine different products. The GREET inputs for petroleum product refining are based on a linear programming analysis of United States refineries, and were used in this analysis (Elgowainy et al. 2014).

## 3.2.2 Transport of Crude Oil

Washington State receives crude oil by vessel, pipeline, and rail. Assessments by the United States Energy Information Administration provide the quantity of oil as well as corresponding API gravity—the measure of petroleum liquid's density relative to water—and sulfur content for all crude oil imported from foreign countries to the United States (US EIA 2018a).

The Washington State Department of Ecology (Ecology) tracks and publishes quarterly reports (Ecology 2018) on all foreign and domestic crude oil receipts via rail car, pipeline, and other vessel transport modes. These data help determine the quantity of Alaska and North Dakota crude oil received and help determine the split between different transport modes for Canadian crude oil.

Table 3-2 presents a summary of the sources of Washington's crude oil. As of 2017, transport of crude oil from Canada, North Dakota, and Alaska's North Slope represents 94 percent of Washington's crude oil influx.

**Table 3-2 Summary of 2017 Crude Oil Influx to Washington State**

| Origin | Quantity (1,000 barrels) | Percentage (%) | Transport Mode |
|---|---|---|---|
| Brazil | 5,855 | 3% | Vessel |
| Brunei | 245 | 0% | Vessel |
| Canada | 66,780 | 31% | Mixed |
| Ecuador | 690 | 0% | Vessel |
| Mexico | 451 | 0.2% | Vessel |
| Russia | 2,480 | 1.2% | Vessel |
| Saudi Arabia | 1,297 | 0.6% | Vessel |
| Trinidad & Tobago | 1,367 | 1% | Vessel |
| North Dakota | 49,715 | 23% | Rail |
| Alaska NS | 84,278 | 40% | Mixed |
| Total Crude | 213,159 | N/A | N/A |
| Total Capacity | 231,301 | N/A | N/A |

Source: Appendix C, Table B.10

#### 3.2.2.1 Pipeline from Canada

The majority of Washington State's foreign crude oil is imported from Canada. Canadian crude oil can be derived from oil sands and upgraded before introducing it to a pipeline or it can be conventional crude oil. Data specifying the share of oil sands-derived versus conventional crude exported to each of the five Petroleum Administration for Defense Districts within the United States is no longer available. Instead, the Canada National Energy Board simply distinguishes between light and heavy crude. For Petroleum Administration for Defense District 5, where Washington State is located, the National Energy Board data indicate that 58 percent of the crude is light and 42 percent is heavy (and assumed to be derived from oil sands)(Natural Resources Canada 2015).

Modeled emissions for the No Action Alternative account for the additional mileage that the oil sands-derived crude is transported from Calgary to Edmonton and then to British Columbia. Shipments from Saskatchewan are assumed to be transported from Saskatoon to Edmonton and then to British Columbia.

#### 3.2.2.2 Tanker from Alaska and Unit Train from North Dakota

In addition to Canadian imports, the most significant sources of crude oil used in Washington are from the Alaska North Slope (via pipeline to Valdez and vessel to the west coast ports) and from North Dakota on rail cars.

The emissions model for the No Action Alternative accounts for the transport of crude oil through the Trans-Alaska pipeline system and its subsequent loading and transport via tanker to Washington State, and 1,500 miles of crude oil transport by rail from North Dakota prior to its entry into eastern Washington near Spokane.

### 3.2.3 Crude Oil Storage, Refining, and Distribution

Petroleum refineries convert crude oil primarily into transportation fuels. There are five refineries in Washington State with a combined refining capacity of over 230 million barrels per year. Although the state is a net exporter of refined product, gasoline and diesel are imported from Montana and Utah into eastern Washington. The most recent available pipeline transfer data (Adelsman 2014) indicated that 6 percent of diesel consumed in Washington is refined in Montana and transported to Washington via the Yellowstone pipeline and 10 percent is refined in Utah and transported via the Tesoro pipeline. In the No Action

Alternative, the balance (84 percent of diesel) is assumed to be refined in Washington State. We assume that all MGO consumed is refined in-state. Crude oil storage GHG emissions values are included in the life-cycle analysis modeling. Crude is processed from various locations and production methods and transported by tanker ship, pipeline, or rail car. GHG emissions from petroleum products also depend upon its sulfur content and density (represented by API gravity), on the energy intensity of the refining process, and CI of the final products. The energy inputs and emissions are described in Appendix B.

The California Air Resources Board utilizes the OPGEE model to quantify the CI of the crude oil recovery and transport portion of petroleum fuel pathways. For this analysis we utilize the 2016 CI values developed for California using OPGEE (California ARB 2017). The CI from refining and finished fuel (gasoline, diesel and MGO) were calculated with the GREET model for each refining location (i.e., Washington, Montana, and Utah). The GREET model adjusts refining energy inputs based on correlations between crude location and both sulfur content at API degree. We have also customized the model to use state average electricity grid mixes at each of the refining locations. Details regarding the energy inputs and emission factors are described in Appendix B.

### 3.2.4 Other Upstream Activities

The majority of upstream GHG emissions under the No Action Alternative would come from production and transport of MGO and diesel fuel. Some upstream emissions would result from natural gas and electricity use, but this is considered marginal and has not been quantified.

## 3.3 End Use Emissions

The life-cycle analysis under the No Action Alternative assumes that the equivalent amount of MGO and diesel fuel would not be displaced by LNG. These fuels would continue to be combusted to power on-road trucking, TOTE marine vessels, other marine vessels by truck-to-ship bunkering, or other marine vessels by bunker barge. The volume and type of use vary slightly depending on the daily capacity (see Table 3-3). As in the LNG estimates, TOTE marine vessel fuel use is estimated to remain the same for both the 250,000 gpd and 500,000 gpd production level scenarios. Under the 500,000 gpd capacity scenario, the increased capacity replaces diesel and MGO for road trucking, truck-to-ship bunkering, and other marine vessels.

**Table 3-3 Fuel End Use Volumes, No Action Alternative**

| LNG Production | Scenario A | | | Scenario B | | |
|---|---|---|---|---|---|---|
| | **End Use Share** | **MGal/ year** | **GBtu/ year** | **End Use Share** | **MGal/ year** | **GBtu/ year** |
| **Total** | **100.00%** | **54.8** | **7,038** | **100.00%** | **110** | **14,035** |
| NG for Gas Customers | 2.15% | 1.18 | 151 | 1.07% | 1.18 | 151 |
| Gig Harbor LNG | 0.00% | - | - | 1.62% | 1.78 | 137 |
| On-road Trucking | 0.00% | - | - | 1.75% | 1.93 | 247 |
| TOTE Marine | 42.83% | 23.47 | 3,014 | 21.34% | 23.47 | 3,014 |
| Truck-to-Ship Bunkering | 0.00% | - | - | 1.00% | 1.10 | 141 |
| Other Marine (by Bunker Barge) | 55.02% | 30.15 | 3,873 | 73.21% | 80.53 | 10,345 |

Key:
GBtu = giga British thermal units
LNG = liquefied natural gas
MGal = million gallons
TOTE = Totem Ocean Trailer Express

### 3.3.1 Peak Shaving

Absent the Tacoma LNG Facility, the additional natural gas needed by these customers during peak demand times would come from other sources of natural gas, potentially including natural gas repurposed from gas transmission . For the purposes of analyzing the No Action Alternative, it is assumed that the same energy content of natural gas from other sources is burned. The different properties of LNG and natural gas are taken into account.

### 3.3.2 Diesel for On-Road Trucking and Truck-to-Ship Bunkering

Under the No Action Alternative, diesel fuel would continue to be used for on-road trucking and by ships that currently use diesel fuel. The amount of diesel displaced by LNG used to estimate diesel from on-road trucking is based on the mileage using the displaced LNG in the Proposed Action, or approximately 1.9 million gallons of diesel for on-road trucking and approximately 1 million gallons of MGO for truck-to-ship bunkering.

### 3.3.3 Use of Marine Gas Oil as a Marine Fuel

Under the No Action Alternative, marine engines would continue to operate on MGO. Under the 250,000 gpd capacity scenario, the Proposed Action would displace 23.47 million gallons of MGO used by TOTE marine vessels, and would provide additional capacity to replace another 30.15 million gallons of MGO used by other marine vessels. Under the 500,000 gpd scenario, the expanded capacity would also displace 23.47 million gallons of MGO used by TOTE marine vessels, and would provide additional capacity to replace up to 81.6 million gallons of MGO used by other marine vessels.

# 4 Affected Environment, Environmental Consequences, and Mitigation

This chapter describes the regulatory framework for GHG emissions, the methodology of the GHG life-cycle analysis; the existing GHG emissions in the Proposed Action area; the potential change in GHG emissions and associated impacts resulting from the construction, operation, and decommissioning of the Tacoma LNG Facility compared to the No Action Alternative.

## 4.1 Regulatory Framework

This section provides an overview of the federal, state, and local agencies with jurisdiction over GHG emissions from the Proposed Action and the Proposed Action area, and a summary of specific regulations that apply to aspects of GHG emissions from construction and operation of the proposed Tacoma LNG Facility.

### 4.1.1 Agency Jurisdiction

Three agencies have jurisdiction over GHG emissions for the areas of the Port of Tacoma, cities of Tacoma and Fife, and Pierce County: the United States Environmental Protection Agency (EPA), Ecology, and PSCAA. PSCAA is the primary regulatory agency responsible for air quality permitting and compliance within King, Kitsap, Pierce, and Snohomish counties.

### 4.1.2 Federal GHG Policy and Regulations

On April 2, 2007, the United States Supreme Court (Massachusetts v. EPA) decided that GHGs were considered “air pollution” covered by the federal Clean Air Act. That decision indicated that if EPA did not choose to regulate GHGs through that authority, it needed to be based on a scientific determination that there was no endangerment from the emissions or any identified cause for those emissions. On December 7, 2009, EPA determined that the presence of six GHGs in the atmosphere endangers public health and public welfare and included them as contributors to air pollution: $CO_2$, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride (EPA 2009a). That led to regulations developed by EPA to address the emissions of GHGs.

On November 8, 2010, EPA finalized reporting requirements for the petroleum and natural gas industry under 40 Code of Federal Regulations Part 98 Subpart W. This subpart was then amended on December 23, 2011. Subpart W requires petroleum and natural gas facilities that emit 25,000 metric tons or more of $CO_2e$ per year to report annual emissions of specified GHGs from various processes within the facility.

EPA also addressed the relationship of GHG emissions for stationary source permitting programs. Currently, sources that are already Title V major emission sources can be considered major GHG emission sources. GHG emissions thresholds for new source review permitting of stationary sources are an increase of 75,000 tons per year (tpy) of $CO_2e$ at existing major sources and facility-wide emissions of 100,000 tpy of $CO_2e$ for a new source or a modification of an existing minor source. The 100,000 tpy of $CO_2e$ threshold defines a major GHG source for both construction (Prevention of Significant Deterioration [PSD]) and operating (Title V) permitting, respectively. (EPA 2009b)

### 4.1.3 State GHG Policies and Regulations

Washington State has had both policies, statutes, and regulations that address GHG emissions and their impacts for many years. Some of these include:

- Revised Code of Washington (RCW) 80.70 Carbon Dioxide Mitigation (2004)
- RCW 80.80 GHG Emissions – Baseload Electric Generation Performance Standard (2007)

- Washington Administrative Code (WAC) 173-407 GHG Mitigation Requirements & Emission Standards for Power Plants (Ecology 2005)
- WAC 173-441 Reporting of GHG Emissions (2011)
- WAC 173-442 Clean Air Rule (2016) *[on hold, litigation pending]*
- WAC 173-485 Petroleum Refinery GHG Emission Requirements (2014)

Washington State's *Preparing for a Changing Climate: Washington State's Integrated Climate Response Strategy* (Ecology 2012) was published to describe the risks of climate change to the state and identify the state's priorities in addressing these risks.

In 2009, the Washington State Legislature approved the State Agency Climate Leadership Act E2SSB 5560, which established GHG emissions reduction limits for state agencies in law (RCW 70.235.050 and RCW 70.235.060) and directed state agencies to quantify GHG emissions, report on actions taken to reduce GHG emissions, and develop a strategy to meet the GHG reduction targets. Washington State has established the following GHG reduction targets to reduce overall emissions (RCW 70.235.020):

- By 2020, reduce overall emissions of GHGs in the state to 1990 levels;
- By 2035, reduce overall emissions of GHGs in the state to 25 percent below 1990 levels; and
- By 2050, the state will do its part to reach global climate stabilization levels by reducing overall emissions to 50 percent below 1990 levels, or 70 percent below the state's expected emissions that year. (Ecology 2016)

In June 2017, Washington Governor Jay Inslee formed the United States Climate Alliance with the governors of New York and California to commit to reducing emissions by 26 to 28 percent from 2005 levels in order to meet or exceed targets of the federal Clean Power Plan (United States Climate Alliance 2018).

The document titled *Guidance for Ecology Including Greenhouse Gas Emissions in SEPA Reviews* (Ecology 2011) was prepared for Ecology staff use as guidance for SEPA review work and indicated as guidance, decisions on impacts were to be made on a case-by-case basis. Prior to the decision to prepare this SEIS for a life-cycle GHG emissions review, Ecology withdrew the 2011 guidance and replacement guidance has not been published. The 2011 guidance indicated that for projects emitting more than 25,000 metric tons per year, a quantitative disclosure of GHG emissions is required under SEPA. The FEIS cited this document and indicated that the direct, operational emissions from the Tacoma LNG Facility site were less than that 25,000 metric tons per year. According to the 2011 guidance, a quantitative analysis should include GHG emissions from all aspects of the Proposed Action, including Scope 1 emissions (project direct), Scope 2 emissions (associated with purchased electricity), and Scope 3 emissions (which include construction emissions as well as new, ongoing transportation emissions associated with the project).

### 4.1.4 PSCAA GHG Policies and Regulations

PSCAA supports, and in some circumstances, has helped implement the state's policies and requirements for GHG emissions. While the agency has engaged on climate action in a variety of capacities for over the last 15 years, a key part of this has been the agency's role in relation to project proposals as presented through SEPA reviews. PSCAA's SEPA checklist requires identification and consideration of GHGs (see PSCAA Reg. I, Section 2.06 Environmental Checklist). GHGs are considered "air contaminants" under the definition of the Washington Clean Air Act (RCW 70.94.030). The agency has requested and established mitigation conditions for GHG impacts through SEPA in the past.

### 4.1.5 Air Quality Permitting Requirements

The air quality permitting requirement for this proposed facility includes the Notice of Construction (NOC) application and the issuance of an Order of Approval. The NOC application has been submitted (NOC No.

11386) and is under review for the Proposed Action. NOC review has several detailed requirements, and will address criteria pollutants, air toxic contaminants, and compliance with any identified applicable air quality standards. A review of GHG emissions and impacts is primarily addressed for a proposal through the SEPA process, which is the exclusive scope of this SEIS analysis.

Among the air quality standards that may apply to the LNG facility (to be addressed in the NOC review process), it is anticipated that the Ecology rule for GHG emission reporting (WAC 173-441) will apply. That is a reporting rule alone and does not establish any substantive emission limitations. The Ecology Clean Air Rule (WAC 173-442) may also apply and could have some emission reduction/offset obligations as part of that program. While that will be noted in the NOC permit application review documents, that rule has been stayed by the courts and is subject to ongoing litigation. Thus, no emission reductions/offsets are assumed or included in the consideration at this time as the final status of that regulation is uncertain.

### 4.1.6 Regional and State Greenhouse Gas Emissions

EPA and Washington State have a number of programs designed to collect and analyze GHG emissions to better understand the sources of GHGs in the state. These programs help the state design policies to reduce GHG emissions and track its progress towards meeting the state's statutory GHG reduction limits.

EPA collects and reports nationally GHG emissions in the *Annual Inventory of U.S. Greenhouse Gas Emissions and Sinks*. The State of Washington's anthropogenic GHG emissions for the period from 1990 to 2013 (see Table 4-1) were developed using a set of generally accepted principles and guidelines for state GHG emission inventories, with adjustments for Washington-specific data and context, as appropriate—including the addition of military aircraft. The most recent inventory was published in October 2016 (Ecology 2016). Data are available from EPA on the county level; however, these data do not include military aircraft operations.

**Table 4-1 Washington State Annual Greenhouse Gas Air Emissions Inventory**

| Million Metric Tons $CO_2e$ | 1990 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| ***Electricity, Net Consumption-based*** | ***16.9*** | ***20.7*** | ***15.7*** | ***15.2*** | ***18.2*** |
| Coal | 16.8 | 15.8 | 12.8 | 12.1 | 13.3 |
| Natural Gas | 0.1 | 4.8 | 2.8 | 3.0 | 4.8 |
| Petroleum | - | 0.1 | 0.1 | 0.1 | 0.07 |
| ***Residential/Commercial/Industrial*** | ***18.6*** | ***19.7*** | ***20.8*** | ***20.5*** | ***21.9*** |
| ***Transportation*** | ***37.5*** | ***42.2*** | ***41.9*** | ***42.5*** | ***40.4*** |
| Onroad Gasoline | 20.4 | 21.9 | 21.3 | 21.2 | 21.7 |
| Onroad Diesel | 4.1 | 8.0 | 8.0 | 7.4 | 7.0 |
| Marine Vessels | 2.6 | 3.0 | 3.3 | 4.1 | 3.4 |
| Jet Fuel and Aviation Gasoline | 9.1 | 8.1 | 7.6 | 8.0 | 6.6 |
| ***Natural Gas Industry*** | ***0.5*** | ***0.8*** | ***0.8*** | ***0.8*** | ***0.8*** |
| ***Industrial Process*** | ***7.0*** | ***4.5*** | ***4.6*** | ***4.6*** | ***4.8*** |
| ***Waste Management*** | ***1.5*** | ***3.1*** | ***3.1*** | ***3.2*** | ***3.3*** |
| ***Agriculture*** | ***6.4*** | ***6.2*** | ***6.5*** | ***6.6*** | ***5.9*** |
| ***Total Gross Emissions*** | ***88.4*** | ***97.2*** | ***93.7*** | ***93.6*** | ***94.4*** |

Source: Ecology 2016
Note:
Bold values are included in the total gross emissions; all other rows and values included are subsets of the category above.
2010-2012 data have been revised based on values contained in the new International Panel on Climate Change Fourth Assessment Report for Global Warming Potential.
Key:
$CO_2e$ = carbon dioxide equivalent

## 4.1.7 GHG Life-Cycle Analysis

The Tacoma LNG Facility would produce LNG that would be used as a fuel for marine and on-road transportation applications, as well as for supplementing natural gas supply in the winter when demand is high (peak shaving). The life-cycle analysis examines the GHG emissions from the Proposed Action and compares these emissions to the alternative of not implementing the Proposed Action, which is the conventional use of distillate fuels in marine and trucking and applications involving pipeline natural gas for peak shaving.

In the life-cycle analyses, there are references to a "Scenario A" and "Scenario B." Scenario A is based on a facility LNG production rate of 250,000 gpd, and Scenario B is based on a production rate of 500,000 gpd. The FEIS stated the facility would produce 250,000-500,000 gpd. Both scenarios have been evaluated and included in these analyses to reflect the Proposed Action that PSE is currently seeking and the full capacity of the facility that was referenced in the FEIS.

Overall, Proposed Action emissions are quantified on a life-cycle basis for each use of LNG with overall life-cycle results weighted by the gallons of LNG consumed by each end use. For the Proposed Action, life-cycle emissions include not only the direct emissions associated with production of LNG, but also the following:

- Upstream life-cycle emissions associated with production and transport of fuels used at the LNG facility: natural gas feedstock, natural gas fuel, diesel fuel, and electricity;
    - Natural gas: emissions due to natural gas recovery**,** processing and transport to the facility;
    - Diesel: emissions due to crude oil recovery, transport to the refinery, refining, and finished product transport end use;

  - Electricity: emissions include recovery, processing, and transport of each fuel type to the electric power plants (generally a mix of coal, nuclear, natural gas, oil, hydro and other renewables); and
  - Upstream emissions are calculated on a life-cycle basis using the Greenhouse Gases, GREET model from Argonne National Laboratory.
- Direct emissions from LNG production include all fuel combustion emissions in addition to fugitive emissions at the plant. Estimates of direct emissions are based on inputs provided by the proponent and verified with a carbon balance such that the carbon in the natural gas feedstock is equal to the carbon in LNG produced plus emissions from LNG production.
- End use emissions from the Proposed Action are calculated based on the capacity to provide 250,000 or 500,000 gpd for 355 days in a year, and end use emissions from the No Action Alterative are estimated based on the amount of marine diesel, on-road diesel, and natural gas that would be replaced by the Proposed Action.

Emissions of nitrous oxide, methane, and $CO_2$ are quantified and reported on a $CO_2$ equivalent basis by applying global warming potential (GWP) factors from Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC 2007), which is the currently accepted international reporting standard and the method for State of Washington GHG reporting. Refer to Appendix B for detailed explanations of methodology and assumptions.

# 4.2 Affected Environment

Increased GHG emissions are the primary cause of climate change, and therefore efforts to reduce GHG emissions are considered the best way to reduce the potential impacts of climate change. The State of Washington has also established goals to minimize climate change impacts and reduce GHG emissions.

Global climate change threatens ecosystems, water resources, coastal regions, crop and livestock production, and human health. The continuing increase in GHG concentrations in the earth's atmosphere will likely result in a continuing increase in global annual average temperature and climate change effects. Global, federal, and state initiatives to reduce GHG emissions have been implemented to reduce the severity of climate change impacts in the future (EPA 2016). Regardless, climate change impacts would occur under both the No Action Alternative and the Proposed Action.

The potential effects of climate change and GHG emissions are, by nature, global and cumulative impacts. While individual sources of GHG emissions are not large enough to have an appreciable effect on climate change, the global accumulation of GHG emissions is resulting in global and local impacts on the climate.

As discussed above, EPA and Washington State have a number of programs designed to collect and analyze GHG emissions to better understand the sources of GHGs in the state. These programs, in addition to state permitting reporting requirements, help the state design policies to reduce GHG emissions and track its progress towards meeting the state's statutory GHG reduction limits.

GHGs are ranked by their GWP. GWP is based on the ability of a GHG to absorb solar radiation, as well as its residence time in the atmosphere, compared to $CO_2$. Applying GWP factors from the Intergovernmental Panel on Climate Change AR4, $CO_2$ has a GWP of 1, methane has a GWP of 25, and $N_2O$ has a GWP of 298. The IPCC has revised the GWP factors for the 100-year time horizon in the IPCC Fifth Assessment Report. The change in GWP factors are examined in a sensitivity analysis (refer to Appendix B). Emissions of GHGs are typically estimated as $CO_2e$. Estimates of individual GHGs are converted to $CO_2e$ by multiplying each pollutant by its GWP relative to $CO_2$.

### 4.2.1 Existing Sources of GHG Emissions in the Proposed Action Area

The Port of Tacoma is a major center for container cargo, bulk, breakbulk, autos, and heavy-lift cargo. Existing sources of GHG emissions in the area associated with the transportation of cargo are on-road and non-road sources. On-road emissions include emissions from vehicles, such as cars and trucks, with nearby Interstate 5 being a significant contributor. Non-road sources of emissions include emissions from sources such as marine vessels (including ocean freighters and harbor vessels such as tugs), cargo handling equipment, railroad locomotive operations, and heavy-duty, off-road vehicles. GHG emissions from these on-road and non-road sources include emissions from the combustion of fossil fuels and from fugitive releases.

Vessel emissions from sources within the vicinity of the Tacoma LNG Facility and TOTE Marine Vessel LNG Fueling System include the existing TOTE Terminal and the Washington United Terminal. Also in the vicinity of the Proposed Action are a refinery, U.S. Oil & Refining Company; a Kraft pulp mill, formerly known as Simpson Tacoma Kraft Company, LLC, but now operated by WestRock Company; and other industrial facilities that generate GHG emissions from the combustion of fossil fuels, most commonly in boilers and heaters.

The Tacoma LNG Facility site itself covers approximately 34.7 acres consisting of four separate parcels. The parcels currently contain a gravel pad and an empty naval building that is sometimes used for freight container storage. Current emissions from the site result from mobile sources used to move the freight containers; these emissions are relatively minor and sporadic in nature.

## 4.3 Potential Impacts of the Proposed Action

For a detailed description of the Proposed Action, refer to Chapter 2 (Description of the Proposed Action) and the 2015 FEIS. The overall stated purpose of the Proposed Action is, in part, to construct and operate a facility with the capability to supply fuel for marine, on-road transportation, and peak shaving that is an alternative to traditional fuels used by these industries. The scope of this SEIS is to provide GHG emissions life-cycle analyses of the alternatives developed in the FEIS. The life-cycle analysis for the Proposed Action evaluates the upstream, direct, and end use GHG emissions, and the change in these emissions compared to the No Action Alternative.

When evaluating direct, upstream, and end use GHG emissions, replacing a diesel propulsion engine with a pure LNG propulsion engine results in reduced life-cycle GHG emissions. The use of LNG produced by the Proposed Action, instead of other fuels for marine vessels, trucks, and peak shaving, is expected to result in an overall decrease in GHG emissions . As demonstrated by the range of potential impacts from the Proposed Action and No Action alternatives based on an LNG capacity of 250,000 to 500,000 gpd, the greater the replacement of other fuels with LNG, the greater the overall reductions in GHG emissions.

### 4.3.1 Construction Impacts

Construction of the Tacoma LNG Facility would generate air emissions temporarily from construction activities over a four-year period. Upstream electric power and direct (end use) construction emissions have been quantified for the 4 years of construction, while upstream life-cycle construction material emissions are estimated based on the volume of material used and the full life-cycle emissions of the products. Total emissions associated with construction are then averaged over the 40-year lifespan of the Tacoma LNG Facility.

**Table 4-2 GHG Emissions from the Tacoma LNG Facility Construction**

| | GHG Emissions | GHG Emissions | Total GHG Emissions (tonnes) |
|---|---|---|---|
| | tonnes/year (based on 40 year average) | % of total annual life-cycle analysis emissions | |
| **Total Construction** | **1,581** | **0.12%** | **63,232** |
| Direct (Equipment) | 182 | | 7,289 |
| Upstream Life-Cycle (Equipment) | 20 | | 812 |
| Upstream Life-Cycle (Power) | 57 | | 2,262 |
| Upstream Life-Cycle (Material) | 1,322 | | 52,869 |

Key:
GHG = greenhouse gas
LNG = liquefied natural gas
tonne = metric ton

## 4.3.2 Operations Impacts

As discussed above, life-cycle GHG emissions from the Proposed Action include not only the direct emissions associated with production of LNG, but also emissions associated with upstream and end use operations. Operational conditions, parameters, and assumptions to complete the life-cycle analyses were detailed in the 2018 Puget Sound Energy Background Information Document (PSE 2018). The life-cycle analyses provides a range of GHG emissions impacts, based on the potential LNG capacity of 250,000 to 500,000 gpd. Appendix B provides additional details on the operational assumptions used to estimate GHG emissions.

The life-cycle GHG emissions for the Tacoma LNG Facility and TOTE Marine Vessel LNG Fueling System are presented in Table 4-3.

**Table 4-3 Proposed Action Life-Cycle Analysis Annual Fuel Use Volume and GHG Emissions, Based on 250,000 gpd (Scenario A) to 500,000 gpd (Scenario B) Capacity**

| Life-Cycle Step | Fuel throughput MGal/year | | Fuel throughput GBtu/year | | GHG Emissions (tonnes/year) | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| Construction Emissions | | | | | | |
| **Total Construction** | | | | | **1,581** | **1,581** |
| Direct (Equipment) | | | | | 182 | **182** |
| Upstream Life-Cycle (Equipment) | | | | | 20 | **20** |
| Upstream Life-Cycle (Power) | | | | | 57 | **57** |
| Upstream Life-Cycle (Material) | | | | | 1,322 | **1,322** |
| Operational Emissions | | | | | | |
| **Upstream Life-Cycle** | | | | | **107,911** | **215,757** |
| Natural Gas | | | | | 82,010 | 164,117 |
| Power LNG Production | | | | | 25,739 | 51,477 |
| Diesel Emergency | | | | | 143 | 143 |
| Power LNG Vaporizer - Peak Shaving | | | | | 19 | 19 |
| Gig Harbor Diesel truck fuel | | | | | 0 | 1.2 |
| **Direct LNG Plant** | | | | | **54,522** | **113,281** |
| LNG Production | | | | | 48,855 | 97,813 |
| Vaporizer - Peak Shaving | | | | | 235 | 235 |
| Bunkering and Transfer LNG | | | | | 5,431 | 15,233 |
| **End Use LNG** | **89** | **177.50** | **6,848** | **13,695** | **519,501** | **1,035,497** |
| Peak Shaving | 1.96 | 1.96 | 151 | 151 | 8,879 | 8,879 |
| Gig Harbor LNG | 0 | 1.78 | 0 | 137 | 0 | 8,041.5 |
| On-road Trucking | 0 | 3.55 | 0 | 274 | 0 | 17,862 |
| TOTE Marine Vessels | 37.93 | 37.93 | 2,927 | 2,927 | 216,545 | 216,545 |
| TOTE Marine Diesel Pilot fuel | | | | | 6,954 | 6,954 |
| Truck-to-Ship Bunkering | 0 | 1.78 | 0 | 137 | 0 | 10,133 |
| Truck-to-Ship Bunkering Pilot Fuel | | | | | 0 | 325 |
| Other Marine Vessels LNG (by Bunker Barge) | 48.86 | 130.51 | 3,770 | 10.070 | 278,215 | 743,122 |
| Other Marine Diesel Pilot Fuel | | | | | 8,908 | 23,635 |
| **Total Emissions, Proposed Action** | | | | | **683,514** | **1,366,115** |

Key:
GBtu = Giga British thermal units
GHG = greenhouse gas
gpd = gallons per day
LNG = liquefied natural gas
MGal = million gallons
tonne = metric ton
TOTE = Totem Ocean Trailer Express

The Proposed Action would emit more than an estimated 10,000 metrics tons of $CO_2$e per year and thus would be subject to GHG reporting requirements, per WAC 173-441. An annual GHG report must be submitted to Ecology each year even if the source does not meet applicability requirements in WAC 173-441-030(1) or (2) in a future year.

### 4.3.3 Decommissioning Impacts

Decommissioning of the Tacoma LNG Facility and TOTE Marine Vessel LNG Fueling System at the end of its useful life would generate impacts similar to those discussed in Section 4.4.1 (Construction Impacts), except without the associated construction material GHG emissions. These emissions are assumed to be below the 1 percent cut-off criteria. The GHG emissions from decommissioning would be temporary and are not anticipated to have any long-term impacts.

## 4.4 Impacts of the No Action Alternative

Under the No Action Alternative, the Proposed Action would not be implemented. As discussed in Chapter 3 (Description of the No Action Alternative), MGO and diesel fuels would continue to provide the source of energy for the fuel use applications that would be displaced under the Proposed Action. LNG would not be produced or stored at the Tacoma LNG Facility site and would not replace MGO for fuel marine vessels or other customers in the Puget Sound area.

### 4.4.1 Construction Impacts

Under the No Action Alternative, additional emissions from construction would not likely occur. If any existing construction on site would have to be removed, there may be some small emissions associated with demolition.

The life-cycle analysis in the SEIS took into account the partial construction existing onsite. The choice of this baseline for the No Action Alternative was appropriate. Including the GHG emissions from all construction activities ensures that they are accounted for in the analysis for the whole life cycle. To consider the baseline for the No Action Alternative at a later point in construction would have excluded from the analysis the emissions that have already been released. The GHG emissions from construction are also very small in comparison to all of the emissions included in the life-cycle analysis. In Table 4-3 of the SEIS, the total life-cycle construction GHG emissions (1,581 tonnes per year) represent <0.2% (less than 0.2%) of the total GHG emissions included in the life-cycle analysis (in either scenario) and a small subset of those onsite construction emissions would be much less (less than 0.02%). Keeping these GHG emissions in the analysis actually reduced the overall GHG reduction identified in the conclusion.

### 4.4.2 Operations Impacts

Direct emissions under the No Action Alternative are negligible; life-cycle GHG emissions consist of upstream and end use activities only. To assess the potential changes from the Proposed Action's operation to supply LNG, it is assumed that the equivalent amount of MGO and diesel fuel would continue to be used. With a capacity to provide 500,000 LNG gallons per day (gpd), the Proposed Action would produce 177.5 million gallons of LNG annually, replacing 105 million gallons of MGO, 1.9 million gallons of diesel fuel, and natural gas in the equivalent of 1.78 million gallons of LNG.

The life-cycle analysis provides a range of GHG emissions impacts, based on the Proposed Action's potential LNG capacity of 250,000 to 500,000 gpd, referred to as "Scenario A" and "Scenario B," respectively, throughout. Appendix B provides additional detail on the operational assumptions used to estimate GHG emissions.

The life-cycle GHG emissions for the No Action Alternative are presented in Table 4-4.

**Table 4-4 No Action Alternative Life-Cycle Analysis Annual Fuel Use Volume and GHG Emissions, Based on Replacement by 250,000 gpd (Scenario A) to 500,000 gpd (Scenario B) LNG Capacity**

| Life-Cycle Step | Fuel throughput MGal/year | | Fuel throughput GBtu/year | | GHG Emissions (tonnes/year) | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| **Total Upstream Emissions** | | | | | **149,319** | **298,719** |
| No Peak Shaving – Natural Gas | | | | | 1,631 | 1,631 |
| Gig Harbor LNG | | | | | 0 | 2,300 |
| On-road trucking | | | | | 0 | 5,297 |
| TOTE Marine Diesel | | | | | 64,640 | 64,640 |
| Truck-to-Ship Bunkering | | | | | 0 | 3,025 |
| Other Marine Diesel (by Bunker Barge) | | | | | 83,049 | 221,826 |
| **Total End Use Diesel /MGO/LNG** | **54.8** | **110** | **7,038** | **14,035** | **553,572** | **1,097,761** |
| NG Peak Shaving | 1.18 | 1.18 | 151 | 151 | 8,973 | 8,973 |
| Gig Harbor LNG | 0 | 1.78 | 0 | 137 | 0 | 8,080 |
| On-road Trucking | 0 | 1.93 | 0 | 247 | 0 | 19,316 |
| TOTE Marine Diesel | 23.47 | 23.47 | 3,014 | 3,014 | 238,764 | 238,764 |
| Truck-to-Ship Bunkering | 0 | 1.10 | 0 | 141 | 0 | 11,173 |
| Other Marine Diesel (by Bunker Barge) | 30.15 | 80.53 | 3,873 | 10,345 | 305,835 | 811,455 |
| **Total Emissions (No Action Alternative)** | | | | | **702,891** | **1,396,480** |

Key:
GBtu = Giga British thermal units
GHG = greenhouse gas
LNG = liquefied natural gas
MGal = million gallons
MGO = marine gas oil
tonne = metric ton
TOTE = Totem Ocean Trailer Express

While marine vessels represent a smaller percentage of State wide GHG emissions, like other transportation related emissions, they have increased in since 1990. As demonstrated by the range of potential impacts from the Proposed Action and No Action alternatives based on an LNG capacity of 250,000 to 500,000 gpd, the greater the replacement of other fuels with LNG, the greater the overall reductions in GHG emissions.

## 4.5 Summary of Impacts

When evaluating direct, upstream and end use GHG emissions, the Proposed Action would result in a reduction of GHG emissions compared to the No Action Alternative, under both 250,000 gpd and 500,000 gpd capacity scenarios (see Figure 4.2). Generally, this is because replacing a diesel propulsion engine with a pure LNG propulsion engine results in reduced life-cycle GHG emissions. The use of LNG produced by the Proposed Action, instead of using other fuels for marine vessels and trucks is expected to result in an overall decrease in GHG emissions. As demonstrated by the range of potential impacts from the Proposed Action and No Action alternatives based on an LNG capacity of 250,000 to 500,000 gpd, the greater the replacement of other fuels with LNG, the greater the overall reductions in GHG emissions (see Figure 4.2). Table 4-5 provides a comparison of the potential range of emissions from the Proposed Action and the No Action Alternative and the change in emissions, with upstream emissions summarized by type of energy.

In the life-cycle analysis, various assumptions needed to be made in order to complete them. Those assumptions are documented in Appendix B. One key assumption is that the source of the gas that supplies the plant is identified by PSE as being exclusively sourced from British Columbia or Alberta, but entering Washington through British Columbia. The life-cycle analysis report indicates that GHG emission factors for natural gas production in the United States may be as much as five times higher than those for Canada. Additional recent research has indicated that the actual realized fugitive emissions from natural gas production in the United States appear to be 60 percent higher than published fugitive emission factors (Alvarez et al. 2018). The net effect of these higher emission rates, if realized as part of the Proposed Action, would be an increase in GHG emissions through the life-cycle analysis rather than the decreases shown in Table 4-5. Thus, the source of the natural gas is an important factor to this analysis and its conclusions.

Comments received on the Draft Supplemental Environmental Impact Statement (DSEIS) included some directed at the assumptions used for the source of natural gas and the associated fugitive leak rate assumptions for natural gas production. Comments were also received on other assumptions made in the GHG emission life-cycle analysis which could affect the calculations and results of the analysis. The DSEIS included a sensitivity analysis that illustrated some of the variable assumptions used in the analysis and how a change in each assumption could affect the final results. In the responses to comments (see Appendix C), additional variables were evaluated and the expanded sensitivity analysis is included in Appendix B (see Section 5 of Appendix B). The expanded sensitivity analysis was similar to the original information provided with the DSEIS. It included variable assumptions that would both increase and/or decrease the GHG emissions included in the life-cycle analysis. Each of these variables are independent of each other and could equally affect the final comparison (up or down). However, the changes each variable could produce are relatively small compared to the GHG emission totals included in the life-cycle analysis.

In response to comments received on the DSEIS, some revisions were made to the life-cycle analysis. The updated calculation values are found throughout the report and the supporting analysis. The results of those revisions to the life-cycle analysis, which can be seen in Appendix B of this FSEIS, changed some of the specific emission estimates shown in the DSEIS. The net effect for the comparison of the Proposed Action with the No Action Alternative was still an overall decrease of GHG emissions in the Final SEIS, as identified in the DSEIS. More information regarding the changes to the life-cycle analysis are also discussed in Appendix C.

**Table 4-5 Comparison of Proposed Action and the No Action Alternative Life-Cycle Analysis GHG Emissions**

| Life-Cycle Step | Proposed Action GHG Emissions (tonnes/year) | | No Action Alternative GHG Emissions (tonnes/year) | | Change GHG Emissions (tonnes/year) | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| Construction Emissions | **1,581** | **1,581** | **0** | **0** | **1,581** | **1,581** |
| Operational Emissions | | | | | **0** | **0** |
| **Upstream Life-Cycle** | **107,911** | **215,757** | **149,319** | **298,719** | **-41,408** | **-82,961** |
| Natural Gas | 82,010 | 164,117 | | | **82,010** | **164,117** |
| Electricity | 25,739 | 51,477 | | | **25,739** | **51,477** |
| Peak Shaving | 143 | 143 | 1,631 | 3,931 | **-1,488** | **-3,788** |
| Trucking | 19 | 19 | 0 | 8,322 | **19** | **-8,303** |
| TOTE Marine Vessels | 0 | 1 | 64,640 | 64,640 | **-64,640** | **-64,639** |
| Other Marine Vessels | | | 83,049 | 221,826 | **-83,049** | **-221,826** |
| **Direct LNG Plant** | **54,522** | **113,281** | **0** | **0** | **54,522** | **113,281** |
| LNG Production | 48,855 | 97,813 | 0 | 0 | **48,855** | **97,813** |
| Vaporizer - Peak Shaving | 235 | 235 | 0 | 0 | **235** | **235** |
| Marine vessel bunkering methane | 5,431 | 15,233 | | | **5,431** | **15,233** |
| **End Use** | **519,501** | **1,035,497** | **553,572** | **1,097,761** | **-34,071** | **-62,265** |
| Peak Shaving | 8,879 | 8,879 | 8,973 | 8,973 | **-94** | **-94** |
| Gig Harbor LNG | 0 | 8,041 | 0 | 8,080 | **0** | **-39** |
| On-road Trucking | 0 | 17,862 | 0 | 19,316 | **0** | **-1,454** |
| TOTE Marine | 216,545 | 216,545 | 238,764 | 238,764 | **-22,219** | **-22,219** |
| TOTE Marine Diesel Pilot fuel | 6,954 | 6,954 | | | **6,954** | **6,954** |
| Truck-to-Ship Bunkering | 0 | 10,133 | 0 | 11,173 | **0** | **-1,040** |
| Truck-to-Ship Bunkering Pilot Fuel | 0 | 325 | | | **0** | **325** |
| Other Marine LNG (by Bunker Barge) | 278,215 | 743,122 | 305,835 | 811,455 | **-27,620** | **-68,333** |
| Other Marine Diesel Pilot Fuel | 8,908 | 23,635 | | | **8,908** | **23,635** |
| **Total Emissions** | **683,514** | **1,366,115** | **702,891** | **1,396,480** | **-19,377** | **-30,365** |

Key:
GHG = greenhouse gas
LNG = liquefied natural gas
tonne = metric ton
TOTE = Totem Ocean Trailer Express

# 4.6 Cumulative Impacts

The potential effects of climate change and GHG emissions are, by nature, global and cumulative impacts. While individual sources of GHG emissions are not large enough to have an appreciable effect on climate change, the global accumulation of GHG emissions is resulting in global and local impacts on the climate.

In Section 3.13 (Cumulative Impacts) of the FEIS, GHGs were referenced twice. The GHG emissions for the LNG facility were identified at 20,751 metric tons $CO_2$e per year in Table 3.13-1 and the socioeconomic discussion on page 3.13-18 stated that "*the substitution of diesel and marine fuels with cleaner-burning LNG could reduce annual greenhouse emissions (including carbon dioxide, nitrogen oxide, sulfur oxide, and particulate emissions), which annually generates approximately $5.7 million in social benefits.*" The SEIS' analysis has shown that the direct onsite GHG emissions for the LNG plant are now estimated to be between 54,522 and 107,922 metric tons $CO_2$e per year. However, the analysis predicts a net GHG reduction would occur with the Proposed Action, contingent upon the source of the natural gas. The SEIS did not reevaluate other projects in the area, but given the net GHG reduction, contingent on the source of the natural gas, the conclusion is that the first portion of the statement on page 3.13-18 appears to be reasonable. No analysis of the *approximately $5.7 million* in social benefits was included in the scope of the SEIS.

# 4.7 Avoidance, Minimization, and Mitigation

The approach to the analysis in the SEIS has been the life-cycle evaluation for GHGs for the Proposed Action in comparison with the No Action (no project) Alternative. This considered the two options on an equivalent basis. The GHG emissions for the Proposed Action are high enough to trigger some regulatory requirements, and they are high enough to have warranted a more thorough evaluation of the GHG emissions from the Proposed Action on a quantitative basis. The life-cycle analysis shows that the Proposed Action (compared to the No Action Alternative) would produce a net reduction in annual GHG emissions provided that the natural gas is sourced from British Columbia or Alberta. This is an important assumption, as discussed previously in this document, and as such, it is recommended that the source of the gas be a required condition for a NOC Order of Approval, if issued. Specifically, the NOC process should establish the requirement that the source of natural gas supply to the facility be solely from British Columbia or Alberta and that specific permit terms and conditions will specify how compliance with this requirement would be demonstrated on a continuous basis. If this recommendation for a conditional requirement is not adopted, the conclusion that the Proposed Action would produce a net reduction of GHG emissions on a life-cycle basis would no longer be valid.

# 4.8 Conclusion

When evaluating direct, upstream, and end use GHG emissions, replacing a diesel propulsion engine with a pure LNG propulsion engine results in reduced life-cycle GHG emissions. The use of LNG produced by the Proposed Action, instead of other fuels for marine vessels, trucks, and peak shaving is predicted to result in an overall decrease in GHG emissions. As demonstrated by the range of potential impacts from the Proposed Action and No Action alternatives based on an LNG capacity of 250,000 to 500,000 gpd, the greater the replacement of other fuels with LNG, the greater the overall reductions in GHG emissions. This conclusion is contingent on the sole source of the natural gas supplied to the facility being through British Columbia or Alberta (as delivered through the Sumas gate). As described above, that condition is a recommended requirement for a NOC Order of Approval, if issued, so this analysis and conclusion is consistent with the proponent's project description.

The GHG emission life-cycle analysis identified small GHG emission reductions when comparing the Proposed Action, as conditioned in the manner described in the previous paragraph, with the No Action Alternative. As discussed in the life-cycle analyses (Appendix B of this SEIS) and in the Summary of Impacts (Section 4.5), an evaluation of the model input variables to complete the analysis shows a range of effects that can either increase or decrease the difference in GHG emission in this comparison. These variables could individually affect the difference in GHG emission in the approximate range of a reduction of 45,000 to an increase of 55,000 tonnes of CO2e per year (using the Scenario B – 500,000 gallons per day of LNG production). These variable emission assumptions are small in comparison to the total life-cycle GHG emission estimate for Scenario B of 1,366,115 tonnes of CO2e per year. It is clear that the small emission reductions identified in the life-cycle analysis are possible in part because the majority of the LNG produced by the proposal would be for existing fuel usage displacement.

The SEIS analysis demonstrates that GHG emissions could be reduced through the completion of the Proposed Action as conditioned. This means that the Proposed Action would not cause a significant adverse impact from GHG emissions. In addition, if the different assumptions in the life-cycle analysis were to change the final comparative amounts of emissions (e.g., to go from a small decrease to a small increase in GHG emissions as described in the previous paragraph), the small increase in GHG emissions, between the Proposed Action in comparison to the No Action Alternative, would still not be considered a significant adverse impact because the increase would be small compared to the total GHG emission identified in the life-cycle analysis. Under this latter scenario, the Proposed Action would still need the condition that the sole source of the natural gas supplied to the facility be through British Columbia (as delivered through the Sumas gate).

**Figure 4-1 Change in GHG Emissions (tonnes/year) Proposed Action Compared to the No Action Alternative**

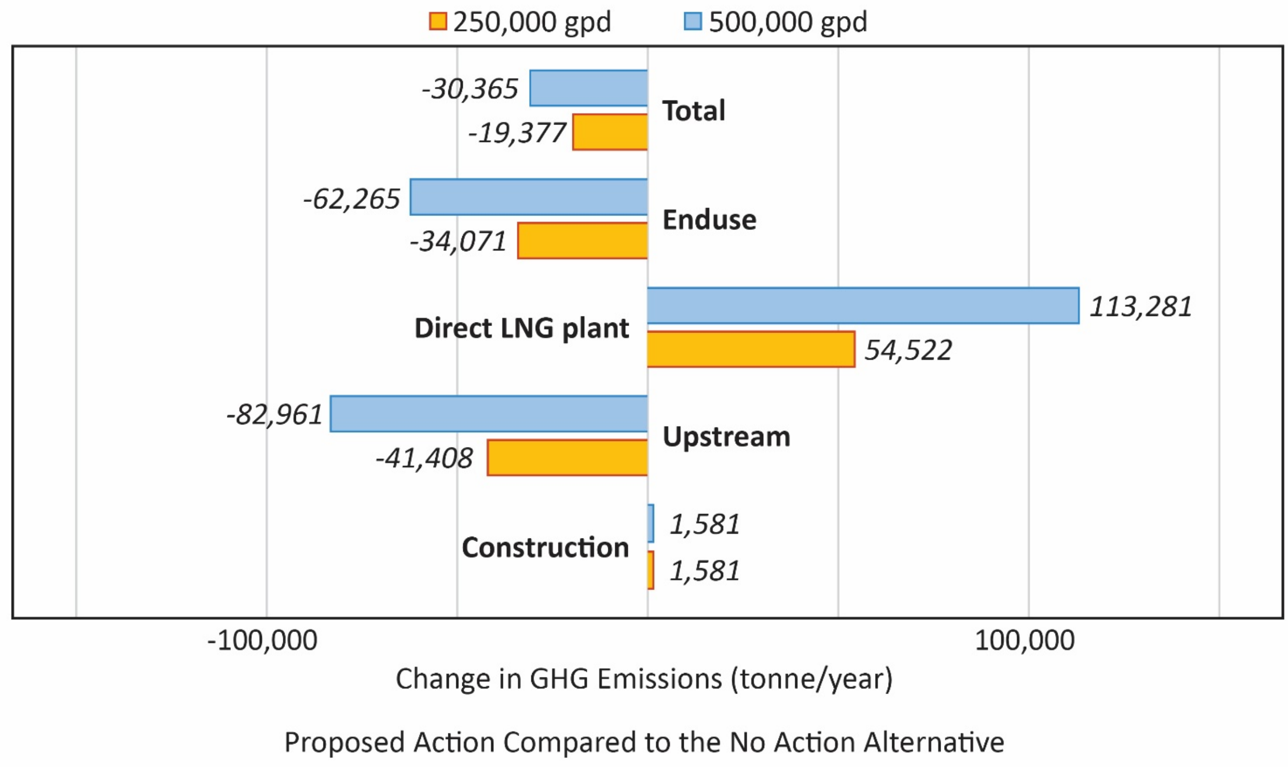
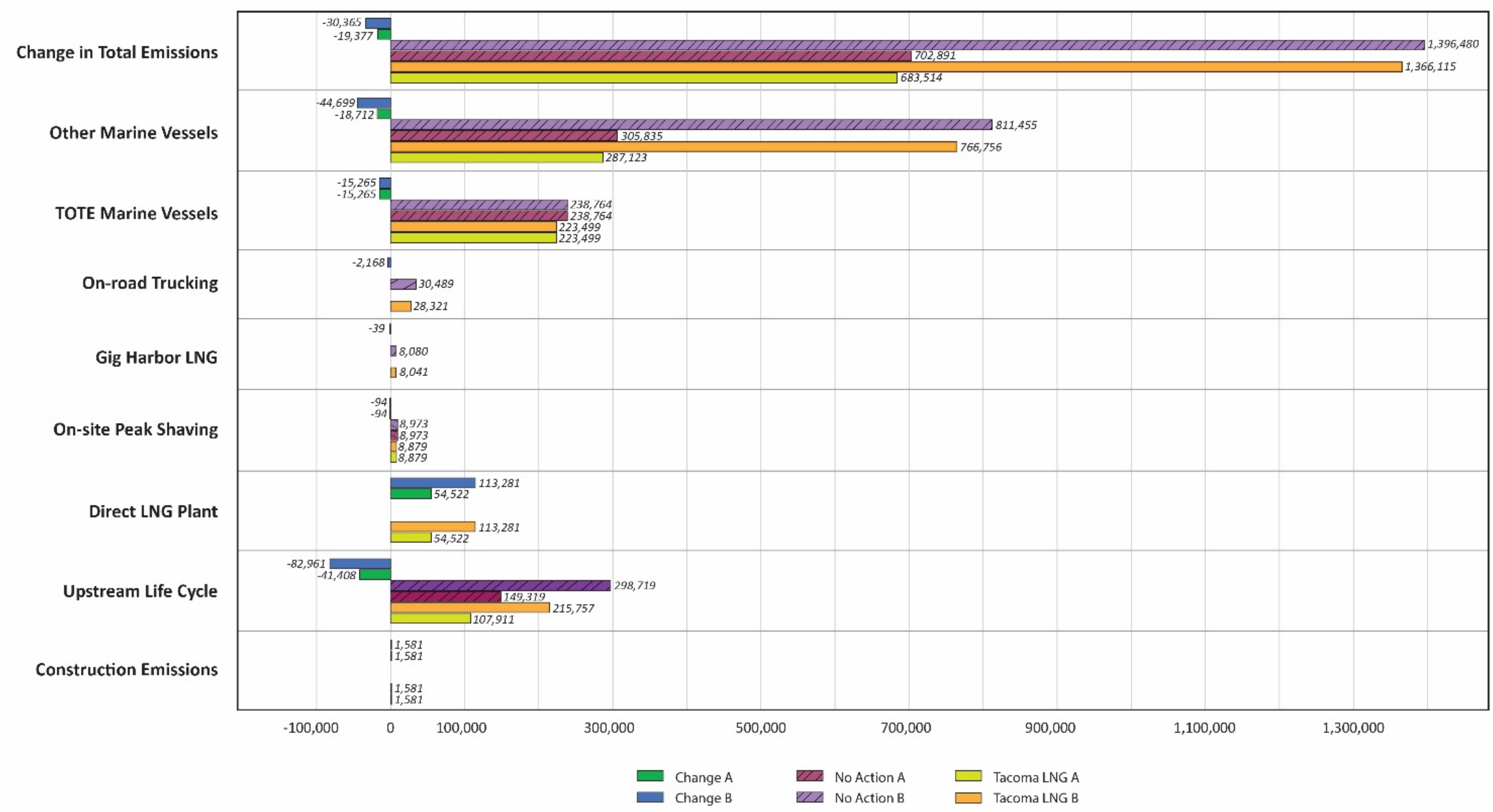


**Figure 4-2 GHG Emissions from Proposed Action vs. No Action Alternative, 250,000 gpd Capacity (Scenario A) and 500,000 gpd Capacity (Scenario B)**



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# APPENDIX A

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# APPENDIX B

PSE Tacoma LNG Project
GHG Analysis Final Report

# PSE Tacoma LNG Project GHG Analysis Final Report

LCA.8117.194.2019
15 February 2019

Prepared by:
Stefan Unnasch
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# DISCLAIMER



# ACKNOWLEDGEMENT

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# TERMS AND ABBREVIATIONS

| | |
|---|---|
| ALCA | Attributional Life Cycle Analysis |
| ANL | Argonne National Laboratory |
| ARB | California Air Resources Board |
| Btu | British thermal unit |
| CA | California |
| CA-GREET | The standard GREET model modified for use in CA LCFS |
| $CH_4$ | Methane |
| CI | Carbon intensity |
| CIG | Climate Impacts Group |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| $CO_2c$ | Fully oxidized $CO_2$ including CO and VOCs |
| $CO_{2e}$ | Carbon dioxide equivalent |
| DOE | U.S. Department of Energy |
| EIA | US Energy Information Agency |
| EMFAC | EPA's Emission Factors Model |
| EPA | U.S. Environmental Protection Agency |
| g $CO_2e$ | Grams of carbon dioxide equivalent |
| GBtu | Giga ($10^9$) Btu |
| GHG | Greenhouse Gas |
| GHGenius | LCA model based on UC Davis Life Cycle Emission Model (LEM) that was developed for Natural Resources Canada |
| GREET | The Greenhouse gas, Regulated Emissions, and Energy use in Transportation model |
| GWh | Gigawatt Hours |
| GWP | Global Warming Potential |
| HC | Hydrocarbon |
| HHV | Higher Heating Value |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Standards Organization |
| JRC | Joint Research Centre |
| LCA | Life Cycle Analysis or Life Cycle Assessment |
| LCI | Life Cycle Inventory |
| LCFS | Low Carbon Fuel Standard |
| LHV | Lower Heating Value |
| mmBtu | Million Btu |
| MDO | Marine Diesel Oil |
| MGO | Marine Gas Oil |
| MW | Megawatt |
| $N_2O$ | Nitrous oxide |
| NETL | National Energy Technology Laboratory |
| NG | Natural Gas |

| | |
|---|---|
| NOx | Oxides of nitrogen |
| RFS2 | Revised Federal Renewable Fuels Standard |
| RPS | Renewable Portfolio Standard |
| SEIS | Supplemental Environmental Impact Statement |
| SEPA | (Washington) State Environmental Policy Act |
| TOTE | Totem Ocean Trailer Express, Inc. |
| UN | United Nations |
| UNFCC | United Nations Framework Convention on Climate Change |
| VOC | Volatile Organic Compound |
| WTT | Well-To-Tank |
| WTW | Well-To-Wake |

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# Executive Summary

The Tacoma LNG project will produce liquefied natural gas (LNG) that will be used as a fuel for marine and on-road transportation applications as well as for supplying vaporized LNG to PSE residential and commercial customers during peak demand times (known as "peak shaving"). This study examines the greenhouse gas (GHG) emissions from the project and compares these emissions to the alternative of not completing the project, which is the conventional use of diesel and marine diesel fuels in marine and trucking applications and conventional natural gas for peak shaving.

Overall project emissions are quantified on a life cycle basis for each use of LNG with overall life cycle results weighted by the gallons of LNG consumed by each end use. For Tacoma LNG, life cycle emissions include not only the direct emissions associated with production of LNG, but also include emissions associated with recovery, refining and transport of each fuel used in production and emissions associated with end use (combustion in marine engines and heavy-duty trucks). Emissions of nitrous oxide ($N_2O$), methane ($CH_4$) and carbon dioxide are quantified and reported on a $CO_2$ equivalent basis by applying global warming potential (GWP) factors from IPCC's 4$^{th}$ annual assessment (AR4), which is the currently accepted international reporting standard and the method for State of Washington GHG reporting.

Life cycle GHG emissions are composed of upstream, direct, and end use emissions. Upstream emissions are the emissions associated with production and transport of fuel used at the LNG production plant: natural gas feedstock, natural gas fuel, diesel fuel, and electricity. For natural gas, upstream emissions include emissions due to natural gas recovery, processing and transport to the facility. For on-site diesel, upstream emissions are those associated with crude oil recovery, transport to the refinery, refining, and finished product transport to end use. For electricity, upstream emissions include recovery, processing and transport of each fuel type to the electricity generating plants (generally a mix of coal, nuclear, natural gas, oil, hydro and other renewables). Upstream emissions are calculated on a life cycle basis using the GREET model from Argonne National Laboratory and the GHGenius model. Both models are used for assessment of GHG emissions for low carbon fuel regulations in the U.S. and Canada.

Direct emissions from LNG production include all fuel combustion emissions as well as fugitive emissions at the plant. Estimates of direct energy inputs, emissions, and fugitive methane losses are based on engineering estimates and data provided by the project applicant. Emission estimates are further verified with a carbon balance such that the carbon in the natural gas feedstock is equal to the carbon in LNG produced plus emissions from LNG production. End use emissions are calculated for the amount of LNG required to displace marine diesel, on-road diesel, and peak shaving applications. The fugitive emissions of methane are taken into account in the analysis as well as the upstream life cycle emissions associated with power generation. Net GHG reductions occur over a range of scenario inputs.

To evaluate the potential change in overall emissions, the life cycle emissions from the Tacoma LNG project are compared with life cycle emissions from fuel that is displaced by the project, assuming operations at a peak capacity of 500,000 gallons of LNG per day for 355 days in the year. Upstream, direct, and end use emissions would occur from the equivalent displaced marine diesel for marine engines, diesel for on-road applications, and natural gas for peak shaving.

Table S.1 shows the potential effect of Tacoma LNG on GHG emissions for the case that the new liquefaction plant will be built compared to the “no project” (no action alternative) scenario. Two production scenarios for the Tacoma LNG project (500,000 gpd production capacity and 250,000 gpd production capacity) were evaluated for comparison with the No Action Alternative and each were estimated to produce GHG emission reductions. These reductions assume that the displacement of petroleum fuels results in their reduction in use and the displaced fuels are not being produced and burned by another user.

**Table S.1.** GHG Emissions from the Tacoma LNG Plant Compared to the “No-Project” Scenario

| Life Cycle Step | Mgal/ year | GBtu/ year | GHG Emissions tonne $CO_2$e/year |
|---|---|---|---|
| **Tacoma LNG** | | | |
| Construction [a] | | | **1,581** |
| Upstream Life Cycle | | | **215,757** |
| Direct LNG Plant | | | **113,281** |
| End Use LNG | **177.5** | **13,695** | **1,035,497** |
| Peak Shaving | 1.96 | 151 | 8,879 |
| Gig harbor LNG | 1.78 | 137 | 8,041 |
| On-road Trucking | 3.55 | 274 | 17,862 |
| TOTE Marine | 37.93 | 2927 | 216,545 |
| TOTE Marine Diesel Pilot Fuel[b] | 0.00 | 0 | 6,954 |
| Truck-to-Ship Bunkering | 1.78 | 137 | 10,133 |
| Truck-to-Ship Bunkering Pilot Fuel[b] | | | 325 |
| Other Marine LNG (by Bunker Barge) | 130.5 | 10070 | 743,122 |
| Other Marine Diesel Pilot Fuel[b] | | | 23,635 |
| Total | **177.5** | **13,695** | **1,366,115** |
| **NO ACTION** | | | |
| Upstream Life Cycle | | | **298,719** |
| Total End Use Diesel /Fuel Oil/LNG | **110** | **14,035** | **1,097,761** |
| Pipeline Natural Gas Peak Shaving[c] | 1.18 | 151 | 8,973 |
| Gig harbor LNG | 1.78 | 137 | 8,080 |
| On-road Trucking | 1.93 | 247 | 19,316 |
| TOTE Marine Diesel | 23.47 | 3,014 | 238,764 |
| Truck-to-Ship Bunkering | 1.10 | 141 | 11,173 |
| Other Marine Diesel (by Bunker Barge) | 80.53 | 10,345 | 811,455 |
| Total | **109.99** | **14,035** | **1,396,480** |
| **Net Emissions** | | -2.17% | **-30,365** |

[a] Construction emissions over 40 years

[b] MGO pilot fuel is 3% of fuel input for LNG operation [c]LNG equivalent gal in NAA

Tacoma LNG GHG Emissions

The GHG emissions from the Tacoma LNG project were examined on full life cycle basis. These include the upstream emissions associated with natural gas, diesel and electric power production, and the direct emissions from the conversion of natural gas to LNG. The end use activities, such as marine transportation, are identical for the Tacoma LNG project and the no action alternative.

Figure S-1 shows the energy inputs and estimated annual life cycle emissions from the proposed Tacoma LNG plant, compared to those from the no action alternative. The estimate of GHG emissions is consistent with steady state operation where energy inputs are closely linked to throughput.
The results for both the 500,000 and 250,000 gal per day scenarios are shown. The larger volume scenarios involved more LNG for marine vessels that is moved by barge to marine vessels. The peak shaving and Totem Ocean Trailer Express, Inc. (TOTE) vessel operation emissions are the same for both scenarios.

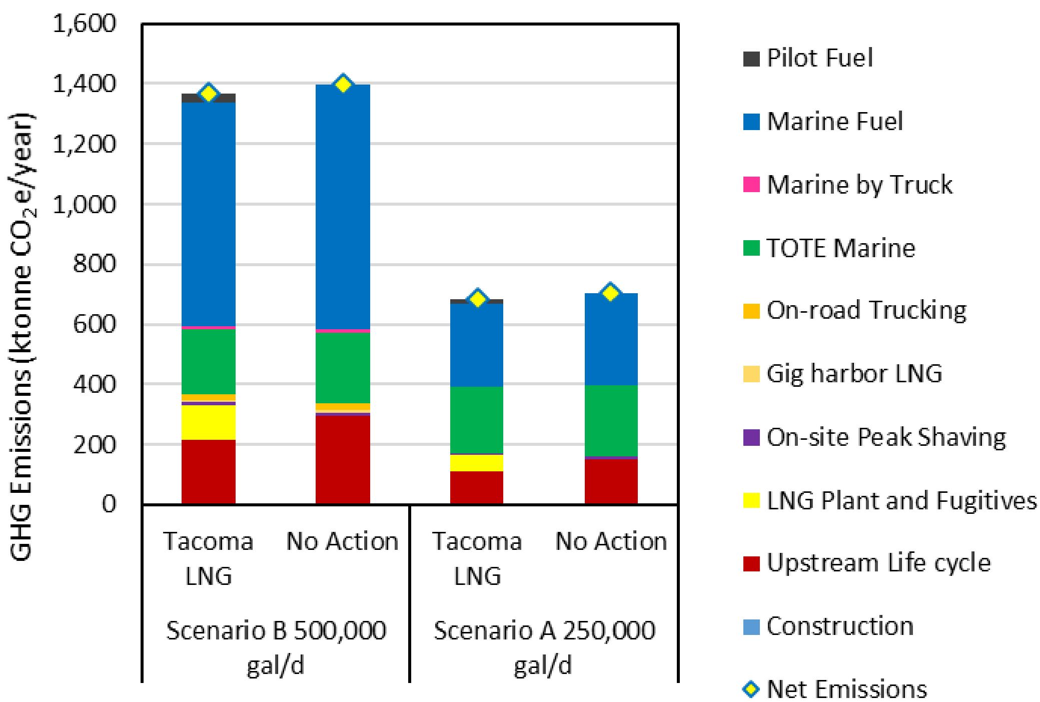


**Figure S.1.** Life Cycle GHG Emissions from Tacoma LNG Facility vs. Displaced Emissions (No Action Alternative)

The life cycle GHG emissions for Tacoma LNG are compared to GHG emissions that would be generated without the use of LNG. This analysis assumes that the LNG is used for the fuel applications identified by the applicant and that LNG displaces other fossil fuels in the no action alternative.[1] Specifically, the displaced petroleum fuels would not be used in other applications because they are available on the market. Tacoma LNG would displace Marine Gas Oil (MGO) for marine vessel fuel and diesel fuel for

[1] For example, LNG used for 1000 miles of marine transport would displace marine diesel that accomplishes the same 1000 miles of transport.

on-road trucking as well as another source of more remote LNG. Marine gas oil is similar to previously available nonroad diesel with a 1000 ppm sulfur content.

Figure S.2 shows the comparison of GHG emissions from Tacoma LNG to the GHG emissions from the no action alternative. The expected use of LNG is primarily for MGO with also some LNG displacing diesel fuel for trucking and for use by residential and commercial customers during peak demand periods.

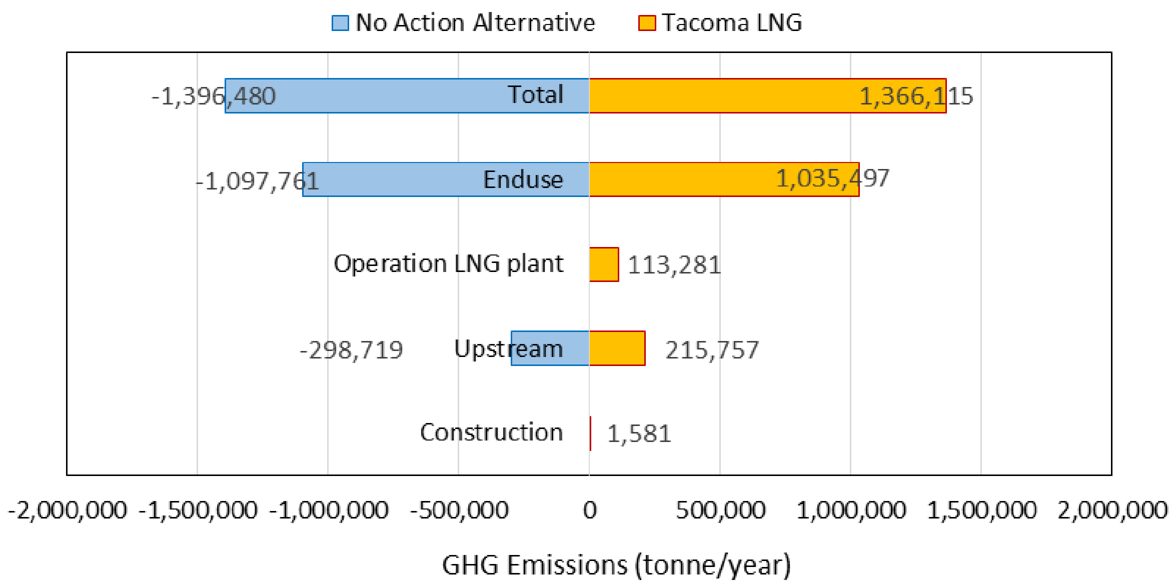


**Figure S.2.** Comparison of Life Cycle GHG Emissions for 500,000 gal/day LNG Use

Key Findings

This study examines the GHG emissions from Tacoma LNG on a life cycle basis. The scope of the analysis includes feedstock extraction through the delivery to an LNG liquefaction plant and its end use as marine vessel fuel, on-road trucking fuel and as natural gas for peak shaving.

Overall, life cycle GHG emissions for the Tacoma LNG project are lower than those from the no action alternative. The key factors that differ between the proposed project and the no action alternative include:

- Lower upstream life cycle emissions from natural gas and power compared to oil production and refining
- Lower carbon content per Btu of LNG compared to diesel and MGO
- Higher $CH_4$ emissions from LNG engines compared to diesel engines
- $CH_4$ emissions from fuel transfer operations
- Flaring of non methane hydrocarbons from natural gas in the LNG facility
- The increased capacity of LNG supply and its end use by other marine vessels in addition to the TOTE vessels offsets the increase in direct emissions from the proposed LNG Facility
- Avoided emission controls or sulfur removal from marine diesel applications

# 1. INTRODUCTION

## 1.1 Analysis Contents

This analysis examines the effect of Tacoma LNG on global greenhouse gas (GHG) emissions. The analysis includes the following sections.

1. Introduction
2. Methods and Data
3. Tacoma LNG Emissions
4. Displaced Emissions
5. Life Cycle Assessment

Appendices

Section 1 provides an introduction to the Tacoma LNG, GHG emissions, and LCA. The methods and data used in the analysis are described in Section 2, which includes a description of upstream fuel cycle inputs as well as the energy inputs and yields for LNG production and other data. Section 3 combines the data in Section 2 applied with inputs for Tacoma LNG to determine construction, operation, and end use emissions. Section 4 compares the energy displacement from Tacoma LNG and calculates the emissions from the no action alternative. Section 5 compares the emissions from Tacoma LNG to the no action alternative to determine net life cycle GHG emissions. The effect of different input parameters is also analyzed.

## 1.2 Proposed Project

The Tacoma LNG project will produce liquefied natural gas (LNG) that will be used as a fuel for marine and on-road transportation applications as well as for supplementing natural gas supply in the winter when demand is high (peak shaving). This study will examine the GHG emissions from the project and compare these emissions to the alternative of not completing the project, which is the conventional use of distillate fuels in marine and trucking and purchased natural gas to supply unmet commercial and residential customer needs  without LNG support.

**Figure 1.1.** Tacoma LNG Facility

The Facility will be located in the industrial Port of Tacoma with access to Puget Sound (see Figure 1-1). The general location of the site is north of East 11th Street, east of Alexander Avenue, south of Commencement Bay, and on the west shoreline of the Hylebos Waterway (see Figure 1-2). The Tacoma LNG Facility site is in an area zoned as Port Maritime Industrial. It is primarily developed for industrial maritime use and has been in industrial use for at least 75 years.


**Figure 1-2.** Existing Conditions and Location of Proposed Tacoma LNG Project Facilities

The boundaries for these parcels include both in-water and upland areas, reflecting a total area of approximately 33 acres. The upland portion of the site is approximately 30 acres, and the aquatic area is approximately 3 acres.

Overall project emissions are quantified on a life cycle basis for each use of LNG with overall life cycle results weighted by the gallons of LNG consumed by each end use. For Tacoma LNG, life cycle emissions include not only the direct emissions associated with production and vaporization of LNG, but also include emissions associated with recovery, refining and transport of each fuel used in production and emissions associated with end use (combustion in marine engines and heavy duty trucks). Life cycle GHG emissions are composed of upstream life cycle, direct, and end use emissions. Upstream life cycle[2] or well to tank (WTT) emissions are the emissions associated with production and transport of fuel used at the LNG production plant: natural gas feedstock, natural gas fuel, diesel fuel, and electricity. For natural gas, upstream life cycle includes emissions due to natural gas recovery, processing and transport to the facility. For on-site diesel, upstream life cycle emissions are those associated with crude oil recovery, transport to the refinery, refining, and finished product transported to end use Tacoma LNG. For electricity, upstream life cycle emissions include recovery, processing and transport of each fuel type to the electricity generating plants and the operation of the plants (generally a mix of coal, nuclear, natural gas, oil, hydro and other renewables). Upstream life cycle emissions are calculated on a life cycle basis using the GREET model from Argonne National Laboratory and the GHGenius model.

[2] Upstream life cycle emissions are referred to as well to tank emissions the GREET modeling framework. The end use of fuels are referred to as tank to wheel or well to wake emissions.

Direct emissions from LNG production include all fuel combustion emissions as well as fugitive emissions at the plant. Estimates of direct emissions are based on inputs provided by the project applicant and verified with a carbon balance such that the carbon in the natural gas feedstock is equal to the carbon in LNG produced plus emissions from LNG production.

End use emissions are calculated for the amount of LNG required to displace marine diesel, on-road diesel, and other LNG use applications.

Finally, the emissions from the Tacoma LNG project emissions are compared with life cycle emissions from the no action alternative which consists of fuel that is displaced by the project (diesel for marine engines, diesel for on-road applications, and natural gas that is made available absent LNG use for peak shaving). The analysis is based on a 1:1 displacement of the end use for the no action alternative. No market induced displacement effects are calculated because these effects are small.[3]

Emissions of nitrous oxide ($N_2O$), methane ($CH_4$) and carbon dioxide ($CO_2$) are quantified and reported on a $CO_2$ equivalent basis by applying global warming potential (GWP) factors from IPCC AR4, which is the currently accepted international reporting standard and the method for State of Washington GHG reporting.

## 1.3 No Action Alternative

Absent the Tacoma LNG project, petroleum fuels will continue to be used to produce marine gas oil (MGO) and on-road diesel. The applicant estimates that peak shaving will occur for up to 10 years absent the Tacoma LNG project. Tacoma LNG would provide re-vaporized natural gas to PSE residential and commercial natural gas customers. Another use of LNG from Tacoma LNG would be to supply the Gig Harbor LNG facility. Tacoma LNG would displace LNG trucked in from Canada and the primary difference is in transporting the LNG. The next application is using LNG to displace marine gas oil in Totem Ocean Trailer Express, Inc. (TOTE) marine vessels which involves using a small amount of pilot diesel fuel with LNG. In the no action alternative, the vessels would continue to be fueled with marine gas oil. Another marine application involves trucking LNG for bunkering. Since the delivery route for the displaced diesel is unknown, this application is comparable to other marine fuel use, except for transfer losses to fuel delivery truck. In the no action alternative the ships would continue to use petroleum-based fuel, delivered by truck or ship. Finally most of the LNG will be used in other unspecified marine

[3] Displacing MGO will have a small effect on MGO consumption. The classical consequential LCA approach is to assume that more MGO is available on the market and that the price of MGO drops in response to increased supply. The drop in price results in an increase in consumption elsewhere due to price induced demand. The effect the Tacoma LNG project on Washington MGO prices will be extremely small since it represents a very small fraction of the total fuel market. Ultimately, this assumption implies that crude oil to make MGO is not produced and that no additional demand for marine diesel fuel or other oil refinery products is induced elsewhere in the world.

applications which are essentially similar to the TOTE marine application. In the no action alternative marine diesel or other marine fuels would continue to be used in these applications.

## 1.4 Effect of Tacoma LNG Project

The Tacoma LNG project will affect several energy use applications including marine diesel, on-road trucking, and natural gas peak shaving. Currently, MGO and on-road diesel fuel are produced in Washington oil refineries. Natural gas from underground storage caverns and natural gas repurposed from another use are used for peak shaving. Puget Sound Energy (PSE) forecasts that additional natural gas storage will be required to meet future wintertime peak demand; (PSE, 2018); stored LNG can be re-gasified and introduced to the pipeline to meet peak demand. The Tacoma LNG project would displace a significant portion of the fuels currently used for marine diesel and on-road diesel applications and increase natural gas for peak shaving capacity.

## 1.5 Greenhouse Gases and Climate Change

### 1.5.1 The Greenhouse Effect

The greenhouse effect is a natural process that results in warmer temperatures on the surface of the earth than that which would occur without it. The effect is due to concentrations of certain gases in the atmosphere that increase trapped heat as infrared radiation from the sun instead of reradiated back to outer space. The greenhouse effect is essential to the survival of most life on earth, by keeping some of the sun’s warmth from reflecting back into space and sustaining temperatures that make the Earth livable. Man-made or anthropogenic GHG emissions are responsible for the majority of the increase in $CO_2$ and other GHGs in the atmosphere (IPCC, 2007; Myhre et al., 2013). The effect on global temperatures, climate, and weather is therefore a source of significant concern.

### 1.5.2 Greenhouse Gases

The gases emitted globally that contribute to the greenhouse effect are known as greenhouse gases (or GHGs). Primary GHGs include water vapor, carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), and other trace gases. Natural sources of GHGs include biological and geological sources such as plant and animal respiration, forest fires and volcanoes. However, industrial sources of GHGs are of concern because they also generate GHGs, adding to the natural concentrations. The GHGs of primary importance emitted by industrial sources are $CO_2$, $CH_4$, and $N_2O$. Because $CO_2$ is the most abundant of these gases, GHGs are usually quantified in terms of $CO_2$ equivalent ($CO_2e$), based on the relative longevity of the gas in the atmosphere and its related global warming potential (GWP).

#### *Global Warming Potential*

The analysis determines the GHG emissions from fuel combustion and fugitive emissions including $CO_2$, $CH_4$, and $N_2O$. These emissions also include fugitive LNG from facility operations and product transfer.

Greenhouse gases (GHGs) warm the Earth by absorbing energy and slowing the rate at which the energy escapes to space; they act like a blanket insulating the Earth. Different GHGs can have different effects on the Earth's warming. Two key ways in which these gases differ from each other are their ability to absorb energy (their "radiative efficiency"), and how long they stay in the atmosphere (also known as their "lifetime")(US EPA, 2018).

The Global Warming Potential (GWP) allows for the weighted summation of greenhouse gases. Specifically, it is a measure of how much energy the emissions of 1 tonne of a gas will absorb over a given period of time, relative to the emissions of 1 tonne of carbon dioxide ($CO_2$). The larger the GWP, the more that a given gas warms the Earth compared to $CO_2$ over that time period. The 100 year time horizon for GWPs are the basis for weighting GHG emissions.

The GWP was introduced in the IPCC First Assessment Report, where it was also used to illustrate the difficulties in comparing components with differing physical properties using a single metric. The 100-year GWP (GWP100) was adopted by the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol and is now used widely as the default metric. Global Warming Potential (GWP) values have been updated in successive IPCC reports; the AR5 GWP100 values are different from those adopted for the Kyoto Protocol's First Commitment Period. The following table shows how the global warming potential of $CH_4$ has been increased by 17% and that of $N_2O$ has decreased by 11% from the $4^{th}$ to the $5^{th}$ Assessment Report (IPCC, 2007; Myhre et al., 2013).

**Table 1.1.** Global Warming Potential of GHG Pollutants

| IPCC Assessment | AR5 | AR4 |
|---|---|---|
| Time Horizon | 100 | 100 |
| $CO_2$ | 1 | 1 |
| $CH_4$ | 30 | 25 |
| $N_2O$ | 265 | 298 |

GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory), and allows policymakers to compare emissions reduction opportunities across sectors and gases. Factors that affect GWP are discussed in Appendix A.4. The IPCC has revised the GWP factors for the 100-year time horizon in the AR5. There GWP factors are examined in a sensitivity analysis. The IPCC and GREET model also examine the effect of black carbon and organic carbon on warming potential. However, these pollutants are not part of the State of Washington or national GHG inventory method and are not examined in this study.

The 100-year GWP provides an assessment of GHG emissions over a meaningful time horizon. The 20-year GWP effectively cuts off the warming effect of $CO_2$ and $N_2O$ after 20 years while capturing the entire warming effect of $CH_4$, which has a lifetime of about 20 years of less. Thus the 20-year GWP is not well suited for assessing the impacts of emissions where the lifetime of one pollutant, $CH_4$, effectively corresponds to the time horizon of the analysis. The project will have a duration of about 40 years and the consequences of the emissions will remain in the atmosphere for the lifetime of the long-lived $CO_2$ emissions. The 100-year GWP is also consistent with the policy targets of the Paris Climate Agreement (United Nations/Framework Convention on Climate Change, 2015) which sets targets with the objective to "reduce aggregate greenhouse gas emission levels in 2025 and 2030" such that temperature increases of 2˚C or greater are avoided.

GHG emissions are weighted based on the 100-year GWP from the United Nations Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC, 2007), which is consistent with the State Environmental Policy Act (SEPA) guidelines and Washington GHG inventory protocols as well as other GHG policy initiatives (WA department of Commerce, 2018). The 100-year GWP is also consistent with the long-term goals of the Paris agreement. The effect of the GHG species is discussed in Appendix A.4.

### 1.5.3 Analysis Scope

The goal of the study is to provide the technical analysis in support of the Supplemental Environmental Impact Statement (SEIS) being prepared for the Puget Sound Clean Air Agency (PSCAA) under the Washington SEPA. The PSCAA determined that although the Final Environmental Impact Statement prepared for the Project addressed GHG, it did not fully account for all GHG emissions, appeared to have incomplete data, and relied on SEPA guidance from the Washington Department of Ecology (WDOE), which has since been withdrawn.

The scope of this analysis is limited to addressing the life-cycle analysis of natural gas used to produce LNG including the extraction and transport of natural gas, construction of the facility and end use of the LNG as a fuel and regasification for peak shaving (proposed action). The scope also includes comparing the GHG emissions from the project to the life-cycle of the extraction and transportation of crude oil, production of marine diesel fuel, and use as a fuel (no-action). For use as a marine fuel the scope for estimating GHG emissions is one complete LNG fueling of a TOTE roll-on/roll-off vessel in transit from the Port of Tacoma to Alaska. The analysis includes the life cycle upstream emissions, fuel delivery, and end use. Construction emissions are included over the project life.

## 1.6 Life Cycle Assessment Background

The following provides background on life cycle analysis (LCA) for fuel applications. Since the effect of GHG emissions occurs over a long duration, the life cycle and total global emissions are considered the relevant metric.

LCA is a technique used to model the environmental impacts associated with a product, from "cradle to grave," or through its useful life. The product assessed can be anything manmade, from breakfast cereals to sneakers to drop in renewable jet fuel. LCA models assess environmental impacts upon a range of categories, including energy consumption, GHG emissions, criteria air pollution, eutrophication, acidification, water use, land use, and others. This is done by taking a full inventory of all the inputs and outputs involved in a product's life cycle. Environmental impacts may be generated whenever a material flow enters or exits the product system and affects the environment.

Most LCA models used for transportation fuels are spreadsheet-based and use a life cycle inventory (LCI) database to calculate the environmental impacts associated with the material flows and inputs to a fuel value chain. Additionally, LCA has been used to support fuel regulatory and/or legislative initiatives for renewable fuel targets, such as targets for GHG emission reductions. The phases of an LCA are outlined below and in Figure 1.4.

a) The goal and scope definition phase: during this phase the study objective is defined, the system boundaries are determined, and modeling approaches are decided upon.

b) The inventory analysis phase: during this phase, inventory data regarding the life cycle inputs and outputs is collected and analyzed.

c) The impact assessment phase: during this phase, life cycle inventory data and impacts results are scrutinized for further accuracy and insight. This often involves sensitivity analysis and can lead to additional data collection and inventory modeling.

d) The interpretation phase: during this phase, results are interpreted, summarized, and discussed. (ISO, 2006)

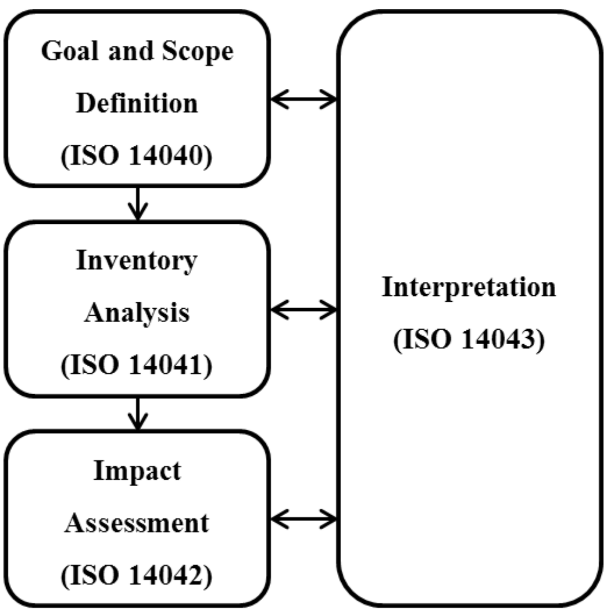


**Figure 1.3.** Process Framework for Life Cycle Assessment

Life cycle emissions are generally considered to cover the full life cycle from resource extraction to end use or the cradle to grave. Life cycle assessments are generally limited to construction and operation. However, the scope can also extend to facility decommissioning and indirect land use conversion (ILUC) effects. A preliminary calculation shows that life cycle decommissioning emissions will be less than 1 percent of the total emissions and therefore lower than the cutoff criteria defined for this analysis. Moreover, ILUC captures emissions associated with diverting crops from one use to another; because this project does not include land cover change from crops or significant vegetation, there are no ILUC emissions. An LCA includes the upstream life cycle emissions for inputs to a process. In most cases, these upstream life cycle emissions occur in the production of upstream inputs. For example, producing fuel used for electric power, an upstream component of LNG production, requires upstream WTT energy inputs.

Because finished fuels are used in recovery of feedstocks (e.g., diesel fuel is used to recover crude oil to produce diesel), determining life cycle emissions for all inputs requires an iterative analysis. Several LCA models perform these calculations for fuels and materials as shown in Table 1.2. All of the models include life cycle data for LNG production. Fuel LCA models provide upstream life cycle emissions for all of the energy inputs considered in this analysis, which consists of natural gas, electric power, diesel fuel, and marine fuel. The GREET and GHGenius models have the most regionally specific detail for the U.S. and Canada. These models also contain an upstream life cycle or WTT analysis for generic natural gas to LNG and are publicly available.

**Table 1.2.** Life Cycle Models and Databases

| Primary Author | Year | Organization | Location of Use | Scope of Products | Model/ Database | Citation |
|---|---|---|---|---|---|---|
| Wang | 2017<br>2013 | ANL | USA | Fuel Vehicles | GREET1<br>GREET2 | (ANL, 2017)<br>(ANL, 2018) |
| O'Conner | 2016 | (S&T)$^2$ | Canada | Fuels | GHGenius | ((S&T)2, 2013) |
| Delucchi | 1998 | UC Davis | USA | Fuels | LEM | (Delucchi, 2003) |
| JRC | 2011 | JRC | Europe | Fuels | JRC/ LBST Database | (JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, 2014) |
| Neeft | 2012 | Intelligent Energy Europe | Europe | Fuels | BioGrace | (JRC, 2012) |
| ThinkStep | 2016 | ThinkStep | Global | All Materials | GaBi TS | (Thinkstep, 2017) |
| Wernet | 2013 | Swiss Centre for Life Cycle Inventories. | Global | All Materials | EcoInvent | (Weidema et al., 2013) |
| NREL | 2005 | NREL | USA | All Materials | USLCI Database | (NREL, 2012) |
| Skone | 2014 | NETL | USA | Fuels | Studies of NG and Coal | (Skone, 2012) |

Several LCA models and databases also include LCI data on materials of construction for LNG facilities and marine vessels. The GaBi TS, EcoInvent, and USLCI databases contain life cycle analysis results for materials such as steel and concrete, which are used in facility construction. The GREET2 model also calculates life cycle emissions for materials of construction used in vehicles. The GREET and GHGenius models provide the basis for the analysis because these models are publicly available and include details for natural gas production, power generation, and petroleum production and refining that are readily modified. Generally, all of the LCA models described here produce the same life cycle GHG results with the same input assumptions.

The GREET and GHGenius models are publicly available and provide complete transparency to calculations. These models provide the basis for the upstream life cycle data in this analysis.

# 2. METHODS AND DATA

This analysis examines the GHG emissions from the Puget Sound Energy Liquefied Natural Gas (Tacoma LNG) facility on a life cycle basis. The life cycle emissions from the Tacoma LNG (including end use) are compared to displaced emissions (e.g., use of diesel fuel) on a life cycle basis. This section describes the system boundary for the analysis, approach for calculating life cycle emissions, scenarios considered in the analysis, and data sources. The discussion of the approach describes a summary of the activity in each step of the life cycle and calculation methods.

For Tacoma LNG, the life cycle analysis will calculate the energy inputs and emissions with each step of the Tacoma LNG process. Each energy input will include a direct and WTT fuel cycle component. The end use of emissions will then be calculated for the volume of fuel used in each LNG application. The life cycle emissions for the alterative use of LNG (No action alternative) are calculated. These emissions will include the direct emissions and upstream fuel cycle or WTT emission. The net difference between the Tacoma LNG project and alternative energy use are reported on an annual basis.

Emissions to be reviewed: for the LNG Project:

- Upstream:
  - Power generation for electricity used at the facility
  - Manufacturing of the materials used to construct the facility
  - Production, processing and transport of the natural gas used as a feedstock
  - Leaks of natural gas from the equipment used to transport, handle and process the natural gas
  - Upstream production, processing and transport of diesel fuel for emergency equipment
- Direct:
  - Combustion of natural gas and natural gas liquids at the facility in the revaporizer and flare
  - Leaks of natural gas and LNG from the equipment at the facility
  - Loading (bunkering) of LNG into TOTE vessels
  - Loading of LNG into trucks and barges
  - Truck transport of LNG
  - Vaporization of LNG for peak shaving
- End Use:
  - Use of LNG in TOTE Marine vessels
  - Use of LNG that is delivered by barge to other (non-TOTE[4]) marine vessels
  - Use of LNG that is delivered by truck to other marine vessels
  - Use of LNG in on-road trucks
  - Use of LNG for regasification and use by PSE residential and commercial natural gas users

[4] LNG would be transferred by bunkering barges.

- Use of LNG trucked to Gig Harbor to displace LNG from Canada

For the no-action alternative (existing use of traditional fuels in marine vessels and trucks and use of pipeline natural gas for peak shaving) the emissions to be reviewed include:

- Upstream Life Cycle (WTT):
  - Production of crude oil for Washington and out of state oil refineries
  - Production, processing and transport of diesel and marine fuel
  - Production, processing and transport of LNG for Gig Harbor
  - Power generation for electricity used to load and transfer diesel and marine fuel
- Direct:
  - Direct emissions for the functional equivalent of fuel storage are included in the upstream step
- End Use:
  - Use of marine diesel fuel in TOTE Marine vessels
  - Use of marine diesel fuel for other (non-TOTE) marine vessels
  - Use of diesel in on-road trucks
  - Use of pipeline natural gas by residential and commercial customers absent peak shaving
  - Trucking of LNG to Gig Harbor

The assumptions used to calculate GHG emissions for the Tacoma LNG project and the no action alternative activities include the following:

- Upstream Life cycle (WTT):
  - GREET model for power generation for electricity used at the facility
  - GHGenius and GREET data for the upstream production of natural gas.
  - CA ARB OPGEE model analysis of crude oil production
  - GREET model analysis of marine gas oil, diesel, and gasoline
  - GREET2 model for manufacturing of metals used to construct the facility
- Direct and end use:
  - Fugitive emissions from MGO and Diesel fuel storage are negligible.
  - GREET emission factors for combustion of petroleum fuels
  - Emission data from the applicant
  - Combustion emission factors for LNG and natural gas based on fuel properties from PSE
  - Loading LNG into barges, trucks and TOTE vessels
  - Transporting LNG by truck
  - Energy consumption data for LNG and alternative equipment
  - Leakage rate from the applicant and literature sources

## 2.1 System Boundary

Life cycle emissions include WTT (upstream), direct and end use emissions.

Life cycle GHG emissions are quantified for production of LNG and four different end uses:

a) In TOTE marine engines for cargo hauling between Tacoma and Anchorage;
b) Transfer to LNG bunkering barges which will fuel other marine engines;
c) Transfer to tanker trucks which will fuel heavy duty vehicles
d) Re-vaporize the LNG to the pipeline and use by PSE residential and commercial natural gas customers during peak shaving
e) Truck LNG to Gig Harbor to displace a Canadian source of LNG.

WTT or Upstream emissions that are part of the proposed action as well as the no action alternative include natural gas feedstock extraction, processing and transmission as well as emissions associated with production of imported grid power. Primarily No Action WTT emissions include crude oil recovery, refining, transport and combustion in a marine engine.

Direct emissions from LNG production include fuel combustion (emergency generator, process heater and flaring) and fugitive emissions.

GHG emissions associated with construction activities and materials of construction are also included in the analysis for Tacoma LNG.

### *Definition of Functional Unit*

The functional unit provides the reference to which all other data in a life cycle assessment are normalized and is use as a reference unit. To define the analyzed system, it is necessary to start with a quantified description of the performance requirements that the product system fulfils. This quantified description is called the “functional unit” of the product system.

The functional unit for this analysis is the LNG produced and used in operation in one year of continuous operation. The life cycle emissions from the Tacoma LNG and displaced emissions are analyzed over this functional unit. The emissions and displaced emissions are also reported per tonne of LNG produced over a 40-year facility life. Current natural gas liquefaction plants are planned with a 30-year technical life time. An analysis about the possibility of extending the life of LNG assets, carried by DNG GL, showed that many existing plants have been running for more than 40 years. Based on this information we defined a lifetime of 40 years for the Tacoma LNG project (Tronskar, 2016).

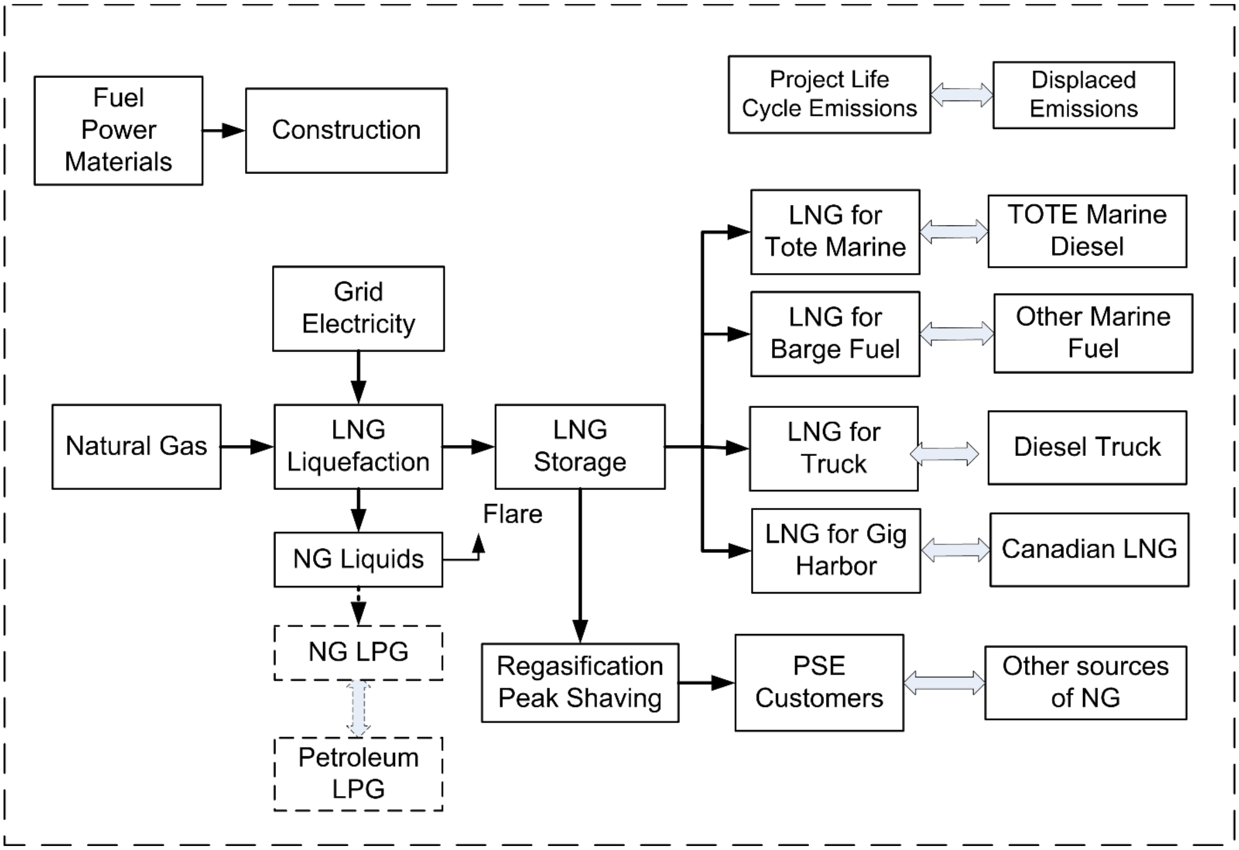


**Figure 2.1.** System Boundary Diagram for Tacoma LNG Life Cycle Analysis and No Action Alternative

Note: WTT emissions are defined in Figure 2.2 and Figure 2.3. Double arrows represent effect of alternative activity. Use of LPG is not planned but treated as an option.

### *Functional Unit*

The functional unit for the analysis is the annual LNG produced in one year of continuous operation. The life cycle emissions from the Tacoma LNG and displaced emissions are analyzed over this functional unit. The emissions are also reported per 1000 gallons of LNG produced.

### *Operational Basis*

The analysis is based on the continuous operation of the facility to allow for a comparison with alternative sources of energy. GHG emissions are calculated on the expected operational basis (for example 500,000 gallons of LNG production per day will be produced for 355 days per year). The life cycle GHG emissions from the Tacoma LNG project are compared with diesel production where the life cycle emissions data are also on a continuous operation basis. Similarly, LNG used for peak shaving is compared with conventional natural gas storage and pipeline natural gas repurposed from other uses.

The analysis of GHG emissions for the Tacoma LNG includes emissions associated with feedstock production and transportation, the production of power, the direct emissions from the Tacoma LNG and the end use as peak shaving[5], truck, or marine diesel fuel.

The analysis is performed on a lifecycle basis. Upstream emissions include natural gas feedstock extraction, processing and transmission as well as imported grid power. Direct emissions from the Tacoma LNG include combustion emissions from construction activities, boilers, power generation, and fugitive emissions[6] associated with construction materials, fuel production and marine diesel are also counted. The same scope of emissions is applied to the displaced fuel.

The system boundary for Tacoma LNG fuel is shown in Figure 2.1.The displacement of fuel or other displacement effects is determined through an economic analysis.

The analysis determines the GHG emissions from fuel combustion and fugitive emissions including $CO_2$, $CH_4$, and $N_2O$. Other GHG emission sources include unburned and fugitive methane and nitrous oxide ($N_2O$) from fuel combustion. Combustion sources include boilers, fired heaters, power generation equipment and engines for transport. Feedstock is also converted to $CO_2$ in the fuel production process and these process emissions are also counted. As discussed in Section 1.5.2, $CO_2$ emissions correspond to fully oxidized fuel. These emissions also include fugitive fuel from storage tanks and product transfers as well as carbon monoxide and VOC emissions from fuel combustion. Other GHG emissions such as fluorocarbons are not a significant source of emissions from Tacoma LNG.

***Cut Off Criteria***

This LCA tracks GHG emissions based on life cycle models. Emissions that are less than 1% of the life cycle GHG emissions from the Tacoma LNG plus upstream and downstream are under the threshold of significance and not examined as emission categories (for example plant decommissioning). The 1% criterion reflects the variability in GHG estimate from life cycle analysis studies. A more detailed assessment of the cut off emissions are included in Appendix D.2. A sensitivity study in Section 5 shows the variability of the net GHG emissions to input parameter and also provides insight into the uncertainty of the analysis.

## 2.2 Activities and Approach to GHG Analysis

The GHG analysis encompasses the emissions associated with construction and operation of the Tacoma LNG Project construction, compared to the no action alternative in which TOTE, other marine vessel, trucking, and peak shaving operations would continue to operate using MGO,

[5] The direct emission for vaporized LNG and very close to those of pipeline natural gas but the fuel properties change and are accounted for in this analysis. The upstream natural gas to produce LNG for peak shaving is higher than that for conventional natural gas since LNG production consumes natural gas. Note that alternative sources of natural gas could come from underground storage, and this storage energy is part of the average emissions of natural gas production.

[6] Upstream life cycle emissions correspond to scope 2 and scope 3 emissions (Greenhouse Gas Protocol, 2013; World Resources Institute, 2004)

Diesel Fuel and pipeline natural gas. The life cycle steps and map to the description of the activities for each step, emission factors, energy inputs, upstream emissions and life cycle results are shown in Table 2.1.

The activities in the life cycle and approach to GHG calculations is first discussed followed by a description of data and inputs for each step.

The GHG analysis encompasses the emissions associated with Tacoma LNG construction and operation and the alternative to not construct the project, which would be the life cycle effect of not producing LNG and using conventional sources of diesel fuel for marine and transportation applications and would also include conventional natural gas storage and repurposed pipeline natural gas for peak shaving. The life cycle analysis of Tacoma LNG follows the steps outlined in Table 2.1. For each step, the emissions include direct plus upstream (WTT) emissions and end use emissions. The table shows the life cycle steps, and the section of this report that contains the description of the activities for each step, emission factors, energy inputs, upstream WTT emissions, life cycle results.

**Table 2.1.** Life Cycle Steps

| Steps in Tacoma LNG LCA | Description |
|---|---|
| Construction | Construction equipment, materials of construction |
| Operational Emissions | |
| Tacoma LNG Upstream | Natural gas, electric power, diesel fuel production [a,b] |
| Tacoma LNG Direct | Boiler, flare, plant operation |
| Tacoma LNG End Use | LNG fueled marine and truck operation LNG vaporization for peak shaving (for residential and commercial gas use) |
| Displaced Emissions | |
| No Action Alternative Upstream | Crude oil production, natural gas production, marine diesel and diesel fuel refining, electric power |
| No Action Alternative Direct Emission[7] | Diesel filling operations Pipeline natural gas peak shaving |
| No Action Alternative End Use | Marine diesel and diesel fueled marine and truck operation. Stored and repurposed natural gas for residential and commercial use |

[a] GREET and GHGenius models include similar emission factors for direct combustion as described in Appendix C
[b] Small amounts of diesel for emergency equipment are used by the Tacoma LNG project which result in both direct and WTT emissions

[7] The Tacoma LNG project would displace current MGO operations, which are the no action or alternative case.

### 2.2.1 Life Cycle Analysis

Life cycle emissions generally consist of direct and upstream life cycle emissions. Depending on the application, the direct emissions are referred to as end use, tank to wheel, or tank to wake phase. The direct emissions are also part of the life cycle of fuels such that the total upstream life cycle emissions for a process consist of the sum of direct and upstream life cycle emissions for all of the inputs to a process. Argonne National Laboratory's GREET (Argonne National Laboratory, 2009) model has been extensively used for quantification of life cycle emissions associated with fuels and other products. This analysis uses the GREET framework to calculate upstream life cycle emissions from cradle to gate (ANL, 2017). Cradle to gate emissions are also referred to as well to tank or upstream life cycle. The term upstream life cycle is used in this Study. Fuel life cycle emissions are referred to as cradle to grave or well to wheels (or wake). The end use for no action alternative is the same as that for Tacoma LNG fuel.

***Upstream Life Cycle Data***

The upstream life cycle for an individual fuel such as natural gas includes direct and upstream life cycle emissions ($\mathbf{E}_u$). Upstream life cycle emissions include a variety of energy inputs and emissions including natural gas, petroleum fuels, and electric power. Emissions ($\mathbf{E}_i$) for each fuel used in the lifecycle are calculated from the specific energy ($S_k$), direct emission factor ($\mathbf{EF}_k$), and upstream emissions for the step such that:

$$\mathbf{E}_i = \sum \left[ S_k \times (\mathbf{EF}_k + \mathbf{E}_{uk}) \right] \qquad (1)$$

Where:
$\mathbf{E}_i$ = Life Cycle Emissions for Fuel i in life cycle
$\mathbf{EF}_k$ = Direct Emission Factor for fuel k, for each type of equipment and fuel[8])
$S_k$ = Specific Energy for each fuel k
$\mathbf{E}_{uk}$ = Upstream emissions for fuel k

This approach applies to upstream life cycle emissions as well as end use emissions and is used to generate the results in the GREET model.

Typically, GHG calculations are based on a specific energy basis.[9] For example, the term $S_i$ for natural gas use is represented in mmBtu/tonne of fuel in this Study. The emission factor (**EF**) depends upon the carbon content of fuel as well as $CH_4$ and $N_2O$ emissions for the type of equipment. For electric power and construction materials, the term EF is zero because they don't emit any GHGs once they used.  Upstream emissions are calculated using the same principles as all other upstream emissions in this analysis, for example upstream emissions from

[8] Upstream emissions for fuel i can include the use of fuel i, which requires handling the use of a fuel within its own fuel pathway.
[9] GREET inputs are typically in Btu/mmBtu. However, the calculations are the same for a functional unit of one tonne of fuel with the appropriate unit conversions. The nomenclature here assumes appropriate unit conversions.

production of diesel fuel. The terms **EF** and **E** represent a data array that includes $CO_2$, $CH_4$ and $N_2O$ emissions.

Upstream emissions ($\mathbf{E}_u$) depend on the energy inputs and emissions for each fuel or material and are calculated in the same manner as shown in Equation 1.

### *Application of Upstream Data to GHG Analysis*

GHG emissions in this Study are calculated using the GREET and GHGenius model with inputs described in Section 2.4. A detailed discussion of the calculations and upstream life cycle approach is described in Appendix A.

In the case of Tacoma LNG, the upstream life cycle emissions are calculated based on the details presented in this analysis. For the no action alternative, the upstream emissions are based on the specific energy for fuel use.

### *Construction Emissions*

Construction activities consist of development of the Tacoma LNG site, construction of the fuel plant, storage tanks at the site. Construction activities include operation of earth moving equipment, cranes, trucks, pile drivers, compressors, pumps, and other equipment. Employee commute traffic and material transport also generates GHG emissions[10] and are included.

### *Upstream Natural Gas Production, Separation and Transport Emissions*

Natural gas produced in British Columbia and Alberta (conveyed through British Columbia) will be the feedstock for the Tacoma LNG. The Energy Information Agency (EIA, 2018a) published the net flows of natural gas among U.S. states. Over 99% of the gas entering Washington comes from Canada as shown in Appendix B.1.3.

A range of GHG emission estimates correspond to natural gas production based on the energy inputs for production as well as fugitive methane releases. The analysis examines the range of GHG estimates in the GREET model and scientific literature. Calculations are based on the GREET inputs for extraction, processing and transport with a sensitivity analysis based on a range in fugitive methane emissions.

GHG emissions from natural gas production are associated with well operation, separation of light hydrocarbons, transport, and fugitive emissions. The GHGenius estimates for energy inputs for natural gas extraction, processing, and transmission provide the primary estimate of upstream life cycle energy inputs for natural gas. The model also includes estimates of fugitive $CO_2$ from gas processing as well as flared natural gas. The study calculations are based on the GHGenius inputs for extraction, processing and transport with a sensitivity analysis bases on a

[10] It is unclear if employee transportation creates a new source of GHG emissions since the employees would be driving to work with or without construction of the Tacoma LNG. These emissions are calculated nonetheless.

range in fugitive methane emissions including a comparison to the U.S. based emissions from the GREET model.

Natural gas is transported by pipeline at pressure of about 800 psi. Natural gas fuel compressor engines compress and move gas along the pipeline network. The GHGenius and GREET models calculate energy inputs for transport based on a transport distance in Btu/ton-mi. The models also calculate distribution emissions as part of compressed natural gas pathways. Since the natural gas for the Tacoma LNG project is supplied directly by a transmission pipeline, the emissions associated with transmission lines are attributed to Tacoma LNG emissions, but the local delivery or distribution portion are estimated as zero.

Natural gas is primarily composed of methane ($CH_4$), with small amounts of light hydrocarbons ($C_2$ to $C_4$) and inert gases ($N_2$ and $CO_2$). The composition of the gas affects its carbon factor discussed in Appendix C. Releases of $CO_2$ from the amine separation system will occur at the Tacoma LNG facility, which lowers the amount of carbon species available to be condensed into LNG, making the carbon factor for LNG lower than that of pipeline natural gas. The bulk of the light hydrocarbons are separated to avoid condensation during pipeline transportation.

The total upstream life cycle emissions are calculated in the GREET model. Figure 2.2 shows the system boundary diagram for natural gas in the GREET model. The model calculates upstream life cycle emissions from natural gas pathways including LNG as well as fuel for applications such as power plants and oil refineries. The pathway for natural gas consists of extraction, processing, and transmission. The key inputs are energy inputs and fugitive emissions for each step. Energy inputs are represented as Btu of fuel used to process each million Btu of natural gas in each step. These include the GREET model default assumptions on extraction efficiency, processing efficiency, mix of process fuels, and flared gas per mmBtu of produced gas. This study focuses on the range of fugitive methane emissions from these activities. Other data from natural gas production are also examined.

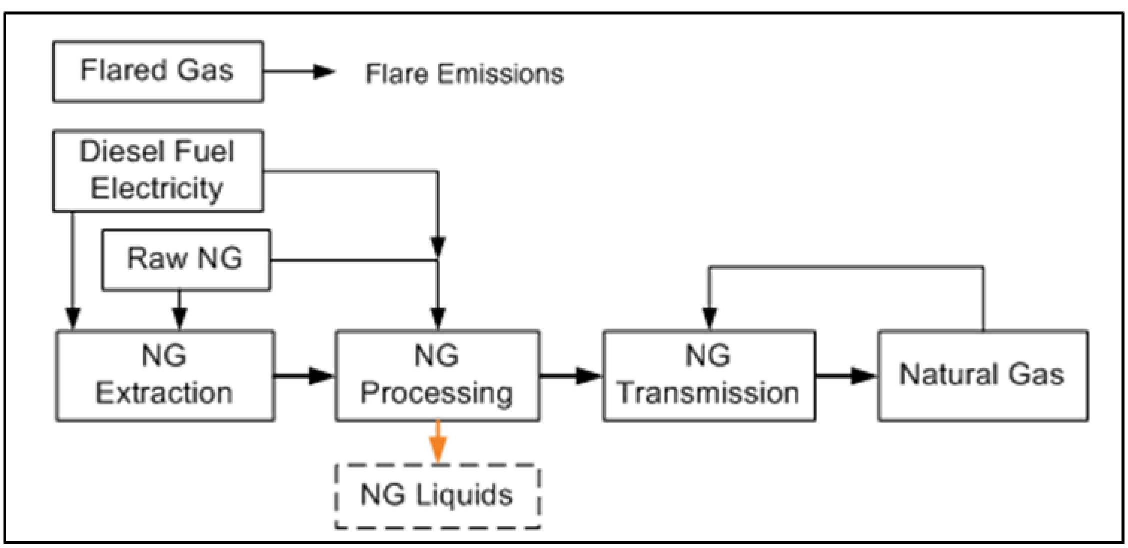


**Figure 2.2.** Natural Gas Production System Boundary Diagram

### *Power Generation and WTT Upstream Life Cycle Emissions*

Emissions from power generation include power plant combustion emissions from natural gas turbines and boilers as well as coal boilers. The life cycle emissions from power also include WTT upstream life cycle inputs for fuels and uranium for nuclear power plants. In Washington, average emissions per kWh are about half of the U.S. average, as most electricity is supplied with hydroelectric. However, the new electricity load from the Tacoma LNG project will not result in an expansion of power generation resources. Therefore generation resources such as hydroelectric, nuclear, and coal will not produce additional power to provide energy for the project.

The system boundary for electric power in Figure 2.3 includes the upstream life cycle activities of each fuel used to produce electricity, direct combustion of these fuels at the power plant, and losses through the transmission and distribution system. This analysis examines a range of power resource mixes due to the complexity of assessing the marginal impact of power generation.  The effect of power generation mix was examined for the local Tacoma Power utility generation mix, Washington state average mix, Northwest eGRID[11] mix, and a marginal mix that excludes hydroelectric and nuclear power that complies with Washington's 15% renewable portfolio standard by 2040. The inputs to the GREET model are the resource mix with GREET model inputs for power generation efficiency and transmission loss, which are described in Appendix B.2.

[11] https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

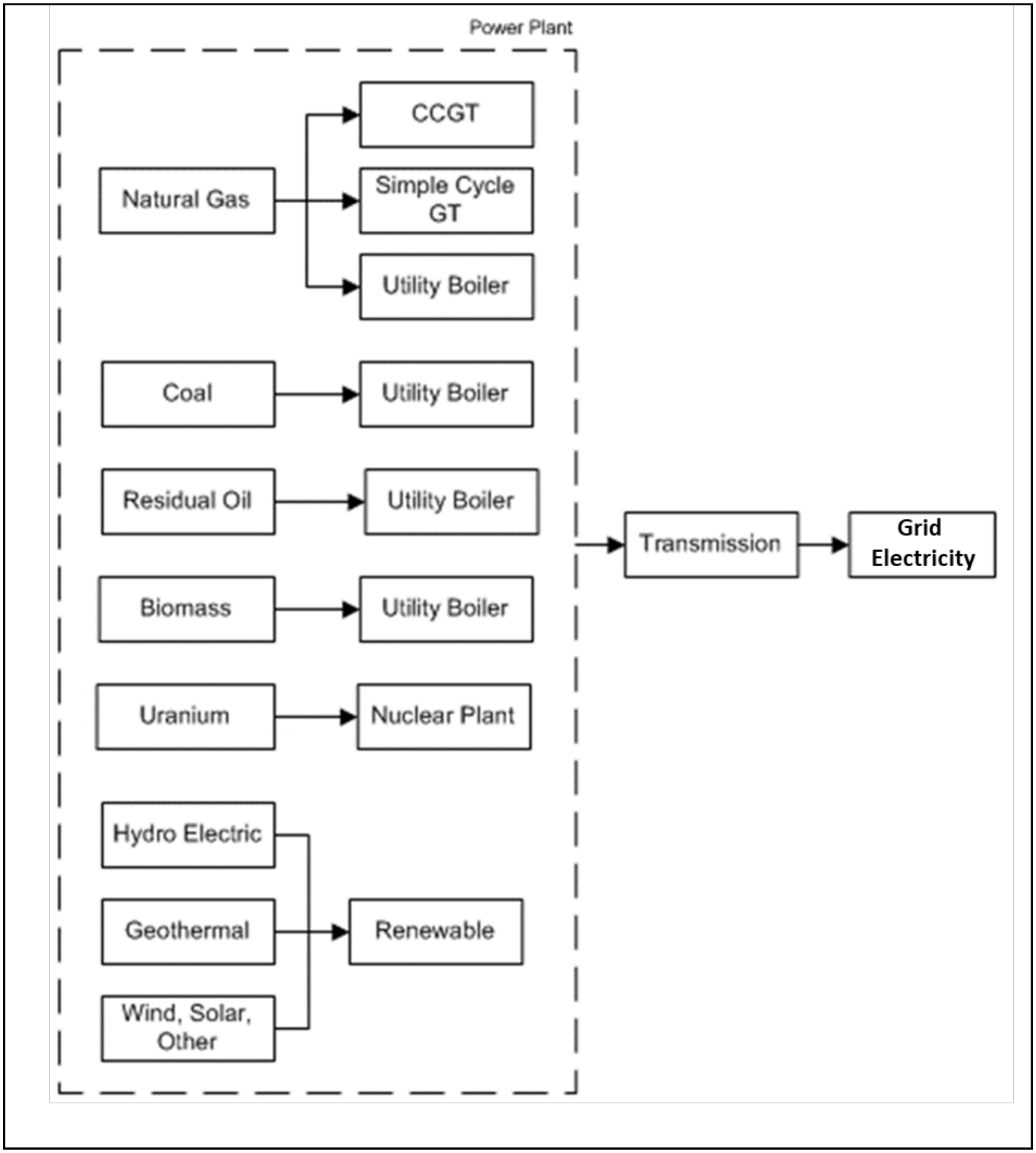


**Figure 2.3.** Electricity Production System Boundary Diagram

The GREET model calculates upstream emissions for the fuel and power generation phase. The emission factors are represented as power delivered to a generic customer which are representative of the emissions for power delivered to Tacoma LNG for grid electricity that includes a loss factor for transmission. The system boundary in the GREET model excludes materials of construction and decommissioning for fuel production and power generation equipment. Therefore, solar, wind, and hydroelectric power are treated with the GHG intensity of 0 g $CO_2e$/kWh.

### *Direct Emissions from LNG Facility Operation*

Direct operating emissions from Tacoma LNG will include the sources shown in Figure 2.4. The natural gas contains higher weight hydrocarbons (non-methane hydrocarbons) as well as small quantities of $CO_2$. The natural gas is separated into $CH_4$ and the before mentioned components. After processing within the LNG production system non-methane hydrocarbons are burned in a flare.

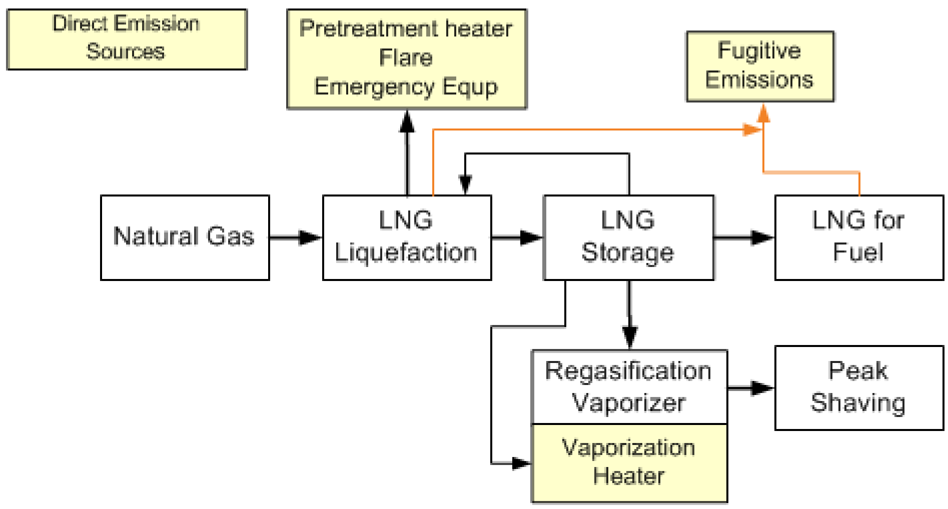


**Figure 2.4.** Direct Emissions Sources from Tacoma LNG

In order to align the natural gas inputs with LNG production and to assure that overall $CO_2$ emissions are consistent with a mass balance, the components and carbon content of the input natural gas are compared with the products.

Net $CO_2$ emissions for the Tacoma LNG ($C_{PSE}$) are verified by carbon balance such that the carbon in each of the components balance. Net carbon emissions ($C_{PSE}$) are calculated such that:

$$C_{PSE} = C_{NG} - C_{LNG} \quad (2)$$

Where:

$C_{PSE}$ = Carbon emissions from Tacoma LNG
$C_{NG}$ = Carbon in natural gas feedstock
$C_{LNG}$ = Carbon in LNG

The carbon balance provides the best estimate of vent $CO_2$ and flared light hydrocarbons based on the gas composition. The carbon balance tracks the carbon in the natural gas feed and LNG product. For 1 million Btu of natural gas $C_{PSE}$ corresponds to the mass balance in Appendix LCA-A.

As shown in the example here, the carbon content of LNG decreases per mmBtu of fuel which results in net emissions. However, the lower carbon content is reflected in the end use phase.

Natural gas also provides fuel for vaporization to re-gasify the LNG for peak shaving. Small portions of the process gas and natural gas are also combusted in the flare. Fugitive emissions occur from the LNG system and during LNG transfers for fuel use. Fugitive emissions primarily consist of methane and these GHG emissions are counted with the global warming potential (GWP) of methane.

### *End Use Applications*

The following end use applications would continue to operate in the no action alternative and LNG is not built.

Peak Shaving

Peak shaving is characterized through the revaporization of the LNG to the pipeline for PSE residential and commercial natural gas customers. The vaporized LNG would replace natural gas, which is supplied by additional purchase contracts, use of other natural gas storage resources, or other measures PSE could identify to meet its supply obligations in the no action alternative.

Gig Harbor LNG Supply

LNG trucked to Gig Harbor displaces LNG from Canada. The upstream emissions from LNG from Canada are assumed to be the same as those for Tacoma LNG.

On-Road Trucking

Without LNG fuel, on-road trucks would continue to operate on diesel fuel. LNG is one of the alternative fuel options for heavy-duty trucks. Other fuel such as biodiesel and renewable diesel will also be used in heavy-duty applications. However, the supply of these fuels is expected to be used in states with a low carbon fuel standard and not exceed 20% of the on-road diesel market. Therefore, any displacement of fuel would primarily be the diesel component as the use of biodiesel and renewable diesel is governed by fuel policies such as the renewable fuel standard. In the NAA case the quantity of diesel fuel corresponds to the same miles traveled on LNG.

Marine Propulsion

Without LNG fuel, marine engines would continue to operate on marine gas oil. Some would use lower sulfur fuel or install emission controls. MGO represents several types of distillate fuels describe in Appendix C.2.2. MGO that meets low emission requirements is similar to off-road diesel. Marine propulsion engines are compression ignition engines. Marine fuel is injected into the cylinder in a manner similar to a diesel engine. The efficiency of the engine would be similar to that of marine diesel. In the NAA case, the quantity of MGO that is displaced corresponds to the same distance traveled on LNG. The effect of removing sulfur from marine diesel and applying emission controls is examined in a sensitivity analysis.

LPG

The sale of light hydrocarbons for LPG or other fuel production is not planned. Propane and other light hydrocarbons will be flared. The use of non-methane hydrocarbons as a source of process heat and for LPG sales is examined in a sensitivity analysis.

### 2.2.2 Displaced Emissions (No Action Alternative)

The life cycle GHG emissions from Tacoma LNG are compared to the alternative of not completing the Tacoma LNG project. Table 2.2 shows the activities in the no action alternative (NAA) that would be displaced by Tacoma LNG. These include peak shaving, on road heavy-duty diesel trucks, and marine diesel for marine engines. The analysis assumes a 1:1 displacement of the end use activity associated with the fuels produced by the Tacoma LNG project.

**Table 2.2.** Activities and End Use Applications Displaced by Tacoma LNG

| Displaced Activity | Fuel | Equipment Type |
|---|---|---|
| Peak Shaving Natural Gas Combustion – Residential and Commercial | Natural Gas | Natural gas-fired Combustion Devices |
| Gig harbor LNG Supply | LNG | Various LNG and LNG transport |
| On-road Trucking | Diesel | Diesel Truck |
| TOTE Marine | Marine Gas Oil | Marine Engine |
| Truck-to-Ship Bunkering | Marine Diesel | Marine Engine |
| Other Marine by Bunker Barge | Marine Diesel | Marine Engine |

The life cycle GHG emissions from the Tacoma LNG project are compared to the alternative of not constructing the facility. Displaced fuel is based on PSE's projections of LNG end use applications.

The no action alternative energy uses include MGO and diesel fuel in marine and truck applications and pipeline natural gas for peak shaving operations. GHG emissions are calculated in the same manner as those for Tacoma LNG. The amount of diesel used for marine, or trucking applications are calculated based on the equivalent LNG use rate and the appropriate efficiency for each application. For diesel fuel combustion, the product of use rate and life cycle emission rates results in total emission $\mathbf{G}_{Alt}$ which calculated by:

$$\mathbf{G}_{Alt} = U_{PS} \times (\mathbf{EF}_N + \mathbf{E}_N) + \Sigma[U_k \times (S_{De} \times \mathbf{E}_e + S_D \times (\mathbf{EF}_D + \mathbf{E}_D))] \quad (3)$$

Where:

$U_{PS}$ = Energy use rate for LNG peak shaving

$\mathbf{EF}_N$ = Emission factor for natural gas combustion

$\mathbf{E}_N$ = WTT Upstream emission rate for natural gas

$U_k$ = Energy use rate of LNG in each application
$S_{De}$ = Specific energy of electricity used for diesel storage and transfer[12]
**$E_e$** = WTT Upstream emission rate for electric power
$S_D$ = Specific energy of diesel fuel and MGO displacing LNG for each fuel application
**$EF_D$** = Emission factor for diesel in marine or truck engines
**$E_D$** = WTT Upstream emission rate for MGO or diesel fuel

The term $S_D$ is a key parameter that relates the energy used in diesel operations with those from LNG fuel use. Electric power is used for diesel distribution so the term $S_{De}$ for no action alternative activities is essentially zero.

The WTT upstream emission rates include the WTT upstream data for diesel and marine diesel production. A small portion of these WTT upstream emissions fall into the scope of distribution which is consistent with the activities of the Tacoma LNG project direct emissions

### *Upstream Life Cycle Emissions Associated with the Production of Petroleum Products*

Crude oil is produced and transported from a variety of resources and regions in the world. In some cases, crude oil production results in the production of associated gas and the cogeneration of electric power. Crude oil is transported to oil refineries and refined into a range of products shown in Figure 2.5. The export of electric power from cogeneration with oil production and the co-production of natural gas are treated by energy allocation within the GREET model data analysis. The allocation factor $X_{Cr}$ is dealt with as an external model input. The allocation between refined products is treated with a refining efficiency ($\eta$fuel)

GHG emissions from petroleum production depend on the crude oil type and the extraction method as well as oil refinery configuration with about a 10% range in life cycle emissions from different crude oil types (Gordon, Brandt, Bergerson, & Koomey, 2015; Keesom, Blieszner, & Unnasch, 2012). The life cycle analysis of petroleum production in the GREET model takes into account the upstream emissions for crude oil production as well as the energy intensity to refine different products. The GREET inputs for petroleum product refining are based on a linear programming analysis of U.S. refineries (Elgowainy et al., 2014). The analysis of refining emissions is oriented toward the production of gasoline and diesel fuel as show in Figure 2.5. Diesel fuel is a co-product to gasoline based on an overall allocation of emissions in the oil refinery.

[12] This small amount of energy provides the functional equivalence of the direct emissions from LNG production which serves also as fuel storage.

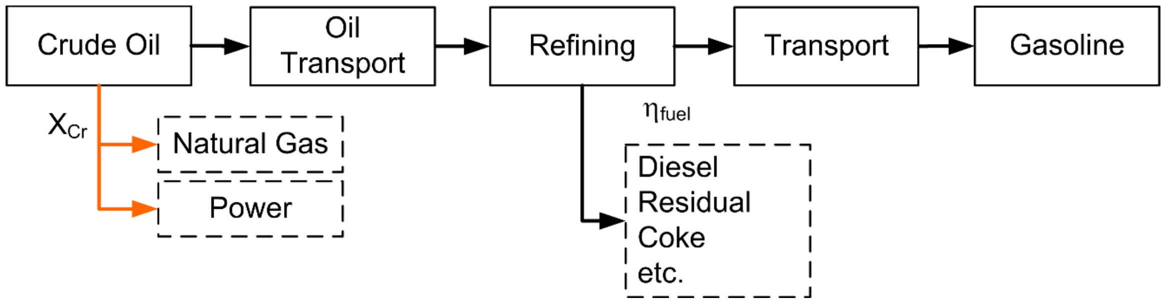


**Figure 2.5.** System Boundary Diagram for Petroleum Products.

The upstream data for refined petroleum products used for fuel transport are shown in Section 2.4.5.

### *Crude Oil Refining*

Five oil refineries operate in Washington State[13] with a combined refining capacity of over 230 million barrels per year. Although the state is a net exporter of refined product, gasoline and diesel are imported from Montana and Utah into eastern Washington. The most recent available pipeline transfer data[14] indicate that 6% of diesel consumed in Washington is refined in Montana and transported to Washington via the Yellowstone pipeline and 10% is refined in Utah and transported via the Tesoro pipeline. The balance (84% of diesel) is assumed to be refined in Washington State. The analysis assumes that all of the marine diesel consumed is refined in-state.

Petroleum refineries convert crude oil primarily into transportation fuels. The first step in refining is fractionation of the petroleum crude oil feed into major components: naphtha, distillate, gas oil, and residual oil. Subsequent steps convert these streams into lighter components or treat them to remove sulfur and nitrogen, improving octane or cetane, or make other changes to optimize refinery output. Crude oil refining is described in more detail in Appendix B. The emissions from crude oil refining to MGO and diesel are based on the GREET model modified for Washington. The U.S. refinery inputs are used to represent the refining in Washington, which is consistent with an analysis of a Clean Fuel Standard for the State of Washington (Pont, Unnasch, Lawrence, & Williamson, 2014).

Crude oil is processed from various locations around the world using various and production methods and transported to oil refineries by tanker ship, pipeline, or rail car. The energy intensity of oil refining depends upon its sulfur content and density (represented by API gravity). The energy inputs and emissions are described in Appendix B. The refinery energy intensity is considerably lower for the U.S. Average refining configuration then that of California (7.5 g $CO_2$e/MJ versus 14 g $CO_2$e/MJ for California refineries). A sensitivity analysis assuming 10 g $CO_2$e/MJ for refining to diesel is included in Section 5.

[13] British Petroleum Cherry Point, Shell Oil Anacortes, Tesoro Anacortes, Phillips 66 Ferndale, and US Oil Tacoma.

[14] 2013 data provided by Hedia Adelman, Washington State Department of Ecology

## 2.3 Key Parameters and Scenarios for GHG Impacts

The Tacoma LNG impacts GHG emissions through several direct and indirect effects. The factors that affect GHG emissions are discussed in the following section. Scenarios that evaluate a range of these factors are described below in Table 2.4. Scenarios that represent the best range of estimates of emissions are identified as Baseline, Lower, and Upper in this analysis.

### 2.3.1 Key Parameters Affecting Life Cycle GHG Emissions

Table 2.3 shows the key parameters that affect GHG emissions, variability in these parameters, and effect on net GHG emissions.

**Table 2.3.** Key Parameters Affecting Life Cycle GHG Emissions

| Parameter | Effect on GHG Emissions |
|---|---|
| a. Tacoma LNG Energy Inputs | Total natural gas input per gallon of LNG affects direct emissions from Tacoma LNG. Upstream natural gas and imported electric power emissions are proportional to the use rates. Other emissions from $CO_2$ venting and light hydrocarbon flaring are based on mass balance. Non methane hydrocarbons from the liquefaction process are flared. |
| b. Loss factors | Fugitive emissions of fuel from storage and distribution requires the production of additional fuel to yield 1 gallon of LNG to the end user. The overall product loss is shown in Appendix A.3. |
| c. Natural Gas Upstream | Leak rates from extraction, processing, and transmission represent about half of the upstream emissions from natural gas, the other half are from operational energy use. Research into the assumptions used to estimate these emissions are on-going, and estimates vary depending on data sources. |
| d. Electric Power Generation | Electric power emissions depend on the generation mix. Several methods for assessing the generation mix were examined based on precedent with other government GHG analyses as well as constraints on the regional electricity grid. |
| e. End use fuel efficiency | The relative efficiency of LNG fueled equipment compared with the equipment used in the no action alternative determines the amount of petroleum fuel that is displaced. A range of fuel efficiency factors are assumed. A mix of end use applications is examined. |
| f. Methane emissions | Key sources of methane include unburned fuel from marine engines as well as boil off emissions that are not captured. A sensitivity analysis covers the range of expected emissions. |
| g. Market displacement | Displacing diesel and MGO will have an effect of petroleum fuel markets. In principal, providing additional supply will reduce the price and induce a small increase in demand. This effect is very small since the amount of petroleum fuel displaced is a small fraction of the global supply. |

The key inputs that affect this study are the energy consumed by the Tacoma LNG project and the displacement of fuels with LNG. The inputs for the project were provided by PSE. The assumption on fuel displacement is that every gallon of LNG displaces an activity associated with its end use. So, a TOTE marine vessel operates on LNG instead of MGO. The displaced fuel is based on the energy economy ratio in Table 2.4. The range of GHG emissions associated with the Tacoma LNG were examined via the scenarios shown in Table 2.4.

**Table 2.4.** Parameters for Sensitivity Analysis

| Parameter \ Scenario | Baseline | Lower | Upper |
|---|---|---|---|
| a. Tacoma LNG | PSE data for LNG facility operation | Use waste gas for pretreatment and LPG sales | PSE data for LNG facility operation |
| b. Loss Factor | PSE estimates for fugitive emissions from LNG transfers | | |
| c. Natural Gas Upstream | BC Gas from GHGenius | British Columbia Gas inventory sensitivity analysis | U.S. GREET |
| d. Electricity Mix | Washington State | Tacoma Power | eGRID NWPP Region sensitivity analysis |
| e. Energy economy ratio | 1.0 for marine<br>0.90 for trucking<br>1.0 for NG peak shaving | 1.015 for marine<br>0.90 for trucking<br>1.0 for NG | 1.0 for marine<br>0.90 for trucking<br>1.0 for NG |
| f. Methane Emissions | 5.3 g $CH_4$/kWh slip<br>95% boil off capture | 5.3 g $CH_4$/kWh slip<br>100% boil off capture | 6.9 g $CH_4$/kWh slip<br>0% boil off capture |
| g. Economic effects | Assume 1:1 displacement of end use for each application. Price induced effects are assumed to be minor. | | |

## 2.4 Assumptions and Data Sources

Calculations of life cycle GHG emissions are based on the energy inputs and emissions factors and assumptions for each step in the fuel production process. The assumptions used to develop direct emissions from fuel production, and inputs to GREET modeling tools for the upstream and downstream emissions in the life cycle are described below. Since many of the data sources apply to both Tacoma LNG as well as displaced emissions, the data are organized by category rather than a linear path along the fuel life cycle.

### 2.4.1 Natural Gas Upstream

Natural gas provides a feedstock for the Tacoma LNG Facility. It is also an input to power generation and crude oil refining. The production of natural gas includes extraction at a gas well, processing to separate natural gas liquids, and transport to the Tacoma LNG Facility or other users of natural gas. The Tacoma LNG Facility will have a capacity to produce an average of 500,000 gallons per day of LNG.

The gas supply for Tacoma LNG Facility would come exclusively from British Columbia or Alberta. No natural gas would be obtained from other regions for the Tacoma LNG Facility since natural gas used in Washington almost entirely comes from Canada as shown in AppendixB.1.3.

The composition of natural gas to the Tacoma LNG facility is shown in Table 2.5. The composition provides the basis for determining the carbon content, heating value, and carbon factor in g $CO_2$e/mmBtu as shown in Appendix A.2.

**Table 2.5.** Composition of Natural Gas Used in Tacoma LNG Facility Project

| NG Composition [a] | Mole Fraction |
|---|---|
| Methane | 0.913137 |
| Ethane | 0.060699 |
| Propane | 0.015437 |
| i-Butane | 0.002239 |
| n-Butane | 0.002415 |
| i-Pentane | 0.000476 |
| n-Pentane | 0.000341 |
| Hexanes, plus | 0.000299 |
| Nitrogen | 0.002717 |
| Carbon Dioxide | 0.002240 |
| Water | 0.000000 |
| Hydrogen Sulfide | 0.000000 |

*Source:* PSE

[a] Major species used to determine mass balance are shown here.
Trace levels of other components may also be present.

Historically, natural gas in the U.S. has been produced from conventional gas wells, but in recent years, there has been substantial growth in production from horizontal wells, which require additional hydraulic fracturing (EIA, 2018b; National Energy Technology Laboratory, 2014). Figure 2.6 shows the growth of natural gas production in the U.S. Conventional gas production has declined while shale gas and other tight gas resources that are recovered through hydraulic fracturing have grown significantly and are expected to result in a doubling of natural gas production by 2040. These natural gas resources are not representative of the production methods used in British Columbia as flaring is prohibited there. Nonetheless, natural gas production is projected to grow significantly (National Energy Board, 2018) and any additional demand from the Tacoma LNG project will represent a small impact on the total natural gas market. British Columbia has adopted comprehensive drilling and production regulations that reduce methane emissions.

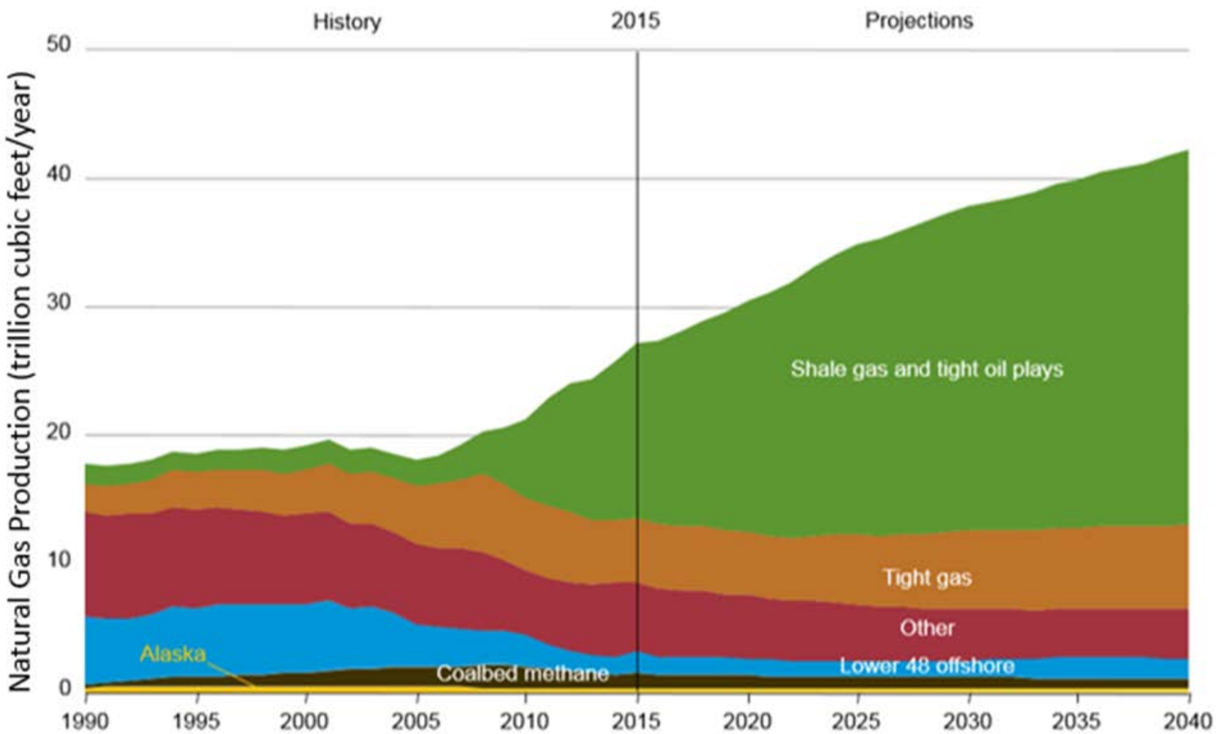


**Figure 2.6.** U.S. Dry Natural Gas Production by Source.
Note: Shale gas is expected to grow as a source of natural gas in the U.S.
*Source:* (U.S. Energy Information Administration, 2015) Figure MT-46 U.S. Dry natural gas production source in reference case

The GHG emissions in BC are regulated by a combination of existing and new legislation at both provincial and federal levels, some of which also encompass methane fugitive emissions. One of the key legislations in BC introduced carbon tax. The carbon tax was introduced in BC in 2008 and covers about 70% of provincial emission sources (Province of British Columbia, 2019).

Currently, the carbon tax applies to emissions from fuels such as gasoline, diesel, natural gas, heating fuel, propane and coal purchased or used in BC by individuals, business, industries or government, unless a specific exemption applies (Ministry of Finance British Columbia, 2018; Osler, 2018). All fuels combusted in BC that are reported in Environment Canada's Climate Change National Inventory Report are captured by the carbon tax. The carbon tax provides an incentive to improve energy efficiency and reduce flaring.

Currently, this carbon tax does not include fugitive methane emissions from gas wells. In 2018, Canada's federal government also introduced a federal carbon tax (Nuccitelli, 2018). As this federal regulation is less stringent that BC's provincial carbon tax regulation, this federal regulation it would not affect the province of BC.

Fugitive emissions from gas wells are being addressed separately at both the federal level as well as the provincial level. At the federal level, the government has committed to reducing the methane emissions by 40% to 45% below 2012 levels by 2025 (Lee-Anderson & Martz, 2017). Pursuing Canada's international commitment through Paris climate agreement, on May 27, 2017 the government proposed the Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector), which was brought in force on April 3, 2018. The regulation targets three primary targets of methane emissions. The restrictions will be effective starting 2020 or 2023 depending on applicability.

1. Hydraulic fracturing wells must conserve (capture) or destroy the methane gas
2. Ceiling and restrictions of emissions from compressors
3. Additional requirements on conservation and destruction equipment
    a. Equipment must capture and conserve at least 95% of the methane emission
    b. Hard limits on methane venting rate
    c. Leak detection and repair (LDAR) system
    d. Emissions from pneumatic controllers and other equipment

On Jan 16, 2019, the BC Oil and Gas Commission announced new regulations aiming to reduce methane emissions from upstream oil and gas operations (BC Oil and Gas Commission, 2019b). The regulation is an amendment to the existing Drilling and Production Regulation incorporating methane emission controls in the regulation (Board of Oil and Gas Commission, 2018).

The new regulation targets to meet or exceed the federal methane reduction targets. This regulation, similar to the federal regulation, also enforces a system of leak detection and repair, beginning Jan 1, 2020. The regulation enforces periodic "screening survey" and "comprehensive survey" of methane leaks followed by any corrective action or repairs. The regulation includes restrictions on emissions from the following sources of methane emissions (BC Oil and Gas Commission, 2019a):

1. Pneumatic devices
2. Equipment leaks
3. Compressor seals
4. Glycol dehydrators
5. Storage tanks
6. Surface casing vents.

### *Natural Gas Production*

Natural gas is transported by pipeline that typically operates at pressures between 200 and 800 psi.[15] Natural gas fueled compressor engines compress and move gas along the pipeline network. Natural gas sold for residential and commercial use also requires distribution through a local network. Energy inputs for natural gas production provide the basis for estimating combustion emissions for the upstream component of natural gas in the GREET and GHGenius

[15] http://naturalgas.org/naturalgas/transport/

model. The baseline analysis uses the upstream parameters from GHGenius version 4.0a, which has regionally specific detail for British Columbia. A newer version of GHGenius v5.0c is available; however, the upstream life cycle GHG emissions for natural gas are lower than those of v4a; so, the values used in the analysis are conservative. A sensitivity analysis reflects the British Columbia inventory and values from the GREET model described in Appendix B. Production from the Montney Formation, a large gas resource extending from northeast British Columbia into northwestern Alberta, has grown significantly. Production of Montney tight gas rose from no production prior to 2006 to 1600 Bcf/year in 2016.

Tight gas production lies along the spectrum of production methods with a growing awareness of hydraulic fracturing or fracking. Fracking involves the introduction of chemicals, water, and sand into the well. Water movement and hauling of materials all contribute to GHG emissions; however, the most significant contribution to GHG emissions is pumping energy and methane losses. On balance, the GHG emissions per million Btu from fracking of shale are similar to those from conventional production as shown in Appendix B.1.2.

### 2.4.2 LNG Plant Operation

Natural gas would enter the Tacoma LNG from a pipeline. The gas is first filtered and pressured before entering clean up systems.

#### *Pretreatment*

The gas entering the Tacoma LNG Facility is composed primarily of methane, but will also contain ethane, propane, butane, and small quantities of pentanes and hexanes as well as nitrogen, $CO_2$, sulfur compounds ($H_2S$ and odorants) and low levels of trace contaminants.

An Amine Pretreatment System will be designed to treat up to 26 million standard cubic feet per day (MMscfd) of inlet gas with a 2 percent $CO_2$ concentration, which is higher than the composition of pipeline gas. $CO_2$ emissions correspond to the difference between the $CO_2$ in the gas and $CO_2$ in the LNG. A natural gas fired Water Propylene Glycol (WPG) heater will provide the energy source. The “rich” aqueous amine solution would then be heated in a regenerator to remove the $CO_2$ and $H_2S$, resulting in a “lean” amine solution that would be reused in the process. The exhaust from the amine regenerator would be routed to the enclosed ground flare which would oxidize $H_2S$.

#### *Hydrocarbon Removal*

Prior to liquefaction of the natural gas, hydrocarbons that may freeze at the cryogenic temperatures encountered downstream would be removed by partial refrigeration. The composition of the hydrocarbons corresponds to the difference between the hydrocarbons in the natural gas feed and the LNG product. There are no plans to capture the hydrocarbons as fuel for pretreatment or sale as liquefied propane gas (LPG). The proposed project would burn the hydrocarbons in a flare. These hydrocarbons could also be used on-site or transported to appropriate markets. $C_3$ and $C_4$ hydrocarbons are a feedstock for LPG or as chemical feedstocks.

The use of the hydrocarbons for other purposes is examined in the sensitivity analysis and discussed in Appendix B.1.1.

#### *Liquefaction*

After the hydrocarbon removal process, the natural gas would be mixed with compressed boil-off gas (BOG) and condensed to a liquid by cooling the gas to approximately negative 260 degrees Fahrenheit (°F). Compressor seal leakage would be captured and sent to the enclosed ground flare. Liquefaction is expected to typically occur during 355 days out of the years. Up to 10 days per year, the Tacoma LNG Facility is expected to operate in a holding mode while LNG is vaporized. Liquefaction will not occur at the same time as vaporization.[16]

**Table 2.6.** Operational Hours of LNG Plant Processes

| Overall Operational Hours | hours/year | days/year |
|---|---|---|
| LNG Liquefaction Plant | 8,520 | 355 |
| LNG Pretreatment | 8,520 | 355 |
| LNG Flaring | 8,760 | 365 |
| LNG Vaporizer[a] | 240 | 10.0 |
| Emergency Diesel Generator | 500 | 20.8 |

[a] Peak shaving is expected to occur for no more than 10 years of facility life. The analysis examines 60 days of peak shaving in the baseline case since peak shaving will occur during 25% of the facilities life. 240 hours of peak shaving are examined as a sensitivity.

#### *LNG Storage*

The facility will include an 8 million gallon LNG storage tank. LNG is stored at 3 psi above ambient pressure and will have a temperature of negative 260°F. The tank is insulated to minimize heat leakage. As heat enters the tank, LNG warms and some of the liquid boils off into the vapor space. The phase change cools the remaining liquid and the boil off gas (BOG) is collected in BOG recovery system to maintain a low pressure in the tank (less than 3 psi gauge). Note that the capture of BOG is more effective than the default assumptions in the GREET model shown in Appendix B.1.1.

### 2.4.3 Electric Power Generation

Tacoma LNG will consume 1.35 kWh/gallon of LNG of grid power to meet its electricity requirements based on information provided by the applicant.

GHG emissions are calculated with the GREET(ANL, 2015) model upstream emission factors using the resource mixes described in this section.[17] This section presents several generation resource mixes in order to assess the effect of electric power generation.

[16] PSE indicates that the turn down of the LNG plant will free up natural gas supplies.

[17] The 2016 EIS examines an imported power with a direct GHG emission factor from eGRID2012 these values include power plant emissions only and is therefore not a life cycle GHG estimate.

The electric power generation mix affects the GHG emissions associated with purchased power. Power will be delivered through Tacoma Power. Due to the changing nature of the regional power grid several scenarios for power generation are examined in this analysis. These include:

- Washington State average mix
- Tacoma Power average mix
- eGRID NWPP mix
- Marginal Washington mix

### 2.4.4 LNG Product Delivery

LNG would be pumped out from the Tacoma LNG facility's storage tank for either (a) vaporization and reintroduction into the local distribution system, or (b) transfer to the Gig harbor LNG facility, use as marine vessel fuel or on-road truck fuel. LNG would be removed from the storage tank by way of submerged motor in-tank pumps. The submerged motor LNG pumps would be contained within the enclosed LNG tank and therefore are not a source of fugitive emissions.

#### *LNG Vaporization*

The LNG vaporization system would produce natural gas for customers connected to PSE's existing distribution system during peak demand periods. LNG vaporization will consume 0.045 kWh/gallon of LNG of grid power to meet its electricity needs.

#### *Marine Vessel Fuel Bunkering and Delivery*

The LNG would be conveyed via cryogenic pipeline to the TOTE Marine Vessel LNG Fueling System. Marine vessels would be bunkered with LNG for fuel using a dedicated marine bunkering arm equipped with a vapor return line. Swivel joints that would be swept with nitrogen to prevent ingress of moisture that could freeze and impede arm movement. When connected to the receiving vessel, the LNG bunkering arm and connected piping would be purged with nitrogen, which would be routed to the enclosed ground flare. Once purged, LNG would be bunkered onto the receiving vessel at a maximum design rate of 2,640 gallons per minute. Once bunkering is complete, the liquid in the bunkering arm and in the adjacent piping would be drained back to the LNG storage tank. After draining, the arm and connected piping would be purged with nitrogen again. The nitrogen purge would be routed to the enclosed ground flare and the arm and piping depressurized prior to disconnection.

LNG may also be supplied to bunker vessels for subsequent transfer to ships. In this process, the bunker vessel would load LNG via the Marine Vessel LNG Fueling System. The bunker vessel would then transit to the LNG-fueled marine vessel, anchor alongside the vessel, and conduct a ship-to-ship transfer of the LNG.

Table 2.7 summarizes the methane loss rates estimates by PSE combined with a review on LNG transfer operations in Appendix A.2. Note that a small portion of LNG production may be transferred to on-road LNG tanker trucks and then bunkered directly into vessels from the LNG tanker trucks. Emissions from this process are assumed to be similar to a Ship-to-Ship transfer where no vapor recovery system is employed.

**Table 2.7.** Methane Loss Rates from LNG Transfer Operations[18]

**Bunker Barge Loading**

| Vapor Displaced | Recovery Rate | Loss per Bunkering Event | Volume per Bunkering Event (gallons) | Loss per Bunkering Event (gallons) | $CH_4$ Emissions (g/mmBtu) |
|---|---|---|---|---|---|
| 0.22% | 95% | 0.011% | 380,994 | 41.9 | 2.4 |

**Bunker Vessel Storage**

| Boil off rate (%/day) | Recovery Rate | Loss per Bunkering Event | Volume per Bunkering Event (gallons) | Loss per Bunkering Event (gallons) | $CH_4$ Emissions (g/mmBtu) |
|---|---|---|---|---|---|
| 0.15% | 95% | 0.0300% | 380,952 | 114 | 6.4 |

**Truck/Ship-to-Ship Transfer**

| Vapor Displaced | Recovery Rate | Loss per Bunkering Event | Volume per Bunkering Event (gallons) | Loss per Bunkering Event (gallons) | $CH_4$ Emissions (g/mmBtu) |
|---|---|---|---|---|---|
| 0.22% | 0.00% | 0.22% | 380,838 | 838 | 47.0 |

### *Truck Loading*

Two loading bays at the Tacoma LNG Facility will have the capacity to load LNG to 10,000-gallon capacity tanker trucks. Each truck bay would have a liquid supply and vapor return hose. After truck loading, the liquid hose would be drained to a common, closed truck station sump connected to the Tacoma LNG Facility vapor handling system where it would be allowed to boil off and be re-liquefied or sent to the pipeline. Nitrogen would be used to purge the hoses and facilitate liquid draining and would then be routed to the enclosed ground flare.

### *Enclosed Ground Flare*

A flare will burn the light hydrocarbons that are removed from the natural gas. These hydrocarbons correspond to the difference in the natural gas and product LNG.

[18] (Corbett, Thomson, & Winebrake, 2015)

### *Fugitives from Equipment Leaks*

Fugitive methane emissions can occur from leaks in valves, pump seals, flanges, connectors, and compressor seals.  Estimates of component leaks are shown in Appendix A.3

### *Emergency Generator*

A 1,500 kW ultra-low sulfur diesel-fired emergency generator will be used for back-up power to maintain critical systems in the event of power loss. Under normal operating conditions this generator would only be used once per month for up to 2 hours for readiness testing. Emissions have been conservatively estimated based on 500 hours per year of operation, but this greatly overstates anticipated levels of operation.

## 2.4.5 LNG Consumption

LNG produced by the Tacoma LNG Facility will be used in one of the following ways: peak shaving, supply the Gig Harbor LNG facility, on-road trucking fuel and marine vessel fuel.

The following end use mix is assumed as input, based on an annual operation of 355 days of the Tacoma liquefaction facility:

**Table 2.8.** LNG End Use Mix of Tacoma LNG Facility

| Scenario B LNG Production | End use share | gal/day | lb/day | Mgal/ year | tonne/ year |
|---|---|---|---|---|---|
| **Total** | **100.00%** | **500,000** | **1,814,384** | **177.50** | **292,165** |
| On-site Peak Shaving | 1.1% | 5,511[a] | 20,000 | 1.96 | 3,221 |
| Gig Harbor LNG | 1.0% | 5,000 | 18,144 | 1.78 | 2,922 |
| On-road Trucking | 2.0% | 10,000 | 36,288 | 3.55 | 5,843 |
| TOTE Marine | 21.4% | 106,849 | 387,732 | 37.93 | 62,435 |
| Truck-to-Ship Bunkering | 1.0% | 5,000 | 18,144 | 1.78 | 2,922 |
| Other Marine (by Bunker Barge) | 73.5% | 367,639 | 1,334,079 | 130.51 | 214,823 |

[a]GHG emissions are calculated to the basis of the average annual peak shaving rate is 22,046 gal per day which corresponds to 66,000 mmBtu/day, HHV.  An average 0f 5,511 gal/day is assumed in the baseline case.

***Peak Shaving***

The Tacoma LNG Facility would provide vaporized LNG for peak shaving to the local PSE natural gas pipeline system. PSE indicates “During times of peak gas demand, 66,000 dekatherms of natural gas per day would be re-gasified and re-injected into PSE’s distribution system and 19,000 dekatherms of NG per day would be diverted from being routed to the liquefaction plant and be left in the pipeline for consumer use”. This vaporized LNG would be supplied to PSE’s residential and commercial customers during peak demand times.  Absent the Tacoma LNG Facility, the additional natural gas needed by these customers during peak demand times would come from other sources of natural gas, potentially including natural gas repurposed from gas transmission. The effect of peak shaving is the upstream energy to provide natural gas to make LNG and fuel for regasification plus the combustion of pipeline gas based on LNG. In the no action alternative the same energy content of natural gas from other sources is burned. The different properties of LNG and natural gas are taken into account. Note that commercial users may operate diesel equipment during periods of peak natural gas demand; however, sufficient data to quantify this activity was not available.

***Gig Harbor LNG***

Tacoma LNG will also be trucked to the Gig Harbor LNG facility. Gig harbor currently receives LNG by truck from Fortis BC in Delta, British Columbia. The transport distance from Fortis is 175 miles compared with 17 miles from Tacoma LNG. Trucking LNG from Tacoma will result in a shorter transport distance. The gas will be transported a slightly longer distance from BC but the additional transport distance was assumed to be covered in the upstream life cycle of natural gas delivered from British Columbia.

For purposes of this analysis, the Fortis BC liquefaction facility was assumed to have similar GHG emissions rates as the proposed facility although the Fortis facility likely does not flare propane. The primary differentiators between Tacoma LNG no action alternative is the tanker truck transport distance. Since it is unlikely that the Fortis facility also flares the light hydrocarbon components in its natural gas feed, no additional emissions associated with hauling LNG the longer distance were counted in the no action alternative.

***On-Road Trucking***

A small portion of the annual LNG production at the facility may be supplied for use in on-road heavy-duty trucks. Based on GREET default assumptions, the natural gas combination tractor has a 10% efficiency penalty relative to the diesel tractor. This input is represented as an energy economy ratio (EER) of 0.9 such that the diesel tractor consumes 90% of the Btus as the LNG tractor.

***TOTE Marine Vessel Fuel***

One of the primary purposes of the Tacoma LNG Facility would be to supply the TOTE Marine Vessel LNG Fueling System. PSE analyzed the load factors for marine vessel operation which affect the methane emissions from these engines. The relative weighting of methane from internal combustion engines and boilers is based on an analysis of emissions factors and methodologies employed in the Puget Sound Maritime Air Emissions Inventory (Emissions Inventory), developed by the Puget Sound Maritime Air Forum.[19] The total carbon emissions are then tied to the fuel properties of MGO and LNG.

The marine engines are dual-fuel LNG engines that rely on a small amount of fuel oil injected to act as a “pilot” to initiate combustion in the engine cylinder. This pilot fuel is typically injected at rates of approximately 1 to 5% of the total fuel rate, with the balance of the fuel being LNG.

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[19] Puget Sound Maritime Emissions Inventory, 2016. Available at: https://pugetsoundmaritimeairforum.org/2016-puget-sound-maritime-air-emissions-inventory/

The pilot fuel contributes to the emissions of the vessel and these contributions are reflected in the emissions factors reported in the studies referenced above. Three percent pilot fuel was assumed in this analysis. The relative energy efficiency for marine diesels operation was assumed to be 1:1 on a lower heating value basis.

Table 2.9 summarizes the assumed route details for the TOTE vessel. These route details are based on direct travel from the Port of Tacoma to the Port of Anchorage. The EER for marine diesel relative to LNG and fuel use determines the GHG emissions.

**Table 2.9**. Route Assumptions for TOTE Vessel Emissions Modeling

| Ship Type | Origin | Distance at Sea | Transit Speed | Transit Time | Maneu -vering Time | Time at Berth (Origin) | Time at Berth (Destination) | Transit | Maneu -vering | Hoteling |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (nm) | (knots) | (hours) | (hours) | (hours) | (hours) | (within 200 nm) | | |
| RoRo | Anchorage | 1450 | 22 | 65.9 | 2 | 10 | 10 | 14% | 50% | 50% |

***Truck-to-Ship Bunkering***

The Tacoma LNG Facility would also be able to load tanker trucks for delivering LNG directly to marine vessels for use as marine vessel fuel. It was assumed that these vessels would receive fuel by truck in the no action alternative.

***Other Marine Vessel Fuel***

The Tacoma LNG will also provide fuel for other marine vessel fueling.  The fuel will be transferred to bunkering barges and then loaded onto the marine vessels.

***Truck Loading***

The Tacoma LNG Facility would have the capacity to load LNG to 10,000-gallon capacity tanker trucks. The loading bays would be designed to fill a tanker truck at a rate of 300 gallons per minute.  LNG in the transfer hoses would be drained and the hoses would be purged with nitrogen and the trapped vapors would then be routed to the enclosed ground flare.

### 2.4.6 Construction Inputs and Materials

***Construction Direct Equipment Emissions***

Construction equipment emissions correspond to the fuel use combined with emission factors for diesel and gasoline during the construction time of about three and a half years. Another portion of construction emissions consists of vehicle trips (workers and heavy-duty trucks).

For construction equipment, the analysis consists of listing the equipment type, count, number of months used, horsepower, load factor, utilization factor and emission factors (grams per horsepower per hour [g/hp-hr]). The emission factors are from the United States Environmental Protection Agency NONROAD model and are specific to Washington State. For GHGs, the fuel consumption is also provided. The assumed average time of operation during the construction is 48 hours per week; 4.28 weeks per month, resulting in 205.4 hours per month.

The other portion of construction emissions consists of vehicle trips (workers and heavy-duty trucks). For these calculations, the winter and summer vehicle miles travelled (VMT) by workers and trucks were quantified for 2015 to 2018 and combined with emission factors from MOVES (g/minute). The IPCC 4th assessment report (AR4) GWPs were used to calculate $CO_2e$. Workers were assumed to drive exclusively passenger cars.

**Table 2.10.** Estimated Trip to and from Construction Site

| | | |
|---|---|---|
| Cars VMT round trip | 40 | mi/day |
| Truck VMT round trip | 100 | mi/day |

| Summary VMTs | | Car VMT/ month | Truck VMT/ month |
|---|---|---|---|
| 1.Year | Winter | 0 | 38 |
| | Summer | 0 | 1,225 |
| 2.Year | Winter | 309,120 | 9,999 |
| | Summer | 309,120 | 5,789 |
| 3.Year | Winter | 302,400 | 6,356 |
| | Summer | 614,880 | 4,160 |
| 4.Year | Winter | 0 | 457 |
| | Summer | 0 | 306 |
| **Total** | | **1,535,520** | **28,330** |

### *Construction Materials*

Materials of construction for the Tacoma LNG Facility include steel and other metals, asphalt, and concrete. PSE estimated the weight of materials based on the facility design as shown in Table 2.11. Concrete was divided between the aggregate and Portland cement components.

**Table 2.11.** Weight of Construction Materials

| Input | Metric Tonnes |
|---|---|
| Steel | 4,745 |
| Rebar | 1,666 |
| Stainless Steel | 290.0 |
| Copper | 26 |
| Asphalt | 7,570 |
| Aggregate | 80,110 |
| Cement | 1,716 |

*Source:* Response Tacoma LNG Supplementary SEIS Questions, July 07, 2018.

The total power consumption during construction is 10.51 GWh based on information supplied by PSE.[20]

### 2.4.7 Petroleum Upstream Emissions

Natural gas and diesel fuel provide energy inputs to the life cycle of fuel from Tacoma LNG or alternative sources of fuel. GREET estimates the emissions from crude oil to a variety of refined products based on the complexity of the oil refineries in different regions of the U.S. Among other parameters the GHG emissions from a refinery are directly related to the density of crude oils measured in API gravity. Crude oils that are light (higher degrees of API gravity or lower density) tend to require less intensive processing which results in lower GHG emissions. Data affecting Washington-specific inputs for crude oil sources are shown in Appendix B.3.

[20] Source: Response Tacoma LNG Supplementary SEIS Questions, July 7, 2018, page 5.

# 3. TACOMA LNG PROJECT EMISSIONS

Tacoma LNG Project emissions are grouped according to construction, operational, and downstream emissions. Direct emissions include fuel combustion and fugitive emissions. Upstream emissions include the upstream WTT emissions for natural gas feedstock, electric power, diesel and other fuels as well as those associated with materials of construction. Downstream emissions include end use emissions from use of LNG as marine vessel fuel, on-road diesel, or natural gas peak shaving. A small amount of LNG will also replace an LNG source from Canada.

## 3.1 Construction Emissions

Construction emissions include the combustion of fuel used to operate construction equipment. Upstream emissions consist of electric power for construction as well as the upstream WTT emissions for diesel fuel. Construction emissions are estimated to be the same for the scenarios examined in this analysis because the capacity of key pieces of equipment such as the LNG storage tank as well as peak shaving heaters would not change with the different volume scenarios.

GHG emissions were calculated for the following:

- Construction equipment fuel use
- Construction equipment power
- Material delivery
- Material manufacturing for Tacoma LNG facility

### 3.1.1 Direct Construction Emissions

Direct emissions from construction correspond to the fuel combusted from cranes, dozers, compressors, and other construction equipment. Table 3.1 shows the direct emissions from construction. These correspond to the fuel use from Appendix A.1 combined with combustion emission factors for diesel fuel from Appendix C. Construction emissions occur over 3.5 years and the average annual construction emissions are calculated over a 40 year project life.

**Table 3.1.** Direct Emissions from Energy Inputs for Construction for Years 1 through 4

| Equipment (Direct) | $CO_2$ (tonne/ year) | $CH_4$ (tonne/ year) | $N_2O$ (tonne/ year) | $CO_2e$ (tonne/ year) |
|---|---|---|---|---|
| 1. Year - Construction Equipment | 1,703 | 0.018 | 0.012 | 1,707 |
| 1. Year - Road Vehicles/Commuting | 3 | 0.000 | 0.000 | 3 |
| 1. Year - Fugitive Dust | | | | 0 |
| 1. Year - Total Emissions | 1,706 | 0.018 | 0.012 | 1,710 |
| | | | | |
| 2. Year - Construction Equipment | 3,417 | 0.049 | 0.030 | 3,427 |
| 2. Year - Road Vehicles/Commuting | 227 | 0.002 | 0.001 | 227 |
| 2. Year - Fugitive Dust | | | | 0 |
| 2. Year - Total Emissions | 3,643 | 0.051 | 0.030 | 3,654 |
| | | | | |
| 3. Year - Construction Equipment | 62 | 0.023 | 0.014 | 67 |
| 3. Year - Road Vehicles/Commuting | 307 | 0.003 | 0.001 | 308 |
| 3. Year - Fugitive Dust | | | | 0 |
| 3. Year - Total Emissions | 369 | 0.026 | 0.015 | 374 |
| | | | | |
| 4. Year - Construction Equipment | 1,545 | 0.028 | 0.017 | 1,550 |
| 4. Year - Road Vehicles/Commuting | 2 | 0.000 | 0.000 | 2 |
| 774. Year - Fugitive Dust | | | | 0 |
| 4. Year - Total Emissions | 1,546 | 0.028 | 0.017 | 1,552 |
| **Project Total:** | **7,265** | **0.123** | **0.074** | **7,289** |

### 3.1.2 Upstream Construction

Upstream emissions for construction activity include the production of diesel and gasoline for construction equipment, as well as the generation of power. Upstream emissions also includes the manufacturing of materials.

Upstream emissions for construction energy inputs correspond to the total energy inputs multiplied by the upstream emission factor from GREET. The Washington State electricity mix is applied to power during the construction phase as this a conservative approach (i.e., it is the mix with the highest GHG emissions) identified by State Energy Office at the Washington Department of Commerce 2017 guidelines.[21] Upstream construction emissions associated with energy inputs from Appendix A.1 are also shown in Table 3.2.

[21] A range of power generation options is examined for LNG operation in the sensitivity analysis in Section 5.

**Table 3.2.** Upstream Construction Emissions

| Equipment (Upstream) | $CO_2$ (tonne/ year) | $CH_4$ (tonne/ year) | $N_2O$ (tonne/ year) | $CO_2e$ (tonne/ year) |
|---|---|---|---|---|
| 1. Year - Construction Equipment | 85 | 0.9 | 0.00 | 107 |
| 1. Year - Road Vehicles/Commuting | 1 | 0.0 | 0.00 | 1 |
| 1. Year - Fugitive Dust | | | | 0 |
| 1. Year - Total Emissions | 85 | 0.9 | 0.00 | 108 |
| 2. Year - Construction Equipment | 180 | 1.9 | 0.00 | 228 |
| 2. Year - Road Vehicles/Commuting | 72 | 0.0 | 0.00 | 72 |
| 2. Year - Fugitive Dust | | | | 0 |
| 2. Year - Total Emissions | 252 | 1.9 | 0.00 | 299 |
| 3. Year - Construction Equipment | 154 | 1.6 | 0.00 | 195 |
| 3. Year - Road Vehicles/Commuting | 97 | 0.0 | 0.00 | 97 |
| 3. Year - Fugitive Dust | | | | 0 |
| 3. Year - Total Emissions | 251 | 1.6 | 0.00 | 292 |
| 4. Year - Construction Equipment | 90 | 0.9 | 0.00 | 113 |
| 4. Year - Road Vehicles/Commuting | 0 | 0.0 | 0.00 | 0 |
| 4. Year - Fugitive Dust | | | | 0 |
| 4. Year - Total Emissions | 90 | 0.9 | 0.00 | 114 |
| **Project TOTAL:** | **678** | **5.3** | **0.01** | **812** |

### *Upstream Construction Materials*

Table 3.3 shows the upstream emissions from manufacturing construction materials based on fuel use rates and upstream life cycle emission rates. The GREET2 model estimated the emissions associated with the manufacture of materials for automotive manufacturing. These upstream results are consistent with the energy inputs and emissions for the GREET1 model and provide the basis for materials such as steel, copper, and stainless steel. The remaining upstream emissions are derived from the USLCI database and the GREET1 model. The heaviest materials of construction include concrete and asphalt. These materials; however, require relatively low upstream emissions in their manufacture as emissions from aggregate are relatively low compared with other materials. GHG emission associated with metals manufacturing includes energy for mining, smelting, and processing to materials of construction.

**Table 3.3.** Upstream Emissions for Construction Materials

| Pollutant | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2e$ | Source |
|---|---|---|---|---|---|
| Life Cycle Emission Factor (g/kg) | | | | | |
| Structural Steel | 2,687 | 4.3 | 0.0 | 2,802 | GREET2_2017 |
| Rebar | 2,020 | 3.5 | 0.0 | 2,115 | GREET2_2017 |
| Stainless Steel | 5,204 | 11.3 | 0.1 | 5,512 | GREET2_2017 |
| Copper | 3,083 | 6.31 | 0.1 | 3,257 | GREET2_2017 |
| Asphalt [a] | 639 | 0.42 | 0.0 | 651 | GREET1_2017 |
| Aggregate | 300 | 0.20 | 0.0 | 305 | GREET1_2017 |
| Cement | 2,900 | 0.70 | 0.0 | 2,918 | GREET1_2017 |
| Emissions (tonne) | | | | | |
| Structural Steel | 12,748 | 20.6 | 0.10 | 13,293 | |
| Rebar | 3,366 | 5.9 | 0.04 | 3,524 | |
| Stainless Steel | 1,509 | 3.3 | 0.03 | 1,598 | |
| Copper | 80.2 | 0.2 | 0.00 | 84.7 | |
| Asphalt | 4,841 | 3.2 | 0.02 | 4,927 | |
| Aggregate | 24,033 | 16.0 | 0.00 | 24,434 | |
| Cement | 4,976 | 1.2 | 0.00 | 5,007 | |
| **Total** | **51,553** | **50.3** | **0.19** | **52,869** | |

[a] Asphalt assumed to be a mixture of residual oil and aggregate. Cement based on CaO. Aggregate based on surface extracted minerals.

### *Upstream Construction Power*

Upstream emissions for power are based on the amount of power used for construction combined with the upstream life cycle emission rates for power generation. The Washington average mix is used as a conservative assumption.

**Table 3.4.** Upstream Emissions for Electric Power

| Power Consumption LNG Construction | Baseline | GHG Emissions (tonnes) | | | |
|---|---|---|---|---|---|
| Power Total during construction (kWh) | 10,512,000 | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2e$ |
| **Mix** | **WAUP** | **2,146.6** | **4.1** | **0.0** | **2,261.6** |

## 3.2 Operational Emissions

Operational emissions from Tacoma LNG include the emissions from fuel combustion, vented $CO_2$ from natural gas, fugitive $CH_4$ and the upstream emissions associated with these inputs. Direct project emissions include the on-site emissions from fuel combustion and evaporative emissions. Downstream emissions correspond to LNG bunkering and marine vessel loading facilities and end use fuel combustion.

Table 3.5 shows the operational emissions from the Tacoma LNG facility. The energy inputs are based on the gas composition and natural gas to LNG yield provided by PSE combined with the natural gas firing rate for pretreatment. Pretreatment emissions include the combustion of natural gas to operate the separation system as well as $CO_2$ in the natural gas. The emission rates for natural gas and waste gas are based on the gas compositions and mass balance shown in Appendix A.2. Natural gas is fired to operate the pretreatment system. Waste gas, which consists of light hydrocarbons are separated as part of the liquefaction process. The emission factors for natural gas and waste gas are based on the compositions in the mass balance. The waste gas is represented as waste gas and the LPG fraction in order to examine the effect of flaring and to illustrate the effect of the carbon balance on overall GHG emissions. The natural gas usage is higher than that of the default GREET usage parameters and the non-methane hydrocarbons grouped as LPG represent most of the difference.

**Table 3.5.** Operational Emissions from Tacoma LNG Facility

| **Direct Combustion Emission Factor** | | **Emissions (g/mmBtu), LHV** | | | |
|---|---|---|---|---|---|
| **Process** | **Equipment** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_2e$** |
| LNG Pretreatment, vaporizer | Boiler, NG | 59,311 | 1.06 | 0.35 | 59,442 |
| Waste gas flaring | Flare | 68,662 | 1.06 | 1.07 | 59,660 |
| LPG flaring | Flare | 68,773 | 1.07 | 1.07 | 69,118 |
| Emergency Generator | Diesel Genset | 78,187 | 4.22 | 0.60 | 78,472 |
| | | **Emissions (tonne/year)** | | | |
| **Process** | **Equipment** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_2e$** |
| LNG Pretreatment | Boiler, NG | 10,713 | 0.19 | 0.06 | 10,737 |
| Pretreatment $CO_2$ | Vent/flare | 1,720 | | | 1,720 |
| Waste LPG flaring | Flare | 57,416 | 0.9 | 0.9 | 57,704 |
| Waste gas flaring | Flare | 26,806 | 0.4 | 0.4 | 26,940 |
| Fugitives | Equip. Leaks | 0 | 7.56 | 0.00 | 189 |
| Emergency Generator | Diesel Genset | 521 | 0.03 | 0.0004 | 523 |
| **Sub - Total** | | **97,175** | **9.08** | **1.38** | **97,813** |
| Vaporizer | Boiler | 235 | 0.004 | 0.001 | 235 |
| Vaporizer | Pump - power | 0.14 | 0.0003 | 0.0 | 0.2 |
| Fugitives | | | | | |
| Ship/Barge Loading | Equip. Leaks | 0 | 6.9 | 0.0 | 171.7 |
| Bunker Vessel Storage | Equip. Leaks | 0 | 562 | 0.0 | 14,049 |
| Truck to Ship | Equip. Leaks | 1.0 | 12.9 | 1.0 | 322.1 |
| **Total** | | **97,411** | **591** | **2.38** | **112,591** |

The flow rate of natural gas is based on the hourly firing rate provided by PSE. The flow rate of the light hydrocarbon is based on the difference in the gas streams such that:

NG input = Fired NG + Pretreatment $CO_2$ + Flared Waste Gas + Fugitive $CH_4$ + LNG

The emission factors for natural gas and the light hydrocarbon components are based on the gas compositions and carbon content calculated in Appendix A.2. Since determining the exact feed gas composition and flared gas compositions is challenging, the overall $CO_2$ emissions tie to a carbon balance in Appendix A.2. The distribution of carbon between the gas streams depends on many design parameters but the total $CO_2$ emissions depend only on the net carbon balance shown above. The net carbon emissions are tied to the mass balance in Appendix A.2.

### 3.2.1 Operational Upstream Emissions

Upstream emissions from Tacoma LNG operation include the emissions for natural gas production and transmission, as well as power generation. The use of petroleum fuels for LNG transport also results in upstream emissions.

#### *Natural Gas Production*

Natural gas is the feedstock for the Tacoma LNG Facility as well as a key energy input for power generation and crude oil refining. Table 3.6 identifies the data sources for upstream natural gas emissions calculations. The assumptions for the feedstock for Tacoma LNG are varied to reflect the range in estimates of methane leakage rates, giving a baseline, a lower and an upper estimate.

The upstream GHG emissions for British Columbia gas are based on the GHGenius model (S&T 2013). The other assumptions on upstream emissions provide a range for sensitivity analysis. The upper bound, is based on the GREET North American Natural Gas model for U.S. natural gas. The upstream data sources are described in Appendix A.

**Table 3.6.** Upstream Data Sources for Natural Gas

| Scenario | Baseline |
|---|---|
| Baseline | GHGenius |
| Lower | BC Inventory Estimate |
| Upper | GREET NA NG[a] |

[a] Environmental Defense Fund results in GREET are also calculated

Table 3.7 shows the upstream emissions for natural gas. The GHGenius result for BC gas is shown here as this estimate is a regionally specific estimate for the feedstock for the Tacoma LNG facility. The input assumptions and results for the other upstream estimates are in Appendix B.1.

**Table 3.7.** Upstream Natural Gas Emissions

| Natural Gas upstream | Emissions (g/mmBtu), LHV | | | |
|---|---|---|---|---|
| **Processing Step** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_2e$** |
| Natural Gas Extraction | 2,303 | 25.1 | 0.110 | 2,962 |
| Gas leaks and flares | 3 | 115.5 | 0.000 | 2,891 |
| Natural Gas Processing | 2,325 | 10.3 | 0.040 | 2,596 |
| Processing Fugitive | 1,101 | 0.0 | 0.000 | 1,101 |
| Transmission & Storage | 1,193 | 2.3 | 0.009 | 1,253 |
| **Total Natural Gas** | **6,925** | **153** | **0.16** | **10,803** |

*Source:* GHGenius v4.0a for BC, transmission fugitive emissions grouped with leaks.

### *Other Upstream Emissions*

Upstream emissions are associated with diesel and gasoline fuel used for construction and LNG transport. Diesel and MGO are also used for the no action alternative. The upstream life cycle emission rate for petroleum fuel are shown in Table 3.8. The crude oil resource mix is based on the analysis in Appendix B.3. The upstream emissions for crude oil production are based on carbon intensity estimates from the OPGEE model. Crude oil refining emissions are based on the GREET model analysis of diesel fuel. Since the GREET model does not have a specific configuration for Washington refineries the U.S. Average configuration provides the results used in the analysis of diesel for trucking. Upstream emissions for MGO are based on the upstream emissions for diesel fuel with an adjustment for the higher sulfur content of MGO. Note that the upstream emissions for the refining component for diesel fuel produced in California refineries is almost twice as high as that of the values shown here. Therefore, the displaced emissions in the no action alternative are conservatively low. The sensitivity of higher upstream emissions for diesel and MGO is included in the sensitivity analysis in Section 5.

**Table 3.8.** Upstream GHG Emission Rates for Petroleum Fuels

| Processing Step | Emissions (g/mmBtu), LHV | | | |
|---|---|---|---|---|
| | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_2e$** |
| WA MGO | | | | |
| Crude Oil Production[a] | 9,250 | 155 | 0 | 13,155 |
| Extraction Fugitive | 0 | 0 | 0 | 0 |
| Crude Oil Refining | 7,386 | 20 | 0 | 7,939 |
| Processing Fugitive | 0 | 0 | 0 | 0 |
| Avoided Hydrotreating | -42.2 | -0.1 | 0.0 | -44.9 |
| Transport | 376 | 1 | 0 | 395 |
| Transport Fugitive | 0 | 0 | 0 | 0 |
| Total U.S. MGO | **16,971** | **176** | **0.244** | **21,443** |
| WA. Diesel Fuel | | | | |
| Crude Oil Production[a] | 9,250 | 155 | 0.1 | 13,155 |
| Extraction Fugitive | 0 | 0 | 0.0 | 0 |
| Crude Oil Refining | 7,386 | 20 | 0.1 | 7,939 |
| Processing Fugitive | 0 | 0 | 0.0 | 0 |
| Transport | 376 | 1 | 0.0 | 395 |
| Transport Fugitive | 0 | 0 | 0.0 | 0 |
| Total WA. Diesel Fuel | **17,013** | **176** | **0.244** | **21,488** |
| WA Gasoline Fuel | | | | |
| Crude Oil Production[a] | 9,003 | 100 | 0.1 | 11,533 |
| Extraction Fugitive | 0 | 0.0 | 0.0 | |
| Crude Oil Refining | 12,732 | 20 | 0.0 | 13,232 |
| Processing Fugitive | 0 | 0.0 | 0.0 | |
| Transport | 475 | 0.7 | 0.0 | 491 |
| Transport Fugitive | 0 | 0.0 | 0.0 | |
| Ethanol blending | -1,006 | 0.0 | 0.0 | -1,006 |
| Total WA. Gasoline Fuel | **21,204** | **120.7** | **0.1** | **24,251** |

*Source:* GREET1_2017 with Washington specific inputs, WA average electricity mix.
[a] Crude oil production emissions determined from CA ARB reporting of OPGEE model results which are reported on a $CO_2e$ basis including $CH_4$ and $N_2O$

Energy use rates are combined with the upstream emission factors to calculate the upstream emissions associated with petroleum fuels for Tacoma LNG. The upstream components of the calculations of emissions are summarized in shown in Table 3.9. The emissions are expressed per 1000 gallons of LNG with the use rate also indicated in the table.

**Table 3.9.** Upstream GHG Emissions for Tacoma LNG Project

| Pollutant | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2e$ | Use Rate | |
|---|---|---|---|---|---|---|
| Emissions (kg/1000 gal), LHV | | | | | | |
| Upstream Natural Gas | 592.7 | 13.1 | 0.014 | 924.6 | 85,585 | Btu/gal |
| Upstream Power LNG production | 275.3 | 0.5 | 0.005 | 290.0 | 1.348 | kWh/gal |
| Upstream Diesel Emergency | 0.64 | 0.01 | 0.000 | 0.8 | 37.6 | Btu/gal |
| **Total Upstream** | **868.6** | **13.6** | **0.019** | **1215.4** | | |
| Upstream Power LNG Vaporizer | 9.2 | 0.018 | 0.0002 | 9.7 | 0.045 | kWh/gal |

### 3.2.2 Direct Operational Emissions

Direct emissions from Tacoma LNG correspond primarily to the combustion of natural gas for pretreatment and the vented $CO_2$ from the LNG production process. Natural gas for process boilers, flares and emergency equipment also contribute to direct GHG emissions. The natural gas use rate affects the upstream natural gas emissions previously discussed.

### 3.2.3 Carbon Balance

Emissions from Tacoma LNG are calculated assuming continuous operation in order to provide a basis of comparison for the no action alternative. Energy inputs and emissions from continuous operation are based on the process design and correspond to a mass and energy balance between the natural gas feed, LNG produced, and emissions. Table 3.10 shows the mass and energy inputs for data based on 500,000 gal/day of production.

**Table 3.10.** Mass Balance of LNG Plant Processes

| Energy Input/Output | NG Feed | LNG Output | Ratio NG/LNG | Btu NG / gal LNG |
|---|---|---|---|---|
| NG Feed (lb/day) | 2,025,990 | 1,814,026 | 1.117 | |
| LHV (mmBtu/day) | 42,695 | 38,570 | 1.107 | 85,407 |
| LHV (Btu/lb) | 21,074 | 21,262 | | |

*Source:* PSE and mass balance in Appendix A.2

GHG emissions from the LNG production process consist of fired natural gas, light hydrocarbons, $CO_2$, and fugitive $CH_4$. A carbon balance provides the basis for the net emissions followed by a summary of the total Tacoma LNG facility emissions in Appendix A. The mass flow of feedstocks, products, and emissions are represented by the carbon balance shown in Figure 3.1. Natural gas is combusted in a boiler. In addition, light hydrocarbons from the LNG plant are burned in a flare. The mass balance shown here represents the maximum emissions since the waste gas is burned in a flare. The composition and mass balance of the waste gas are calculated based on the gas composition and natural gas to LNG yield provided by PSE. The carbon balance shows the mass, energy content and carbon in the natural gas to the facility. Thus, the carbon in the fuel gas is determined by difference and is also consistent with the process design reported by PSE.

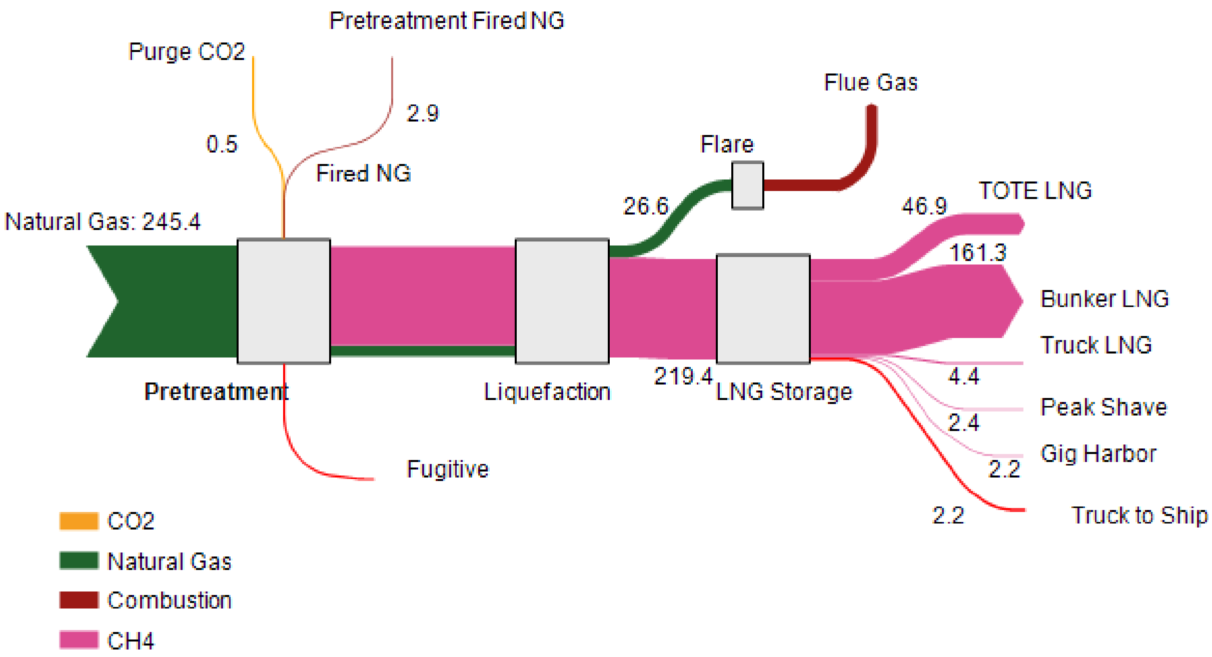


**Figure 3.1.** Carbon Balance for Tacoma LNG Plant k tonne C/year)
*Source:* Appendix A.2, 60 hours peak shaving

Figure 3.1 also shows the distribution of LNG among end use applications. The most significant uses are as marine fuel for TOTE vessels or other marine applications. Note that the peak shaving use may only occur for 10 years but the amount of LNG used is a small fraction of the overall use and presumably the LNG would be used for applications similar to the ones analyzed here. Table 3.11 summarizes the mass flow for the LNG production system. No LPG is produced and the incoming natural gas and products are based on information provided by PSE. Note that the carbon in is equal to the carbon exiting the LNG production system. The carbon balance reflects the configuration in Appendix A.2 with 60 hours per year of peak shaving.

**Table 3.11.** Carbon Mass Balance of LNG Plant Processes

| | Input/Output | | $CO_2$ | Methane | C content |
|---|---|---|---|---|---|
| | **lb/day** | **tonne/yr** | **tonne/yr** | **tonne/yr** | **tonne/yr** |
| <u>Input NG</u> | | | | | |
| Natural gas | 2,025,990 | 326,239 | | | **245,411** |
| **Total NG Input** | 2,025,990 | 326,239 | | | **245,411** |
| <u>Products</u> | - | | | | |
| LPG sold | 0 | 0 | | | **0** |
| LNG | 1,814,026 | 291,636 | | | **218,988** |
| **Total Products** | 1,814,026 | 291,636 | | | **218,988** |
| <u>Emissions</u> | - | | | | |
| Pretreatment | | | 10,716 | | **2,922** |
| $CO_2$ Separated (non-combustion) | | | 1,720 | | **469** |
| Flaring (combustion) | | | 54,696 | | **15,673** |
| Flaring from LPG (combustion) | | | 26,806 | | **7,289** |
| Fugitives $CH_4$ | | | | 7.56 | **6** |
| Vaporizing for peak shaving | | | 235 | | **64** |
| **Total Emissions** | | | 95,169 | 8 | **26,423** |
| **Total Product + Emissions** | | | 95,169 | 8 | **245,411** |
| **Total NG Input - Product + Emissions** | | | Mass Balance Closes | | **0** |

The carbon balance Figure 3.1 provides the basis for determining $CO_2$ emissions and validates the net waste gas that is flared. The energy inputs to the boiler, flare, and diesel equipment provides the basis for determining $CH_4$ and $N_2O$ emissions based on emission factors per mmBtu of combusted fuel in Appendix C.

### 3.2.4 Peak Shaving Vaporizer

Emissions from the vaporizer for peak shaving include fired and electric power. Energy consumption for the vaporizer corresponds to 66 mmBtu/h of fired fuel and 4.5 kWh of power 1000 gal of LNG. Table 3.12 shows the average annual GHG emissions from the operation of

**Table 3.12.** End Use Emissions from On-site Peak Shaving

| | | Average Annual Emissions (tonne/year) | | | |
|---|---|---|---|---|---|
| **Process** | **Equipment** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_2e$** |
| Vaporizer | Small Industrial NG Boiler | 234.9 | 0.004 | 0.001 | 235.4 |
| Vaporizer | Pump - power | 0.14 | 0.0003 | 0.000 | 0.15 |

## 3.3 Downstream Tacoma LNG End Use Emissions

LNG from the Tacoma facility will primarily deliver the LNG to marine vessels as marine fuel at the Tacoma port. LNG will also be vaporized and injected into the pipeline for use by PSE residential and commercial customers.

The following end use mix is assumed as input, based on an annual operation of 355 days of Tacoma LNG.

**Table 3.13.** LNG End Use Mix of Tacoma LNG Facility – 500,000 gal/yr Production

| LNG End use | Mgal/yr | GBtu/yr, LHV |
|---|---|---|
| Peak Shaving | 1.96 | 151 |
| Gig Harbor LNG | 1.78 | 137 |
| On-road Trucking | 3.55 | 274 |
| TOTE Marine | 37.93 | 2,927 |
| Truck-to-Ship Bunkering | 1.78 | 137 |
| Other Marine (by Bunker Barge) | 130.61 | 10,070 |
| Total LNG | 177.5 | 13,695 |

PSE Indicated that peak shaving would occur for 10 years. The values here show the average over 40 years or 1/4 of the level for the first 10 years. After 10 years of peak shaving, LNG would be used for other marine fuel.

**Table 3.14.** Tacoma LNG End Use Emissions –500,000 gal/yr Production

| | | Emissions (tonne/year) | | | |
|---|---|---|---|---|---|
| **LNG Project** | **Equipment Type** | **$CO_2c$** | **$CH_4$** | **$N_2O$** | **$CO_2e$** |
| Peak Shaving | | | | | |
| LNG | NG Combustion | 8,859 | 0.2 | 0.1 | 8,879 |
| Gig Harbor Delivery | | | | | |
| LNG | Truck Engine | 4 | 0 | 0 | 4 |
| LNG End Use | NG Boiler | 8,037 | 0.1 | 0.05 | 8,055 |
| On-road Trucking | | | | | |
| LNG | Truck Engine | 15,738 | 85 | 0.01 | 17,862 |
| TOTE Marine | | | | | |
| LNG | Marine Engine | 166,648 | 1,865 | 11 | 216,545 |
| Pilot fuel | Marine Engine | 6,859 | 0.1 | 0.3 | 6,954 |
| Truck-to-Ship Bunkering | | | | | |
| LNG | Marine Engine | 7,798 | 87.3 | 0.5 | 10,133 |
| Pilot fuel | Marine Engine | 321 | 0 | 0 | 356 |
| Diesel Truck | Truck Engine | Assumed same for no action alternative | | | |
| Other Marine (by Bunker Barge) | | | | | |
| LNG | Marine Engine | 571,889 | 6,401 | 37.6 | 743,122 |
| Pilot fuel | Marine Engine | 23,540 | 0.1 | 0.3 | 23,635 |
| **Total End Use** | | **809,695** | **8,438** | **50** | **1,035,514** |

## 3.3.1 Gig Harbor LNG

LNG shipped to Gig Harbor will displace LNG from Fortis, British Columbia. The primary effect will be a difference in transport distance. The life cycle analysis of the Fortis facility was assumed to be the same as that for Tacoma LNG.

**Table 3.15.** Inputs and Calculation for End Use Emissions from Gig Harbor Transport

| General inputs | | |
|---|---|---|
| Total LNG delivery to Gig Harbor per year | 1,775,000 | Gal |
| Truck capacity | 10,000 | Gal |
| Number of trips | 177.5 | |

| Calculation of annual Diesel Truck Consumption | LNG Project | |
|---|---|---|
| Distance to Gig Harbor | 17 | miles/trip |
| Annual miles for delivery | 3,018 | miles/year |
| Diesel consumption per mile | 17,738 | Btu/mile |
| **Total Diesel Consumption** | **53.52** | **mmBtu/year** |

**Table 3.16.** End Use Emissions from Gig Harbor LNG Delivery

| | Diesel Consumption | Emissions (t/year) | | | |
|---|---|---|---|---|---|
| **Processing Step** | **mmBtu/year** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_{2e}$** |
| LNG Project | 53.5 | 4.18 | 0.00023 | 0.00003 | 4.2 |

### 3.3.2 On-road Trucking

Energy inputs and emission for trucking are shown below. $CO_2$ emissions include all of the carbon in the fuel including CO and VOC emissions.

**Table 3-17.** LNG Consumption from On-road Trucking

| | | Consumption | |
|---|---|---|---|
| | **Equipment** | **Mgal/year** | **GBtu/year** |
| LNG | Tractor engine | 3.55 | 274 |

**Table 3.18.** End Use Emissions from LNG On-Road Trucking

| | Consumption | Emissions (t/year) | | | |
|---|---|---|---|---|---|
| **Processing Step** | **mmBtu/year** | **$CO_2c$** | **$CH_4$** | **$N_2O$** | **$CO_{2e}$** |
| LNG Project - LNG Tractor | 273,902 | 15,738 | 84.85 | 0.01 | 17,862 |
| Diesel tractor | 246,512 | 19,274 | 1.17 | 0.04 | 19,316 |

### 3.3.3 Marine Vessel LNG Consumption

Based on the described modeling in Section 2.4.5, the emissions rates for TOTE and other marine vessels are calculated from fuel use and the emission factors in Appendix C.

# 4. DISPLACED EMISSIONS

The use of LNG as marine vessel and truck fuel as well as peak shaving primarily replaces the use of the following fuels:

1. MGO
2. On-road diesel fuel
3. Pipeline natural gas during periods of peak shaving

Fuel use that would represent the alternative use of LNG is calculated based on the energy consumed and the Energy Economy Ratios (EER) values in Table 4.1.

For ships operating outside designated Emission Control Areas (ECA) IMO has set a limit for sulfur in fuel oil used on board ships of 0.50% m/m (mass by mass) from 1 January 2020. The current global limit for sulfur content of ships' fuel oil is 3.50% m/m (mass by mass). Sulphur Emission Control Areas (SECAs), or Emission Control Areas (ECAs), are sea areas in which stricter controls were established to minimize airborne emissions from ships as defined by Annex VI[1] of the 1997 MARPOL Protocol. Current limits for sulfur content in these areas is 1000 ppm wt (0.1% m/m).

Several options are available to comply with the new limits, including MGO. These include LNG, heavy fuel oil operation with scrubbers, or the production of low sulfur fuel oil. Since marine gas oil is more expensive than heavy fuel oil, scrubbers have received attention over the last years and the number of scrubbers installed onboard of ships has increased.

Scrubbers reduce the emission of sulfur to the atmosphere by more than 90%. Also PM emissions, in terms of mass not number, are reduced significantly, by 60-90%. The emission of NOx is reduced by 10% or less. Due to the additional power needed to drive pumps and caustic soda consumption, the estimated additional GHG emissions range between 1.5 and 3.5%, including caustic soda consumption for the latter figure. It should be noted, however, that also the use of additional MGO in the SECA causes an increase of GHG refinery emissions by roughly 6.5%.

The use of scrubbers increases the fuel consumption by 3 % in case of seawater scrubber and by 1% in case of freshwater scrubber (Boer & Hoen, 2015; Yang et al., 2017). Based on the above mentioned state of the art in reducing the sulfur content in MGO an energy efficiency ratio of 1.015 for marine vessels using MGO compared to ships using LNG as fuel was examined in the sensitivity analysis in Section 5. The Baseline scenario assumes an EER of 1.0 for marine fuel displacement.

### *EER of On-Road Trucking*

The EER for on-road trucking for LNG displacing diesel is 0.9, which is based on the value analyzed by the California Air Resources Board for the Low Carbon Fuel Standard. The EER corresponds to spark-ignited LNG engines displacing more efficient diesel engines. For spark-ignited LNG engines displacing spark-ignited gasoline engines or for diesel pilot injected LNG engines displacing diesel engines, the EER would be 1.0 but the prior comparison is more common for commercial trucking applications.

**Table 4.1.** Fuel Consumption and Applied Energy Economy Ratios (EERs) for Scenario B

| | | Consumption | | | |
|---|---|---|---|---|---|
| **LNG End Use** | **Equipment Type** | **Mgal/yr** | **GBtu, LHV/yr** | **EER** | **Btu/gal** |
| Peak Shaving | | | | | |
| LNG | NG Boiler | 1.96 | 151 | 1 | 77,156 |
| Displaced NG | NG Boiler | 1.96 | 151 | | 984 Btu/scf |
| Gig Harbor LNG | | - | | | |
| LNG | NG Boiler | 1.78 | 137 | 1 | 77,156 |
| LNG | NG Boiler | 1.78 | 137 | | 77,156 |
| On-road Trucking | | - | | | |
| LNG | Truck Engine | 3.55 | 274 | 0.9 | 77,156 |
| Diesel | Truck Engine | 1.93 | 247 | | 127,464 |
| TOTE Marine | | - | | | |
| LNG | Marine Engine | 37.93 | 2,927 | 1 | 77,156 |
| Pilot diesel fuel for LNG | Marine Engine | 0.68 | 88 | 1 | 128,450 |
| Displaced MGO Fuel | Marine Engine | 23.47 | 3,014 | | 128,450 |
| Truck-to-Ship Bunkering | | | | | |
| LNG | Marine Engine | 1.78 | 137 | 1 | 77,156 |
| Pilot Fuel for LNG | Marine Engine | 0.03 | 4 | | 128,450 |
| Displaced MGO Fuel | Marine Engine | 1.10 | 141 | | 128,450 |
| Other Marine (by Bunker Barge) | | | | | |
| LNG | Marine Engine | 130.51 | 10,043 | 1 | 77,156 |
| Pilot Fuel for LNG | Marine Engine | 2.35 | 301 | 1 | 128,450 |
| Displaced MGO Fuel | Marine Engine | 80.53 | 10,345 | | 128,450 |
| Total LNG | | 177.5 | 13,669 | | |

EER: Energy Economy Ratio

In the case of not building Tacoma LNG total displaced end use emissions and corresponding upstream emissions would be as follows:

**Table 4.2.** Displaced Upstream and End Use Emission for Tacoma LNG Project for Scenario B

| | | Emissions (tonne/year) | | | |
|---|---|---|---|---|---|
| **NO LNG Project** | **Equipment Type** | **$CO_2c$** | **$CH_4$** | **$N_2O$** | **$CO_2e$** |
| Peak Shaving | | | | | |
| Natural Gas Upstream | | 1,045 | 23 | 0.01 | 1,631 |
| Natural Gas Use | NG Boiler | 8,954 | 0.2 | 0.1 | 8,973 |
| Gig harbor Delivery | | | | | |
| LNG | Truck Engine | 43 | 0.0 | 0.0 | 43 |
| LNG End Use | NG Boiler | 8,037 | 0.1 | 0.0 | 8,055 |
| On-road Trucking | | | | | |
| Diesel | Truck Engine | 19,274 | 1.2 | 0.0 | 19,316 |
| TOTE Marine | | | | | |
| MGO - Upstream | | 51,157 | 530.6 | 0.7 | 64,640 |
| MGO fuel | Marine Engine | 235,508 | 3.6 | 10.6 | 238,764 |
| Truck-to-Ship Bunkering | | | | | |
| MGO Fuel | Marine Engine | 11,021 | 0.2 | 0.5 | 11,173 |
| Other Marine (by Bunker Barge) | | | | | |
| MGO - Upstream | | 175,556 | 1,820.8 | 2.5 | 221,826 |
| MGO fuel | Marine Engine | 808,199 | 3.6 | 10.6 | 811,455 |
| **Total End Use** | | **1,317,748** | **2,360** | **25** | **1,384,245** |

[a] natural gas used to make LNG is counted as part of Tacoma LNG emissions. The natural gas displaced during peak shaving has slightly different direct emissions. Also, the upstream emissions of this natural gas are different than that of the Tacoma LNG Project.

# 5. Life Cycle Assessment

Net greenhouse gas emissions were evaluated for the two volumetric scenarios considered in this analysis. Scenario A corresponds to 250,000 gal per day of LNG production and Scenario B corresponds to 500,000 gal per day of production. Scenarios A and B both include the same amount of TOTE marine vessels and peak shaving. Additional fuel applications are included in Scenario B. The operational and displaced emissions are further broken out by upstream direct and downstream emissions.

### *Scenario B*

Scenario B includes the use of more LNG for marine applications where the LNG is transferred by bunkering barge. This LNG transfer results in potential fugitive emissions. This scenario results in the greatest GHG emissions from the project but since the LNG produced to displace petroleum fuels is also greater than that of Scenario A.

Table 5.1 shows the life cycle GHG emissions for Tacoma LNG for Scenario B which is consistent with the technical life expectancy for the Tacoma LNG facility. Emissions are grouped according to construction, operational, and end use emissions. Note that energy outputs from the facility displace another source of energy for the no action alternative, which is shown in Table 5.2.

**Table 5.1.** Life Cycle GHG Emissions for Tacoma LNG over 1 Year – Scenario B

| Life Cycle Step | Mgal/ year | GBtu/ year | GHG Emissions tonne/year |
|---|---|---|---|
| **NEW LNG PLANT** | | | |
| Construction Emissions | | | |
| **Total Construction** | | | **1,581** |
| Direct (Equipment) | | | 182 |
| Upstream Life Cycle (Equipment) | | | 20 |
| Upstream Life Cycle (Power) | | | 57 |
| Upstream Life Cycle (Material) | | | 1,322 |
| Operational Emissions | | | |
| **Upstream Life cycle** | | | **215,757** |
| Natural Gas | | | 164,117 |
| Power LNG production | | | 51,477 |
| Diesel Emergency | | | 143 |
| Power LNG Vaporizer -Peak Shaving | | | 19 |
| Gig harbor Diesel truck fuel | | | 1.2 |
| **Direct LNG Plant** | | | **113,281** |
| LNG Production | | | 97,813 |
| Vaporizer - Peak Shaving | | | 235 |
| Bunkering and Transfer $CH_4$ | | | 15,233 |
| **End Use LNG** | **177.50** | **13,695** | **1,035,497** |
| On-site Peak Shaving | 1.96 | 151 | 8,879 |
| Gig Harbor LNG | 1.78 | 137 | 8,041.5 |
| On-road Trucking | 3.55 | 274 | 17,862 |
| TOTE Marine | 37.93 | 2,927 | 216,545 |
| TOTE Marine Diesel Pilot fuel | | | 6,954 |
| Truck-to-Ship Bunkering | 1.78 | 137 | 10,133 |
| Truck-to-Ship Bunkering Pilot Fuel | | | 325 |
| Other Marine LNG (by Bunker Barge) | 130.51 | 10,070 | 743,122 |
| Other Marine Diesel Pilot Fuel | | | 23,635 |
| **Total Emissions (Tacoma LNG)** | | | **1,366,115** |

Fuel from the Tacoma LNG facility will be used in applications that either require low emissions or where natural gas is unavailable. The LNG will displace petroleum diesel, marine diesel, or other sources of LNG. The analysis is based on a 1:1 displacement, which assumes that the petroleum fuels are not used elsewhere and that the emissions reductions propagate throughout the life cycle of petroleum and effectively crude oil remains unused.

**Table 5.2.** Displaced Emissions over 1 Year – Scenario B

| Life Cycle Step | Mgal/ year | GBtu/ year | GHG Emissions tonne/year |
|---|---|---|---|
| Upstream Displaced Emissions | | | |
| **Total Upstream** | | | **298,719** |
| No Peak Shaving – Natural Gas | | 151 | 1,631 |
| Upstream Gig Harbor LNG | | 137 | 2,300 |
| Upstream On-road trucking | | 247 | 5,297 |
| Upstream TOTE MGO | | 3014 | 64,640 |
| Upstream Truck-to-Ship Bunkering | | 141 | 3,025 |
| Upstream Other Marine Diesel (by Bunker Barge) | | 10,345 | 221,826 |
| End Use Emissions | | | |
| **Total End Use Diesel /MGO/LNG** | **110** | **14,035** | **1,097,761** |
| Natural Gas for Commercial | 1.18[a] | 151 | 8,973 |
| Gig Harbor LNG | 1.78 | 137 | 8,080 |
| On-road trucking | 1.93 | 247 | 19,316 |
| TOTE MGO | 23.47 | 3,014 | 238,764 |
| Truck-to-Ship Bunkering | 1.10 | 141 | 11,173 |
| Other Marine Diesel (by Bunker Barge) | 80.53 | 10,345 | 811,455 |
| **Total Emission (No Action)** | | | **1,396,480** |
| **Net Emission reduction** | | | **-30,365** |
| in percentage | | | -2.17% |

[a] equivalent gallons of LNG

The displacement of LNG for each end use application is shown in Figure 5.1. The annual emissions are also shown for the major end use applications and aggregate upstream life cycle emissions.[22] The analysis shows the scenario with peak shaving for residential and commercial gas supply.[23] This end use application is expected to continue for 10 years and the LNG would presumably be used for other applications that displace petroleum fuels. For each end use application, GHG emissions of LNG plus pilot fuel are lower than those of the displaced petroleum product. This trend persists for all of the end use applications although the displacement of GHG emissions from LNG to petroleum varies with carbon content of the displaced fuel as well as the methane emissions that occur during combustion.

[22] The construction emissions, emergency equipment diesel plus upstream life cycle of power, fuels, and materials are aggregated together as "Construct Diesel Materials". LNG facility emissions include fuel combustion for pretreatment, flare, and peak shaving heater, and fugitive emissions from equipment. LNG fugitives for fuel loading include transfer to TOTE vessels, bunker barge, trucks as well as boil off loss during barge operation.

[23] Note that the total direct end use emissions for LNG are slightly lower than those of natural gas due to the properties of the fuels. The upstream emissions correspond to LNG and natural gas also.

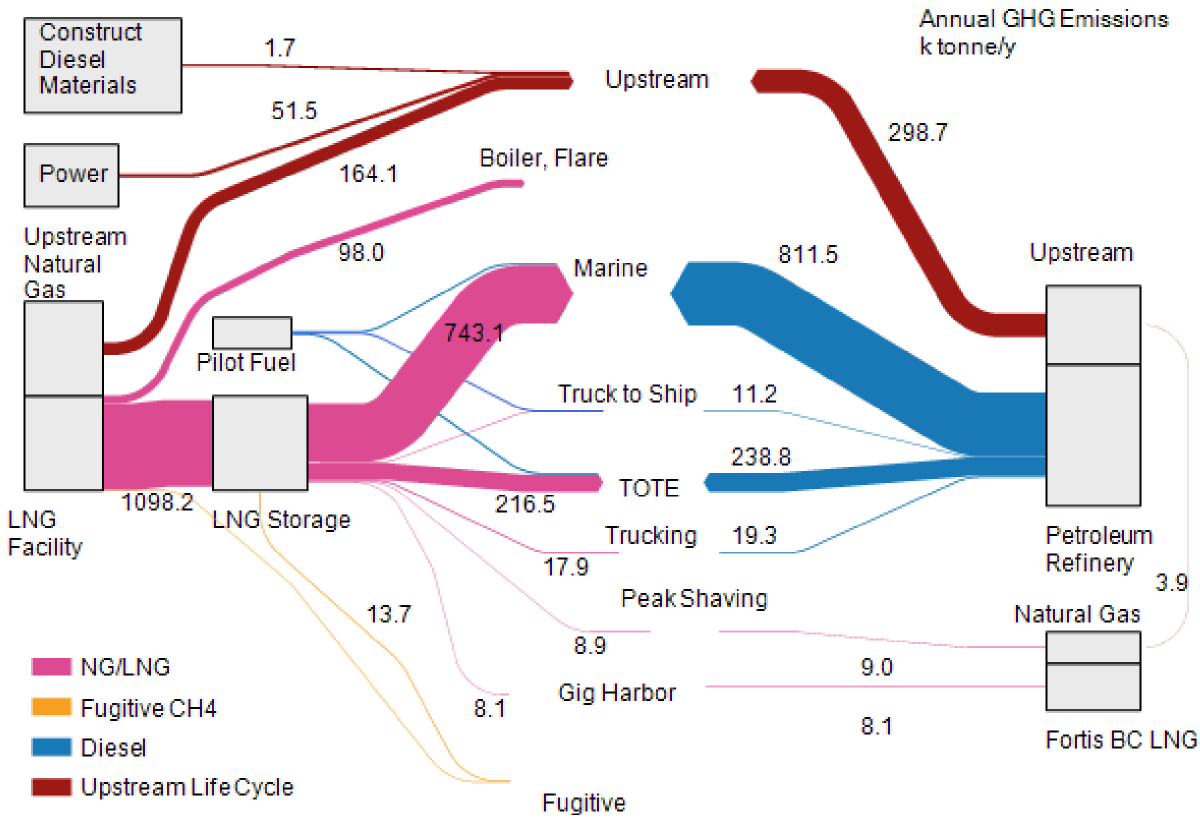


**Figure 5.1.** Direct and Upstream Life Cycle GHG Emissions from LNG and Displaced Fuel Applications for Scenario B
*Source:* Appendix A.2, 60 hours per year peak shaving

Net GHG emissions for each category are also shown in Figure 5.2. Note that the emissions from the LNG facility plus upstream emissions are higher than those for the no action alternative. However, the carbon content of LNG results in lower end use emissions; so, the net life cycle GHG emissions are reduced under most situations.

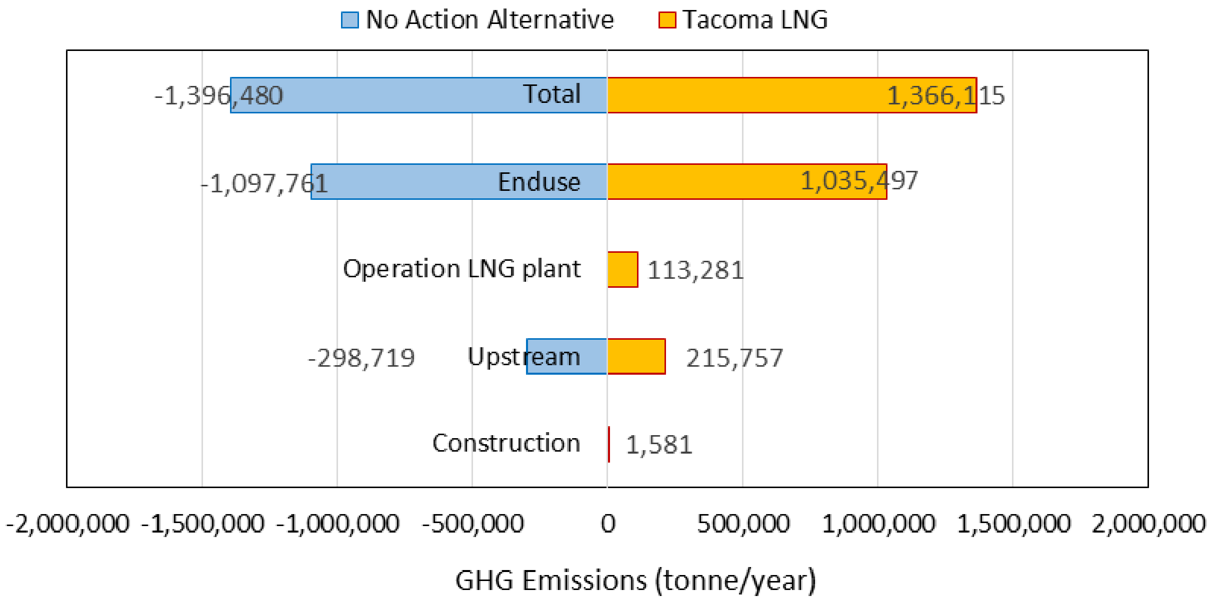


**Figure 5.2.** GHG Emissions from the Tacoma LNG Plant Compared to the No Action Alternative for Scenario B

### *Scenario A*

Scenario A includes the use of proportionately less LNG for marine applications where the LNG is transferred by bunkering barge. Scenario A is based on a smaller fuel volume than Scenario B.

Table 5.3 shows the life cycle GHG emissions for Tacoma LNG for Scenario A which is consistent with the technical life expectancy for the Tacoma LNG facility. Emissions are grouped according to construction, operational, and end use emissions. Emissions from the no action alternative are shown in Table 5.4.

**Table 5.3.** Life Cycle GHG Emissions for Tacoma LNG over 1 Year – Scenario A

| Life Cycle Step | Mgal/ year | GBtu/ year | GHG Emissions tonne/year |
|---|---|---|---|
| **NEW LNG PLANT** | | | |
| Construction Emissions | | | |
| **Total Construction** | | | **1,581** |
| Direct (Equipment) | | | 182 |
| Upstream Life Cycle (Equipment) | | | 20 |
| Upstream Life Cycle (Power) | | | 57 |
| Upstream Life Cycle (Material) | | | 1,322 |
| Operational Emissions | | | |
| **Upstream Life cycle** | | | **107,911** |
| Natural Gas | | | 82,010 |
| Power LNG production | | | 25,739 |
| Diesel Emergency | | | 143 |
| Power LNG Vaporizer -Peak Shaving | | | 19 |
| Gig harbor Diesel truck fuel | | | 0.0 |
| **Direct LNG Plant** | | | **54,522** |
| LNG Production | | | 48,855 |
| Vaporizer - Peak Shaving | | | 235 |
| Marine vessel bunkering $CH_4$ | | | 5,431 |
| **End Use LNG** | **88.75** | **6,848** | **519,501** |
| Peak Shaving | 1.96 | 151 | 8,879 |
| Gig Harbor LNG | 0.00 | 0 | 0.0 |
| On-road Trucking | 0.00 | 0 | 0 |
| TOTE Marine | 37.93 | 2,927 | 216,545 |
| TOTE Marine Diesel Pilot fuel | | | 6,954 |
| Truck-to-Ship Bunkering | 0.00 | 0 | 0 |
| Truck-to-Ship Bunkering Pilot Fuel | | | 0 |
| Other Marine LNG (by Bunker Barge) | 48.86 | 3,770 | 278,215 |
| Other Marine Diesel Pilot Fuel | | | 8,908 |
| **Total Emissions (Tacoma LNG)** | | | **683,514** |

**Table 5.4.** Displaced Emissions over 1 Year – Scenario A

| Life Cycle Step | Mgal/ year | GBtu/ year | GHG Emissions tonne/year |
|---|---|---|---|
| Upstream Displaced Emissions | | | |
| **Total Upstream** | | | **149,319** |
| Upstream Natural Gas | | 151 | 1,631 |
| Upstream Gig Harbor LNG | | 0 | 0 |
| Upstream On-road trucking | | 0 | 0 |
| Upstream TOTE MGO | | 3014 | 64,640 |
| Upstream Truck-to-Ship Bunkering | | 0 | 0 |
| Upstream Other Marine Diesel (by Bunker Barge) | | 3,873 | 83,049 |
| End Use Emissions | | | |
| **Total End Use Diesel /Fuel Oil/LNG** | **54.8** | **7,038** | **553,572** |
| Natural Gas for PSE customers | 1.18 | 151 | 8,973 |
| Gig Harbor LNG | 0 | 0 | 0 |
| On-road trucking | 0 | 0 | 0 |
| TOTE MGO | 23.47 | 3,014 | 238,764 |
| Truck-to-Ship Bunkering | 0 | 0 | 0 |
| Other Marine Diesel (by Bunker Barge) | 30.15 | 3,873 | 305,835 |
| **Total Emission (No Action)** | | | **702,891** |
| **Net Emission reduction** | | | **-19,377** |
| in percentage | | | -2.76% |

The displacement of LNG for each end use application is shown in Figure 5.3. The annual emissions are also shown for the major end use applications and aggregate upstream life cycle emissions. The analysis shows the effect of peak shaving over the average of the project life or ¼ of the annual peak shaving rate. This end use application is expected to continue for 10 years. Absent peak shaving, the LNG would presumably be used for other applications that displace petroleum fuels.

For each end petroleum use application except peak shaving, GHG emissions of LNG plus pilot fuel are lower than those of the displaced petroleum product. This trend persists for all of the end use applications although the displacement of GHG emissions from LNG to petroleum varies with carbon content of the displaced fuel as well as the methane emissions that occur during combustion.

Net GHG emissions for each category are also shown in Figure 5.4. Note that the emissions from the LNG facility plus upstream emissions are higher than those for the no action alternative. However, the carbon content of LNG results in lower end use emissions; so, the net life cycle GHG emissions are reduced under most situations.

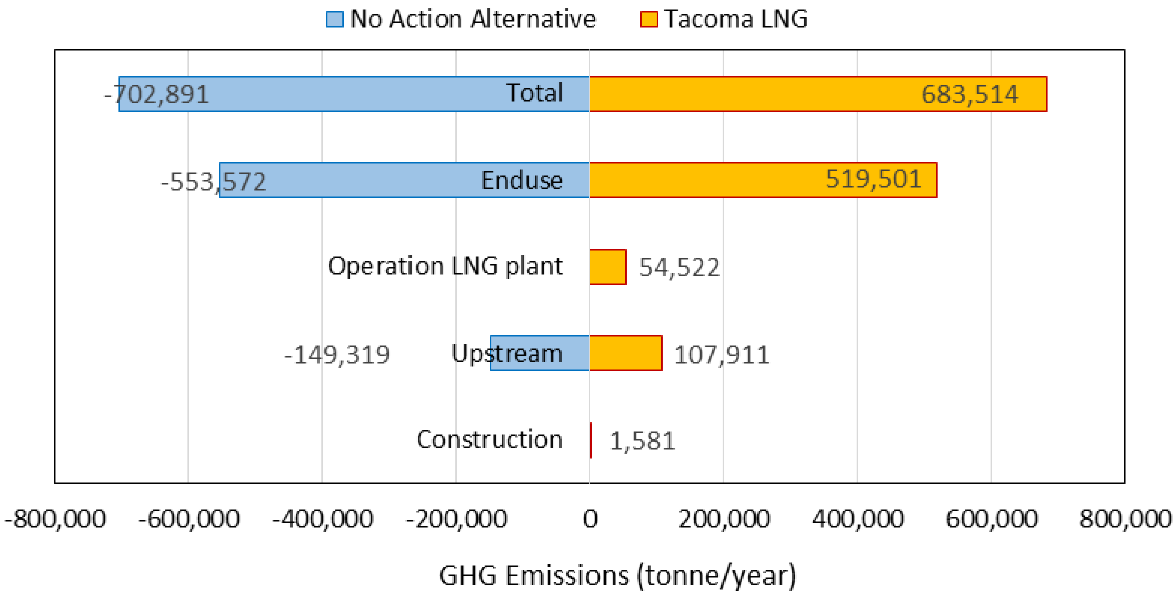


**Figure 5.3.** GHG Emissions from the Tacoma LNG Plant Compared to the No Action Alternative for Scenario A

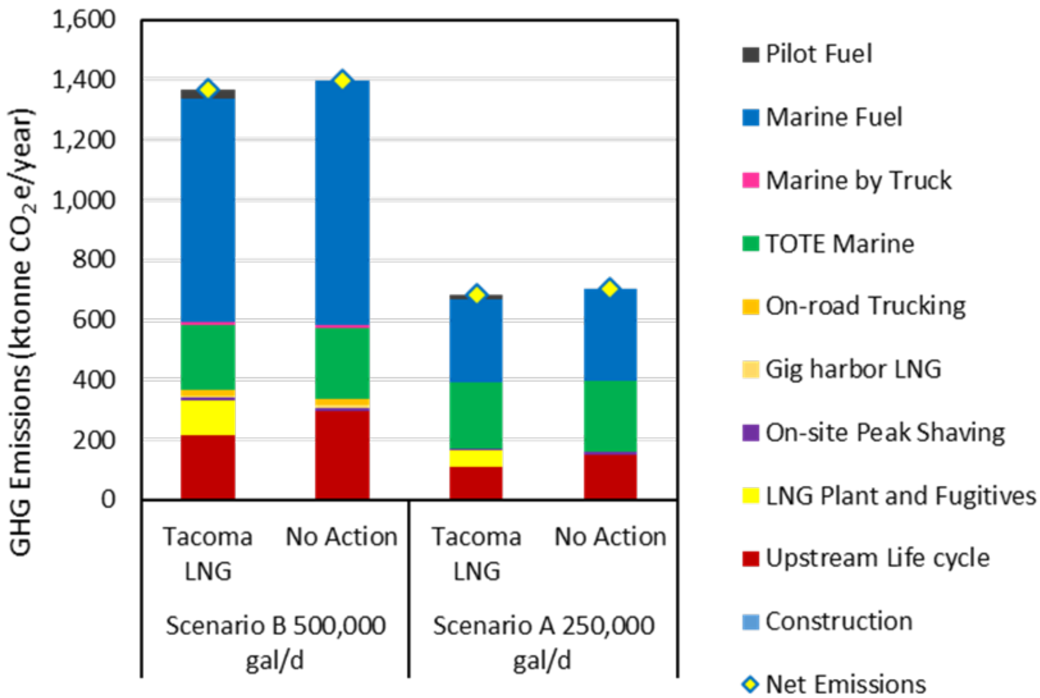


**Figure 5.4.** Range of GHG Emissions for Different Fuel Volume Scenarios

***Sensitivity Analysis***

Many factors affect the net life cycle GHG emissions as shown in Figure 5.5. The Baseline Scenario with 500,000 gal/day of LNG production is represented as a green line with the effect of different inputs illustrated. The effect of key inputs is also indicated to illustrate the effect on net GHG emissions.

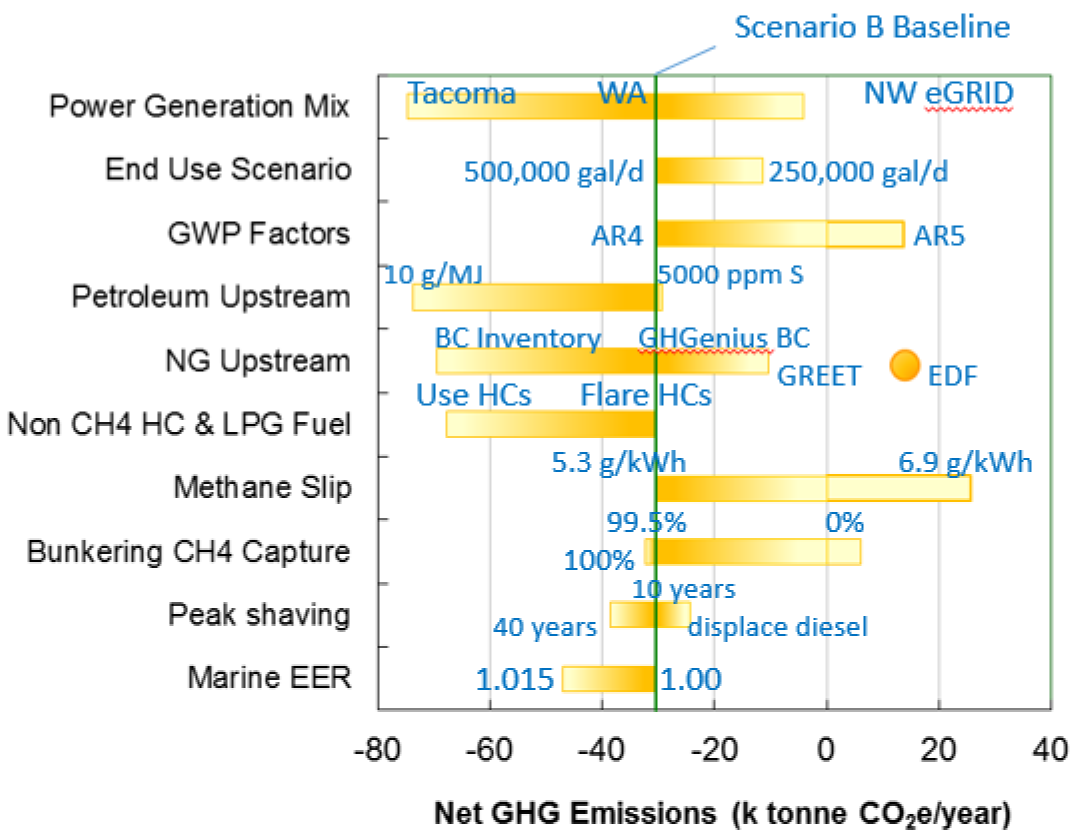


**Figure 5.5.** Sensitivity of Net GHG Emissions to Key Assumptions

Key parameters that net GHG emissions are shown in the figure. The facts that affect the range in emissions are described below.

Power generation mix and upstream of natural gas have a significant effect on the estimates of life cycle GHG emission for natural gas production and distribution. The effect of the eGRID Northwest region illustrates the effect of power generation mix on the upstream emission. However, this resource mix represents a very large geographical area and includes significant coal power generation. Since coal power is declining, such emissions are unlikely to be related to the Tacoma LNG project. The eGRID mix is more GHG intense than a marginal mix based on natural gas combined with the requirements of Washington's renewable portfolio standard.

Upstream emission estimates for natural gas also affect overall GHG emissions. The baseline estimate is based on the BC specific analysis from GHGenius. Emissions associated with specific components of the BC inventory result in a lower estimate and the U.S. emissions estimated by

GREET result in a higher estimate; though these extraction practices in BC are represented in GHGenius. The GWP values also effect the overall emissions due to the higher GWP in the AR5 compared to the AR4. The higher methane leak rate rates from different GHG estimates also result in a considerable range in GHG emissions.

The volumetric Scenario with 250,000 gal/day results in lower net GHG reductions than the 500,000 gal/day Scenario.

Variability in the upstream emissions associate with diesel and MGO refining results in significant range in the net emissions. The emissions in this study are based on the GREET model configured for the state of Washington. The upstream emissions for diesel refining are considerably lower than those in the California GREET model. The crude oil mix is customized to Washington state parameters. A GHG intensity of 10 g/MJ for crude oil refining (between this study and CA_GREET) is examined as a sensitivity. If the refining intensity of Washington MGO were as high as that in California, the net GHG emissions would be significantly lower. The effect of higher sulfur MGO is also shown assuming the energy required to produce hydrogen to hydrotreat the fuel.

The analysis was based on flaring non methane hydrocarbons, although these could be used for process fuel or LPG. The use of waste gas is a significant potential GHG savings.

Since peak shaving is projected to occur for 10 years, the effect over the life of the project is relatively small. Peak shaving results in higher GHG emissions since the LNG must first be produced before injection into the pipeline and light hydrocarbons are flared as part of the process.

The effect of marine fuel parameters is also shown including the effect of capturing $CH_4$ from bunkering barges and the relative efficiency of LNG compared to marine fuel with emission controls or sulfur removal.

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# A. Appendix LCA-A: Calculation Approach

The following paragraphs summarize the generalized approach utilized to quantify construction emissions and emissions associated with operation of the plant. A description of evaporative emission estimation methods is also provided.

## A.1. Construction Emissions

Construction activities consist of development of the Tacoma LNG site, construction of equipment, and storage tanks. Construction activities would include operation of earth moving equipment, cranes, trucks, pile drivers, compressors, pumps, and other equipment. Employee commute traffic for construction workers would also generate GHG emissions.[24]

Construction emissions consist of diesel burned in construction equipment, imported power. Construction emissions also include emissions from power used and other sources of emissions generated in the production of the construction materials. Life cycle construction emissions were calculated based on the following:

$$\mathbf{G}_C = \Sigma(U_{DC} \times (\mathbf{EF}_D + \mathbf{E}_D)) + T + U_{eC} \times \mathbf{E}_e + \Sigma(U_m \times \mathbf{E}_m) \qquad (4)$$ [25]

Where:

$\mathbf{G}_C$ = Tacoma LNG Construction GHG emissions in total tonnes
$\Sigma$ refers to summation of inputs for each specific energy input or material input
$U_{DC}$ = Use rate for diesel fuel use for each type of equipment
$\mathbf{EF}_D$ = Emission factor for diesel equipment
$\mathbf{E}_D$ = WTT emission rate from diesel fuel
T = Construction employee commute emissions
$U_{eC}$ = Use rate for electric power used during constructions
$\mathbf{E}_e$ = WTT emission rate for imported electric power
$U_m$ = Use rate for materials used in construction
$\mathbf{E}_m$ = WTT emission rate for materials of construction

Emissions from diesel equipment are summed over the totally fuel use for each type of construction equipment. Similarly, emissions from construction materials are summed over all the materials used for the Tacoma LNG. Inputs, emission factors, and WTT emission data are described in Section 2.4 and the construction emission results are examined. WTT emission

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[24] It is unclear if employee transportation creates a new source of GHG emissions since the employees would be driving to work with or without construction of the PSEL. These emissions are calculated nonetheless.
[25] The nomenclature assumes appropriate unit conversions such as grams to tonnes or Btu to mmBtu. For example, gallons of diesel fuel use × Btu/gal diesel × (diesel equipment emission factor in g/mmBtu + upstream diesel emission factor from GREET in g/mmBtu) for each pollutant $CO_2$, $CH_4$, and $N_2O$. Similarly, for construction materials tons of steel × g/ton of steel.

rates for fuels are obtained from the GREET1_2017 model.[26] Upstream life cycle emission rates for materials or construction were obtained from the GREET2 model as well as the USLCI database (NREL, 2012) and other sources.

[26] The upstream life cycle emissions from natural gas and petroleum fuels are very similar in the newer GREET1_2018 model on a $CO_2$e basis when weighted with the AR4 GWP factors.

**Table A.1.** Equipment List with Technical Specifications used During Construction

| Equipment List | No. | Horsepower | Utilization | Load Factor |
|---|---|---|---|---|
| **Upland Construction (demo, soil, utilities)** | | | | |
| Cat 345 Backhoe 4 cy | 1 | 165 | 75% | 21% |
| 100 Ton Crawler Crane | 1 | 250 | 85% | 43% |
| 200 Ton Crawler Crane | 1 | 300 | 85% | 43% |
| 22 Ton Hydrocrane | 1 | 85 | 85% | 43% |
| 30 Ton Hydrocrane | 1 | 100 | 85% | 43% |
| Air Compressor | 2 | 55 | 100% | 43% |
| Cat Compactor | 2 | 65 | 85% | 59% |
| Cat D6 Dozer | 2 | 65 | 85% | 59% |
| Crew Truck, 3/4 ton | 2 | 250 | 85% | 59% |
| Dump Trucks 15 cy | 2 | 285 | 75% | 59% |
| Flatbed Truck (Matl. Handling) | 1 | 200 | 85% | 59% |
| Forklift, 8,000 lbs | 1 | 85 | 50% | 59% |
| Fuel Truck | 2 | 200 | 85% | 59% |
| Loader, Cat 966, 4 cy | 2 | 100 | 85% | 21% |
| Manlifts | 1 | 50 | 85% | 21% |
| *In-water Construction* | | | | |
| Forklift, 8,000 lbs | 2 | 65 | 75% | 59% |
| Air Compressor | 4 | 55 | 100% | 43% |
| Crane, 60 ton | 3 | 290 | 85% | 43% |
| Crew Truck, 3/4 ton | 3 | 250 | 25% | 59% |
| Diesel Pile Driver Hammer | 3 | 85 | 85% | 59% |
| Flatbed Truck (Matl. Handling) | 3 | 200 | 85% | 59% |
| Fuel Truck | 2 | 200 | 25% | 59% |
| Loader, Cat 966, 4 cy | 2 | 100 | 75% | 21% |
| Personnel Work Boat | 1 | 30 | 75% | 45% |
| Tug/Work Barge w/crane | 1 | 250 | 85% | 45% |
| *LNG Facility Construction* | | | | |
| Cat 345 Backhoe 4 cy | 1 | 165 | 85% | 21% |
| 100 Ton Crawler Crane | 2 | 250 | 85% | 43% |
| 200 Ton Crawler Crane | 3 | 300 | 85% | 43% |
| 22 Ton Hydrocrane | 4 | 85 | 85% | 43% |
| 30 Ton Hydrocrane | 3 | 100 | 85% | 43% |
| Air Compressor | 4 | 55 | 85% | 43% |
| Cat Compactor | 3 | 65 | 85% | 59% |
| Cat D6 Dozer | 3 | 65 | 85% | 59% |
| Concrete Pump | 3 | 150 | 85% | 43% |
| Crane, 60 ton | 1 | 290 | 50% | 43% |
| Crew Truck, 3/4 ton | 6 | 250 | 85% | 59% |
| Dump Trucks 15 cy | 1 | 285 | 75% | 59% |
| Flatbed Truck (Matl. Handling) | 3 | 200 | 85% | 59% |
| Forklift, 8,000 lbs | 3 | 85 | 50% | 59% |
| Fuel Truck | 3 | 200 | 85% | 59% |
| Loader, Cat 966, 4 cy | 3 | 100 | 85% | 21% |
| Manlifts | 6 | 50 | 85% | 21% |

**Table A.2.** Equipment List with Emission Factors

| Equipment List | Fuel Use Rate (gal/hr) | CO Emission Factor (g/hp-hr) | VOC Emission Factor (g/hp-hr) | $CO_2$ Emission Factor (g/hp-hr) | $CO_2$c Emission Factor (g/hp-hr) |
|---|---|---|---|---|---|
| **Upland Construction (demo, soil, utilities)** | | | | | |
| Cat 345 Backhoe 4 cy | 0.52 | 2.330 | 0.606 | 625 | 631 |
| 100 Ton Crawler Crane | 0.17 | 0.429 | 0.175 | 530 | 531 |
| 200 Ton Crawler Crane | 0.17 | 0.429 | 0.175 | 530 | 531 |
| 22 Ton Hydrocrane | 0.42 | 1.542 | 0.230 | 590 | 593 |
| 30 Ton Hydrocrane | 0.42 | 1.542 | 0.230 | 590 | 593 |
| Air Compressor | 1.02 | 0.908 | 0.207 | 590 | 592 |
| Cat Compactor | 0.73 | 2.408 | 0.280 | 595 | 600 |
| Cat D6 Dozer | 0.49 | 1.769 | 0.192 | 596 | 599 |
| Crew Truck, 3/4 ton | 0.07 | 0.203 | 0.137 | 536 | 537 |
| Dump Trucks 15 cy | 0.07 | 0.203 | 0.137 | 536 | 537 |
| Flatbed Truck (Matl. Handling) | 0.11 | 0.322 | 0.141 | 536 | 537 |
| Forklift, 8,000 lbs | 0.65 | 2.265 | 0.257 | 595 | 599 |
| Fuel Truck | 0.11 | 0.322 | 0.141 | 536 | 537 |
| Loader, Cat 966, 4 cy | 0.65 | 5.288 | 0.839 | 693 | 704 |
| Manlifts | 3.66 | 5.873 | 1.516 | 691 | 705 |
| *In-water Construction* | | | | | |
| Forklift, 8,000 lbs | 0.65 | 2.265 | 0.257 | 595 | 599 |
| Air Compressor | 1.02 | 0.908 | 0.207 | 590 | 592 |
| Crane, 60 ton | 0.17 | 0.429 | 0.175 | 530 | 531 |
| Crew Truck, 3/4 ton | 0.07 | 0.203 | 0.137 | 536 | 537 |
| Diesel Pile Driver Hammer | 0.73 | 2.408 | 0.280 | 595 | 600 |
| Flatbed Truck (Matl. Handling) | 0.11 | 0.322 | 0.141 | 536 | 537 |
| Fuel Truck | 0.11 | 0.322 | 0.141 | 536 | 537 |
| Loader, Cat 966, 4 cy | 0.65 | 5.288 | 0.839 | 693 | 704 |
| Personnel Work Boat | 3.90 | 3.728 | 0.224 | 515 | 521 |
| Tug/Work Barge w/crane | 15.90 | 3.728 | 0.224 | 515 | 521 |
| *LNG Facility Construction (including Storage Tank)* | | | | | |
| Cat 345 Backhoe 4 cy | 0.52 | 2.330 | 0.606 | 625 | 631 |
| 100 Ton Crawler Crane | 0.17 | 0.429 | 0.175 | 530 | 531 |
| 200 Ton Crawler Crane | 0.17 | 0.429 | 0.175 | 530 | 531 |
| 22 Ton Hydrocrane | 0.42 | 1.542 | 0.230 | 590 | 593 |
| 30 Ton Hydrocrane | 0.42 | 1.542 | 0.230 | 590 | 593 |
| Air Compressor | 1.02 | 0.908 | 0.207 | 590 | 592 |
| Cat Compactor | 0.73 | 2.408 | 0.280 | 595 | 600 |
| Cat D6 Dozer | 0.49 | 1.769 | 0.192 | 596 | 599 |
| Concrete Pump | 1.06 | 2.355 | 0.473 | 589 | 594 |
| Crane, 60 ton | 0.17 | 0.429 | 0.175 | 530 | 531 |
| Crew Truck, 3/4 ton | 0.07 | 0.203 | 0.137 | 536 | 537 |
| Dump Trucks 15 cy | 0.07 | 0.203 | 0.137 | 536 | 537 |
| Flatbed Truck (Matl. Handling) | 0.11 | 0.322 | 0.141 | 536 | 537 |
| Forklift, 8,000 lbs | 0.65 | 2.265 | 0.257 | 595 | 599 |
| Fuel Truck | 0.11 | 0.322 | 0.141 | 536 | 537 |
| Loader, Cat 966, 4 cy | 0.65 | 5.288 | 0.839 | 693 | 704 |
| Manlifts | 3.66 | 5.873 | 1.516 | 691 | 705 |

## **Table A.3.** Construction Emissions during 1. Year

| Construction Emission during 1. Year | | | | | | | | | | | | | | | | | | Upstream Emission Diesel production | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment List | No. | Equipment Use Duration (months) | Horsepower | Utilization | Load Factor | Fuel Use Rate (gal/hr) | CO Emission Factor (g/hp-hr) | VOC Emission Factor (g/hp-hr) | $CO_2$ Emission Factor (g/hp-hr) | $CO_2$c Emission Factor (g/hp-hr) | $CH_4$ Emission Factor (g/gal) | $N_2O$ Emission Factor (g/gal) | CO2c (tonne/ year) | CH4 (tonne/ year) | N2O (tonne/ year) | CO2e use (tonne/ year) | Fuel consumption (mmBtu/year) | Upstream CO2 (tonne/ year) | Upstream CH4 (tonne/ year) | Upstream N2O (tonne/ year) | Upstream CO2e (tonne/ year) | Total CO2e (tonne/ year) |
| **Upland Construction (demo, soil, utilities)** | | | | | | | | | | | | | | | | | | | | | | |
| Cat 345 Backhoe 4 cy | 1 | 6 | 165 | 75% | 21% | 0.52 | 2.600 | 0.664 | 624 | 630 | 0.740 | 0.450 | 20 | 0.0004 | 0.0002 | 20.3 | 82 | 1.7156 | 0.0017 | 0.00001 | 1.7624 | 22.0 |
| 100 Ton Crawler Crane | 1 | 6 | 250 | 85% | 43% | 0.17 | 0.491 | 0.188 | 530 | 531 | 0.740 | 0.450 | 60 | 0.0001 | 0.0001 | 59.9 | 28 | 0.5763 | 0.0006 | 0.00000 | 0.5920 | 60.5 |
| 200 Ton Crawler Crane | 1 | 6 | 300 | 85% | 43% | 0.17 | 0.491 | 0.188 | 530 | 531 | 0.740 | 0.450 | 72 | 0.0001 | 0.0001 | 71.8 | 28 | 0.5763 | 0.0006 | 0.00000 | 0.5920 | 72.4 |
| 22 Ton Hydrocrane | 1 | 6 | 85 | 85% | 43% | 0.42 | 1.733 | 0.255 | 590 | 594 | 0.740 | 0.450 | 23 | 0.0003 | 0.0002 | 22.8 | 67 | 1.3976 | 0.0014 | 0.00001 | 1.4358 | 24.2 |
| 30 Ton Hydrocrane | 1 | 6 | 100 | 85% | 43% | 0.42 | 1.733 | 0.255 | 590 | 594 | 0.740 | 0.450 | 27 | 0.0003 | 0.0002 | 26.8 | 67 | 1.3976 | 0.0014 | 0.00001 | 1.4358 | 28.2 |
| Air Compressor | 2 | 6 | 55 | 100% | 43% | 1.02 | 1.090 | 0.227 | 590 | 592 | 0.740 | 0.450 | 35 | 0.0019 | 0.0011 | 34.9 | 323 | 6.7564 | 0.0068 | 0.00005 | 6.9407 | 41.9 |
| Cat Compactor | 2 | 6 | 65 | 85% | 59% | 0.73 | 2.600 | 0.664 | 595 | 601 | 0.740 | 0.450 | 48 | 0.0011 | 0.0007 | 48.5 | 232 | 4.8487 | 0.0049 | 0.00003 | 4.9810 | 53.5 |
| Cat D6 Dozer | 2 | 6 | 65 | 85% | 59% | 0.49 | 2.663 | 0.309 | 595 | 600 | 0.740 | 0.450 | 48 | 0.0008 | 0.0005 | 48.4 | 155 | 3.2391 | 0.0033 | 0.00002 | 3.3275 | 51.7 |
| Crew Truck, 3/4 ton | 2 | 6 | 250 | 85% | 59% | 0.07 | 2.090 | 0.216 | 536 | 540 | 0.740 | 0.450 | 167 | 0.0001 | 0.0001 | 166.9 | 23 | 0.4902 | 0.0005 | 0.00000 | 0.5035 | 167.4 |
| Dump Trucks 15 cy | 2 | 6 | 285 | 75% | 59% | 0.07 | 0.274 | 0.141 | 536 | 537 | 0.740 | 0.450 | 167 | 0.0001 | 0.0001 | 166.9 | 23 | 0.4902 | 0.0005 | 0.00000 | 0.5035 | 167.4 |
| Flatbed Truck (Matl. Handling) | 1 | 6 | 200 | 85% | 59% | 0.11 | 0.519 | 0.150 | 536 | 537 | 0.740 | 0.450 | 66 | 0.0001 | 0.0001 | 66.4 | 18 | 0.3709 | 0.0004 | 0.00000 | 0.3811 | 66.8 |
| Forklift, 8,000 lbs | 1 | 6 | 85 | 50% | 59% | 0.65 | 2.535 | 0.284 | 595 | 600 | 0.740 | 0.450 | 19 | 0.0003 | 0.0002 | 18.6 | 103 | 2.1627 | 0.0022 | 0.00001 | 2.2217 | 20.8 |
| Fuel Truck | 2 | 6 | 200 | 85% | 59% | 0.11 | 0.519 | 0.150 | 536 | 537 | 0.740 | 0.450 | 133 | 0.0002 | 0.0001 | 132.9 | 35 | 0.7419 | 0.0007 | 0.00001 | 0.7621 | 133.7 |
| Loader, Cat 966, 4 cy | 2 | 6 | 100 | 85% | 21% | 0.65 | 5.700 | 0.924 | 693 | 705 | 0.740 | 0.450 | 31 | 0.0010 | 0.0006 | 31.2 | 205 | 4.2790 | 0.0043 | 0.00003 | 4.3958 | 35.6 |
| Manlifts | 1 | 6 | 50 | 85% | 21% | 3.66 | 6.316 | 1.643 | 691 | 706 | 0.740 | 0.450 | 8 | 0.0028 | 0.0017 | 8.4 | 580 | 12.1250 | 0.0122 | 0.00008 | 12.4559 | 20.8 |
| In-water Construction | | | | | | | | | | | | | | | | | | | | | | |
| Forklift, 8,000 lbs | 2 | 6 | 65 | 75% | 59% | 0.65 | 2.535 | 0.294 | 595 | 600 | 0.740 | 0.450 | 43 | 0.0009 | 0.0005 | 42.7 | 207 | 4.3254 | 0.0044 | 0.00003 | 4.4434 | 47.2 |
| Air Compressor | 4 | 6 | 55 | 100% | 43% | 1.02 | 1.090 | 0.181 | 590 | 592 | 0.740 | 0.450 | 69 | 0.0037 | 0.0023 | 69.8 | 646 | 13.5127 | 0.0136 | 0.00009 | 13.8814 | 83.7 |
| Crane, 60 ton | 3 | 6 | 290 | 85% | 43% | 0.17 | 0.491 | 0.098 | 530 | 531 | 0.740 | 0.450 | 208 | 0.0004 | 0.0002 | 208.2 | 83 | 1.7288 | 0.0017 | 0.00001 | 1.7760 | 210.0 |
| Crew Truck, 3/4 ton | 3 | 6 | 250 | 25% | 59% | 0.07 | 2.090 | 0.219 | 536 | 540 | 0.740 | 0.450 | 74 | 0.0001 | 0.0000 | 73.6 | 35 | 0.7353 | 0.0007 | 0.00001 | 0.7553 | 74.4 |
| Diesel Pile Driver Hammer | 3 | 6 | 85 | 85% | 59% | 0.73 | 2.663 | 0.327 | 595 | 600 | 0.740 | 0.450 | 95 | 0.0017 | 0.0010 | 95.0 | 348 | 7.2730 | 0.0073 | 0.00005 | 7.4715 | 102.4 |
| Flatbed Truck (Matl. Handling) | 3 | 6 | 200 | 85% | 59% | 0.11 | 0.519 | 0.121 | 536 | 537 | 0.740 | 0.450 | 199 | 0.0003 | 0.0002 | 199.3 | 53 | 1.1128 | 0.0011 | 0.00001 | 1.1432 | 200.4 |
| Fuel Truck | 2 | 6 | 200 | 25% | 59% | 0.11 | 0.519 | 0.121 | 536 | 537 | 0.740 | 0.450 | 39 | 0.0001 | 0.0000 | 39.1 | 35 | 0.7419 | 0.0007 | 0.00001 | 0.7621 | 39.8 |
| Loader, Cat 966, 4 cy | 2 | 6 | 100 | 75% | 21% | 0.65 | 5.700 | 0.832 | 693 | 705 | 0.740 | 0.450 | 27 | 0.0009 | 0.0005 | 27.5 | 205 | 4.2790 | 0.0043 | 0.00003 | 4.3958 | 31.9 |
| Personnel Work Boat | 1 | 4.99 | 30 | 75% | 45% | 3.90 | 3.728 | 0.298 | 515 | 521 | 0.020 | 0.090 | 5 | 0.0001 | 0.0003 | 5.5 | 513 | 10.7362 | 0.0108 | 0.00007 | 11.0291 | 16.5 |
| Tug/Work Barge w/crane | 1 | 1.04 | 500 | 85% | 45% | 31.80 | 3.728 | 0.224 | 515 | 521 | 0.020 | 0.090 | 21 | 0.0001 | 0.0005 | 21.5 | 876 | 18.3325 | 0.0185 | 0.00013 | 18.8328 | 40.4 |
| | | | | | | | | | | | | Annual To | 1,703 | 0.0178 | 0.0115 | 1707.1 | 4969 | 103.9 | 0.1 | 0.0 | 106.8 | 1,813.9 |

## **Table A.4.** Construction Emissions during 2. Year

| Construction Emission during 2. Year | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment List | No. | Equipment Use Duration (months) | Horsepower | Utilization | Load Factor | Fuel Use Rate (gal/hr) | CO Emission Factor (g/hp-hr) | VOC Emission Factor (g/hp-hr) | $CO_2$ Emission Factor (g/hp-hr) | $CO_2c$ Emission Factor (g/hp-hr) | $CH_4$ Emission Factor (g/gal) | $N_2O$ Emission Factor (g/gal) | $CO_2c$ (tonne/ year) | CH4 (tonne/ year) | N2O (tonne/ year) | CO2e use (tonne/ year) | Fuel consumption (mmBtu/year) | Upstream CO2 (tonne/ year) | Upstream CH4 (tonne/ year) | Upstream N2O (tonne/ year) | Upstream CO2e (tonne/ year) | Total CO2e (tonne/ year) |
| **Upland Construction (demo, soil, utilities)** | | | | | | | | | | | | | | | | | | | | | | |
| Cat 345 Backhoe 4 cy | 1 | 6 | 165 | 75% | 21% | 0.52 | 2.330 | 0.606 | 625 | 631 | 0.740 | 0.450 | 20.2 | 0.0004 | 0.0002 | 20.3 | 82 | 1.7222 | 0.0017 | 0.00001 | 1.7692 | 22.0 |
| 100 Ton Crawler Crane | 1 | 6 | 250 | 85% | 43% | 0.17 | 0.429 | 0.175 | 530 | 531 | 0.740 | 0.450 | 59.8 | 0.0001 | 0.0001 | 59.9 | 27 | 0.5630 | 0.0006 | 0.00000 | 0.5784 | 60.4 |
| 200 Ton Crawler Crane | 1 | 6 | 300 | 85% | 43% | 0.17 | 0.429 | 0.175 | 530 | 531 | 0.740 | 0.450 | 71.8 | 0.0001 | 0.0001 | 71.8 | 27 | 0.5630 | 0.0006 | 0.00000 | 0.5784 | 72.4 |
| 22 Ton Hydrocrane | 1 | 6 | 85 | 85% | 43% | 0.42 | 1.542 | 0.230 | 590 | 593 | 0.740 | 0.450 | 22.7 | 0.0003 | 0.0002 | 22.8 | 66 | 1.3910 | 0.0014 | 0.00001 | 1.4290 | 24.2 |
| 30 Ton Hydrocrane | 1 | 6 | 100 | 85% | 43% | 0.42 | 1.542 | 0.230 | 590 | 593 | 0.740 | 0.450 | 26.7 | 0.0003 | 0.0002 | 26.8 | 66 | 1.3910 | 0.0014 | 0.00001 | 1.4290 | 28.2 |
| Air Compressor | 2 | 6 | 55 | 100% | 43% | 1.02 | 0.908 | 0.207 | 590 | 592 | 0.740 | 0.450 | 34.5 | 0.0019 | 0.0011 | 34.9 | 323 | 6.7564 | 0.0068 | 0.00005 | 6.9407 | 41.8 |
| Cat Compactor | 2 | 6 | 65 | 85% | 59% | 0.73 | 2.408 | 0.280 | 595 | 600 | 0.740 | 0.450 | 48.2 | 0.0011 | 0.0007 | 48.4 | 231 | 4.8354 | 0.0049 | 0.00003 | 4.9674 | 53.4 |
| Cat D6 Dozer | 2 | 6 | 65 | 85% | 59% | 0.49 | 1.769 | 0.192 | 596 | 599 | 0.740 | 0.450 | 48.2 | 0.0008 | 0.0005 | 48.3 | 155 | 3.2457 | 0.0033 | 0.00002 | 3.3343 | 51.7 |
| Crew Truck, 3/4 ton | 2 | 6 | 250 | 85% | 59% | 0.07 | 0.203 | 0.137 | 536 | 537 | 0.740 | 0.450 | 165.9 | 0.0001 | 0.0001 | 165.9 | 22 | 0.4637 | 0.0005 | 0.00000 | 0.4763 | 166.4 |
| Dump Trucks 15 cy | 2 | 6 | 285 | 75% | 59% | 0.07 | 0.203 | 0.137 | 536 | 537 | 0.740 | 0.450 | 166.9 | 0.0001 | 0.0001 | 166.9 | 22 | 0.4637 | 0.0005 | 0.00000 | 0.4763 | 167.4 |
| Flatbed Truck (Matl. Handling) | 1 | 6 | 200 | 85% | 59% | 0.11 | 0.322 | 0.141 | 536 | 537 | 0.740 | 0.450 | 66.4 | 0.0001 | 0.0001 | 66.4 | 17 | 0.3643 | 0.0004 | 0.00000 | 0.3743 | 66.8 |
| Forklift, 8,000 lbs | 1 | 6 | 85 | 50% | 59% | 0.65 | 2.265 | 0.257 | 595 | 599 | 0.740 | 0.450 | 18.5 | 0.0003 | 0.0002 | 18.6 | 103 | 2.1528 | 0.0022 | 0.00001 | 2.2115 | 20.8 |
| Fuel Truck | 2 | 6 | 200 | 85% | 59% | 0.11 | 0.322 | 0.141 | 536 | 537 | 0.740 | 0.450 | 132.8 | 0.0002 | 0.0001 | 132.8 | 35 | 0.7286 | 0.0007 | 0.00001 | 0.7485 | 133.6 |
| Loader, Cat 966, 4 cy | 2 | 6 | 100 | 85% | 21% | 0.65 | 5.288 | 0.839 | 693 | 704 | 0.740 | 0.450 | 31.0 | 0.0010 | 0.0006 | 31.2 | 206 | 4.3055 | 0.0043 | 0.00003 | 4.4230 | 35.6 |
| Manlifts | 1 | 6 | 50 | 85% | 21% | 3.66 | 5.873 | 1.516 | 691 | 705 | 0.740 | 0.450 | 7.8 | 0.0028 | 0.0017 | 8.3 | 579 | 12.1217 | 0.0122 | 0.00008 | 12.4525 | 20.8 |
| *In-water Construction* | | | | | | | | | | | | | | | | | | | | | | |
| Forklift, 8,000 lbs | 2 | 1 | 65 | 75% | 59% | 0.65 | 2.265 | 0.257 | 595 | 599 | 0.740 | 0.450 | 7.1 | 0.0001 | 0.0001 | 7.1 | 34 | 0.7176 | 0.0007 | 0.00000 | 0.7372 | 7.9 |
| Air Compressor | 4 | 1 | 55 | 100% | 43% | 1.02 | 0.908 | 0.207 | 590 | 592 | 0.740 | 0.450 | 11.5 | 0.0006 | 0.0004 | 11.6 | 108 | 2.2521 | 0.0023 | 0.00002 | 2.3136 | 13.9 |
| Crane, 60 ton | 3 | 1 | 290 | 85% | 43% | 0.17 | 0.429 | 0.175 | 530 | 531 | 0.740 | 0.450 | 34.7 | 0.0001 | 0.0000 | 34.7 | 13 | 0.2815 | 0.0003 | 0.00000 | 0.2892 | 35.0 |
| Crew Truck, 3/4 ton | 3 | 1 | 250 | 25% | 59% | 0.07 | 0.203 | 0.137 | 536 | 537 | 0.740 | 0.450 | 12.2 | 0.0000 | 0.0000 | 12.2 | 6 | 0.1159 | 0.0001 | 0.00000 | 0.1191 | 12.3 |
| Diesel Pile Driver Hammer | 3 | 1 | 85 | 85% | 59% | 0.73 | 2.408 | 0.280 | 595 | 600 | 0.740 | 0.450 | 15.8 | 0.0003 | 0.0002 | 15.8 | 58 | 1.2089 | 0.0012 | 0.00001 | 1.2418 | 17.1 |
| Flatbed Truck (Matl. Handling) | 3 | 1 | 200 | 85% | 59% | 0.11 | 0.322 | 0.141 | 536 | 537 | 0.740 | 0.450 | 33.2 | 0.0000 | 0.0000 | 33.2 | 9 | 0.1822 | 0.0002 | 0.00000 | 0.1871 | 33.4 |
| Fuel Truck | 2 | 1 | 200 | 25% | 59% | 0.11 | 0.322 | 0.141 | 536 | 537 | 0.740 | 0.450 | 6.5 | 0.0000 | 0.0000 | 6.5 | 6 | 0.1214 | 0.0001 | 0.00000 | 0.1248 | 6.6 |
| Loader, Cat 966, 4 cy | 2 | 1 | 100 | 75% | 21% | 0.65 | 5.288 | 0.839 | 693 | 704 | 0.740 | 0.450 | 4.6 | 0.0001 | 0.0001 | 4.6 | 34 | 0.7176 | 0.0007 | 0.00000 | 0.7372 | 5.3 |
| Personnel Work Boat | 1 | 1 | 30 | 75% | 45% | 3.90 | 3.728 | 0.224 | 515 | 521 | 0.020 | 0.090 | 1.1 | 0.0000 | 0.0001 | 1.1 | 103 | 2.1528 | 0.0022 | 0.00001 | 2.2115 | 3.3 |
| Tug/Work Barge w/crane | 1 | 1 | 250 | 85% | 45% | 15.90 | 3.728 | 0.224 | 515 | 521 | 0.020 | 0.090 | 10.2 | 0.0001 | 0.0002 | 10.3 | 420 | 8.7767 | 0.0089 | 0.00006 | 9.0161 | 19.3 |
| *LNG Facility Construction (including Storage Tank)* | | | | | | | | | | | | | | | | | | | | | | |
| Cat 345 Backhoe 4 cy | 1 | 7 | 165 | 85% | 21% | 0.52 | 2.330 | 0.606 | 625 | 631 | 0.740 | 0.450 | 26.7 | 0.0005 | 0.0003 | 26.8 | 96 | 2.0092 | 0.0020 | 0.00001 | 2.0641 | 28.9 |
| 100 Ton Crawler Crane | 2 | 7 | 250 | 85% | 43% | 0.17 | 0.429 | 0.175 | 530 | 531 | 0.740 | 0.450 | 139.6 | 0.0003 | 0.0002 | 139.7 | 63 | 1.3137 | 0.0013 | 0.00001 | 1.3496 | 141.0 |
| 200 Ton Crawler Crane | 3 | 7 | 300 | 85% | 43% | 0.17 | 0.429 | 0.175 | 530 | 531 | 0.740 | 0.450 | 251.3 | 0.0005 | 0.0003 | 251.4 | 94 | 1.9706 | 0.0020 | 0.00001 | 2.0244 | 253.4 |
| 22 Ton Hydrocrane | 4 | 7 | 85 | 85% | 43% | 0.42 | 1.542 | 0.230 | 590 | 593 | 0.740 | 0.450 | 106.0 | 0.0015 | 0.0009 | 106.3 | 310 | 6.4914 | 0.0066 | 0.00004 | 6.6685 | 113.0 |
| 30 Ton Hydrocrane | 3 | 7 | 100 | 85% | 43% | 0.42 | 1.542 | 0.230 | 590 | 593 | 0.740 | 0.450 | 93.5 | 0.0011 | 0.0007 | 93.8 | 233 | 4.8686 | 0.0049 | 0.00003 | 5.0014 | 98.8 |
| Air Compressor | 4 | 7 | 55 | 85% | 43% | 1.02 | 0.908 | 0.207 | 590 | 592 | 0.740 | 0.450 | 68.5 | 0.0037 | 0.0022 | 69.2 | 754 | 15.7649 | 0.0159 | 0.00011 | 16.1950 | 85.4 |
| Cat Compactor | 3 | 7 | 65 | 85% | 59% | 0.73 | 2.408 | 0.280 | 595 | 600 | 0.740 | 0.450 | 84.3 | 0.0020 | 0.0012 | 84.7 | 405 | 8.4620 | 0.0085 | 0.00006 | 8.6929 | 93.4 |
| Cat D6 Dozer | 3 | 7 | 65 | 85% | 59% | 0.49 | 1.769 | 0.192 | 596 | 599 | 0.740 | 0.450 | 84.3 | 0.0013 | 0.0008 | 84.6 | 272 | 5.6800 | 0.0057 | 0.00004 | 5.8350 | 90.4 |
| Concrete Pump | 3 | 7 | 150 | 85% | 43% | 1.06 | 2.355 | 0.473 | 589 | 594 | 0.74 | 0.450 | 140.5 | 0.0029 | 0.0017 | 141.1 | 587 | 12.2873 | 0.0124 | 0.00008 | 12.6226 | 153.8 |
| Crane, 60 ton | 1 | 7 | 290 | 50% | 43% | 0.17 | 0.429 | 0.175 | 530 | 531 | 0.740 | 0.450 | 47.6 | 0.0001 | 0.0001 | 47.7 | 31 | 0.6569 | 0.0007 | 0.00000 | 0.6748 | 48.3 |
| Crew Truck, 3/4 ton | 6 | 7 | 250 | 85% | 59% | 0.07 | 0.203 | 0.137 | 536 | 537 | 0.740 | 0.450 | 580.6 | 0.0004 | 0.0002 | 580.7 | 78 | 1.6229 | 0.0016 | 0.00001 | 1.6671 | 582.4 |
| Dump Trucks 15 cy | 1 | 7 | 285 | 75% | 59% | 0.07 | 0.203 | 0.137 | 536 | 537 | 0.740 | 0.450 | 97.3 | 0.0001 | 0.0000 | 97.4 | 13 | 0.2705 | 0.0003 | 0.00000 | 0.2779 | 97.6 |
| Flatbed Truck (Matl. Handling) | 3 | 7 | 200 | 85% | 59% | 0.11 | 0.322 | 0.141 | 536 | 537 | 0.740 | 0.450 | 232.3 | 0.0003 | 0.0002 | 232.4 | 61 | 1.2751 | 0.0013 | 0.00001 | 1.3099 | 233.7 |
| Forklift, 8,000 lbs | 3 | 7 | 85 | 50% | 59% | 0.65 | 2.265 | 0.257 | 595 | 599 | 0.740 | 0.450 | 64.8 | 0.0010 | 0.0006 | 65.1 | 360 | 7.5347 | 0.0076 | 0.00005 | 7.7403 | 72.8 |
| Fuel Truck | 3 | 7 | 200 | 85% | 59% | 0.11 | 0.322 | 0.141 | 536 | 537 | 0.740 | 0.450 | 232.3 | 0.0003 | 0.0002 | 232.4 | 61 | 1.2751 | 0.0013 | 0.00001 | 1.3099 | 233.7 |
| Loader, Cat 966, 4 cy | 3 | 7 | 100 | 85% | 21% | 0.65 | 5.288 | 0.839 | 693 | 704 | 0.740 | 0.450 | 54.2 | 0.0018 | 0.0011 | 54.6 | 360 | 7.5347 | 0.0076 | 0.00005 | 7.7403 | 62.3 |
| Manlifts | 6 | 7 | 50 | 85% | 21% | 3.66 | 5.873 | 1.516 | 691 | 705 | 0.740 | 0.450 | 54.3 | 0.0199 | 0.0121 | 58.4 | 4,056 | 84.8520 | 0.0856 | 0.00058 | 87.1673 | 145.6 |
| | | | | | | | | | | | | Annual To | 3,417 | 0.0486 | 0.0298 | 3427 | 10587.4376 | 221.4642 | 0.2235 | 0.0015 | 227.5070 | 3,654 |

## **Table A.5.** Construction Emissions during 3. Year

**Construction Emission during 3. Year**

| Equipment List | No. | Equipment Use Duration (months) | Horsepower | Utilization | Load Factor | Fuel Use Rate (gal/hr) | CO Emission Factor (g/hp-hr) | VOC Emission Factor (g/hp-hr) | CO2 Emission Factor (g/hp-hr) | CO2c Emission Factor (g/hp-hr) | $CH_4$ Emission Factor (g/gal) | $N_2O$ Emission Factor (g/gal) | CO2c (tonne/ year) | CH4 (tonne/ year) | N2O (tonne/ year) | CO2e use (tonne/ year) | Fuel consumption (mmBtu/year) | Upstream CO2 (tonne/ year) | Upstream CH4 (tonne/ year) | Upstream N2O (tonne/ year) | Upstream CO2e (tonne/ year) | Total CO2e (tonne/ year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LNG Facility Construction (no Storage Tank Construction)** | | | | | | | | | | | | | | | | | | | | | | |
| 100 Ton Crawler Crane | 2 | 12 | 250 | 85% | 43% | 0.17 | 0.371 | 0.166 | 531 | 532 | 0.740 | 0.450 | 240 | 0.0005 | 0.0003 | 239.8 | 110 | 2.3051 | 0.0023 | 0.00002 | 2.3680 | 242.2 |
| 200 Ton Crawler Crane | 2 | 12 | 300 | 85% | 43% | 0.17 | 0.371 | 0.166 | 531 | 532 | 0.740 | 0.450 | 288 | 0.0005 | 0.0003 | 287.8 | 110 | 2.3051 | 0.0023 | 0.00002 | 2.3680 | 290.2 |
| 22 Ton Hydrocrane | 3 | 12 | 85 | 85% | 43% | 0.42 | 1.359 | 0.208 | 590 | 593 | 0.740 | 0.450 | 136 | 0.0020 | 0.0012 | 136.6 | 401 | 8.3858 | 0.0085 | 0.00006 | 8.6147 | 145.2 |
| 30 Ton Hydrocrane | 2 | 12 | 100 | 85% | 43% | 0.42 | 1.359 | 0.208 | 590 | 593 | 0.740 | 0.450 | 107 | 0.0013 | 0.0008 | 107.1 | 267 | 5.5906 | 0.0056 | 0.00004 | 5.7431 | 112.8 |
| Air Compressor | 3 | 12 | 55 | 85% | 43% | 1.02 | 0.734 | 0.189 | 590 | 592 | 0.740 | 0.450 | 88 | 0.0047 | 0.0029 | 89.0 | 969 | 20.2691 | 0.0205 | 0.00014 | 20.8222 | 109.8 |
| Cat Compactor | 2 | 12 | 65 | 85% | 59% | 0.73 | 2.163 | 0.254 | 595 | 599 | 0.740 | 0.450 | 96 | 0.0023 | 0.0014 | 96.8 | 464 | 9.6974 | 0.0098 | 0.00007 | 9.9620 | 106.7 |
| Cat D6 Dozer | 2 | 12 | 65 | 85% | 59% | 0.49 | 1.503 | 0.177 | 596 | 599 | 0.740 | 0.450 | 96 | 0.0015 | 0.0009 | 96.6 | 310 | 6.4782 | 0.0065 | 0.00004 | 6.6549 | 103.2 |
| Concrete Pump | 2 | 12 | 150 | 85% | 43% | 1.06 | 2.214 | 0.445 | 589 | 594 | 0.740 | 0.450 | 161 | 0.0033 | 0.0020 | 161.2 | 670 | 14.0161 | 0.0141 | 0.00010 | 14.3986 | 175.6 |
| Crane, 60 ton | 1 | 12 | 290 | 50% | 43% | 0.17 | 0.371 | 0.166 | 531 | 532 | 0.740 | 0.450 | 82 | 0.0002 | 0.0001 | 81.8 | 55 | 1.1526 | 0.0012 | 0.00001 | 1.1840 | 83.0 |
| Crew Truck, 3/4 ton | 4 | 12 | 250 | 85% | 59% | 0.07 | 0.163 | 0.135 | 536 | 537 | 0.740 | 0.450 | 664 | 0.0005 | 0.0003 | 663.6 | 94 | 1.9607 | 0.0020 | 0.00001 | 2.0142 | 665.6 |
| Flatbed Truck (Matl. Handling) | 2 | 12 | 200 | 85% | 59% | 0.11 | 0.239 | 0.137 | 536 | 537 | 0.740 | 0.450 | 265 | 0.0003 | 0.0002 | 265.5 | 71 | 1.4838 | 0.0015 | 0.00001 | 1.5242 | 267.1 |
| Forklift, 8,000 lbs | 2 | 12 | 85 | 25% | 59% | 0.65 | 2.007 | 0.233 | 595 | 599 | 0.740 | 0.450 | 37 | 0.0006 | 0.0004 | 37.1 | 414 | 8.6508 | 0.0087 | 0.00006 | 8.8868 | 46.0 |
| Fuel Truck | 2 | 12 | 200 | 85% | 59% | 0.11 | 0.239 | 0.137 | 536 | 537 | 0.740 | 0.450 | 265 | 0.0003 | 0.0002 | 265.5 | 71 | 1.4838 | 0.0015 | 0.00001 | 1.5242 | 267.1 |
| Loader, Cat 966, 4 cy | 2 | 12 | 100 | 85% | 21% | 0.65 | 4.895 | 0.759 | 694 | 704 | 0.740 | 0.450 | 62 | 0.0020 | 0.0012 | 62.4 | 409 | 8.5581 | 0.0086 | 0.00006 | 8.7916 | 71.2 |
| Manlifts | 4 | 12 | 50 | 85% | 21% | 3.66 | 5.441 | 1.393 | 692 | 705 | 0.740 | 0.450 | 62 | 0.0227 | 0.0138 | 66.7 | 4,637 | 97.0002 | 0.0979 | 0.00067 | 99.6470 | 166.4 |
| | | | | | | | | | | | | Annual To | 2,649 | 0.0428 | 0.0260 | 2,658 | 9,052 | 189 | 0 | 0 | 195 | 2,852 |

## **Table A.6.** Construction Emissions during 4. Year

**Construction Emission during 4. Year**

| Equipment List | No. | Equipment Use Duration (months) | Horsepower | Utilization | Load Factor | Fuel Use Rate (gal/hr) | CO Emission Factor (g/hp-hr) | VOC Emission Factor (g/hp-hr) | CO2 Emission Factor (g/hp-hr) | CO2c Emission Factor (g/hp-hr) | $CH_4$ Emission Factor (g/gal) | $N_2O$ Emission Factor (g/gal) | CO2c (tonne/ year) | CH4 (tonne/ year) | N2O (tonne/ year) | CO2e use (tonne/ year) | Fuel consumption (mmBtu/year) | Upstream CO2 (tonne/ year) | Upstream CH4 (tonne/ year) | Upstream N2O (tonne/ year) | Upstream CO2e (tonne/ year) | Total CO2e (tonne/ year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LNG Facility Construction (no Storage Tank Construction)** | | | | | | | | | | | | | | | | | | | | | | |
| 100 Ton Crawler Crane | 2 | 7 | 250 | 85% | 43% | 0.17 | 0.317 | 0.159 | 531 | 532 | 0.740 | 0.450 | 140 | 0.0004 | 0.0002 | 139.9 | 64 | 1.3446 | 0.0014 | 0.00001 | 1.3813 | 141.3 |
| 200 Ton Crawler Crane | 2 | 7 | 300 | 85% | 43% | 0.17 | 0.317 | 0.159 | 531 | 532 | 0.740 | 0.450 | 168 | 0.0004 | 0.0002 | 167.8 | 64 | 1.3446 | 0.0014 | 0.00001 | 1.3813 | 169.2 |
| 22 Ton Hydrocrane | 3 | 7 | 85 | 85% | 43% | 0.42 | 1.183 | 0.188 | 590 | 592 | 0.740 | 0.450 | 79 | 0.0013 | 0.0008 | 79.7 | 234 | 4.8917 | 0.0049 | 0.00003 | 5.0252 | 84.7 |
| 30 Ton Hydrocrane | 2 | 7 | 100 | 85% | 43% | 0.42 | 1.183 | 0.188 | 590 | 592 | 0.740 | 0.450 | 62 | 0.0008 | 0.0005 | 62.5 | 156 | 3.2612 | 0.0033 | 0.00002 | 3.3501 | 65.8 |
| Air Compressor | 3 | 7 | 55 | 85% | 43% | 1.02 | 0.572 | 0.172 | 590 | 591 | 0.740 | 0.450 | 51 | 0.0031 | 0.0019 | 51.9 | 565 | 11.8236 | 0.0119 | 0.00008 | 12.1463 | 64.1 |
| Cat Compactor | 2 | 7 | 65 | 85% | 59% | 0.73 | 1.930 | 0.232 | 595 | 599 | 0.740 | 0.450 | 56 | 0.0015 | 0.0009 | 56.4 | 270 | 5.6568 | 0.0057 | 0.00004 | 5.8112 | 62.3 |
| Cat D6 Dozer | 2 | 7 | 65 | 85% | 59% | 0.49 | 1.257 | 0.164 | 596 | 598 | 0.740 | 0.450 | 56 | 0.0010 | 0.0006 | 56.3 | 181 | 3.7789 | 0.0038 | 0.00003 | 3.8820 | 60.2 |
| Concrete Pump | 2 | 7 | 150 | 85% | 43% | 1.06 | 2.078 | 0.417 | 589 | 594 | 0.740 | 0.450 | 94 | 0.0021 | 0.0013 | 94.0 | 391 | 8.1761 | 0.0083 | 0.00006 | 8.3992 | 102.4 |
| Crane, 60 ton | 1 | 7 | 290 | 50% | 43% | 0.17 | 0.317 | 0.159 | 531 | 532 | 0.740 | 0.450 | 48 | 0.0001 | 0.0001 | 47.7 | 32 | 0.6723 | 0.0007 | 0.00000 | 0.6907 | 48.4 |
| Crew Truck, 3/4 ton | 4 | 7 | 250 | 85% | 59% | 0.07 | 0.139 | 0.133 | 536 | 537 | 0.740 | 0.450 | 387 | 0.0003 | 0.0002 | 387.1 | 55 | 1.1437 | 0.0012 | 0.00001 | 1.1749 | 388.3 |
| Flatbed Truck (Matl. Handling) | 2 | 7 | 200 | 85% | 59% | 0.11 | 0.192 | 0.134 | 536 | 537 | 0.740 | 0.450 | 155 | 0.0002 | 0.0001 | 154.9 | 41 | 0.8655 | 0.0009 | 0.00001 | 0.8891 | 155.8 |
| Forklift, 8,000 lbs | 2 | 7 | 85 | 25% | 59% | 0.65 | 1.762 | 0.211 | 595 | 598 | 0.740 | 0.450 | 22 | 0.0004 | 0.0002 | 21.7 | 241 | 5.0463 | 0.0051 | 0.00003 | 5.1840 | 26.8 |
| Fuel Truck | 2 | 7 | 200 | 85% | 59% | 0.11 | 0.192 | 0.134 | 536 | 537 | 0.740 | 0.450 | 155 | 0.0002 | 0.0001 | 154.9 | 41 | 0.8655 | 0.0009 | 0.00001 | 0.8891 | 155.8 |
| Loader, Cat 966, 4 cy | 2 | 7 | 100 | 85% | 21% | 0.65 | 4.557 | 0.694 | 694 | 703 | 0.740 | 0.450 | 36 | 0.0013 | 0.0008 | 36.4 | 239 | 4.9922 | 0.0050 | 0.00003 | 5.1284 | 41.5 |
| Manlifts | 4 | 7 | 50 | 85% | 21% | 3.66 | 5.021 | 1.273 | 692 | 704 | 0.740 | 0.450 | 36 | 0.0150 | 0.0089 | 39.2 | 2,705 | 56.5835 | 0.0571 | 0.00039 | 58.1274 | 97.3 |
| | | | | | | | | | | | | Annual To | 1,545 | 0.0280 | 0.0168 | 1,550 | 5,280 | 110 | 0 | 0 | 113 | 1,664 |

Notes:
- Assume 48 hours per week; 4.28 weeks per month 205 hrs/month
- Emission factors for CO, VOC, and CO2 are average NONROAD emission rates for the State of Washington.
- Emission factors for CH4 and N2O are from the Climate Registry 2014 Default Emission Factors, Table 13.7.
- Tugboat, Workboat, and Personnel Boat Emissions factors from U.S. Environmental Protection Agency Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories Final Report April 2009, Table 3-8: Harbor Craft Emission Factors (g/kWh)

**Table A.7.** Road Vehicle Terminal Construction Criteria Pollutant Emissions for 1. and 2. Year of Construction

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Road Vehicle Terminal Construction Criteria Pollutant Emissions** | | | | | | | | | | | | | | | | | | |
| PSE LNG | | | | | | | | | | | | | | | | | | |
| Construction Vehicle Emissions - Winter 1. Year | | | | | | | | | | | | | | | | | | |
| Vehicle Class | Area From Which Workers Commute | VMT | $CO_2$ (g/VMT) | $CH_4$ (g/VMT) | $N_2O$ (g/VMT) | CO (g/VMT) | VOCs (g/VMT) | $CO_2c$ (g/VMT) | $CO_2$ (tonne/ year) | $CH_4$ (tonne/ year) | $N_2O$ (tonne/ year) | $CO_2e$ (tonne/ year) | Fuel consumption (mmBtu/ year) | Upstream $CO_2$ (tonne/ year) | Upstream $CH_4$ (tonne/ year) | Upstream $N_2O$ (tonne/ year) | Upstream $CO_2e$ (tonne/ year) | Total $CO_2e$ (tonne/ year) |
| Construction Workers Car | Seattle-Tacoma | 0 | 311.0 | 0.0 | 0.0 | 2.83 | 0.0 | 316 | 0.0 | 0.000 | 0.000 | 0.00 | 0.000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| Heavy Duty Delivery Trucks | | 38 | 1942.0 | 0.0 | 0.0 | 3.11 | 0.5 | 1,949 | 0.074 | 0.000 | 0.000 | 0.07 | 0.949 | 0.02300 | 0.00000 | 0.00000 | 0.02300 | 0.09710 |
| | | | | | | | | Total | 0.074 | 0.000 | 0.000 | 0.074 | 0.949 | 0.023 | 0.000 | 0.000 | 0.023 | 0.097 |
| Construction Vehicle Emissions - Summer 1. Year | | | | | | | | | | | | | | | | | | |
| Vehicle Class | Area From Which Workers Commute | VMT | $CO_2$ (g/VMT) | $CH_4$ (g/VMT) | $N_2O$ (g/VMT) | CO (g/VMT) | VOCs (g/VMT) | $CO_2c$ (g/VMT) | $CO_2$ (tonne/ year) | $CH_4$ (tonne/ year) | $N_2O$ (tonne/ year) | $CO_2e$ (tonne/ year) | Fuel consumption (mmBtu/ year) | Upstream $CO_2$ (tonne/ year) | Upstream $CH_4$ (tonne/ year) | Upstream $N_2O$ (tonne/ year) | Upstream $CO_2e$ (tonne/ year) | Total $CO_2e$ (tonne/ year) |
| Construction Workers Car | Seattle-Tacoma | 0 | 325.2 | 0.0 | 0.0 | 1.83 | 0.0 | 328 | 0.0 | 0.000 | 0.000 | 0.00 | 0.000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| Heavy Duty Delivery Trucks | | 1,225 | 2017.0 | 0.0 | 0.0 | 3.11 | 0.5 | 2,024 | 2.5 | 0.000 | 0.000 | 2.48 | 31.756 | 0.77011 | 0.00000 | 0.00000 | 0.77011 | 3.25051 |
| | | | | | | | | Total | 2.5 | 0.000 | 0.000 | 2.48 | 31.756 | 0.770 | 0.000 | 0.000 | 0.770 | 3.251 |
| | | | | | | | | **Annual Total** | **2.6** | **0.0** | **0.0** | **2.6** | **32.7** | **0.8** | **0.0** | **0.0** | **0.8** | **3.3** |
| Construction Vehicle Emissions - Winter 2. Year | | | | | | | | | | | | | | | | | | |
| Vehicle Class | Area From Which Workers Commute | VMT | $CO_2$ (g/VMT) | $CH_4$ (g/VMT) | $N_2O$ (g/VMT) | CO (g/VMT) | VOCs (g/VMT) | $CO_2c$ (g/VMT) | $CO_2$ (tonne/ year) | $CH_4$ (tonne/ year) | $N_2O$ (tonne/ year) | $CO_2e$ (tonne/ year) | Fuel consumption (mmBtu/ year) | Upstream $CO_2$ (tonne/ year) | Upstream $CH_4$ (tonne/ year) | Upstream $N_2O$ (tonne/ year) | Upstream $CO_2e$ (tonne/ year) | Total $CO_2e$ (tonne/ year) |
| Construction Workers | Seattle-Tacoma | 309,120 | 306.0 | 0.0 | 0.0 | 2.68 | 0.0 | 310 | 95.9 | 0.001 | 0.000 | 96.03 | 1250.964 | 30.33651 | 0.00000 | 0.00000 | 30.33651 | 126.37105 |
| Heavy Duty Delivery Trucks | | 9,999 | 1942.0 | 0.0 | 0.0 | 2.86 | 0.5 | 1,948 | 19.5 | 0.000 | 0.000 | 19.49 | 249.548 | 6.05165 | 0.00000 | 0.00000 | 6.05165 | 25.54304 |
| | | | | | | | | Total | 115.4 | 0.001 | 0.000 | 115.53 | 1500.512 | 36.388 | 0.000 | 0.000 | 36.388 | 151.914 |
| Construction Vehicle Emissions - Summer 2. Year | | | | | | | | | | | | | | | | | | |
| Vehicle Class | Area From Which Workers Commute | VMT | $CO_2$ (g/VMT) | $CH_4$ (g/VMT) | $N_2O$ (g/VMT) | CO (g/VMT) | VOCs (g/VMT) | $CO_2c$ (g/VMT) | $CO_2$ (tonne/ year) | $CH_4$ (tonne/ year) | $N_2O$ (tonne/ year) | $CO_2e$ (tonne/ year) | Fuel consumption (mmBtu/ year) | Upstream $CO_2$ (tonne/ year) | Upstream $CH_4$ (tonne/ year) | Upstream $N_2O$ (tonne/ year) | Upstream $CO_2e$ (tonne/ year) | Total $CO_2e$ (tonne/ year) |
| Construction Workers Car | Seattle-Tacoma | 309,120 | 319.3 | 0.0 | 0.0 | 1.70 | 0.0 | 322 | 99.6 | 0.001 | 0.000 | 99.68 | 1298.405 | 31.48698 | 0.00000 | 0.00000 | 31.48698 | 131.16349 |
| Heavy Duty Delivery Trucks | | 5,789 | 2018.0 | 0.0 | 0.0 | 2.86 | 0.5 | 2,024 | 11.7 | 0.000 | 0.000 | 11.72 | 150.110 | 3.64025 | 0.00000 | 0.00000 | 3.64025 | 15.36491 |
| | | | | | | | | Total | 111.3 | 0.001 | 0.000 | 111.40 | 1448.515 | 35.127 | 0.000 | 0.000 | 35.127 | 146.528 |
| | | | | | | | | **Annual Total** | **226.7** | **0.0** | **0.0** | **226.9** | **2949.0** | **71.5** | **0.0** | **0.0** | **71.5** | **298.4** |

**Table A.8.** Road Vehicle Terminal Construction Criteria Pollutant Emissions for 3. and 4. Year of Construction

Construction Vehicle Emissions - Winter 3. Year

| Vehicle Class | Area From Which Workers Commute | VMT | $CO_2$ (g/VMT) | $CH_4$ (g/VMT) | $N_2O$ (g/VMT) | CO (g/VMT) | VOCs (g/VMT) | $CO_2c$ (g/VMT) | $CO_2$ (tonne/ year) | $CH_4$ (tonne/ year) | $N_2O$ (tonne/ year) | $CO_2e$ (tonne/ year) | Fuel consumption (mmBtu/ year) | Upstream $CO_2$ (tonne/ year) | Upstream $CH_4$ (tonne/ year) | Upstream $N_2O$ (tonne/ year) | Upstream $CO_2e$ (tonne/ year) | Total $CO_2e$ (tonne/ year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Construction Workers Car | Seattle-Tacoma | 302,400 | 300.0 | 0.0 | 0.0 | 2.56 | 0.0 | 304 | 92.0 | 0.001 | 0.000 | 92.07 | 1199.349 | 29.08482 | 0.00000 | 0.00000 | 29.08482 | 121.15696 |
| Heavy Duty Delivery Trucks | | 6,356 | 1942.0 | 0.0 | 0.0 | 2.62 | 0.4 | 1,947 | 12.4 | 0.000 | 0.000 | 12.39 | 158.591 | 3.84592 | 0.00000 | 0.00000 | 3.84592 | 16.23300 |
| | | | | | | | | Total | 104.3 | 0.001 | 0.000 | 104.46 | 1357.940 | 32.931 | 0.000 | 0.000 | 32.931 | 137.390 |

Construction Vehicle Emissions - Summer 3. Year

| Vehicle Class | Area From Which Workers Commute | VMT | $CO_2$ (g/VMT) | $CH_4$ (g/VMT) | $N_2O$ (g/VMT) | CO (g/VMT) | VOCs (g/VMT) | $CO_2c$ (g/VMT) | $CO_2$ (tonne/ year) | $CH_4$ (tonne/ year) | $N_2O$ (tonne/ year) | $CO_2e$ (tonne/ year) | Fuel consumption (mmBtu/ year) | Upstream $CO_2$ (tonne/ year) | Upstream $CH_4$ (tonne/ year) | Upstream $N_2O$ (tonne/ year) | Upstream $CO_2e$ (tonne/ year) | Total $CO_2e$ (tonne/ year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Construction Workers Car | Seattle-Tacoma | 614,880 | 313.8 | 0.0 | 0.0 | 1.59 | 0.0 | 316 | 194.5 | 0.002 | 0.001 | 194.76 | 2536.972 | 61.52286 | 0.00000 | 0.00000 | 61.52286 | 256.28219 |
| Heavy Duty Delivery Trucks | | 4,160 | 2018.0 | 0.0 | 0.0 | 2.62 | 0.4 | 2,023 | 8.4 | 0.000 | 0.000 | 8.42 | 107.846 | 2.61531 | 0.00000 | 0.00000 | 2.61531 | 11.03881 |
| | | | | | | | | Total | 202.9 | 0.002 | 0.001 | 203.18 | 2644.818 | 64.138 | 0.000 | 0.000 | 64.138 | 267.321 |
| | | | | | | | | **Annual Total** | **307.3** | **0.0** | **0.0** | **307.6** | **4002.8** | **97.1** | **0.0** | **0.0** | **97.1** | **404.7** |

Construction Vehicle Emissions - Winter 4. Year

| Vehicle Class | Area From Which Workers Commute | VMT | $CO_2$ (g/VMT) | $CH_4$ (g/VMT) | $N_2O$ (g/VMT) | CO (g/VMT) | VOCs (g/VMT) | $CO_2c$ (g/VMT) | $CO_2$ (tonne/ year) | $CH_4$ (tonne/ year) | $N_2O$ (tonne/ year) | $CO_2e$ (tonne/ year) | Fuel consumption (mmBtu/ year) | Upstream $CO_2$ (tonne/ year) | Upstream $CH_4$ (tonne/ year) | Upstream $N_2O$ (tonne/ year) | Upstream $CO_2e$ (tonne/ year) | Total $CO_2e$ (tonne/ year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Construction Workers Car | Seattle-Tacoma | 0 | 295.0 | 0.0 | 0.0 | 2.46 | 0.0 | 299 | 0.0 | 0.000 | 0.000 | 0.00 | 0.000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| Heavy Duty Delivery Trucks | | 457 | 1942.0 | 0.0 | 0.0 | 2.38 | 0.4 | 1,947 | 0.9 | 0.000 | 0.000 | 0.89 | 11.400 | 0.27646 | 0.00000 | 0.00000 | 0.27646 | 1.16689 |
| | | | | | | | | Total | 0.9 | 0.000 | 0.000 | 0.89 | 11.400 | 0.276 | 0.000 | 0.000 | 0.276 | 1.167 |

Construction Vehicle Emissions - Summer 4. Year

| Vehicle Class | Area From Which Workers Commute | VMT | $CO_2$ (g/VMT) | $CH_4$ (g/VMT) | $N_2O$ (g/VMT) | CO (g/VMT) | VOCs (g/VMT) | $CO_2c$ (g/VMT) | $CO_2$ (tonne/ year) | $CH_4$ (tonne/ year) | $N_2O$ (tonne/ year) | $CO_2e$ (tonne/ year) | Fuel consumption (mmBtu/ year) | Upstream $CO_2$ (tonne/ year) | Upstream $CH_4$ (tonne/ year) | Upstream $N_2O$ (tonne/ year) | Upstream $CO_2e$ (tonne/ year) | Total $CO_2e$ (tonne/ year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Construction Workers Car | Seattle-Tacoma | 0 | 308.5 | 0.0 | 0.0 | 1.51 | 0.0 | 311 | 0.0 | 0.000 | 0.000 | 0.00 | 0.000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| Heavy Duty Delivery Trucks | | 306 | 2019.0 | 0.0 | 0.0 | 2.38 | 0.4 | 2,024 | 0.6 | 0.000 | 0.000 | 0.62 | 7.935 | 0.19243 | 0.00000 | 0.00000 | 0.19243 | 0.81221 |
| | | | | | | | | Total | 0.6 | 0.000 | 0.000 | 0.62 | 7.935 | 0.192 | 0.000 | 0.000 | 0.192 | 0.812 |
| | | | | | | | | **Annual Total** | **1.5** | **0.0** | **0.0** | **1.5** | **19.3** | **0.5** | **0.0** | **0.0** | **0.5** | **2.0** |

Notes:
EFs from EPA MOVES model.
Construction Worker vehicles assumed to be ID 21 - Passenger Car. Heavy-Duty Delivery trucks assumed to be 61 - Combination Short-haul truck.
Assume 48 hours per week; 4.28 weeks per month

## **Table A.9.** Monthly Car and Truck Trips during Construction

| Month/Year | Season | # of work days/ month | # of Cars/day | # of cars/ month | Car VMT/ month | # of Trucks/ month | Truck VMT/ month | Total On-Site VMT/ month (Car and Truck) |
|---|---|---|---|---|---|---|---|---|
| Jan-1. Year | Winter 1. Year | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Feb-1. Year | | 24 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Mar-1. Year | | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Apr-1. Year | Summer 1. Year | 25.7 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| May-1. Year | | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Jun-1. Year | | 25.7 | 0 | 0 | 0 | 85.00 | 331 | 331 |
| Jul-1. Year | | 26.6 | 0 | 0 | 0 | 85.00 | 320 | 320 |
| Aug-1. Year | | 26.6 | 0 | 0 | 0 | 75.00 | 282 | 282 |
| Sep-1. Year | | 25.7 | 0 | 0 | 0 | 75.00 | 292 | 292 |
| Oct-1. Year | Winter 1. Year | 26.6 | 0 | 0 | 0 | 5.00 | 19 | 19 |
| Nov-1. Year | | 25.7 | 0 | 0 | 0 | 5.00 | 19 | 19 |
| Dec-1. Year | | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Jan-2. Year | Winter 2. Year | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Feb-2. Year | | 24.9 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Mar-2. Year | | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Apr-2. Year | Summer 2. Year | 25.7 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| May-2. Year | | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Jun-2. Year | | 25.7 | 0 | 0 | 0 | 174.00 | 677 | 677 |
| Jul-2. Year | | 26.6 | 98 | 2,604 | 104,160 | 244.00 | 918 | 105,078 |
| Aug-2. Year | | 26.6 | 98 | 2,604 | 104,160 | 294.00 | 1,106 | 105,266 |
| Sep-2. Year | | 25.7 | 98 | 2,520 | 100,800 | 794.00 | 3,088 | 103,888 |
| Oct-2. Year | Winter 2. Year | 26.6 | 98 | 2,604 | 104,160 | 844.00 | 3,176 | 107,336 |
| Nov-2. Year | | 25.7 | 98 | 2,520 | 100,800 | 894.00 | 3,477 | 104,277 |
| Dec-2. Year | | 26.6 | 98 | 2,604 | 104,160 | 889.00 | 3,346 | 107,506 |
| Jan-3. Year | Winter 3. Year | 26.6 | 98 | 2,604 | 104,160 | 888.00 | 3,342 | 107,502 |
| Feb-3. Year | | 24 | 98 | 2,352 | 94,080 | 329.00 | 1,371 | 95,451 |
| Mar-3. Year | | 26.6 | 98 | 2,604 | 104,160 | 279.00 | 1,050 | 105,210 |
| Apr-3. Year | Summer 3. Year | 25.7 | 98 | 2,520 | 100,800 | 279.00 | 1,085 | 101,885 |
| May-3. Year | | 26.6 | 98 | 2,604 | 104,160 | 252.00 | 948 | 105,108 |
| Jun-3. Year | | 25.7 | 98 | 2,520 | 100,800 | 189.00 | 735 | 101,535 |
| Jul-3. Year | | 26.6 | 98 | 2,604 | 104,160 | 139.00 | 523 | 104,683 |
| Aug-3. Year | | 26.6 | 98 | 2,604 | 104,160 | 139.00 | 523 | 104,683 |
| Sep-3. Year | | 25.7 | 98 | 2,520 | 100,800 | 89.00 | 346 | 101,146 |
| Oct-3. Year | Winter 3. Year | 26.6 | 0 | 0 | 0 | 78.00 | 294 | 294 |
| Nov-3. Year | | 25.7 | 0 | 0 | 0 | 39.00 | 152 | 152 |
| Dec-3. Year | | 26.6 | 0 | 0 | 0 | 39.00 | 147 | 147 |
| Jan-4. Year | Winter 4. Year | 26.6 | 0 | 0 | 0 | 39.00 | 147 | 147 |
| Feb-4. Year | | 24 | 0 | 0 | 0 | 39.00 | 163 | 163 |
| Mar-4. Year | | 26.6 | 0 | 0 | 0 | 39.00 | 147 | 147 |
| Apr-4. Year | Summer 4. Year | 25.7 | 0 | 0 | 0 | 41.00 | 159 | 159 |
| May-4. Year | | 26.6 | 0 | 0 | 0 | 39.00 | 147 | 147 |
| Jun-4. Year | | 25.7 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Jul-4. Year | | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Aug-4. Year | | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Sep-4. Year | | 25.7 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Oct-4. Year | Winter 4. Year | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Nov-4. Year | | 25.7 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Dec-4. Year | | 26.6 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Total | | | | | 1,535,520 | | 28,330 | |
| Note: Commute round-trip distance was assumed | | | | | | | | |

## A.2. Operational Emissions

Emissions during plant operation include WTT emission rates from natural gas production and transport and power generation, as well as emissions from direct facility operation including fuel combustion on site, and emissions from end use fuel transfer for transfer operations[27] and fuel combustion. The emissions are grouped according to upstream, direct project, and end use. All of these emissions have WTT components such that the product of LNG use rate $U_{TLNG}$ and total emission rate per gallon of LNG, $\mathbf{E}_{TLNG}$ correspond to the total GHG emissions $\mathbf{G}_{LNG}$ via the following:

$$\mathbf{G}_{LNG} = U_{TLNG} \times \mathbf{E}_{TLNG} = U_{TLNG} \times [S_{NG} \times \mathbf{E}_N + S_e \times \mathbf{E}_e + V_{TLNG} + \Sigma(S_i \times \mathbf{EF}_i)] + \Sigma[U_k \times (\mathbf{EF}_L + V_O)] + U_{PS} \times (S_{NPS} \times \mathbf{EF}_{PS}) + \Sigma[U_t \times (\mathbf{EF}_D + \mathbf{E}_D)] \quad (5)$$

Where:

$U_{TLNG}$ = Total LNG use rate for Tacoma LNG = LNG produced
$\mathbf{E}_{TLNG}$ =Average WTT emission rate for Tacoma LNG
$S_{NG}$ = Specific energy of natural gas feedstock (Btu/mmBtu LNG) for Tacoma LNG
$\mathbf{E}_N$ = WTT natural gas emission rate
$S_e$ = Specific Energy of electric power consumed per unit of LNG (kWh/gal)
$\mathbf{E}_e$ = WTT emission rate for electric power
$V_{TLNG}$ = Tacoma LNG fugitive emission rate (g/gal)
$S_i$ = Specific energy for Tacoma LNG combustion emissions and process emissions for LNG production
$\mathbf{EF}_i$ = Emission factor for combustion equipment for each fuel type (natural gas, light hydrocarbons, etc.)
$U_k$ = Use rate of LNG for marine vessel and diesel truck combustion
$\mathbf{EF}_L$ = Emission factor for LNG Marine vessel and on-road truck combustion as well as natural gas for residential and commercial operation
$V_O$ = Fugitive emission rate from LNG operations in marine and truck operations
$U_{PS}$ = Use rate of LNG for peak shaving
$S_{NPS}$ = Specific energy of fuel uses for vaporization in peak shaving
$\mathbf{EF}_{PS}$ = Emission factor for fuel fired in peak shaving vaporizer (LNG or light hydrocarbons)
$U_t$ = Diesel use rate for LNG transport and bunkering
$\mathbf{EF}_D$ = Emission factor for diesel trucks
$\mathbf{E}_D$ = WTT emission rate for diesel

[27] The fuel transfer emissions are tracked for each type of fuel transfer activity including filling TOTE ships, barges, and trucks. The fuel transfer hardware for trucks will be different than that for ships.

Example Calculation of emissions for 22 million gallons of LNG for marine applications

$U_{TLNG} \times [\mathbf{S}_N \times \mathbf{E}_N + \mathbf{S}_e \times \mathbf{E}_e + V_{TLNG}]$: 22 million gallons × (85,630 Btu/gal LNG × 10,803 g $CO_2$e/mmBtu NG WTT) + (1.348 kWh/gal LNG × 215 g $CO_2$e/kWh power) + 0.17 g $CH_4$/gal LNG × 25 GWP] = 20,352 + 6,380 + 23 tonne GHG/year

$U_{TLNG} \times \Sigma(S_i \times \mathbf{EF}_i)$: + 22 million gal × [(865 + 154) Btu/gal for fired heaters × 59,442 g $CO_2$e/mmBtu NG] + $CO_2$ vent + Flared waste gas + flared propane from mass balance in Appendix A.2 = 1,331 + 213 + 7,251 + 3,339 tonne GHG /year

$U_k \times (\mathbf{E}_{FL} + V_O)$: + 22 million gallons LNG for marine engines × 77,156 Btu/gal × (73,798 g $CO_2$e/mmBtu LNG + 4.3 g $CH_4$/gal LNG boil off loss/gal LNG × 25 GWP) = 125,266 + 2,368 tonne GHG/year

Note: Calculations show for upstream natural gas, LNG production, and LNG combustion. Pilot fuel emissions follow similar approach. Calculation method represents individual GHG pollutants and $CO_2$e values are shown here to compare with overall results.

$S_{NG}$ is a representative value for all of the natural gas to the Tacoma LNG during normal operation. The term $E_{TLNG}$ represents emissions from both the combustion of natural gas as well as combustion of process gas from the separation unit. Each emission factor is based on the equipment type and design of the LNG production system

### *Direct Emissions from LNG Facility Operation*

Direct emissions from the LNG facility include fired heaters, waste $CO_2$ and flared light hydrocarbons. The emissions from fired heaters are based on the firing rates provided by PSE combined with the emission factor for natural gas. $CO_2$ and flaring emissions are based on the mass balance. The emission factors for flaring also include combustion emission of $CH_4$ and $N_2O$.

Natural gas also provides fuel for vaporization to re-gasify the LNG for peak shaving. Small portions of the process gas and natural gas are also combusted in the flare. Fugitive emissions occur from the LNG system and during LNG transfers for fuel use. Fugitive emissions primarily consist of methane and these GHG emissions are counted with the global warming potential (GWP) of methane.

### *Energy Efficiency of the Tacoma LNG Facility*

The Tacoma LNG facility consists of natural gas clean-up steps followed by liquefaction. The energy for liquefaction is provided by grid electric power. The parameters for the Tacoma LNG facility compared to the default GREET parameters are shown in Table A.10. The table compares the aggregate natural gas inputs and power input for LNG production with the CA_GREET default value (ARB, 2014). These values are based on Argonne National Laboratory's GREET model and typically represent a state-of-the-art-fuel production system. The overall energy efficiency for Tacoma LNG is 86.1 % compared to 91 % in GREET for comparable processing steps. The lower efficiency is due to the design of the Tacoma LNG facility based on imported power for liquefaction combined with the flaring of the waste gas. The natural gas to LNG yield may also represent potentially conservative assumptions provided by PSE. In contrast, the configuration modeled in GREET uses natural gas and the waste gas to provide process energy for liquefaction.

The scope of the proceeding to LNG includes the conversion of pipeline natural gas to LNG and LNG storage. The LNG facility in the GREET model uses natural gas to power compressor engines. Excess light hydrocarbons in the natural gas are effectively burned to provide process heat or engine fuel for the liquefaction process in the GREET analysis. The GREET analysis uses very little electric power and the total process fuel (96,923 Btu/mmBtu) is less than the flared hydrocarbons plus fired natural gas from Tacoma LNG. In contrast, the Tacoma LNG facility will burn the light hydrocarbons identified in the following material balance and natural gas is the source of fuel for pretreatment. The light hydrocarbons (heavier than methane) including propane that could be recovered from the gas will be flared. Note that the flared gas corresponds to about 88,000 Btu/mmBtu of LNG. The flared gas is also consistent with the mass balance shown in Table A.11, which is based on mass flow inputs provided by PSE. The energy in the light hydrocarbons would be sufficient to generate about half of the power for liquefaction; however, other design factors could favor grid power as the source of energy for compression. For example, the parameters for the SEIS could be a conservative design basis and the fraction of light hydrocarbons in the natural gas could be variable.

Methane losses from storage and distribution are somewhat different for Tacoma LNG compared with GREET. For Tacoma LNG, most of the fuel is transferred to marine applications with relatively few transfer interconnects per gallon of LNG compared to LNG for truck applications, which are modeled in GREET. Boiled off LNG is either captured at the Tacoma LNG facility or captured on bunkering barges or LNG powered ships. Note that the control of boil off LNG from bunkering barges or LNG powered ships are not part of the permitting of the Tacoma LNG project and the emission assumptions are based on current best practices.

**Table A.10.** Energy Inputs for Tacoma LNG Compared to GREET Parameters

| GREET Parameter | GREET | | | Tacoma LNG | |
|---|---|---|---|---|---|
| | NG Liquefaction: As an Intermediate Fuel | LNG Transportation and Distribution: As a Transportation Fuel | LNG Storage: As a Transportation Fuel | Tacoma LNG | LNG Storage and Distribution |
| **NG Use Rate (lb/lb LNG)** | 1.109 | | | 1.118 | |
| **Energy efficiency** | 91.0% | | | 86.1% | |
| **Urban emission share** | 0.0% | | | | |
| **Loss factor** | 1.00101 | | | 1.00003 | |
| **Share of feedstock input as feed (the remaining input as process fuel)** | | | | | |
| **Shares of process fuels** | | | | | |
| Residual oil | 0.0% | | | 0.0% | |
| Diesel fuel | 0.0% | | | 0.0% | |
| Flared propane and hydrocarbons | 0.0% | | | 55.0% | |
| Natural gas: process fuel | 98.0% | | | 8.2% | |
| Electricity | 2.0% | | | 36.8% | |
| Feedstock loss | 0.0% | | | 0.0% | |
| **Energy use: Btu/mmBtu of fuel throughput** | 99,906 | | | 161,587 | |
| Residual oil | 0 | | | 0 | |
| Diesel fuel | 0 | | | 0 | |
| Flared propane and hydrocarbons | a | | | 88,767 | |
| Natural gas: process fuel | 96,923 | | | 13,201 | |
| Electricity | 1,978 | | | 59,614 | |
| Feedstock loss | 1,005 | 538 | 4,186 | 5 | 2,090 |
| Leak Recovery | 80% | | | | |
| $CH_4$ Leakage (g/mmBtu LNG) | 21.80 | 11.67 | 90.82 | 0.59 | 44.58 |
| Boil off before recovery (g/mmBtu) | 109.0 | | | | |
| $CH_4$ Leakage | 0.10% | 0.05% | 0.42% | 0.0027% | 0.21% |

[a] Included in natural gas process fuel.

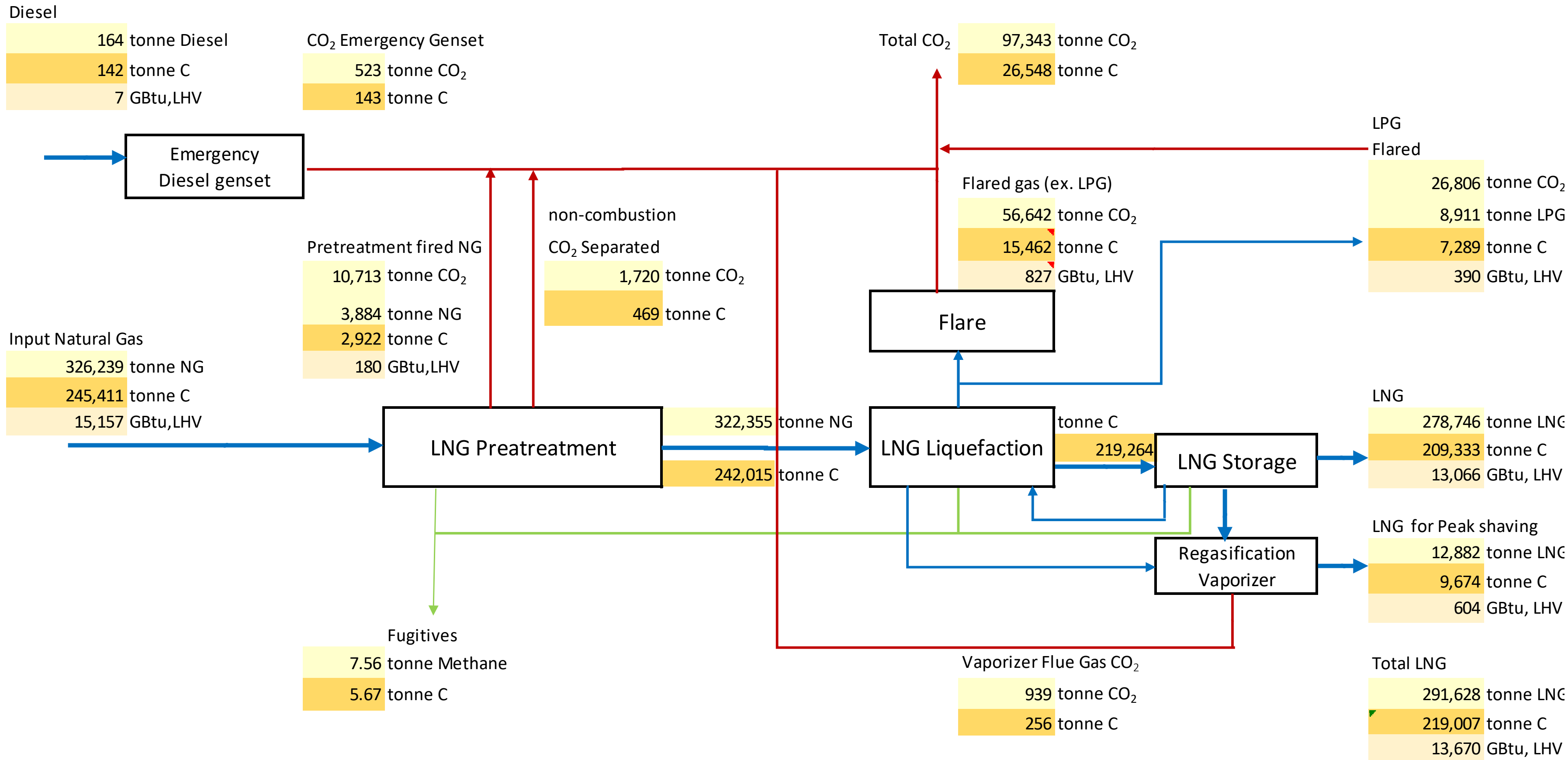
Table A.11 shows the elemental balance based on 100 moles of LNG produced. The composition of the input natural gas and produce LNG allows for the composition, carbon content, and heating value and proportional flow rate of the flared light hydrocarbons. The heating value of the natural gas and LNG are also determined from the compositions shown here.

**Table A.11.** Carbon Balance of Natural Gas Input to LNG

| Component | Natural Gas fired | Pretreatment Vent | To LNG | Waste Gas | LPG | Tacoma LNG |
|---|---|---|---|---|---|---|
| | **mol%** | **mol%** | **mol%** | **mol%** | **mol%** | **mol%** |
| CH4 | 91.31% | 0.00% | 5.12% | 5.01% | 5.36% | 94.36% |
| C2H6 | 6.07% | 0.00% | 55.73% | 79.83% | 2.86% | 4.32% |
| | | | | | | 0.00% |
| C3H8 | 1.54% | 0.00% | 21.83% | 1.59% | 66.26% | 0.83% |
| i-C4H10 | 0.22% | 0.00% | 3.72% | 0.27% | 11.28% | 0.10% |
| n-C4H10 | 0.24% | 0.00% | 4.55% | 0.33% | 13.79% | 0.09% |
| i-C5H12 | 0.05% | 0.00% | 1.08% | 1.41% | 0.34% | 0.01% |
| n-C5H12 | 0.03% | 0.00% | 0.81% | 1.18% | 0.00% | 0.01% |
| C6+ | 0.03% | 0.00% | 0.84% | 1.23% | 0.00% | 0.00% |
| N2 | 0.27% | 54.81% | 0.04% | 0.05% | 0.00% | 0.28% |
| CO | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| H2 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| H2S | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| O2 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| He | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CO2 | 0.22% | 45.19% | 6.29% | 9.11% | 0.10% | 0.01% |
| **Total** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** |
| C factor (lb $CO_2$/mmBtu), HHV | 118.11 | 0.00 | 136.68 | 136.87 | 136.42 | 116.87 |
| C factor (lb $CO_2$/scf) | 0.1287 | 0.0000 | 0.2741 | 0.2339 | 0.3625 | 0.1236 |
| LHV (MJ/kg) | 49.0 | 0.0 | 43.3 | 41.5 | 46.2 | 49.5 |
| (g $CO_2$/mmBtu), LHV | 59333.7 | 0.0 | 68663.1 | 68755.6 | 68532.5 | 58709.2 |
| average molar weight | 17.7 | 35.2 | 36.9 | 32.8 | 45.8 | 17.0 |
| mol "C" per mol gas | 1.11 | 0.45 | 2.36 | 2.01 | 3.12 | 1.06 |
| carbon weight % | 75.22% | 15.40% | 76.88% | 73.74% | 81.81% | 75.10% |
| Carbon factor, g$CO_2$/MJ | 56.2 | 0.0 | 65.1 | 65.2 | 65.0 | 55.6 |
| g $CO_2$/mmBtu, LHV | 59,333 | 0 | 68,662 | 68,755 | 68,531 | 58,708 |
| Btu/scf (LHV) | 983.9 | 0.0 | 1811.0 | 1542.8 | 2399.4 | 954.7 |
| Btu/scf (HHV) | 1089.7 | 0.0 | 2005.6 | 1708.6 | 2657.4 | 1057.3 |
| MJ/$m^3$ | 36.7 | 0.0 | 67.5 | 57.5 | 89.4 | 35.6 |
| Specific Gravity | 0.610 | 1.216 | 1.272 | 1.132 | 1.581 | 0.587 |
| Density (g/$ft^3$) | 21.2 | 42.2 | 44.1 | 39.3 | 54.9 | 20.4 |
| Density (g/$m^3$) | 747.9 | 1490.2 | 1558.8 | 1386.3 | 1937.1 | 719.3 |

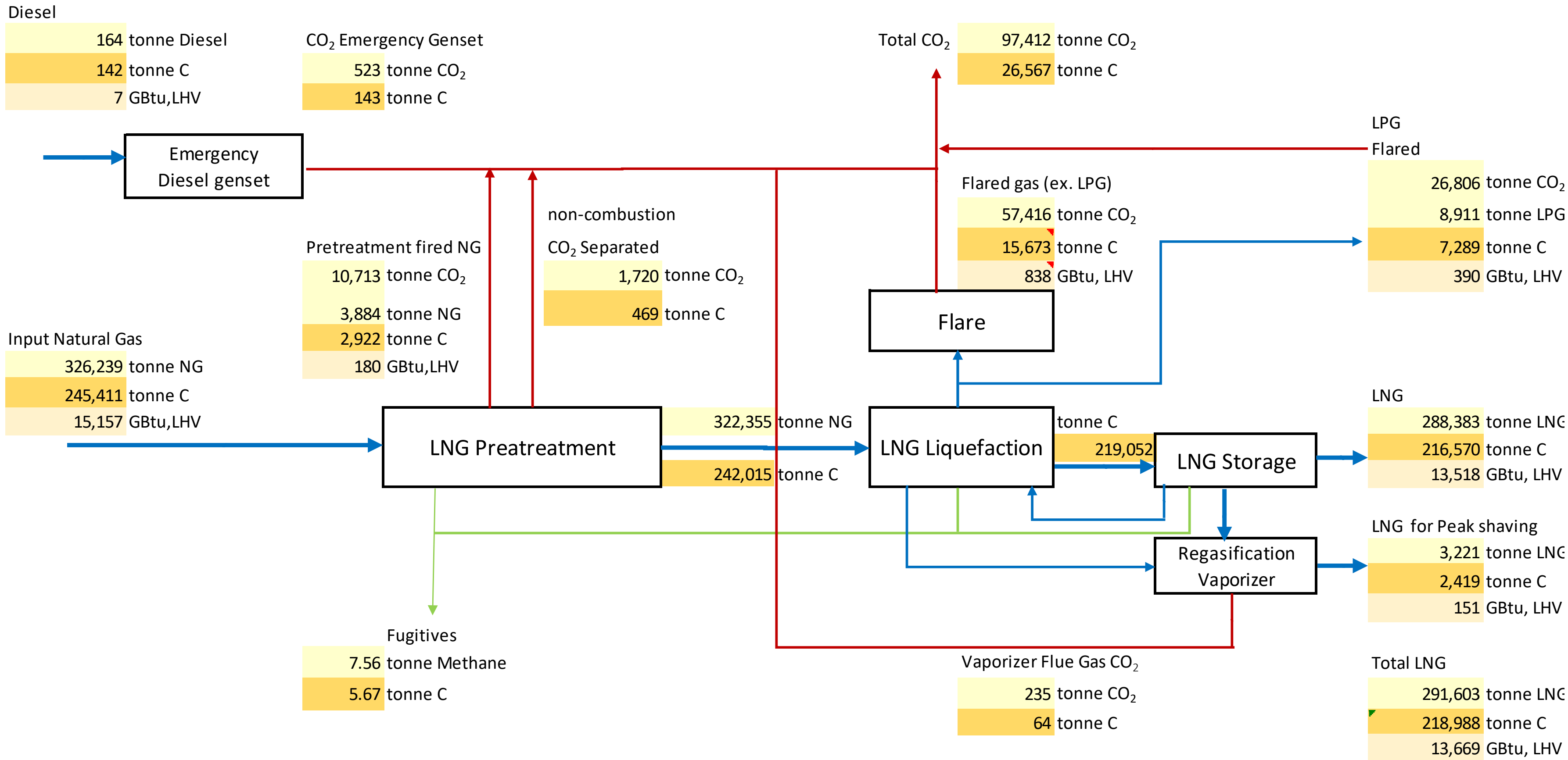
| Component | Natural Gas fired | Pretreatment Vent | To LNG | Waste Gas | LPG | Tacoma LNG |
|---|---|---|---|---|---|---|
| | mol/d | mol/d | mol/d | mol/d | mol/d | mol/d |
| $CH_4$ | 94.536 | 0.000 | 0.181 | 0.121 | 0.059 | 94.356 |
| $C_2H_6$ | 6.284 | 0.000 | 1.967 | 1.935 | 0.032 | 4.317 |
| $C_3H_8$ | 1.598 | 0.000 | 0.771 | 0.039 | 0.732 | 0.828 |
| i-$C_4H_{10}$ | 0.232 | 0.000 | 0.131 | 0.007 | 0.125 | 0.101 |
| n-$C_4H_{10}$ | 0.250 | 0.000 | 0.160 | 0.008 | 0.152 | 0.090 |
| i-$C_5H_{12}$ | 0.049 | 0.000 | 0.038 | 0.034 | 0.004 | 0.011 |
| n-$C_5H_{12}$ | 0.035 | 0.000 | 0.029 | 0.029 | 0.000 | 0.007 |
| $C_6$+ | 0.031 | 0.000 | 0.030 | 0.030 | 0.000 | 0.001 |
| $N_2$ | 0.281 | 0.281 | 0.001 | 0.001 | 0.000 | 0.280 |
| CO | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $H_2$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $H_2S$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $O_2$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| He | | | | | | |
| $CO_2$ | 0.232 | 0.232 | 0.222 | 0.221 | 0.001 | 0.010 |
| Total | 103.5 | 0.5 | 3.5 | 2.4 | 1.1 | 100.0 |
| | | | | | | |
| **Mass** | **NG Feed** | **CO2** | **Flare** | **Waste Gas** | **LPG** | **LNG** |
| | t/d | t/d | t/d | | | t/d |
| $CH_4$ | 1516.5 | 0.0 | 2.9 | 1.9 | 1.0 | 1513.6 |
| $C_2H_6$ | 188.9 | 0.0 | 59.1 | 58.2 | 1.0 | 129.8 |
| | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| $C_3H_8$ | 70.5 | 0.0 | 34.0 | 1.7 | 32.3 | 36.5 |
| i-$C_4H_{10}$ | 13.5 | 0.0 | 7.6 | 0.4 | 7.2 | 5.8 |
| n-$C_4H_{10}$ | 14.5 | 0.0 | 9.3 | 0.5 | 8.9 | 5.2 |
| i-$C_5H_{12}$ | 3.6 | 0.0 | 2.7 | 2.5 | 0.3 | 0.8 |
| n-$C_5H_{12}$ | 2.5 | 0.0 | 2.1 | 2.1 | 0.0 | 0.5 |
| $C_6$+ | 2.6 | 0.0 | 2.5 | 2.5 | 0.0 | 0.1 |
| $N_2$ | 7.9 | 7.9 | 0.0 | 0.0 | 0.0 | 7.8 |
| CO | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2S$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $O_2$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| He | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $CO_2$ | 10.2 | 10.2 | 9.8 | 9.7 | 0.1 | 0.4 |
| Total | 1830.7 | 18.1 | 130.1 | 79.5 | 50.6 | 1700.7 |
| Mass ratio: LNG | 1.0765 | 0.0106 | 0.0765 | 0.0467 | 0.0298 | 1 |

## Annual throughput




The carbon balance accounts for the hydocarbons and $CO_2$ in the natural gas such that the carbon entering the LNG system is equal to the carbon in the combustion gas, fugitive emissions and LNG. Carbon in the Flared gas ex. LPG is determined by difference. Inputs to the analysis include overall NG to LNG mass balance, and fired pretreament NG. Waste gas to flare is based on elemental composition and mass flows.

## Annual throughput, 60 hours of peak shaving




The carbon balance accounts for the hydocarbons and $CO_2$ in the natural gas such that the carbon entering the LNG system is equal to the carbon in the combustion gas, fugitive emissions and LNG. Carbon in the Flared gas ex. LPG is determined by difference. Inputs to the analysis include overall NG to LNG mass balance, and fired pretreament NG. Waste gas to flare is based on elemental composition and mass flows.

### *Displaced Emissions (No Action Alternative)*

The life cycle GHG emissions from the Tacoma LNG project are compared to the alternative of not constructing the facility. Displaced LNG is based on PSE's projections of LNG end use applications.

Alternative energy uses include marine diesel and diesel fuel in marine and truck applications as well as pipeline natural gas used for peak shaving operations. The difference between vaporized LNG and natural gas is accounted for in the analysis. The overall upstream emissions associated with natural gas is also accounted for. GHG emissions are calculated in the same manner as those for Tacoma LNG. The amount of diesel used for marine and trucking are calculated based on the LNG use rate and the appropriate efficiency for each application. For diesel fuel combustion, the product of use rate and life cycle emission rates results in total emission $\mathbf{G}_{Alt}$ which calculated by:

$$\mathbf{G}_{Alt} = U_{PS} \times (\mathbf{EF}_N + \mathbf{E}_N) + \Sigma[U_k \times (S_{De} \times \mathbf{E}_e + S_D \times (\mathbf{EF}_D + \mathbf{E}_D))] \quad (6)$$

Where:
$U_{PS}$ = Energy use rate for LNG peak shaving
$\mathbf{EF}_N$ = Emission factor for natural gas
$\mathbf{E}_N$ = WTT emission rate for natural gas
$U_k$ = Energy use rate of LNG in each application
$S_{De}$ = Specific energy of electricity used for diesel storage and transfer[28]
$\mathbf{E}_e$ = WTT emission rate for electric power
$S_D$ = Specific energy of diesel fuel and marine diesel displacing LNG for each fuel application[29]
$\mathbf{EF}_D$ = Emission factor for diesel in marine or truck engines
$\mathbf{E}_D$ = WTT emission rate for MGO or diesel fuel

The term $S_D$ is a key parameter that relates the energy used in diesel operations with those from LNG fuel use. Electric power for diesel distribution so the term $S_{De}$ for alternative activities is essentially zero.

The WTT emission rates include the WTT data for diesel and marine diesel production. A small portion of these WTT emissions fall into the scope of distribution which is consistent with the activities of the Tacoma LNG project direct emissions.

[28] This small amount of energy provides the functional equivalence of the direct emissions from LNG production which serves also as fuel storage.
[29] The specific energy of displaced diesel or marine fuel is based on the EER for each application.

**Table A.12.** Direct Emissions from Tacoma LNG and NAA

| Scenario B | | Emissions (tonne/year) | | | |
|---|---|---|---|---|---|
| **GHG Emissions** | **Equipment Type** | **$CO_2c$** | **$CH_4$** | **$N_2O$** | **$CO_2e$** |
| Peak Shaving | | | | | |
| LNG | Boiler | 8,859 | 0.16 | 0.05 | 8,879 |
| Natural Gas NAA | Boiler | 8,954 | 0.16 | 0.05 | 8,973 |
| Gig Harbor Delivery | | | | | |
| LNG Tacoma | Truck Engine | 4 | 0.00 | 0.00 | 4.2 |
| LNG | Truck Engine | 43 | 0.00 | 0.00 | 43 |
| LNG Tacoma End Use | NG Boiler | 8,037 | 0.15 | 0.05 | 8,055 |
| LNG End Use - NAA | NG Boiler | 8,037 | 0.15 | 0.05 | 8,055 |
| On-road Trucking | | | | | |
| LNG | Truck Engine | 15,738 | 85 | 0.01 | 17,862 |
| Diesel - NAA | Truck Engine | 19,274 | 1.2 | 0.04 | 19,316 |
| TOTE Marine | | | | | |
| LNG | Marine Engine | 166,648 | 1,865.1 | 11.0 | 216,545 |
| Pilot fuel | Marine Engine | 6,859 | 0.1 | 0.31 | 6,954 |
| MGO Fuel - NAA | Marine Engine | 235,508 | 3.6 | 10.62 | 238,764 |
| Truck-to-Ship Bunkering | | | | | |
| LNG | Marine Engine | 7,798 | 87 | 0.51 | 10,133 |
| Pilot fuel | Marine Engine | 321 | 0 | 0.01 | 325 |
| Diesel Truck | Truck Engine | Assume same delivery mode in NAA | | | |
| MGO Fuel - NAA | Marine Engine | 11,021 | 0.17 | 0.50 | 11,173 |
| Other Marine (by Bunker Barge) | | | | | |
| LNG | Marine Engine | 571,889 | 6,401 | 38 | 743,122 |
| Pilot fuel | Marine Engine | 23,540 | 0.1 | 0.31 | 23,635 |
| MGO Fuel - NAA | Marine Engine | 808,199 | 4 | 10.62 | 811,455 |

Assume barge delivers MGO for displaced emissions in NAA. Diesel emissions for truck and barge delivery were assumed to be the same since LNG weighs less than MGO per mmBtu but fuel volume is larger.

## A.3. Evaporative Emissions and Loss Factor

Fugitive emissions from LNG production facilities include LNG and other light hydrocarbons that escape from storage tanks and vents as well as LNG vapors that are displaced from the transfer of LNG from storage tanks to transport vessels or trucks and back to storage tanks. The Tacoma LNG will implement controls of fugitive vapors that either return these components to re-liquefy them or combust them to form $CO_2$. LNG transfers also result in fugitive emissions due to trapped volumes. These are the volume between hose and connector. Table A.13 and Table A.14 shows fugitive emissions from LNG operation and transfer activities.

### *Boil Off Gas during Holding Period on LNG Bunker Barges*

Pressurized offshore bunker systems have been designed and their concept follows the idea of minimizing maintenance on key units such as rotating equipment. LNG is transferred to the customer by increasing the pressure in the IMO C-Type tank. Pressure build-up units (PBU) ensure the necessary pressure level. Boil-off gas is generated during loading of the C-Type tanks or during the holding time. Typically, the boil-off gas is consumed by the ship engine. Boil-off gas compressors pressurize BOG to transfer it for use in engines or to route it to a flare. Due to the fact that LNG bunker barges have higher standstill times, boil-off gas is also used to increase the pressure inside the C-type tanks. If the pressure increases above the design level, boil-off gas is transferred to a thermal oxidation unit. No methane from the boil-off gas is released to the environment (Gastech, 2018; MAN Diesel and Turbo, 2016).

Other LNG bunker vessels on the market are equipped with a re-liquefaction unit, which cools down the boil-off gas and re-liquefies about 70% of the boil-off gas to LNG (Wärtsilä Oil & Gas Systems AS, 2014). Based on the above state of the art in treating boil-off gas on LNG bunker barges a recovery rate of 95% for the boil-off gas during the holding period on LNG bunker barges was assume for this analysis

**Table A.13.** Inventory of Fugitive Equipment Leak Components

| Component | Acid | BOG | Ethylene | Fuel Gas | HC Liquid | Liquefied NG | Mixed Refrigerant | NG | Untreated NG |
|---|---|---|---|---|---|---|---|---|---|
| Valves | 39 | 9 | 12 | 36 | 33 | 244 | 112 | 185 | 30 |
| Pressure Relief Valves | 3 | -- | 1 | 3 | 1 | 19 | 8 | 9 | 2 |
| Flanges/ Connectors | -- | 7 | 2 | 15 | 6 | 114 | 28 | 77 | 15 |
| Pump Seals | -- | -- | -- | | 1 | -- | -- | -- | -- |
| Compressor Seals | -- | 2 | -- | -- | -- | -- | 1 | 1 | -- |
| Swivel Joints | | | | | | 4 | | | |

HC = hydrocarbon NG = natural gas

**Table A.14.** Fugitive Emissions from LNG Transfer Operations

**Activity:**
**Bunker Barge Loading** — **Emissions (g/mmBtu)**

| Vapor Displaced | Recovery Rate | Loss per Bunkering Event | Volume per Bunkering Event (gallons) | Volume Lost per Bunkering Event (gallons) | $CH_4$ | $CO_2e$ |
|---|---|---|---|---|---|---|
| 0.22% | 95.00% | 0.011% | 380,994 | 41.9 | 2.4 | 59 |

**Bunker Vessel Storage**

| Boil off rate (%/day) | Duration (days) | Recovery Rate | Loss per Bunkering Event | Volume per Bunkering Event (gallons) | Volume Lost per Bunkering Event (gallons) | $CH_4$ | $CO_2e$ |
|---|---|---|---|---|---|---|---|
| 0.15% | 4 | 95.00% | 0.0300% | 380,952 | 114 | 6.4 | 160 |

**Truck/Ship-to-Ship Transfer**

| Vapor Displaced | Recovery Rate | Loss per Bunkering Event | Volume per Bunkering Event (gallons) | Volume Lost per Bunkering Event (gallons) | $CH_4$ | $CO_2e$ |
|---|---|---|---|---|---|---|
| 0.22% | 0.00% | 0.22% | 380,838 | 838 | 47.0 | 1,176 |

*Source:* PSE

**Table A.15.** Fugitive Emission Rates for Fuel Transfers

| LNG Bunkering and Vessel loading Emissions for Scenario B | $CH_4$ (g/mmBtu delivered) | $CO_{2e}$ (g/mmBtu delivered) | Fraction of Gas Delivered by this Process |
|---|---|---|---|
| Ship/Barge Loading | 2.4 | 58.82 | 96% |
| Bunker Vessel Storage | 6.4 | 160 | 74% |
| Truck/Ship-to-Ship Transfer | 47.0 | 1,176 | 76% |
| Total | 55.8 | 1,074 | |
| | | | |
| **Loss Factor** | 0.209% | Gas lost through the system | |
| Net Delivered LNG | 380,000 | gallons per typical bunkering event | |

*Source:* PSE BID

## A.4. Greenhouse Gases and Global Warming Potential

The gases emitted globally that contribute to the greenhouse effect are known as greenhouse gases (or GHGs). Natural sources of GHGs include biological and geological sources such as forest fires, volcanoes and living creates. However, industrial sources of GHGs are the primary concern. The GHGs of primary importance are $CO_2$, methane, and nitrous oxide because they represent the largest contribution to radiative forcing from fuel combustion. Because $CO_2$ is the most abundant of these gases, GHGs are usually quantified in terms of $CO_2$ equivalent ($CO_2$e), based on the relative longevity in the atmosphere and the related global warming potential (GWP)

The greenhouse effect is due to concentrations of gases in the atmosphere that trap heat as infrared radiation is reradiated back to outer space. The phenomena of natural and human-caused effects on the atmosphere that cause changes in long-term meteorological patterns due to global warming and other factors is generally referred to as climate change. Due to the importance of the greenhouse effect and related atmospheric warming to climate change, the gases emitted globally that affect such warming are called GHGs.

The atmospheric lifetime of a species measures the time required to restore equilibrium following a sudden increase or decrease in its concentration in the atmosphere. Individual atoms or molecules may be lost or deposited to sinks such as the soil, the oceans and other waters, or vegetation and other biological systems, reducing the excess to background concentrations. The average time taken to achieve this is the mean lifetime.
Carbon dioxide has a variable atmospheric lifetime of about 30 to 95 years. This figure accounts for $CO_2$ molecules being removed from the atmosphere by mixing into the ocean, photosynthesis, and other processes. However, this excludes the balancing fluxes of $CO_2$ into the atmosphere from the geological reservoirs, which have slower characteristic rates. Although more than half of the $CO_2$ emitted is removed from the atmosphere within a century,

some fraction (about 20%) of emitted $CO_2$ remains in the atmosphere for many thousands of years. Similar issues apply to other greenhouse gases, many of which have longer mean lifetimes than $CO_2$. e.g., $N_2O$ has a mean atmospheric lifetime of 121 years (Myhre et al., 2013).

Figure A.1 shows the components of radiative forcing in the atmosphere. The largest contributor to warming is $CO_2$, which depends on its radiation absorbing characteristics as well as the concentration in the atmosphere.  The next most prominent heat trapping gas is methane. Its heat trapping effect is about half that of $CO_2$ and the lifetime of methane in the atmosphere is much shorter. Each of the greenhouse gases also result in secondary effects.  For example, methane dissociates to form $CO_2$.  It also has a role in ozone formation in the atmosphere.

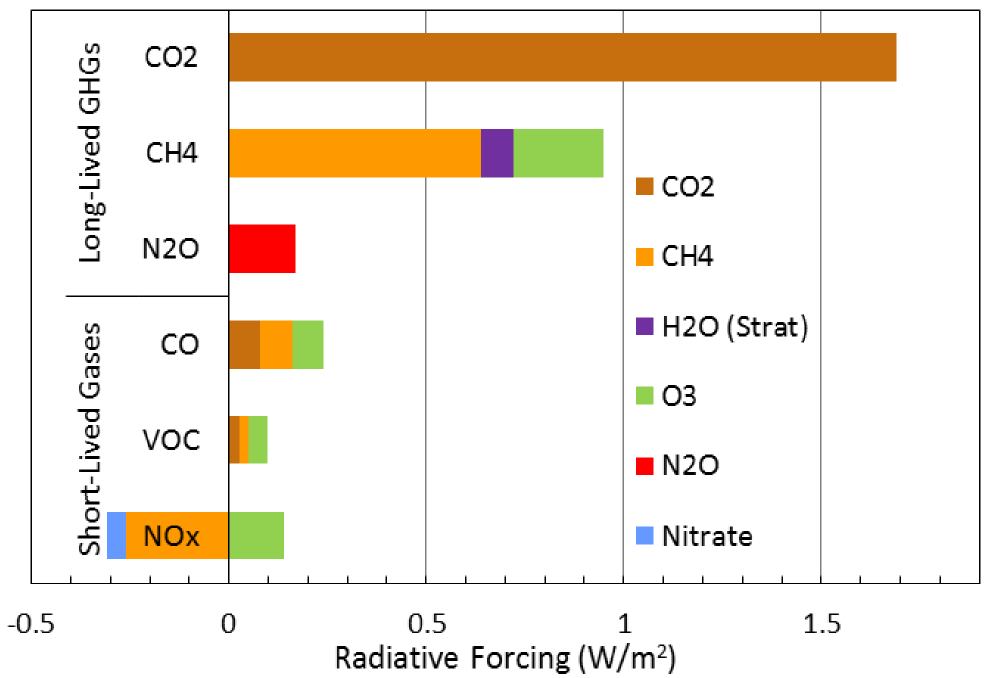



**Figure A.1.** Components of Radiative Forcing for Principal Emissions
*Source:* (Myhre et al., 2013)

The absolute global warming potential (AGWP) of greenhouse gases is shown in Figure A.2. This figure shows the heat trapping effect of different gases over time. The yellow and blue curves show how the AGWPs changes with increasing time horizon. Because of the integrative nature the AGWP for $CH_4$ (yellow curve) reaches its primary effect after two decades as $CH_4$ is removed from the atmosphere. The AGWP for $CO_2$ continues to increase for centuries. Thus, the ratio which is the GWP (black curve) drops with increasing time horizon as the relative importance of $CO_2$ is reflected with its longer atmospheric lifetime.

The time horizon affects the relative GWP of $CO_2$, $CH_4$, and $N_2O$ emissions. As indicated in Figure A.2, most of the cumulative effect of CH4 takes place after 20 years. Subsequently, the $AGWP_{CH4}$ curve levels off while the cumulative effect of $CO_2$ continues on for several hundred years. Therefore, the 100 year GWP provides a representation of GHG emissions that take into account more of the warming effect of the pollutants.

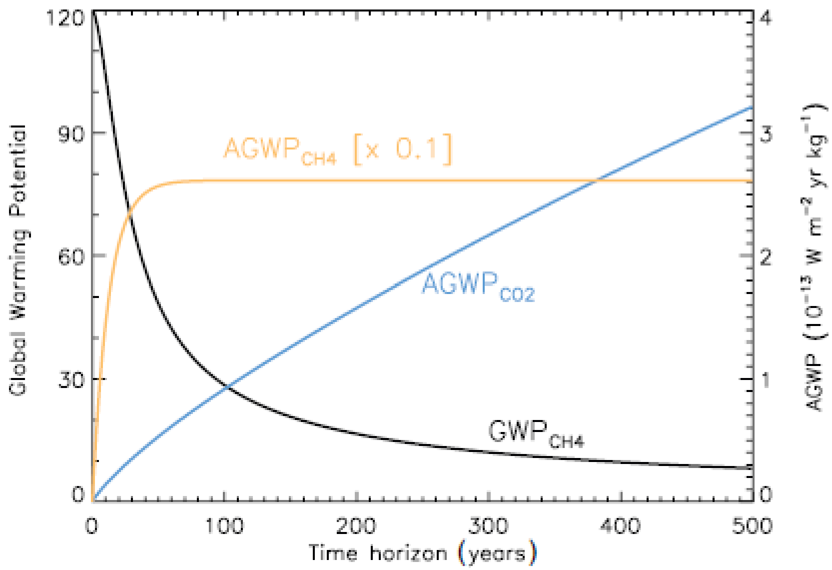



**Figure A.2.** Development of AGWP-$CO_2$, AGWP-$CH_4$ and GWP-$CH_4$ with Time Horizon
*Source:* (Myhre et al., 2013)

Most of the GHG emissions and warming effect of the proposed project are due to $CO_2$.Therefore, The 20 year GWP is not appropriate because it omits the warming effects of $CO_2$ after 20 years while it counts almost all of the warming effect of methane.

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# B. Appendix LCA-B: Upstream Life Cycle Emissions

For each direct emission event, upstream life cycle emissions correspond to the overall life cycle emissions. The upstream life cycle contribution are the emissions associated with producing and transporting the fuel to the point of use. This section describes the quantification of upstream life cycle emissions for natural gas, electricity and petroleum fuels.

## B.1. Natural Gas

The upstream life cycle emission events for natural gas include extraction, processing, transport and distribution. The emissions are accounted for in several GHG accounting systems including regional GHG inventories and LCA models such as GREET and GHGenius. The GHGenius model includes regionally specific estimates of the upstream life cycle emissions for natural gas production in Canada. GHGenius results were calculated for British Columbia. The model reports GWP weighted emissions as shown in Table B.1. The upstream emissions for British Columbia are consistent with the provincial GHG inventory and the estimates lie between the range of an independent estimate of the inventory and GREET values described in the following sections.

**Table B.1.** Upstream Life Cycle GHG Emissions for Natural Gas from GHGenius, HHV Basis

| Model Result [a] | Results for CNG from v4.03a | | | | | | GHGenius v5.0c | |
|---|---|---|---|---|---|---|---|---|
| Pollutant | $CO_2e$ | $CO_2+CH_4$ | $CO_2+N_2O$ | $CO_2c$ | $CH_4$ | $N_2O$ | $CO_2e$ | $CO_2e$ |
| Fuel ------> | CNG | CNG | CNG | CNG | CNG | CNG | BC | Alberta |
| Feedstock ------> | NG | NG | NG | NG | NG | NG | NG | NG |
| Fuel dispensing | 0 | | | | | | 0 | 0 |
| Fuel distribution and storage | 1,131 | 1,129 | 1,080 | 1,077 | 2 | 0.009 | 471 | 471 |
| Fuel production | 2,344 | 2,333 | 2,111 | 2,100 | 9 | 0.036 | 2,333 | 2,372 |
| Feedstock transmission | 0 | 0 | 0 | 0 | | | 1,347 | 688 |
| Feedstock recovery | 2,675 | 2,645 | 2,109 | 2,080 | 23 | 0.099 | 3,743 | 3,745 |
| Feedstock upgrading | 0 | 0 | 0 | 0 | | | 0 | 0 |
| Land-use changes, cultivation* | 0 | 0 | 0 | 0 | | | 0 | 0 |
| Fertilizer manufacture | 0 | 0 | 0 | 0 | | | 0 | 0 |
| Gas leaks and flares** | 2,610 | 2,610 | 2 | 2 | 104 | 0.000 | 0 | 0 |
| $CO_2$, $H_2S$ removed from NG^ | 994 | 994 | 994 | 994 | | | 519 | 519 |
| Emissions displaced | 0 | 0 | 0 | 0 | | | 0 | 0 |
| Total | 9,755 | 9,711 | 6,296 | 6,253 | 138 | 0.14 | 8,414 | 7,795 |

[a]GHGenius also shows results to Industry with a lower transport distance. Gas leaks and flares are zero in v5.

GHGenius reports upstream life cycle emissions on a higher heating value basis. The version 4 results from Table B.1. were converted to a lower heating value basis. Note that versions 5c is now available but this version shows zero emissions from gas leaks and flares, presumably because the incremental emissions are zero with growing regulation of gas production practices. Therefore the version 4 results are used in this study to provide a conservative estimate. The individual $CO_2$, $CH_4$ and $N_2O$ emissions were also obtained by running the model consecutively with zero values for the GWP of $CH_4$ and $N_2O$. Since methane emissions result in a greater heat trapping effect than $CO_2$, the variability in CH4 estimates are examined in the following sections.

### B.1.1. Factors Affecting Natural Gas Emissions

Table B.2 shows the inputs for natural gas production and processing as well as the mix of shale gas and conventional gas as GREET inputs. The recovery efficiency and processing efficiency[30] are converted to Btu/mmBtu of natural gas in the GREET model as indicated in the table. As can be seen, the process fuels used for recovery and processing are mainly natural gas with small amounts of diesel, gasoline, residual oil, and electricity. The upstream life cycle emissions resulting from process fuel use is also accounted for recursively in the model. This includes the upstream emissions associated with electricity production, petroleum recovery and refining, as well as natural gas recovery and processing emissions (the upstream emissions of the upstream emissions). The GREET analysis includes flared natural gas as well as fugitive methane and $CO_2$ which are discussed in more detail below.

**Table B.2.** GREET 1_2017 Default Inputs for Conventional Gas Production

| | NG Recovery | | NG Processing | |
|---|---|---|---|---|
| **Energy Inputs** | **Fuel Shares** | **Btu/mmBtu** | **Fuel Shares** | **Btu/mmBtu** |
| Total | | 25,641 | | 26,694 |
| Residual oil | 1% | 256 | | |
| Diesel fuel | 11% | 2,821 | 1% | 267 |
| Gasoline | 1% | 256 | | |
| Natural gas fuel | 86% | 22,051 | 96% | 25,626 |
| Natural gas flared | -- | 9,940 | | |
| Electricity | 1% | 256 | 3% | 801 |
| Fugitive Emissions (g/mmBtu), LHV | | | | |
| $CH_4$ | | 135.4 | | 6.8 |
| $CO_2$ | | | | 776 |

[a] Efficiency combined with fuel shares determines energy input per mmBtu of natural gas such that 1,000,000 × (1/efficiency-1) × fuel shares = energy input for each fuel.

Note that the GREET default values in Table B.2 reflect the allocation of emissions between natural gas and natural gas liquids.[31]

[30] The GREET model efficiency inputs which are represented as efficiencies and fuel shares are derived from statistics on energy use.

[31] The original GREET documentation shows the relationship between energy inputs for the natural gas industry and the allocation of the inputs to natural gas and natural gas liquids on an energy basis. Subsequent updates to GREET presumably followed this approach. Studies on leaks from natural gas systems generally do not allocate

Although Table B.1 provides the GREET default assumptions for conventional NG recovery, the calculation to convert process efficiency to fuel consumption is the same for shale gas recovery. Table B.3 provides the GREET assumptions regarding the relative shares of conventional and shale gas production as well as their corresponding recovery and processing efficiencies. Note that the energy inputs (and therefore emissions) for conventional gas and shale gas production are very similar. The GREET projection for growth in shale gas is less than that shown in Figure 2.6. The energy inputs for conventional and shale gas are essentially the same as the GREET defaults utilized in this study (Yaritani & Matsushima, 2014).

**Table B.3.** GREET1_2017 Inputs for North American NG Recovery and Processing

| Year | NG Supply from Shale | Recovery Efficiency[a] | | Processing Efficiency | |
|---|---|---|---|---|---|
| | | Conventional | Shale | Conventional | Shale |
| 2016 | 51.5% | 97.5% | 97.6% | 97.4% | 97.4% |
| 2020 | 53.6% | 97.5% | 97.6% | 97.4% | 97.4% |
| 2040 | 55.2% | 97.5% | 97.6% | 97.4% | 97.4% |

[a] Efficiency in combination with fuel shares input determined energy input per mmBtu of natural gas.

The GREET model also calculates energy inputs and emissions from compressors used for natural gas transport. The GREET values provide the basis for natural gas transmission.

In response to increased natural gas production and recognizing the significant uncertainty associated with fugitive methane emissions this subject has received intense investigation in recent years. The Environmental Defense Fund (EDF) recently commissioned a suite of studies to try to better quantify natural gas industry methane emissions. The EDF sponsored reports include one for gas field emissions (Allen et al., 2013), and another for gathering and processing emissions (Marchese et al., 2015), a report by (Zimmerle et al., 2015) on methane emissions in transmission, and another (Lamb et al., 2015) on distribution emissions. To compare the emission estimates, ANL divided the emission estimates in these reports by EIA estimated total withdrawals to arrive at an emission rate normalized to gas throughput. The EPA cites these studies as references for methane fugitive emissions in the most recent (2016) national emission inventory.

The previously mentioned ANL papers on quantifying fugitive methane emissions provide comparisons between the EPA GHGI values divided by throughput, the GREET model values and the aggregated values from the EDF studies. Table B.4 summarizes these estimates. The EPA estimate for gas field emissions more than doubled between 2015 and 2016; the GREET value followed suit and is slightly lower for the 2017 version of the model (based on 2015 year data), but slightly higher than the EDF study composite.[32]

emissions to natural gas liquids. From EIA in 2015 Dry Natural Gas production 27,065 bcf (EIA, 2018b). 289.5 bcf vented and flared Natural Gas liquids as NG 1817 bcf with allocation factor of 93.7% to natural gas. .

[32] Which is the EPA gas field value plus Marchese's gathering emissions.

The current GREET estimate for processing emissions has decreased based on EPA's 2017 estimates of reduced emissions from reciprocating engines and centrifugal compressors. Transmission and distribution emissions in GREET1_2017 are similar to those from the EDF studies. For this analysis, the GHGenius inputs and GREET inputs span the range of GHG emissions

Alternatively, British Columbia quantifies its methane leakage as 4.65 billion cubic feet from all oil and gas operations (Province of British Columbia, 2018). Dividing by the total natural gas production in the province (1,801 billion cubic feet) yields a methane leak rate of 0.26%. A recently published study of atmospheric methane emission estimates 111,800 tonne compared to the bottom up inventory of 78,000 tonne (Atherton, 2017).

**Table B.4.** Summary of Recent Upstream Natural Gas Leakage Estimates (% of gas delivered)

| Activity | Type | Gas Field | Processing | Transmission | Distribution | Total |
|---|---|---|---|---|---|---|
| GREET1_2015 | Shale | 0.34% | 0.13% | 0.41% | 0.43% | 1.30% |
| | Conv | 0.30% | | | | 1.26% |
| GREET1_2016 | Shale | 0.77% | 0.13% | 0.36% | 0.14% | 1.38% |
| | Conv | 0.70% | | | | 1.32% |
| GREET1_2017[a] | Shale | 0.67% | 0.03% | 0.22% | 0.08% | 1.00% |
| | Conv | 0.66% | | | | 0.99% |
| GREET1_2018[a] | Shale | 0.681% | 0.03% | 0.21% | 0.09% | 1.02% |
| | Conv | 0.664% | | | | 1.00% |
| EPA GHGI 2013 data[b] | U.S. | 0.31% | 0.15% | 0.36% | 0.22% | 1.04% |
| EPA GHGI 2014 data [b] | U.S. | 0.68% | 0.15% | 0.20% | 0.07% | 1.11% |
| Allen, 2013 [c] | | 0.38% | n/a | n/a | n/a | |
| EDF Studies 2015 [d] | | 0.58% | 0.09% | 0.25% | 0.07% | 0.99% |
| (Tong, Jaramillo, & Azevedo, 2015) [e] | | 0.49% | 0.04% | 0.46% | 0.31% | 1.30% |
| GHGenius 2016, BC | BC | 0.18% | 0.003% | 0.014% | 0.13% | 0.32% |
| Province of British Columbia 2017 | BC | 0.26% | 0.1% | 0.03% | 0.01% | 0.4% |
| G7 study (Brandt et al., 2017) | BC | 0.18% | n/a | n/a | n/a | n/a |
| (Alvarez et al., 2018) | U.S. | 1.8% | 0.13% | 0.32% | 0.08% | 2.3% |

[a] The extraction and transmission fugitives are 143.6 and 44.7 g $CH_4$/mmBtu respectively. GREET model identifies the distribution but does not utilize it since industrial and commercial NG users are upstream of the local distribution.

[b] Reported in EPA 2015, @ Reported in EPA 2016

[c] Taken from ANL "Updates to $CH_4$ Emissions with Natural Gas Pathways in GREET1_2015" Table 5 – ANL divided reported methane emission values by EIA gross withdrawals.

[d] The Gas Field value utilizes EPA's value for gas field emissions (0.31%) and Marchese's value for gathering (0.27%). The processing value is a combination of EPA's value for routine maintenance and (Marchese et al., 2015)'s processing value. Transmission is from (Zimmerle et al., 2015).; Distribution is from (Lamb et al., 2015)

[e] Gas field estimate also includes road construction, well drilling, and fracking emissions

Fugitive methane emissions from the natural gas delivery chain are material to the project's Life Cycle GHG emissions. The methane leak (i.e. fugitive emissions) assumptions in the GREET model reflect the most recent emissions published by the EPA in the national emission inventory as quantified by ANL (Burnham, 2016, 2017; Burnham, Han, Elgowainy, & Wang, 2015; Cai, Burnham, Chen, & Wang, 2017). Recent studies e.g., (Heath, Warner, Steinberg, & Brandt, 2015; Lamb et al., 2015; Peischl et al., 2016; Zimmerle et al., 2015) have reported a range in methane emissions from natural gas that compare to the U.S.GHG inventory (GHGI).

It is worth noting that fugitive gas emissions are significantly different from jurisdiction to jurisdiction due to both geophysical considerations and regulatory regimes. As Ravinder and Brandt noted that measurements in the Bakken Shale in North Dakota have demonstrated emission rates over 10% while recent data from the Marcellus shale show emission rates lower than 1% (Ravikumar & Brandt, 2018).

Estimate of upstream GHG emissions from natural gas in British Columbia and Canada are lower than United States averages. The GHGenius model estimates BC GHG emissions of 0.32% of production vs estimates of US emissions from 1.0% to 1.5%, or higher .Similarly average US emissions measured in $CO_2e$/MJ are about 12 (ICF International, 2017) vs Natural Resources Canada estimates of Canadian emissions of 7 to 8 (ICF Consulting CANADA, 2012).

An analysis from Stanford University for the Alberta G7 project estimate methane losses from Canadian projects that correspond to 0.18% of the produced gas (Brandt et al., 2017). These emissions are due to better management practices and potentially Canadian requirements on emission controls. Brandt et al measured emissions from Canadian company Seven Generations Energy, at 0.18% (Wellhead only) which corresponds to the GHGenius result. Finally, newer wells have distinctly lower emissions than older wells, and pads and “super pads” (the drilling of multiple wells from a single site which is now common practice) have distinctly lower emissions (This is common practice in BC).

### B.1.2. Hydraulic Fracturing

Several LCA assessments have examined the energy inputs and emissions from hydraulic fracturing of shale to produce natural gas.  Fracking includes the introduction of water, chemical, sand, and other materials into the gas well.  While these inputs represent a significant volume of material, their emissions represent a small fraction of the overall life cycle emissions associated with natural gas production. Tables B.5 and B.6 compare the methane leaks and emissions from different gas production methods. Note that the methane emissions in GREET1_2018 are higher than those in the 2017 model but the flared $CO_2$ is lower; so, the overall upstream emissions remain about the same.

**Table B.5.** GREET1_2018 Inputs for Natural Gas Production

| | | EPA 2018 | | EDF 2018 | |
|---|---|---|---|---|---|
| | Unit | Conventional NG | Shale gas | Conventional NG | Shale gas |
| Recovery - CH4 Leakage and Venting | g CH4/mmBtu NG | 137.1 | 140.6 | 214.3 | 214.3 |
| Recovery - Completion CH4 Venting | g CH4/mmBtu NG | 0.5 | 3.3 | N/A | N/A |
| Recovery - Workover CH4 Venting | g CH4/mmBtu NG | 0.0 | 0.7 | N/A | N/A |
| Recovery - Liquid Unloading CH4 Venting | g CH4/mmBtu NG | 4.4 | 4.4 | N/A | N/A |
| Well Equipment - CH4 Venting and Leakage | g CH4/mmBtu NG | 132.2 | 132.2 | N/A | N/A |
| Processing - CH4 Venting and Leakage | g CH4/mmBtu NG | 5.9 | 5.9 | 9.5 | 9.5 |
| Transmission and Storage - CH4 Venting and Leakage | g CH4/mmBtu NG/68 | 43.6 | 43.6 | 60.4 | 60.4 |
| Distribution - CH4 Venting and Leakage | g CH4/mmBtu NG | 19.4 | 19.4 | 19.4 | 19.4 |

**2 emission rate for recovery and processing in conventional NG and shale gas pathways**

| | | Used in calculation: EPA 2018 | | EDF 2018 | |
|---|---|---|---|---|---|
| | Unit | onventional NG | Shale gas | nventional NG | Shale gas |
| Recovery - Flaring | Btu NG/mmBtu NG | 1,749 | 1,484 | 1,749 | 1,484 |
| Recovery - Venting | g CO2/mmBtu NG | 19 | 19 | 19 | 19 |
| Processing - Flaring | Btu NG/mmBtu NG | 3,018 | 3,018 | 3,018 | 3,018 |
| Processing - Venting | g CO2/mmBtu NG | 547 | 547 | 547 | 547 |

* EDF values are reported in GREET for total recovery emissions. Breakout by step is not reported in the model.

**Table B.6.** Role of Fracking Water in Upstream of Natural Gas Production (g $CO_2$e/MJ)

| GHG Emissions (g $CO_2$e/MJ Natural Gas), LHV | Yaritani | | GREET1_2018 | | BC v4.0a |
|---|---|---|---|---|---|
| **Step** | **Conventional** | **Shale Gas** | **Conventional** | **Shale Gas** | **GHGenius** |
| Preproduction | | | | | |
| Well Pad Construction | 0.16 | 0.16 | | | |
| Well Drilling | 0.23 | 0.2 | | | |
| Fracking Water | -- | 0.26 | | | |
| Fracking Chemicals | -- | 0.07 | | | |
| Fugitive Emissions and Well Completion | 0.18 | 1.2 | | | |
| Production/Processing [a] | | | | | |
| Flaring | 0.6 | 0.6 | | | |
| Plant Energy | 3.1 | 3.1 | 2.46 | 2.36 | 2.81 |
| Fugitive at Well | 2.7 | 2.7 | 3.22 | 3.26 | 2.74 |
| Vented CO2 | 1.2 | 1.2 | 1.86 | 2.60 | 2.46 |
| Fugitive at Plant | 1.8 | 1.8 | 0.90 | 0.16 | |
| Workover | -- | 1.1 | | | |
| Liquid Unloading | 3.8 | -- | | | |
| Transmission | | | | | |
| Compression Fuel | 0.4 | 0.4 | 2.59 | 2.59 | |
| Fugitive transmission | 1.9 | 1.9 | 1.06 | 1.06 | |
| Total | 16.1 | 14.69 | 12.08 | 12.03 | 8.01 |

[a]Values adjusted to account for rounding

### B.1.3. Natural Gas Flows

Natural get enters Washington from Canada and Idaho. The primary gas producers in the region are British Columbia, Alberta, and the Rocky Mountains. Data from EIA shows interstate transfers of natural gas to Washington are from Canada and Idaho (EIA, 2018a). Almost all of the gas entering Idaho arrives from Canada. Gas produced in the Rocky Mountains flows primarily to California by way of Utah and Nevada as shown in Figure B.1.

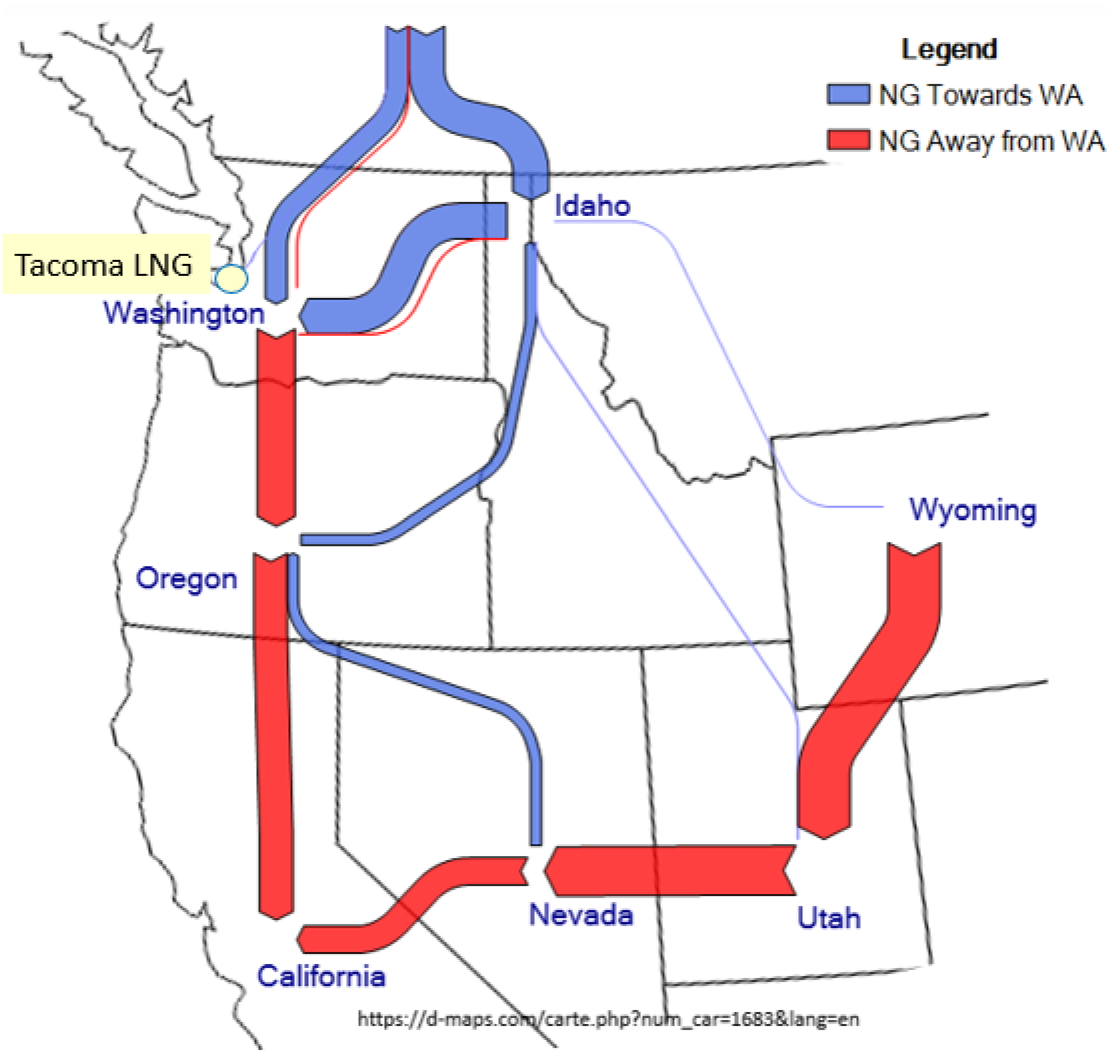


**Figure B.1.** Natural Gas Flows in Western United States

## B.2. Power Generation

One key input for life cycle GHG quantification is the resource mix used to generate electricity that is purchased by the plant. 239 GWh of electricity will be purchased each year[33] for scenario B. Several different resource mixes that could be used for the electricity purchased by the

[33] 1.348kWh/gallon LNG x 500,000 gal/day

Tacoma LNG facility are discussed below. A key question is whether to use an average mix or the resources that come online to service the new demand (marginal mix).

### *Average Mix*

The Tacoma LNG facility will consume electricity from the regional power market for the Bonneville Power Administration (BPA) and Tacoma Power. Regional power consists of dozens of federal hydroelectric plants, the Columbia Nuclear Generating Station (publicly owned), various wind facilities as well as natural gas and coal-fired plants.

Washington State publishes the Electric Utility Fuel Mix Disclosure Report (State Energy Office at the Washington Department Of Commerce, 2017) each year, summarizing the statewide and utility level (e.g., Tacoma Power) retail power sales by fuel type. In addition to state and local resource mixes, the U.S. EPA manages the eGRID database which catalogs electricity generation data for a number of electricity generating regions. The Tacoma LNG facility is located within the Northwest Power Pool (NWPP) region shown in Figure B.2.

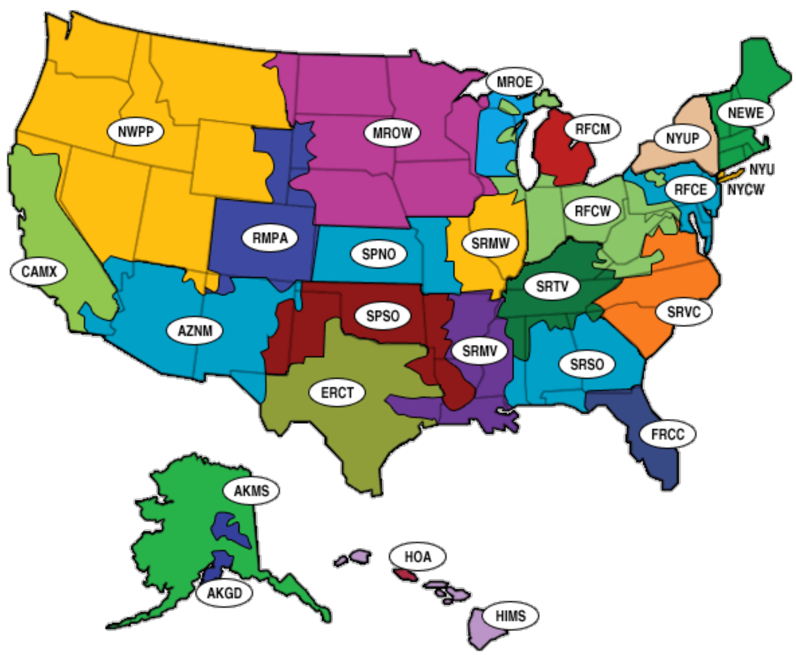


**Figure B.2.** Map of eGRID Subregions

Resource mix data for Tacoma Power and Washington State in 2016 are summarized in Table B.7. Also shown are the 2014 and 2016 eGRID data for the NWPP region. The Tacoma Power mix results in very low GHG emissions per kWh since it predominately consists of hydro and nuclear power. The Washington state average mix for 2016 has more fossil generation and less hydro than the Tacoma Power mix. The NWPP mix is higher carbon due to its larger share of coal generation. Note that between 2014 and 2016 coal generation in the NWPP decreased significantly while hydro, renewables and natural gas generation all increased.

**Table B.7.** Applicable Electric Power Generation Resource Mixes

| Resource | 2016 Washington Average | 2014 NWPP eGRID[34] | 2016 NWPP eGRID[35] | Tacoma Power |
|---|---|---|---|---|
| Residual oil | 0.1% | 0.2% | 0.2% | 0% |
| Natural gas | 11.5% | 11.9% | 15.3% | 1% |
| Coal | 14.1% | 36.2% | 22.5% | 2% |
| Nuclear | 4.9% | 2.8% | 3.4% | 6% |
| Biomass, LFG | 1.1% | 1.1% | 1.3% | 0% |
| Hydroelectric | 64.0% | 40.0% | 47.2% | 84% |
| Geothermal, Wind, Solar | 4.2% | 8.0% | 9.7% | 7% |
| Others | 0.1% | 0.0% | 0.4% | 0% |

### *Marginal Mix*

One question that might be raised regarding electricity emission estimates is whether an average grid mix or a marginal grid mix should be utilized. Specifically, which new resources will come online to meet the new load. Given the load growth anticipated for the Tacoma LNG facility is 20% of the recent decrease between 2014 and 2016, one approach is to simply assume the growth is met by conservation.

The second trend that must be considered is the decline in the coal fleet. Table B.8 provides the coal fired units within the NW Power and Conservation Council's territory (Idaho, Montana, Washington, Oregon). As shown in the table, the two remaining coal plants in Washington State will both retire by 2025 and 61% of the region's coal generating capacity will have retired by 2025. Note that even though Washington's two coal plants will have retired by 2025, utilities will still import coal generated electricity from other states as needed.

[34] eGRID2014v2 Generation Resource Mix eGRID2014v2 Generation Resource Mix (US EPA, 2014)
[35] eGRID2016 https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid eGrid 2016 (US EPA, 2016)

**Table B.8.** Regional Coal Plant Retirement Dates

| Coal Fired Boiler | State | MW | Retirement |
|---|---|---|---|
| Colstrip Energy LP | MT | 46 | |
| Colstrip Unit 1 | MT | 360 | 2022 |
| Colstrip Unit 2 | MT | 360 | 2022 |
| Colstrip Unit 3 | MT | 780 | |
| Colstrip Unit 4 | MT | 780 | |
| Lewis & Clark | MT | 50 | |
| Hardin Gen Project | MT | 116 | |
| Boardman | OR | 642 | 2021 |
| Centralia 1 | WA | 730 | 2020 |
| Centralia 2 | WA | 730 | 2025 |
| | Total Coal | 4594 | |
| | Total Retiring | 2822 | |

The third trend to consider is the Washington State Energy Independence Act of 2006 which establishes a renewable portfolio standard of 15% new renewables (hydro plants existing before 1999 do not count) by 2020 and each year after.

Given the uncertainty and complexity of calculating a marginal grid electricity mix, use of an average grid mix can be more appealing. Moreover, there is considerable precedence for using an average resource grid mix. For example, CalEEMod, the model utilized in California to quantify project emissions for CEQA purposes (California's version of the Washington State Environmental Policy Act) stipulates that to quantify GHG emissions for electricity consumption, the emission factors for the local utility should be used. The Washington State Agency GHG Calculator tool[36] utilizes electricity emission factors from the State Fuel Mix Disclosure Report. Finally, the California Air Resources Board chose an average mix for quantification of electric vehicle carbon intensity values for use in their Low Carbon Fuel Standard.

The assorted resource mixes considered in this Study are summarized in Table B.9. The corresponding GHG emissions from the GREET model with these mixes is provided in Table B.10. The Washington state average is approximately 60 g $CO_2$e/MJ (215 g $CO_2$e/kWh), the current NWPP eGRID value is 90 g $CO_2$e/MJ and the estimated marginal mix is 69 g $CO_2$e/MJ.

[36] The tool may be downloaded at https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Climate-change-emissions-reporting/State-agency-reports-tools

**Table B.9.** Resource Mixes Evaluated

| Fuel | 2016 WA State Average | 2016 NWPP eGRID | Tacoma Power | WA State Marginal |
|---|---|---|---|---|
| Residual oil | 0.1% | 0.2% | 0% | 0.0% |
| Natural gas | 11.5% | 15.3% | 1% | 44% |
| Coal | 14.1% | 22.5% | 2% | 2% |
| Nuclear | 4.9% | 3.4% | 6% | 0.0% |
| Biomass | 0.9% | 1.3% | 0% | 1% |
| Other (Renewable) | 68.5% | 57.3% | 91% | 52% |

**Table B.10.** GREET Estimated GHG Emissions for Each Electricity Resource Mix

| | g/MMBtu | | | | $gCO_2e/MJ$ |
|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2c$ | GHG* |
| 2016 WA State Avg | 59,684 | 112 | 1 | 59,751 | 59.6 |
| 2016 Tacoma Power | 13,413 | 31 | 1 | 13,537 | 13.9 |
| 2014 NWPP eGRID | 127,042 | 213 | 2 | 127,141 | 126.2 |
| 2016 NWPP eGRID | 90,466 | 166 | 2 | 95,118 | 90.2 |
| Marginal 2040 | 67,990 | 192 | 1 | 75,351 | 69.3 |

* AR4 100-yr GWP factors

## B.3. Petroleum Upstream Life Cycle

Upstream life cycle GHG emissions for petroleum fuels including diesel, marine gas oil, and gasoline, were calculated based on the regional resource mix for Washington. Inputs for the life cycle of petroleum fuels include:

- Location of crude oil resources
- Transportation distance and mode
- API gravity of crude oil

These inputs were applied to the GREET analysis of crude oil refining. GHG emissions were based on the more detailed regionally specific OPGEE analysis published by the California Air Resources Board (California ARB, 2018; El-Houjeiri, Masnadi, Vafi, Duffy, & Brandt, 2018).

### B.3.1. Petroleum Fuels Consumed in Washington

Five refineries operate in Washington State[37] with a combined refining capacity of over 230 million barrels per year. Although the state is a net exporter of refined product, gasoline and diesel are imported from Montana and Utah into eastern Washington. The most recent available pipeline transfer data[38] indicate that 6% of diesel consumed in Washington is refined in Montana and transported to Washington via the Yellowstone pipeline and 10% is refined in Utah and transported via the Tesoro pipeline. The balance (84% of diesel) is assumed to be refined in Washington State. We assume that all marine gas oil consumed is refined in-state. The following sections describe quantification of CI values for petroleum products refined in Washington, Utah and Montana and also provide composite CI values for marine gas oil, gasoline and diesel consumed in Washington State.

***Sources of Crude Oil Refined in Washington, Utah and Montana***

Washington State receives crude oil by vessel, pipeline, and rail. DOE's Energy Information Administration (EIA) provides quantity of oil as well as corresponding API and sulfur content for all crude oil imported from foreign countries to each state. The Washington state foreign imports are indicated in Table B.11. Most of the foreign crude oil comes from Canada. Canadian crude oil can be derived from oil sands and upgraded before introducing it to the pipeline or it can by conventional crude oil. Data are no longer published specifying the share of crude exported to each PADD that is oil sands derived vs conventional. Instead, the Canada National Energy Board simply distinguishes between light and heavy where heavy is defined as upgraded bitumen (Natural Resources Canada, 2015). For PADD 5 (where Washington state is located), the NEB data indicate that 58% of the crude is light and 42% is heavy (assumed to be oil sands derived).

[37] British Petroleum Cherry Point, Shell Oil Anacortes, Tesoro Anacortes, Phillips 66 Ferndale, and US Oil Tacoma.

[38] 2013 data provided by Hedia Adelman, Washington State Department of Ecology

**Table B.11.** Foreign Crude Imports to Washington State, 2017 per EIA

| | 2017 Foreign Imports | | | |
|---|---|---|---|---|
| **Country** | **1000 bbl** | **Share** | **Avg API** | **Avg S** |
| Brazil | 5,855 | 7% | 28.9 | 1.3 |
| Brunei | 245 | 0% | 40.9 | 0.2 |
| Canada | 66,780 | 84% | 32.7 | 1.4 |
| Ecuador | 690 | 1% | 20.7 | 1.9 |
| Mexico | 451 | 1% | 20.0 | 4.3 |
| Russia | 2,480 | 3% | 43.2 | 0.3 |
| Saudi Arabia | 1,297 | 2% | 39.5 | 1.1 |
| Trinidad & Tobago | 1,367 | 2% | 39.9 | 0.3 |

EIA Company Level Imports sorted for Washington state refineries
https://www.eia.gov/petroleum/imports/companylevel

In addition to foreign imports, Washington receives crude oil from the Alaska North Slope (via pipeline to Valdez and vessel to the west coast ports) and from North Dakota on rail cars. The Department of Ecology tracks and publishes quarterly reports (Washington State Department of Ecology, 2017) on all crude oil receipts (foreign and U.S.), distinguishing between rail car, pipeline and vessel transport modes. These data help determine the quantity of Alaska and North Dakota crude oil received and also helps determine the split between different transport modes for Canadian crude oil.

The railcar deliveries are posted weekly and provide source and route taken. The routes through Washington are provided in Figure B.3. For crude shipments from Alberta, additional mileage is added to reflect travel from Calgary to Edmonton and then to British Columbia. Shipments from Saskatchewan are assumed to travel from Saskatoon to Edmonton and then British Columbia. North Dakota crude oil is assumed to travel 1500 miles before entering eastern Washington near Spokane. Table B.12 summarizes the crude oil receipts by rail and associated total transport miles. As indicated, the total shipments by rail from Canada in 2017 was 4,691 thousand bbl. The quarterly reports also state that an additional 60,728 thousand bbl came by pipeline. The EIA data provided below is for all crude from Canada, so the amount by tanker is determined by difference to be 1,361 thousand bbl.


**Figure B.3.** Crude Oil Rail Routes to Washington Refineries
*Source:* (Washington State Department of Ecology, 2017)

**Table B.12.** Washington State Crude Oil Receipts by Rail, 2017

| Source | API | 1000 bbl | Rail Miles |
|---|---|---|---|
| North Dakota | 31-50 | 49,585 | 2,183 |
| North Dakota | 10-22 | 130 | 2,080 |
| Alberta | 31-50 | 536 | 1,124 |
| Alberta | 22-31 | 956 | 1,175 |
| Alberta | 10-22 | 2,601 | 1,344 |
| Saskatchewan | 31-50 | 534 | 1,156 |
| Saskatchewan | 10-22 | 65 | 1,145 |
| Total by Rail | | 54,407 | |

Finally, the quarterly reports state that the total amount received by vessel is 98,024 thousand bbl. The foreign imports in Table B.12 total to 12,385 bbl (excluding Canada). If we add the portion from Canada determined to come by vessel, we find that the total foreign crude arriving by vessel is 13,746 thousand bbl. The difference between the total from the quarterly reports and the foreign crude arriving by vessel is 84,278 thousand bbl and is assumed to be Alaska North Slope crude. Table B.13 summarizes the sources of crude oil and their mode of transport. Also shown is total crude supplied and total refinery capacity. Comparing to crude slates in the 2013 timeframe, the main difference is a large increase in crude sourced from North Dakota at the expense of crude from Alaska.

**Table B.13.** Summary of 2017 Crude Oil Influx to Washington State

| Origin | Quantity | | API | S | Transport |
|---|---|---|---|---|---|
| | 1000 bbl | % | degree | % | Mode |
| Brazil | 5,855 | 3% | 29 | 1.3 | Vessel |
| Brunei | 245 | 0% | 41 | 0.2 | Vessel |
| Canada | 66,780 | 31% | 33 | 1.4 | Mixed |
| Ecuador | 690 | 0% | 21 | 1.9 | Vessel |
| Mexico | 451 | 0.2% | 20 | 4.3 | Vessel |
| Russia | 2,480 | 1.2% | 43 | 0.3 | Vessel |
| Saudi Arabia | 1,297 | 0.6% | 39 | 1.1 | Vessel |
| Trinidad & Tobago | 1,367 | 1% | 40 | 0.3 | Vessel |
| North Dakota | 49,715 | 23% | 40 | | Rail |
| Alaska NS | 84,278 | 40% | 40 | | Mixed |
| Total Crude | 213,159 | | | | |
| Total Capacity | 231,301 | | | | |

According to the Montana Department of Natural Resources (Department of Natural Resources and Conservation of the State of Montana, 2016), the crude oil refined in Montana is largely from Canada. As can be seen in Table B.14, most of the crude refined in Montana is from Canada. The Canadian Energy Board states that 89% of crude sent to PADD 4 was heavy (oil sands).

**Table B.14.** Sources of Crude Oil for Montana Refineries, 2016

| Source | Share |
|---|---|
| MT | 2% |
| WY | 7% |
| Canada | 91% |

The most recent published tabulation of Utah sources (Utah Department of Natural Resources, 2016) of crude oil is from 2015 and is provided in Table B.15. A small portion of crude is supplied from Canada; because Utah is in the same PADD as Montana, the mix of Canada heavy and light is assumed to be the same.

**Table B.15.** Sources of Crude Oil for Utah Refineries, 2015

| Source | Share |
|---|---|
| Utah | 43% |
| Colorado | 13% |
| Wyoming | 36% |
| Canada | 8% |

### *Crude Oil CI Estimate (Recovery & Transport)*

The California Air Resources Board (ARB) utilizes the Oil Production Greenhouse Gas Emission Estimator (OPGEE) model, developed by researchers at Stanford University to quantify the carbon intensity of the crude oil recovery and transport portion of petroleum fuel pathways. Each year the CI is quantified for all of the oil fields that supply California refineries. For this analysis we utilize the 2016 CI values developed for California using OPGEE (California Air Resources Board, 2017); the underlying assumption is that the emission difference between transport to California and transport to Washington is very minor. In many cases, the OPGEE results provide data from a number of oil fields in a given country. For example, CI values four different oil fields in Brazil are provided along with barrels of oil transferred. For this analysis, a volume weighted average of the four Brazil oil field CI values is assumed to represent crude oil CI from Brazil.

The sources of crude oil for Washington refineries and corresponding CI values are provided in Table B.16, indicating that the average value for Washington refineries is 12 g/MJ.[39] Composite crude CI values for Montana (17 g/MJ) and Utah (14 g/MJ) are provided in
Table B.**17** and Table B.18. These values are combined with refining and finished fuel transport CI estimates from the GREET model based on crude type and electricity mix at the refinery.

**Table B.16.** Sources of Crude for Washington State Refineries

| Source | Share | OPGEE CI ($gCO_2e/MJ$) |
|---|---|---|
| Brazil | 2.8% | 11.1 |
| Canada Conventional | 18.3% | 8.3 |
| Canada Oil Sands Derived | 13.3% | 17.7 |
| Ecuador | 0.3% | 10.3 |
| Mexico | 0.2% | 10.2 |
| Russia | 1.2% | 13.5 |
| Saudi Arabia | 0.6% | 9.1 |
| North Dakota Bakken | 23.5% | 10.2 |
| Alaska North Slope | 39.8% | 12.9 |
| | **Weighted Average** | **12.0** |

**Table B.17.** Sources of Crude Oil for Montana Refineries

| Source | Share | OPGEE CI ($gCO_2e/MJ$) |
|---|---|---|
| Montana (Bakken) | 2% | 12.9 |
| Wyoming | 7% | 24.11 |
| Canada Conventional | 10% | 8.3 |
| Canada Oil Sands Derived | 81% | 17.7 |
| | **Weighted Average** | **17.1** |

**Table B.18.** Sources of Crude for Utah Refineries

| Source | Share | OPGEE CI ($gCO_2e/MJ$) |
|---|---|---|
| Utah | 43% | 5.99 |
| Colorado | 13% | 8.03 |
| Wyoming | 36% | 24.1 |
| Canada Conventional | 0.90% | 8.3 |
| Canada Oil Sands Derived | 7.10% | 17.7 |
| | **Weighted Average** | **13.6** |

[39] a very small amount of crude also came from Brunei and Trinidad & Tobago, because OPGEE did not provide CI values for oil fields in these countries they were omitted from the average.

### *Refining & Transport CI Estimates from GREET*

The CI from refining and finished fuel (gasoline, diesel and marine gas oil) were calculated with the GREET model for each refining location (Washington, Montana, and Utah). The GREET model adjusts refining energy inputs based on correlations between crude location and both sulfur content at API degree. We have also customized the model to use state average electricity grid mixes at each of the refining locations. The electricity grid mixes are shown in Table B.19.

**Table B.19.** Electricity Grid Mixes for each Refining Location

| | Residual Oil | Natural Gas | Coal | Nuclear | Biomass | Non-Emitting |
|---|---|---|---|---|---|---|
| Washington | 0.1% | 11.5% | 14.1% | 4.9% | 0.9% | 68.5% |
| Montana | 1.7% | 2.1% | 55.3% | 0.0% | 0.0% | 40.9% |
| Utah | 0.7% | 15.3% | 80.6% | 0.0% | 0.4% | 3.0% |

The well-to-tank (WTT) CI values for gasoline blendstock, low sulfur diesel and residual oil refined in Washington, Montana and Utah are shown in Table B.20. These values do not include the tank-to-wheel (TTW) contribution from burning the fuel. Montana products have the highest CI values because they have a high content of Canada oil sands crude oil. The Montana refining emissions are highest because of the high Canadian crude slate. Again, we assume 82% of gasoline blendstock is refined in Washington with 11% from Montana and 6% from Utah. For distillate, 84% is refined in Washington with 6% from Montana and 10% from Utah. Residual oil consumed in Washington is assumed to be refined in state.

**Table B.20.** WTT Carbon Intensity Values

| Fuel | Refined in | | | Consumed in Washington |
|---|---|---|---|---|
| | Washington | Montana | Utah | |
| Gasoline Blendstock | 22.8 | 31.6 | 25.3 | 23.9 |
| Low Sulfur Diesel | 19.7 | 26.8 | 22.1 | 20.4 |
| Residual Oil | 16.5 | 22.7 | 18.5 | 16.5 |

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# C. APPENDIX LCA-C: DIRECT COMBUSTION EMISSIONS

## C.1. GHG Emission Factors for Fuel Combustion

Direct combustion emissions occur from a variety of sources in the life cycle. These emissions include $CO_2$, $CH_4$ and $N_2O$ which depend on the carbon content and heating value of the fuel as well as the combustion characteristics of how the fuel is burned. Table C.1 shows the calculation of the carbon factor (g $CO_2$/mmBtu) for the primary fuels in the life cycle of LNG and alternative fuels. The carbon factor is calculated such that the carbon per Btu is multiplied by the molecular weight ratio of $CO_2$ to carbon via:

Carbon factor = wt% C/HHV (Btu/lb) × 453.59 g/lb x 44/12.01 × $10^6$

**Table C.1.** Calculation of $CO_2$ Emission Factors from Fuel Properties

| Fuel | Natural Gas | LNG | MGO | On-Road Diesel |
|---|---|---|---|---|
| Carbon Content (wt%) | 75.2% | 75.1% | 86.5% | 86.5% |
| Heating Value (Btu/lb), HHV | 21,074 | 21,262 | 19,676 | 19,212 |
| Heating Value (Btu/lb), LHV | 984 | 955 | 18,397 | 18,402 |
| Heating Value (Btu/unit), HHV | 1089 | 1057 | 128,450 | 127,464 |
| Unit | scf | scf | gal | gal |
| Fully oxidized (g $CO_2$/mmBtu) | 59,314 | 58,690 | 78,130 | 78,199 |
| Source: | from composition | from composition | App. C.2.2. GREET | GREET |

Hydrocarbon and carbon monoxide emissions are treated as fully oxidized $CO_2$ under most GHG accounting systems including IPCC AR4 (IPCC, 2007) and Argonne's GREET model (ANL, 2017). In the IPCC assessment, for example, the global warming potential (GWP) of carbon monoxide is considered to be 1.5 to 2 which is consistent with the fully oxidized treatment of CO (ratio of 44/28 = 1.57) which is the value used in the GREET model.[40] State of Washington SEPA identified emission factors and sources are consistent with this approach (Washington State Department of Ecology, 2018a).

The carbon factor is the same for each fuel regardless of its end-use application. However, the methane and $N_2O$ emissions depend on combustion properties for engines, turbines, and boilers. $CO_2$ emissions for fuel combustion depend upon the carbon content, density, and heating value of fuels such that all of these properties are consistent. Table C.3 show the

[40] When fuel use is represented as an emission factor per MMBtu of fuel, this factor typically includes all of the carbon in the fuel. However, emission factors individual types of equipment such as marine engines might include separate values for $CO_2$ and CO emissions. In order to be consistent with IPCC and SEPA reporting protocols, CO should be counted as fully oxidized $CO_2$. The effect of this detail is typically less than 0.5% of $CO_2$ emissions from any source. This study includes VOC and CO emissions as $CO_2$c because these emissions are counted in the GREET LCA framework. Also, many emission inventory methods show $CO_2$ as fully oxidized carbon in fuel.

carbon factor which represents $CO_2$ emissions per unit of fuel is calculated based on these properties. In this study, emission factors are identified in the units based on the original data source including the higher (HHV) or lower heating value (LHV) basis.

Emission factors for each energy source in the study are based either on SEPA emission factors, actual fuel properties, or GREET emission factors. Note that fuel combustion occurs through the upstream fuel cycle for all of the energy inputs associated with the project and displaced emissions. Therefore, calculations based on the GREET direct emission factors are more consistent than mixing and matching data from various sources.

## C.2. Fuel Property Data

### C.2.1. Natural Gas and LNG

The composition of natural gas and LNG affect its carbon and energy content as well the $CO_2$ emissions emitted per unit of energy. The relative fraction of light hydrocarbons as well as $CO_2$ affect the carbon factor in g $CO_2$/mmBtu. The compositional data in Table A.11 provide the basis for determine heating values and carbon factors for natural gas and LNG.

### C.2.2. Diesel Fuels

Diesel fuels provide energy inputs for the no action alternative as well as fuel for truck transport and marine pilot fuel in the Tacoma LNG scenario. Marine fuel is broadly classified as Marine Gas Oil (MGO), or Marine Diesel Oil (MDO). MGO roughly approximates No. 2 fuel oil, or diesel fuel, but has several distinct differences. Table C.2 shows physical property data for the different grades of fuel oil and MGO, as well as F-76 (Navy-spec fuel oil), conventional diesel fuel, and residual oil.

**Table C.2.** Properties of Distillate Fuels and $CO_2$ Emissions

| | Product | API Gravity | Density (lb/gal) | Sulfur (%) | Carbon (%) | Btu/gal (LHV) | Btu/gal (HHV) | Btu/lb (LHV) | C Factor $gCO_2$/lb | C Factor $gCO_2$/MJ | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | MGO Range | | | | | | | | | | |
| | No 1 | 40 | 6.87 | 0.1 | 86.5 | 128,095 | 137,000 | 18,646 | 1,437 | 73.1 | Penn State |
| | No 2 | 32 | 7.206 | 0.4 - 0.7 | 86.4 | 131,835 | 141,000 | 18,295 | 1,436 | 74.4 | Penn State |
| **MGO** | MGO | 32 | 7.05 | 0.7 | 86.3 | 129,231 | 138,215 | 18,331 | 1,434 | 74.1 | Lam |
| | MGO | 32 | 7.42 | 1.5 | 86.3 | 133,953 | 143,266 | 18,053 | 1,434 | 75.3 | Lin |
| | MGO | 33 | 7.13 | 0.6 | 86.3 | 131,649 | 140,805 | 18,464 | 1,434 | 73.6 | Corbett |
| | MDO Range | | | | | | | | | | |
| | No 4 | 21 | 7.727 | 0.4 - 1.5 | 86.1 | 136,510 | 146,000 | 17,667 | 1,431 | 76.8 | Penn State |
| **MDO** | No 5 | 17 | 7.935 | 2 | 85.55 | 138,380 | 148,000 | 17,439 | 1,422 | 77.3 | Penn State |
| | No 6 | 12 | 8.212 | 2.8 | 85.7 | 140,250 | 150,000 | 17,079 | 1,424 | 79.0 | Penn State |
| | F-76 | 36 | 7.029 | 0.572 | 85.8 | 129,151 | 138,129 | 18,374 | 1,426 | 73.5 | SWRI |
| | US Conv Diesel | 37.6 | 6.982 | 0.02 | 86.5 | 128,450 | 137,380 | 18,397 | 1,437 | 74.1 | GREET |
| | Low S Diesel | 35.6 | 7.068 | 0.0011 | 87.1 | 129,488 | 138,490 | 18,320 | 1,447 | 74.9 | GREET |
| | Non Road Diesel | 37.6 | 6.982 | 0.228 | 86.5 | 128,450 | 137,380 | 18,397 | 1,437 | 74.1 | GREET |
| | Diesel | 35.0 | 7.093 | 0.0010 | 86.5 | 130,000 | 139,038 | 18,328 | 1,437 | 74.3 | Chevron |
| | Low S Diesel | 39.0 | 6.927 | 0.0011 | 86.5 | 127,464 | 133,075 | 18,402 | 1,437 | 74.0 | CA_GREET |
| | Residual Oil | 11.3 | 8.272 | 0.50 | 86.8 | 140,353 | 150,110 | 16,968 | 1,442 | 80.6 | GREET |

MGO is more generally a fuel blend, rather than a single refinery cut or process. It is produced commonly through 4 different processes; straight-run, vacuum distillation, thermal cracking, or catalytic cracking. These 4 primary processes are listed in order of decreasing sulfur content in the product produced, which is the primary difference between MGO and diesel fuel. Diesel fuel, as provided in GREET, has a maximum Sulphur content of 200 ppm by weight. MGO, in contrast, ranges from 0.1% to 1.5% sulfur by weight. Europe has a directive regarding the Sulphur content specifically in marine fuels (Worren, 2010). For the purposes of this study, the properties of non-road diesel from GREET were used to represent low sulfur MGO and the properties of low sulfur diesel provide the parameters for on-road diesel. LNG from the Tacoma project would displace low sulfur MGO.

Figure C.1 and C.2 shows the relationship between heating value and density, which is shown as the API gravity. The mass-specific LHV increases with API gravity, while the volumetric LHV decreases with increasing API. The MGO data points align closely with expected values as seen in literature, and are comparable to non-road diesel in the GREET fuel specifications. Residual oil, has a much greater content of sediment, tar, moisture, and other impurities which skew the carbon content trend but the relationship between carbon factors and API gravity remain consistent with the fuels shown here.

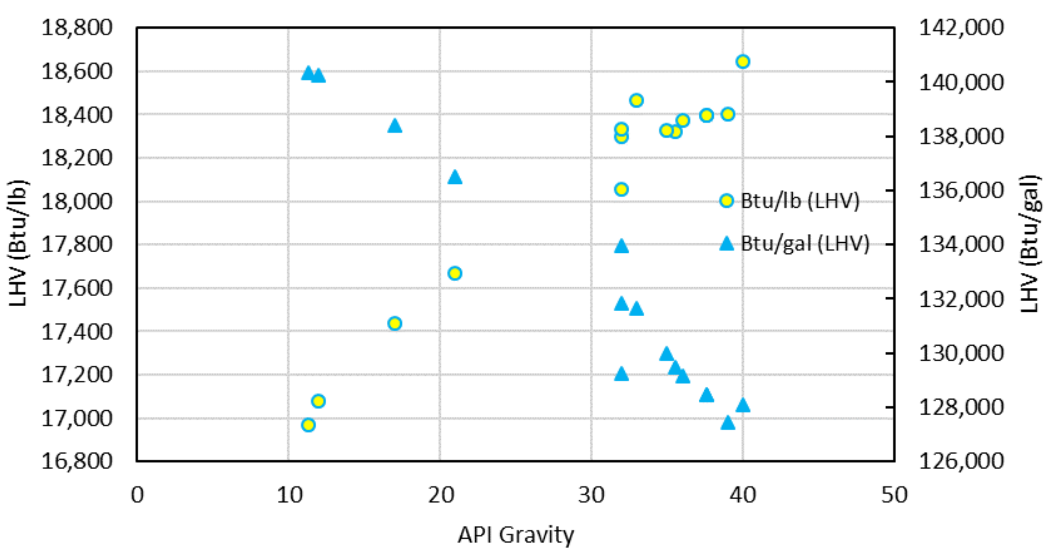


**Figure C.1.** Relationship between Heating Value and API Gravity

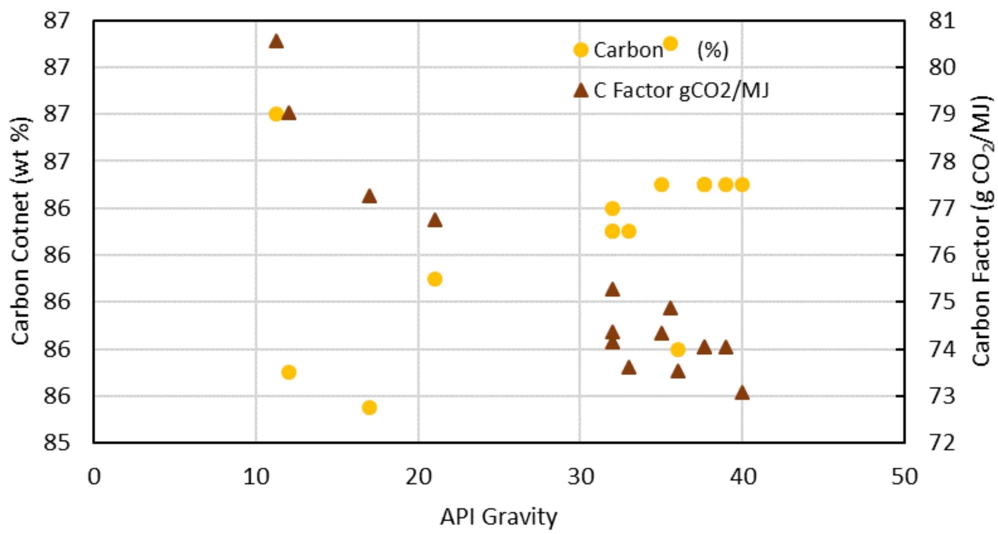


**Figure C.2.** Relationship of Carbon Factor with API Gravity

Table C.3 shows the fully oxidized $CO_2$ emissions as well as $CH_4$ and $N_2O$ emissions from various combusting sources in this study. The carbon factor of fully oxidized $CO_2$ ($CO_2c$) is based on the fuel properties. Note that the $CO_2c$ factor includes methane because the fully oxidized effect is not reflected in the GWP of methane. Emission factors for $CH_4$ and $N_2O$ depend on the type of equipment and are identified in the GREET model. Finally, the GWP –weighted GHG emissions in $CO_2$ equivalent ($CO_2e$) are calculated. The emission factors are converted to other units (g/gallon, g/mmBtu, HHV as needed based on fuel specifications in GREET.

**Table C.3.** Direct Combustion Emissions

| Fuel/ Application | Equipment Type | $CO_2c$ | $CH_4$ | $N_2O$ | $CO_2e$ |
|---|---|---|---|---|---|
| Direct Emissions (g/mmBtu), LHV | | | | | |
| Diesel | Diesel Engine | 78,187 | 4.2 | 0.6 | 78,472 |
| Diesel | HD Truck | 78,186 | 4.7 | 0.2 | 78,357 |
| Diesel | Industrial Boiler | 78,198 | 0.2 | 0.9 | 78,477 |
| Gasoline, E10 | Gasoline Engine | 76,829 | 3.0 | 0.6 | 77,083 |
| MGO | Marine Engine | 78,127 | 1.2 | 3.5 | 78,127 |
| Natural Gas | IC Engine | 58,333 | 392 | 0.1 | 68,175 |
| Natural Gas | Turbine, CC | 59,410 | 1.1 | 0.1 | 59,474 |
| Natural Gas | Small Boiler | 59,330 | 1.1 | 0.4 | 59,461 |
| Natural Gas | Large Boiler | 59,410 | 1.1 | 0.8 | 59,660 |
| LNG | Marine Engine | 58,090 | 686.3 | 4.0 | 76,450 |
| LNG | Truck | 57,459 | 309.8 | 0.0 | 65,213 |
| LNG for peak shaving | Boiler[c] | 58,308 | 1.1 | 0.4 | 58,439 |
| LPG from Tacoma LNG | Boiler | 68,058 | 1.1 | 1.1 | 68,403 |
| Waste Flare LPG | Flare | 68,729 | 1.1 | 1.1 | 69,074 |
| Waste Flare gas | Flare | 67,144 | 1.1 | 0.8 | 59,660 |

[a] Fuel properties in GREET are on the Fuel_Specs sheet with same properties at those in Table C.1.

[b] SEPA permits calculations of GHG emissions based on EPA, AP-42 The emission factors are comparable to those in the GREET model. Note that $CO_2c$ factor for natural gas engines is lower than that for other end uses because of the higher $CH_4$ emissions.

Sources: (American Bureau of Shipping, 2018), (Corbett & Winebrake, 2008), (Engineering ToolBox, 2003), (Oak Ridge National Laboratory, 2011), (Penn State College of Earth and Mineral Sciences, 2018), (Dehart et al., 2015).

[c]Residential and Commercial Heating Equipment

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# D. APPENDIX LCA-D: REVIEW COMMENTS AND CUT OFF ANALYSIS

## D.1. Response to Comments

The analysis of GHG emissions was made available for public comment as part of a Supplemental Environmental Impact Study (SEIS). The comments fell primarily into the categories shown in Table D.1 which provides a brief description of the topic and identifies the section in the study that provides additional information.

**Table D.1.** Summary of Response to Comments

| | Category | Description | Section |
|---|---|---|---|
| 1 | AR5 | Explain AR5 vs AR4, run sensitivity with AR5. | App. LCA-A.4<br>Sec.1.5.2 |
| 2 | 20 year GWP | Discuss 20 year versus 100 year GWP. | App. LCA-A.4<br>Sec.1.5.2 |
| 3 | Particulate Matter | Explain that GHG impacts associated with PM are not part of WA protocol. Effect of particulate and organic carbon is small.[a] | App. LCA-A.4<br>Sec.1.5.2 |
| 4 | $CH_4$ emissions | Explain sources of $CH_4$ emissions and examine new GREET model. Identify emissions for LNG transfers and bunkering. | App. LCA-B.1 |
| 5 | BC Natural Gas | Provide more data on natural gas production in BC. Examine emissions from gas processing plants. | App. LCA-B.1 |
| 6 | BC Gas Flow | Show EIA data on gas flows. | App. LCA-B.1 |
| 7 | Fracking | Provide data on hydraulic fracturing. | App. LCA-B.1 |
| 8 | MGO Properties | Discuss MGO properties, carbon factor and upstream emissions for refining. | App. LCA-C<br>App. LCA-B.3 |
| 9 | LNG Properties | Discuss calculation of fuel properties from LNG composition. | App. LCA-C |
| 10 | LNG Use | Explain sources of LNG use | Section 2 |
| 11 | Peak Shaving | Examine 10 years of peak shaving and explain marginal source of fuel | Section 2,<br>Section 5 |
| 12 | Marginal Power | Explain rationale for Washington State average power. | App. LCA-B.2 |
| 13 | Carbon Balance | Update carbon balance to reflect data from PSE. | App. LCA-A |
| 14 | 1% Cut Off | Provide further analysis of de minimis emissions | App. LCA-D |

[a] (TRANSPHORM, 2012). Criteria air pollutant emission requirements for Washington are determined by the Washington Clean Air Act (RCW 10.94) (Washington State Department of Ecology, 2018b)

## D.2. Cut Off Criteria

Minor inputs and emissions that have a small effect on life cycle GHG emissions were excluded from the study. The study team selected a cut off level of relevance of 1% of the life cycle GHG emissions, which is less than the variability in most LCA studies on similar products. Table D.2

describes the assumptions underlying those choices regarding the activities that were identified but excluded from the Study. In many cases the alternative use of LNG would include similar activities. The exclusion of these activities is consistent with the ISO 14040 standards

**Table D.2.** Assumptions for Exclusion of Activities from the Analysis

| Parameter | Activity Estimate | Cut-off Basis |
|---|---|---|
| Facility Decommissioning | Remove facility and recycle materials. | Decommissioning emissions would be lower than construction since no materials would be required. Recycled materials would generate co-product credit. Construction emissions excluding materials are less than 0.25% of annual emissions. |
| Employee Commute | Less than 100 employees | < 0.1% of annual emissions |
| Employee Air Travel | Less than 20 trip/ year | < 0.1% of annual emissions |
| Economic effects | 0.1% change in price of displaced fuels or natural gas | Both petroleum and natural gas supplies are large global markets. Fuel use or displacement would have a small effect on supply and demand. |

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# APPENDIX C

Draft SEIS
Comments and Responses

# Appendix C.1 Introduction

Puget Sound Clean Air Agency (PSCAA) would like to thank the Tribes, state agencies, business and community organizations, and individuals for taking the time to review the Draft Supplemental Environmental Impact Statement (DSEIS), attend the October 30, 2018 public hearing, and submit comments to PSCAA on the DSEIS. This appendix to the *Final Proposed Tacoma Liquefied Natural Gas Project SEIS* contains comments on the DSEIS and PSCAA responses to the comments received by PSCAA within the comment period.

**How do I find my comment and response?**
**Access an electronic version via Flash drive-insert of the hard copy FSEIS or visit PSCAA's website: http://www.pscleanair.org/460/Current-Permitting-Projects**

1. Refer to **Appendix C.1: Introduction** for an overview of the comment receipt and response procedure.
2. If you submitted a comment, use the keyboard "Search" shortcut (Ctrl-F) to locate your last name in the electronic version of **Appendix C.3: Comment Summary Table**. The list of issues associated with your comment(s) are presented in the table.
3. Refer to **Appendix C.2: Comment Responses**, which are organized by issue to locate the responses relevant to your concerns. Due to the overlap between many issues, it may be informative to read responses to issues that are not listed by your name in Appendix C.3.
4. If you submitted a form letter, email, or signed a petition, refer to Appendix C.4 to locate examples of each form type and the associated issues.

On January 24, 2018, PSCAA issued a notice declaring its intent to prepare a SEIS to conduct a life cycle analysis of greenhouse gases (GHGs) for the proposed Tacoma Liquefied Natural Gas (LNG) Project. This notice was placed on the Washington State Environmental Policy Act (SEPA) Register and PSCAA's website, advertised in the Tacoma News Tribune, and an email announcement sent to all parties that had indicated interest in the project by subscribing to PSCAA's project list serve. On April 23, 2018, and September 28, 2018, PSCAA provided updated schedule information regarding the SEIS on its website and sent email announcements to the project list serve.

On October 8, 2018, PSCAA issued the DSEIS and began a 45-day comment period, with a public hearing on October 30, 2018. Notice of the DSEIS, with a link to the DSEIS and corresponding documents on PSCAA's website, as well as information on the date and time of the public hearing and instructions on submitting public comments, was made available consistent with the applicable SEPA requirements and was sent to agencies with jurisdiction over the project, over 15 Tribes within the PSCAA's four county jurisdiction, and all parties on the project list serve. Notice of the DSEIS availability, public hearing, and comment period was published in the Daily Journal of Commerce and the Tacoma News Tribune. Release of the DSEIS was also featured in local news stories. The DSEIS was published on PSCAA's website and the SEPA Register. Paper copies of the DSEIS were placed in all Tacoma libraries and one community center for viewing, were available at the public hearing, and were available for pickup at PSCAA's office for the duration of the comment period.

The comment period on the DSEIS closed November 21, 2018. At the conclusion of the comment period, PSCAA had received approximately 14,820 comments from the public in the form of email, paper, fax, oral testimony, video, and petitions. Additionally, one printed copy and two electronic copies of an online petition containing 63,800+ signatures, 517 pages of comments, and 66 pages of petition updates was received. Pursuant to dates on the petition, much of it was compiled before the DSEIS was released on October 8, 2018; however, PSCAA received it as a comment on the DSEIS and has reviewed and responded to it as such.

# Comment Response Process

Comments received by PSCAA during the comment period fell into three general categories across all mediums: Unique, Form Letters, and Petitions. All comments received in all categories were evaluated on whether the subject matter was substantive in relation to the SEIS. Substantive comments generally are those that relate to the accuracy, contents, methodology, or assumptions used in the environmental analysis. They can also present new information relevant to the environmental analysis or alternative analytical methods. Substantive comments may or may not lead to changes in the SEIS.

In accordance with Washington Administrative Code 197-11-560, substantive comments were considered and responded to as follows:

- The PSCAA project team carefully reviewed the comments received and sorted the comments by submittal method, whether the comment was substantive, and the comment's relevancy to the scope of the SEIS. Substantive comments were then grouped by shared common topic areas and responses were prepared. Some topic areas, grouped by issue, overlapped with others; for this reason, commenters are encouraged to look for responses beyond their topic area for information relevant to their concerns.
- In response to the comments, the SEIS was then updated with new information, revised and/or enhanced analysis, and clarifying language as needed. Responses also identify, as appropriate, sections of the SEIS where revisions were made or details on where additional information is provided within the SEIS, or an explanation for why a comment did not require a change to the SEIS.

In summary, the comments received on the DSEIS have resulted in some technical edits that improve the accuracy and thoroughness of the SEIS analysis. For more information on changes that were made to the DSEIS and the LCA Report, refer to Appendix C.2: Responses.

Some substantive concerns were raised in Form Emails, Letters, and Petitions, but those comments are not presented in their entirety in Appendix C.4: Comment Database. Instead, a summary of issues associated with each form comment and petition is contained in Appendix C.3: Comment Summary Table. Examples of each form comment are presented in Appendix C.4 with a complete list of stakeholders who submitted or signed the form comment. Stakeholders that signed a petition are listed on the petitions themselves, which can be found in Appendix C.4. Comments submitted that were not generally form emails, letters, or petitions (unique comments), are located in Appendix C.4.

# Appendix C Content

## Appendix C.2: Comment Responses (Print and Electronic)

Comment responses are organized numerically by topic area, or issue. Refer to Appendix C.3 for the list of issues associated with your comment(s). The "Comment Response Process" section above contains an overview of the comment response process. Because some topic areas and issues overlapped with others, commenters are encouraged to look at responses beyond their topic area for information relevant to their concerns.

Please note that PSCAA generated a separate response for Petition 4, which contained some comments that were generated prior to the beginning of the public comment period for the DSEIS on October 8, 2018.

## Appendix C.3: Comment Summary Table (Print and Electronic)

The comment summary table is a comprehensive list of all participants who submitted unique comments to PSCAA during the public commenting process and the issues associated with each comment. The comment summary table is organized in alphabetical order by name for Tribal, State, or Organizations. For groups of individuals, comments are organized by the last name and first initial of the first commenter. For individuals, comments are organized by last name and first initial. All comments are tagged with a unique comment identification number. Commenters who submitted multiple unique letters should refer to the comment number to locate their letters in Appendix C.4. Additionally, a summary of issues associated with each form comment and petition can also be found at the end of Appendix C.3.

## Appendix C.4: Comment Database (Electronic Only)

All unique comments received by PSCAA are displayed in Appendix C.4 alphabetically and in order of comment identification number. Comment letters are tagged with the associated issues raised in that letter. Duplicate comments submitted by different methods may be presented in Appendix C.4, but they have not been assigned issues. Appendix C.3 is a tabular summary of Appendix C.4. Individuals who submitted form letters, emails, or petitions can refer to Appendix C.4 to see an example of the form comment, the associated issues, and the list of stakeholders that submitted that comment type. Petitions are presented in their complete form.

# Appendix C.2 Comment Responses

Puget Sound Clean Air Agency (PSCAA) thanks all commenters for comments submitted on the Draft Supplemental Environmental Impact Statement (DSEIS).

## 1. Determination of SEIS Scope – Comparison to FEIS

Comments received noted that the greenhouse gas (GHG) emissions and end uses of the liquified natural gas (LNG) differ from the information presented in the Final Environmental Impact Statement (FEIS). Responses to these comments follow.

The stated purpose of the Supplemental Environmental Impact Statement (SEIS) was to supplement the FEIS issued by the City of Tacoma on November 9, 2015, specifically to address GHG emissions through a life-cycle analysis. The FEIS repeatedly stated that the Proposed Action was to "produce approximately 250,000 to 500,000 gallons LNG daily" (for example, in the FEIS, see p. 2 of the SEPA Fact Sheet, p. 1 of the Executive Summary, and p. 1-1 of Chapter 1). The Notice of Construction (NOC) application that was submitted by Puget Sound Energy (PSE) to this PSCAA on May 22, 2017, requested an approval for a plant with a proposed capacity of 250,000 gallons LNG per day. A project applicant may request a permit approval to install a smaller facility than that which was reviewed under Washington State Environmental Policy Act (SEPA).

When evaluating the inputs for the Life Cycle Associates, LLC (LCA) model, PSCAA concluded that the analysis in the SEIS should be consistent with the stated proposal in the FEIS, since that is the document being supplemented. PSE provided technical input to distinguish the differences between the 250,000 and 500,000 gallons per day scenarios (see also the section of response #3 Outside of Scope related to comparisons to the FEIS) and PSCAA included details on each in the SEIS analysis for clarity. The SEIS analyzes GHG emissions based on a proposed facility with a daily capacity of up to 500,000 gallons per day. The GHG emissions, identified through a life-cycle analysis, provided information that was not analyzed or provided in the FEIS documents. To complete this analysis, reasonable assumptions were made on the end use of LNG at this capacity level.

When PSCAA began working on the SEIS for GHG emissions, technical information was requested from PSE to support the technical review. In addition to the specific information provided in response to questions, PSE submitted their own life-cycle analysis prepared by a separate consultant. That analysis was completed on a 250,000 gallons/day LNG production rate. PSCAA concluded that the analysis in the SEIS should be consistent with the stated proposal in the FEIS, since that is the document being supplemented.

Regarding comments that addressed additional trucking and barging of LNG in Scenario B, the FEIS did contemplate trucking and barging of LNG from the proposed facility; see Section 2.2.1.1 of the FEIS.

In addition, the specific details regarding the number of truck trips per day that were assumed for the 500,000 gallons per day operation were tied to the previously identified FEIS understanding. PSE confirmed that the number of truck trips stated in the FEIS at two trucks/day would equate to a total of 7,300,000 gallons of LNG per year. That total was included in the end-use assumptions for LNG produced to complete the life-cycle analysis and was distributed between deliveries to the Gig Harbor LNG storage facility, to unspecified marine vessel use, and an unspecified on-road truck diesel fuel displacement. The amount of LNG produced to leave the site via truck was more specifically identified to support the life-cycle analysis for GHG emissions as end-use assumptions are necessary to complete that work.

Some comments noted that the reported GHG emissions in the FEIS differ markedly from those reported in the DSEIS. The purpose of the SEIS was to evaluate GHG emissions impacts from the Proposed Action through a life-cycle analysis. The FEIS stated that there would be a GHG emission reduction resulting from the project without showing the analysis of how that could occur. That lack of detail was a factor in the determination to proceed with the SEIS for GHG emissions. See also the sections in responses #3 Outside of Scope and #19 LCA Inputs and Assumptions – End Use related to comparisons the FEIS.

Comments inferred the SEIS should include an economics section to evaluate the GHG emissions and end uses of the LNG. SEPA does not necessarily require an economic analysis in an EIS. For example, Washington Administrative Code (WAC) 197-11-448 states: "Examples of information that are not required to be discussed in an EIS are: Methods of financing proposals, economic competition, profits and personal income and wages, and social policy analysis…" PSCAA concluded that the analysis in the SEIS should be consistent with the stated proposal in the FEIS, since that is the document being supplemented.

Some comments questioned the assumption in the SEIS that all natural gas that would supply the project would come through British Columbia because this condition was not identified in the FEIS. Since the FEIS was published, PSE has stated to PSCAA that all gas will come from British Columbia or Alberta, but entering Washington through British Columbia. The SEIS analysis was based on this understanding. If an air permit is issued for this proposal, PSCAA will take appropriate steps to ensure that a condition related to the origin of the gas is included.

Regarding comments related to the City of Tacoma's post-FEIS Frequently Asked Questions (FAQs) posted on its website, the City of Tacoma does not speak for PSCAA and the FAQs were not part of the DSEIS. PSCAA has reviewed the portions of the FAQs cited by the commenters.

# 2. Determination of SEIS Scope

Some comments inquired about the SEIS and NOC review process and PSCAA's ability to review the document. PSCAA has followed the requirements of Chapters 70.94 RCW (the Washington Clean Air Act) and 43.21C RCW (SEPA), and PSCAA's associated implementing regulations, in its review process for the NOC application submitted to it by PSE. For the SEIS, PSCAA concluded it needed special expertise and staffing resources to help complete a SEIS, which is why PSCAA hired consultants to help prepare the SEIS. PSCAA has the experience and knowledge to complete the authorized work on the proposed NOC application, including compliance with the requirements of SEPA, and will continue to do so in the future. In addition, PSCAA necessarily relied on information provided by the applicant, including the description of the Proposed Action and its operating parameters, in preparing the SEIS. All information from the applicant was independently reviewed by PSCAA or the PSCAA consulting team before inclusion in the SEIS.

Some comments suggested that the SEIS does not meet SEPA requirements and should be started over and re-opened for public comment. PSCAA disagrees with this characterization of the work completed to date and is proceeding with the preparation of a FSEIS based upon the review of all comments received during the comment period, and additional analyses included in the updated documents, report, and the existing analyses in the DSEIS.

# 3. Outside of Scope

The stated purpose of the SEIS was to supplement the FEIS issued by the City of Tacoma on November 9, 2015, specifically to address GHG emissions through a life-cycle analysis. Comments, or segments of comments, that did not relate to the contents the analysis in the SEIS were determined to be "outside of scope," and generally were not specifically responded to in the Response to Comments. Comments, or segments of comments, that were categorized as outside of scope differ from "general opposition" or "general support," which are addressed in these responses under those headings.

The "outside of scope" topic areas are summarized as follows:

- The decision-making process for the NOC Air Quality Permit is informed by the SEPA environmental review process, but the NOC process is distinct.

- General statements related to global climate change impacts and references to International Panel on Climate Change reports that are unrelated to this project-specific GHG analysis.
- The City of Tacoma's post-FEIS FAQs posted on its website are unrelated to the scope of analysis in the SEIS.
- General comments about hydraulic fracturing at the location of extraction (and non-related to GHG emissions), for example:
    - Causation of earthquakes locally in the Pacific Northwest or at the site of extraction and re-injection of wastewater;
    - Degradation of the quality of groundwater, animal habitat, and general air quality;
    - Use of excessive water in hydraulic fracturing process and associated "flow back";
    - Concerns about the use of proprietary chemicals and holding ponds;
    - Public safety concerns associated with hydraulic fracturing; and
    - Comparisons of natural gas extraction methods to those for coal and other hydrocarbons.
- References to resource areas or elements of the environment that were previously assessed as part of the FEIS, for example:
    - Earth (FEIS Section 3.1), including Geology and Geologic Hazards; Groundwater; and Existing Contaminated Sites and Remedial Action (FEIS Section 3.1.3);
    - Water (FEIS Section 3.3), including Wetlands and Waterbodies; Existing Contaminated Soils and Sediments; Flood Hazards; and Groundwater (FEIS Section 3.3.3);
    - Health and Safety (FEIS Section 3.5), including Safety History of the LNG Industry; Tacoma LNG Facility and TOTE Marine Vessel LNG Fueling System; and PSE Natural Gas Distribution System (FEIS Section 3.5.3); and
    - Socioeconomics (FEIS Section 3.12), including Population; Housing; Employment; Economy (FEIS Section 3.12.3).

# 4. Language

These comments are related to word choice and terminology within the DSEIS.

Some comments expressed concern regarding the use of the phrase "Puget Sound region" when describing the geographic extent of the net GHG emissions. PSCAA agrees that limiting the extent of the GHG emissions to the Puget Sound region is not accurate when characterizing the extent of the impacts described in the life-cycle analysis. The phrase "Puget Sound region" has been removed from the final SEIS from ES.4 and Sections 4.3, 4.5, and 4.8.

Comments stated that the use of the phrase "cleaner fuel" was inappropriate. PSCAA agrees that use of the term "cleaner fuel" when referring to LNG is presumptive for the SEIS's consideration of GHG emissions. The phrase "cleaner fuel" is accurate when referring to the criteria pollutant emission effects from substituted product use. The FSEIS uses the term "alternative fuel" or completely deletes the term as appropriate. This replacement occurs in Section ES.2, paragraph 1; Section 1.1 in paragraphs 1 and 2; and in Section 4.3, paragraph 1.

A commenter requested that all acronyms used in the document be defined. A list of acronyms and their definitions are provided in the FSEIS after the table of contents, list of tables, and list of figures.

# 5. Regulatory Framework

These comments relate to the regulatory process and procedures associated with this SEPA environmental review.

First, PSCAA thanks the members and representatives of the Puyallup Tribe and many other members of the public for comments regarding tribal consultation for this SEIS and the Proposed Action. PSCAA has discussed the request for formal consultation with the Tribe and PSCAA's Executive Director and General Counsel met with the Puyallup Tribe (its Tribal leaders and Tribal staff) on December 13, 2017, regarding PSE's proposal. PSCAA has also promptly responded to all requests for information and records as requested by the Tribe or its representatives. PSCAA is a local air authority pursuant to the State of Washington Clean Air Act, Ch. 70.94 Revised Code of Washington (RCW) (WA CAA) and its authorities in these circumstances are determined by the WA CAA and SEPA, Ch. 43.21C RCW. PSCAA is not considered an agency of the United States federal government or the State of Washington. To date and as stated to the Tribe before this response, PSCAA knows of no specific authority, and has not been presented with specific authority, that allows PSCAA to alter or change any process in the WA CAA or SEPA or PSCAA's implementing regulations to provide formal consultation as requested by the Tribe in this SEIS process. Despite the lack of authority to add process that would enable formal Tribal consultation for PSE's pending application, PSCAA will continue to provide notice to the Tribe of developments related to PSE's application, will continue to promptly respond to requests for information and records from the Tribe, and will consider closely all comments the Tribe has presented to PSCAA regarding the DSEIS.

The Tribe also appears to state that the proposed Tacoma LNG Facility is proposed to be located within the 1873 Survey Boundary for the Puyallup Tribe's Reservation. While PSCAA does not speak to the Tribe's description of its lands, the FEIS does not show the proposed plant to be located on Puyallup Tribal lands or Future Tribal lands. See FEIS, Figure 3.7-4. In addition, the applicant's NOC application relates to stationary air emission units for production of LNG (in the proposed facility), and does not include approval of any associated pipelines.

Other comments expressed concern that the Proposed Action would disproportionately expose the Puyallup Tribe to hazards, including the impacts of climate change. As described previously, the scope of the SEIS was limited to a life-cycle analysis of GHG emissions. The conclusion of the analysis as discussed in the Executive Summary and supported by the LCA report is that this proposed project demonstrates a reduction in GHG emissions.

Comments questioned whether the natural gas extraction regulations are substantially different between the United States and Canada. Other commenters stated that limiting the supply to Canadian sources would unfairly prevent United States distributers from supplying LNG to the proposed project. The quantitative differences resulting from the different regulatory efforts in Canada and the United States are difficult to specify, but the updated LCA report (see Section 2.4.1) provides more details on the regulatory actions in Canada and British Columbia that supports the information and conclusions provided in the DSEIS. There are national regulations that apply to all of Canada (which will include Alberta produced natural gas supplied through British Columbia) that will become effective in 2020 or 2023, depending on specific applicability. The Canadian regulations have been established to support Canada's commitments to the Paris Agreement. The provincial government in British Columbia announced additional regulations by the British Columbia Oil & Gas Commission in January 2019, which will be effective in January 2020. These provincial regulations are projected to meet or exceed the performance of the national standards.

A range of emission estimates for gas production in British Columbia has been published. Additional data has been presented in Appendix LCA-B. While there is some uncertainty in the range of GHG emissions associated with gas production in British Columbia, the values used in the life-cycle analysis are consistent with the British Columbia inventory and fall within the ranges of estimates of GHG emissions from gas production and transport. The information reviewed and summarized in Appendix LCA-B attributes some of the differences in gas leakage rates to geophysical factors and regulatory environments. The range of leak rate emission factors considered in this life-cycle analysis are identified in Table B-4 of the LCA report.

Regarding PSCAA's authority to condition the source of the LNG, PSE voluntarily has stated it will accept a condition, as described in the SEIS, for the natural gas supply to the facility be from British Columbia or Alberta, but entering Washington through British Columbia. Thus, the asserted legal concerns as posed by commenters are inapplicable. As part of SEPA review, an applicant, like PSE, may voluntarily provide information to PSCAA or voluntarily agree to or suggest mitigation or conditions to PSCAA, and PSCAA may rely upon that information and/or mitigation/conditions.

# 6. Purpose and Need

These comments relate to the Purpose and Need statement of the Proposed Action described in Chapter 1 of the DSEIS.

Some comments suggest that the need for the project is based on incorrect assumptions or erroneous information. Changes to PSE's stated need for this project is outside the scope of this SEIS, which was a life-cycle analysis of GHG emissions needed for review of the NOC application submitted to PSCAA by PSE. The DSEIS statement of Purpose and Need is based upon the statement of Purpose and Need in the FEIS; no changes were needed for the Final SEIS.

Comments were received that suggested the Purpose and Need section should be revised to reflect the 2017 Integrated Resource Plan. The SEIS did not alter the Purpose and Need statement as stated in the FEIS, and altering the Purpose and Need for the proposal is outside the scope of the SEIS. In addition, PSCAA's SEPA responsibility is to evaluate the project as proposed by a private applicant. The SEIS analyzes GHG emissions based on a proposed facility with a daily capacity of up to 500,000 gallons per day, the size of the proposal as identified in the FEIS. To complete the SEIS analysis, reasonable assumptions were made on the end use of LNG at this capacity level. The SEIS end-use assumptions do not need to match the FEIS for this analysis.

Comments were received asserting the shipping industry's demand for the project's LNG is not supported, and that there are other ways to achieve compliance with the North American Emission Control Area air quality standards. The International Maritime Organization (IMO) is a United Nations' agency responsible for the safety and security of shipping as well as the prevention of marine pollution by ships. The IMO developed a multimedia pollution control document in 1973, referred to as the International Convention for the Prevention of Pollution from Ships (abbreviated as MARPOL). MARPOL covers many types of pollution, but Annex VI is specific to air pollution. Annex VI contains limits on the amount of sulfur in fuels used by ships and it also established Emission Control Areas (ECAs), including the North American ECA. The fuel sulfur limit within the ECA is more stringent than the limit outside the ECA. As of January 1, 2015, the fuel sulfur limit inside the North American ECA is 0.10 percent sulfur. There is also an option to use emission control equipment on the engine exhaust to meet an equivalent reduction in sulfur dioxide. The commenter is correct that Totem Ocean Trailer Express (TOTE) is currently using fuel that meets the 0.10 percent sulfur content limit.

A commenter suggested that the bulk of the facility's LNG will be exported to Asian markets. This is not accurate. PSE has stated that it does not have the proper federal (Federal Energy Regulatory Commission) approval to operate as an export facility. The facility is designed and sized as a LNG "bunkering facility," which is significantly smaller than an LNG export facility, and PSE has stated that the LNG facility cannot be used for export. In comments PSE submitted on the DSEIS, the error of an export assumption was clarified in several ways. An LNG export facility would require an approval from the Federal Energy Regulatory Commission, which has not been sought for this facility. For comparison, in the United States Energy Information Administration (US EIA) LNG Export Terminal Status published in December 2018

(US EIA 2018d), it was projected that the U.S. LNG export capacity would reach 4.9 billion cubic feet of natural gas per day by the end of 2018. A single LNG module producing product for export is typically capable of .5 billion cubic feet of natural gas per day. That single LNG export module is over 12 times larger than the proposed Tacoma LNG Facility at the capacity of 500,000 gallons per day. Based on the size of the facility, PSE indicated that it would take six months of full production to fill one LNG export tanker.

# 7. SEPA Alternatives

These comments are related to the SEPA alternatives presented in the DSEIS Chapters 2 and 3.

Comments expressed concerns regarding the alternatives presented in the DSEIS, and many stated that the SEIS should have considered alternatives that were not considered in the FEIS, including fuel alternatives or additives for marine vessels, such as: hydrogen fuel cells, electric engines, marine gasoil, exhaust scrubbers, and low-sulfur fuel oil. Other operational modifications to marine vessels that were presented by commenters included optimized ship trim, slow steaming, hull cleaning, enhanced network routing, solar panels mounted on shipping containers, installation of selective catalytic reducers, diesel particulate filters, and engine maintenance.

The creation and/or consideration of new alternatives was neither needed nor reasonable for an adequate analysis in the SEIS. One, the creation of new alternatives in the SEIS would have been inconsistent with the FEIS, as the scope of the SEIS was only to consider a life-cycle analysis of GHGs from PSE's proposal as evaluated in the FEIS. Two, the proposed suggested alternatives (marine gas oil, exhaust scrubbers, and low-sulfur fuel oil) are stated by the commenters as alternatives for compliance with ECA, which is not the only stated purpose of PSE's proposal (see FEIS, Section ES.2) and it would not be reasonable to create new alternatives in a SEIS that focus only one aspect of the stated purpose and need of a proposal. Three, for purposes of evaluating impacts associated with emissions from GHGs in a life-cycle analysis, PSCAA did not reasonably need to evaluate alternatives other than the two identified by the City of Tacoma in the FEIS.

Some comments also identify as needing evaluation what appear to be operational changes that could be used by ships using LNG created by PSE (although this latter detail is unstated). While PSCAA does not disagree that there could be practices used by ships that may reduce certain air emissions, this type of potential decrease is too remote and speculative to be analyzed in the SEIS given that PSE's proposal would not directly regulate any ship's specific operations and given that any ship's or group of ships' potential reduction of GHG emissions using the methods suggested by the commenter would also be speculative.

Some comments also describe the No Action Alternative identified in the FEIS and the SEIS as unreasonable given the existence of North American ECA. PSCAA disagrees with these comments. One, because the FEIS is final (appeal deadlines for the FEIS have passed), the adequacy of the FEIS is beyond the appropriate scope of comments on the SEIS. Thus, to the extent the commenter is trying to re-open the adequacy of the FEIS, it cannot do so in comments on the SEIS. Two, PSCAA believes the No Action Alternative was defined properly in the SEIS for purposes of evaluating GHG emissions in a life-cycle analysis because it reflects what TOTE is currently doing and would likely continue to do to comply with the sulfur limits required within the ECA (i.e., use marine gas oil).

Comments also expressed the following concerns with the presentation of the No Action Alternative: 1) It assumes a static or near-static view of the future in which technological and regulatory circumstances will remain unchanged over the lifespan of the project, and 2) It makes over-simplified assumptions about the future in absence of the project. PSCAA disagrees with this characterization of the No Action Alternative. PSCAA's choice in the methodology to complete the GHG life-cycle analysis used the identified baseline No Action Alternative to allow comparison with the project as proposed. PSCAA used reasonable judgement in deciding which variables to include in the analysis.

Please also see the following responses for more information: #2 Determination of SEIS Scope and #6 Purpose and Need.

# 8. No Action Alternative

These comments relate to the analysis of the No Action Alternative presented in the draft SEIS.

Comments appear to opine that partial activities on site were not included in SEIS life-cycle analysis. The SEIS reasonably evaluated current conditions at the applicant site. For example, the estimated construction emissions onsite identified in the SEIS included all of the emissions, from the start of construction. By including the GHG emissions from all of the construction activities and not removing emissions from partial activities to date, ensures that they are accounted for in the analysis for the whole life cycle.

The total construction emissions for the site were estimated in the original FEIS and were also included in the estimates for the life-cycle analysis for the proposed project. The original construction emission estimates provided in the FEIS were not calculated in a life-cycle analysis manner. The question regarding whether the "actual" emissions are substantially identical to those included in the FEIS is also not a technical requirement for this work. It is unclear how an emission estimate for a partial construction effort would or should compare to the total estimate for the project but it would reduce the total emissions included in the analysis. Additionally, as stated below, these emissions are small in comparison to the total GHG emissions included in the life-cycle analysis and would not meaningfully alter the analysis. That is why a more detailed evaluation on this group of emissions is not needed.

A commenter questioned whether PSCAA's consideration of the No Action Alternative in the SEIS would lead to a kind of snowballing effect. This is incorrect. The SEIS follows the preparation of the 2015 FEIS for PSE's proposal, and is limited to consideration of impacts of GHGs from the proposal. Considering additional analysis (in a SEIS) after publication of prior analysis (in the FEIS) for PSE's proposal falls squarely within SEPA.

The first step for the development of this for the proposed LNG facility was to complete the demolition and removal of existing structures and other improvements. That is typical of many industrial sites, in that when previous owner/operations activity ceases, facilities are often left onsite until the next development opportunity presents itself. So, it is unlikely that a complete demolition of the site after LNG production use would occur until the next occupant or proponent was identified. If it were removed from the site, it would be expected to be another small value, relative to the life-cycle emission totals (see also Appendix D of the LCA report).

Some comments asked questions about the Notice of Violation issued to the applicant in April 2017, with the implication that the DSEIS's description of the Proposed Action and No Action Alternative do not reflect the current condition of the site. The Notice of Violation these comments reference is part of an open enforcement case at PSCAA and does not relate to the SEIS analysis.

As it relates to the GHG emissions from onsite construction activities, PSCAA's choice of the baseline for the No Action Alternative was appropriate. Including the GHG emissions from the construction activities ensure that they are accounted for in the analysis for the whole life cycle. To consider the baseline for the No Action Alternative at a later point would have excluded from the analysis the emissions that have already been released. The GHG emissions from construction also are very small in comparison to all of the emissions included in the analysis. In Table 4.5 of the DSEIS, the total life-cycle construction GHG emissions (1,581 tonnes per year) represent <0.2 percent (less than 0.2 percent) of the total GHG emissions included in the life-cycle analysis (in either scenario) and a small subset of those onsite construction emissions (as identified by the commenter) would be much less (less than 0.02 percent). Keeping these GHG emissions in the analysis, as identified in our No Action Alternative, actually reduced the overall GHG reduction identified in the conclusion.

Comments indicated that the No Action Alternative assumes that the mix of marine fuels used in vessels would remain the same for the next 40 years, and that GHG emissions factors should be extrapolated to accommodate for future trends. PSCAA does not agree with this characterization of the No Action

Alternative included in the analysis. PSCAA's choice in the methodology to complete the GHG life-cycle analysis used the identified baseline No Action Alternative to allow comparison with the project as proposed. PSCAA used reasonable judgement in deciding which variables to include in the analysis.

# 9. LCA Methodology

These comments pertain to the methodology used to develop the life-cycle analysis. The complete LCA Methodology was presented in Appendix B of the DSEIS.

Comments were received questioning the methane leakage rates used in the analysis. A range of emission estimates for gas production in British Columbia has been published. Additional data has been presented in Appendix LCA-B. While there is some uncertainty in the range of GHG emissions associated with gas production in British Columbia, the values used in the life-cycle analysis are consistent with the British Columbia inventory and fall within the ranges of estimates of GHG emissions from gas production and transport. The information reviewed and summarized in Appendix LCA-B attributes some of the differences in gas leakage rates to geophysical factors and regulatory environments. The range of leak rate emission factors considered in this life-cycle analysis are identified in Table B-4 of the LCA report. The updated LCA report (see Section 2.4.1) provides more details on the regulatory actions in Canada and British Columbia which supports the information and conclusions provided in the SEIS. There are national regulations which apply to all of Canada (which will include Alberta produced natural gas supplied through British Columbia) that will become effective in 2020 or 2023, depending on specific applicability. The Canadian regulations have been established to support their commitments to the Paris Agreement. The provincial government in British Columbia announced additional regulations by the British Columbia Oil & Gas Commission in January 2019, which will be effective in January 2020. These provincial regulations are projected to meet or exceed the performance of the national standards. Methane leakage rates from natural gas production are also evaluated in the sensitivity analysis provided in Section 5 (and Figure 5.5) of the LCA report.

Commenter(s) noted that the terms in Tables 4-3 and 4-4 do not match the terms in the alternatives comparison Table 4-5, and that these tables require more clarification. The tables referenced in these comments have been updated to be more clear and consistent. The information in these tables are drawn from the LCA report attached to the FSEIS.

A commenter requested a reference for the fugitive leaks components in Table A.10 of the LCA report. The inventory of fugitive leaks components is from the design details provided by PSE which was in the air permit application submitted to PSCAA (PSE, NOC No. 11386 Application, May 22, 2017).

Comments were received suggesting an alternate reference for radiative forcing of carbon dioxide, methane, and nitrous oxide. The more recent assessment from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) includes a higher global warming potential (GWP) for methane and a lower GWP for nitrogen oxide ($N_2O$). The AR5 represents newer data on radiative forcing of methane and other gases, secondary effects and their lifetime in the atmosphere. The updated LCA report includes an updated sensitivity analysis that considered AR5 GWP values. Refer to Section 1.5.2 (and Appendix A.4) of the LCA report. The results of that sensitivity analysis are shown in Section 5 (see Figure 5.5) of the LCA report. That analysis indicates that the use of the AR5 GWP values, by itself, would not change the conclusions identified in the DSEIS.

Evaluation of the GHG emissions using the 100-year GWP protocol is consistent with United Nations IPCC Fourth Assessment Report (AR4) (IPCC 2007) and other policy directions and initiatives in Washington State as prescribed in WAC 173-441-040. It is also consistent with the long-term goals of the Paris Agreement. The comment regarding a 100-year analysis methodology as contrasted to the 20-year analysis relates to the differences in GWP for methane on a longer versus a shorter lifetime. The analysis has not been revised to adjust the results of the life-cycle analysis on a 20-year basis because most of the GHG emissions and warming effects from the emissions considered in this analysis are carbon dioxide ($CO_2$), not methane ($CH_4$).

A 20-year GWP based analysis would omit the warming effect of $CO_2$ after 20 years and the $CO_2$ has much longer cumulative effects. $CO_2$ has a persistent effect in the atmosphere for over 100 years. Please refer to the discussion in Appendix LCA-A, Section A.4.Greenhouse Gases and Global Warming Potential and also the final report in Section 2.5.2 Greenhouse Gases.

The comments related to the GWP values (AR4 vs. AR5) and time horizon for the emissions lifespan (100-year vs. 20-year) have been addressed as described above. The methodology selected by PSCAA and the project team to follow a protocol based on AR4 values for a 100-year life remains a valid, reasonable approach. The GHG emission reporting requirements for the federal government (40 Code of Federal Regulations 98 - Mandatory Greenhouse Gas Reporting) and Washington State (see WAC 173-441 - Reporting of Emissions of Greenhouse Gases) follow these protocols. It is both appropriate and reasonable to evaluate the GHG emissions from this proposal in a life-cycle analysis on the same basis as those inventory values to support comparisons and understanding of the emissions as was done in the SEIS.

Commenters asked if GHGenius version 4.03 was used throughout the analysis. GHGenius version 4.03 was used for the upstream analysis of natural gas for the baseline scenario. Additional information was added to Appendix B (Section B.1) of the LCA report which discusses other information, including versions of the GHGenius model. The actual reference citation for any GHGenius model version referenced is the vendors website and is shown in the references listing in the LCA report as (S&T)2 (2013) http://www.ghgenius.ca/.

Comments requested information on some specific references in in the life-cycle analysis. The two specific references requested were referred to in the report as “BC 2017” and “Province of British Columbia 2018.” A list of detailed references has been updated at the end of the LCA report, and these specific references can be found in the response below. These sources allow for the determination of the fugitive emissions in the British Columbia inventory related to natural gas production and the total natural gas produced.

The “BC 2017” reference is updated in the report and it refers to Province of British Columbia, 1990-2016 Provincial Greenhouse Gas Emissions Inventory. Retrieved from https://www2.gov.bc.ca/gov/content/environment/climate-change/data/provincial-inventory.

The “Province of British Columbia, 2018” reference is to this webpage: British Columbia. (2018). Production & Distribution of Natural Gas in British Columbia 2017. Retrieved from https://www2.gov.bc.ca/gov/content/industry/natural-gas-oil/statistics.

# 10. LCA Calculations

These comments addressed specific calculations and values used in the life-cycle analysis. As a response to some of these comments, some revisions were made to the analyses in the SEIS. However, none of these changes resulted in a change to the SEIS conclusion.

Comments noted that the SEIS appendices contained “placeholder” values and outstanding or missing data. All necessary data was available and was used in the DSEIS. The places where the DSEIS indicated missing data were typographical errors in the document. The actual data for the project was available, shown in the spreadsheets and report, and used in the analysis. The revised GHG analysis has been updated to correct these typographical errors.

Some comments suggested using the updated GHGenius model (v5) due to updated methane leakage rates. Appendix B compares the GHG emissions from GHGenius v4 and v5 (see Table B.1). The results for the two versions of the model are similar. A comparison of the leakage rates from LCA models is also included in Table B.4 of the LCA report.

A commenter questioned the oil and gas volume production numbers used in the analysis, and noted the reference cited for the production values is insufficient. The volumetric units have been corrected in the final LCA report. Additionally, the reference information has been updated.

The Puyallup Tribe submitted a comment that the emissions calculation spreadsheets associated with the DSEIS were locked and therefore could not be verified. PSCAA provided the unprotected spreadsheets to the Puyallup Tribal attorney on Oct. 16, 2018 by e-mail.

Comments were received that the values in Table A.11 are incorrect. The contents of Table A.11 in the LCA report have been revised as suggested by these comments.

Some comments noted errors in the carbon balance in Appendix A of the LCA report. The errors identified in this comment regarding the carbon material balance for the LNG operations have been addressed and the calculations revised, as shown in the updated material balance flow diagrams provided in Appendix A (Section A.2 Operational Emissions) of the LCA report. Some information from these updated flow diagrams is also provided in Section 3.2.3 (Carbon Balance) and Table 3.11 of the LCA report. Some of the specific values identified were revised further based on other comments on fuel assumptions (e.g., marine gas oil [MGO] versus marine diesel oil [MDO]).

A question was posed about the location of the sensitivity analysis of the electric system mix. The results are summarized Figure 5.5 of the LCA report and the end of Section 5 of that report discusses that information. The sensitivity analysis summarized in Section 5 (and Figure 5.5) of the LCA report discusses various assumptions that can affect the overall results.

Comments noted that the use of bunker fuel to calculate downstream emissions in the No Action Alternative is incorrect. The SEIS and calculations of GHGs were updated to reflect the correct fuel currently being used by TOTE, which is MGO. The updated fuel information resulted in small changes to the GHG emissions in this analysis, but did not alter the overall conclusions. The upstream petroleum life-cycle emissions are discussed in Appendix B (Section B.3) and the properties of the MGO (compared to other liquid fuels used) are included in Appendix C (Section C.2.2) of the LCA report. The updated calculation values are found through the report and the supporting analyses.

Comments were received suggesting current marginal power emission factors be used in the analysis. Washington GHG reporting guidelines indicate that the local utility mix is appropriate for GHG reporting. Therefore, the Washington average is a conservative assumption because it includes more coal based power generation than the Tacoma Power mix. A marginal mix would result in similar GHG emissions since coal power is being decommissioned. By 2040, Washington requires a 15 percent renewable portfolio standard (RPS) of new renewables. The requirement of the RPS will result in a growth in renewable power.

For more discussion regarding marginal power, please see Appendix LCA-B, Section B.2. The life-cycle analysis provided with the DSEIS provided a quantitative comparison of the utility mix assumptions (Tacoma vs. Washington vs. Northwest PowerPool (NWPP) e-Grid) as shown in the sensitivity analysis provided in Section 5 (and Figure 5.5) of the LCA report. That information shows the range and effects of this assumption.

A commenter asked for a reference to support a statement in the LCA report that this project would not lead to an expansion of power generation resources. Additional information has been included in the LCA report (see Appendix LCA-B.2) to discuss the power mix for completing the GHG life-cycle analysis. The capacity of the electrical supply system to support this proposed facility was not in the scope of this review. The electric supply capacity for the proposed project was addressed in the City of Tacoma FEIS (see 3.11 – 19 Electricity) which states "Tacoma Power… has sufficient capacity to serve the facility as an additional customer."

Comments were received stating that the example calculations of total GHG emissions from the Proposed Action were difficult to understand. The details and the explanation for example calculations have been revised to provide additional details and more clarity. Additionally, some comments were received regarding the overall readability and clarity of the analyses. Where possible, additional language was added to the analyses to improve readability and clarity.

# 11. LCA Inputs and Assumptions - General

These comments addressed specific inputs and values used in the life-cycle analysis. As a response to some of these comments, some revisions were made to the analyses in the SEIS. However, none of these changes resulted in a change to the SEIS conclusion.

Comments were received regarding LCA's inputs to the GHG model and assumptions made about those inputs. Responses to those comments are grouped into sub-categories related to those inputs. Responses to comments relating to general LCA inputs and assumptions that do not fall into those sub-categories are provided here.

Commenters recommended that the SEIS should be revised to account for methane emissions during natural gas extraction. A range of emission estimates for gas production in British Columbia has been published. Additional data has been presented in Appendix LCA-B. While there is some uncertainty in the range of GHG emissions associated with gas production in British Columbia, the values used in the life-cycle analysis are consistent with the British Columbia inventory and fall within the ranges of estimates of GHG emissions from gas production and transport. The information reviewed and summarized in Appendix LCA-B attributes some of the differences in gas leakage rates to geophysical factors and regulatory environments. The range of leak rate emission factors considered in this life-cycle analysis are identified in Table B-4 of the LCA report. The updated LCA report (see Section 2.4.1) provides more details on the regulatory actions in Canada and British Columbia, which supports the information and conclusions provided in the SEIS. There are national regulations which apply to all of Canada (which will include Alberta produced natural gas supplied through British Columbia) that will become effective in 2020 or 2023, depending on specific applicability. The Canadian regulations have been established to support their commitments to the Paris Agreement. The provincial government in British Columbia announced additional regulations by the British Columbia Oil & Gas Commission in January 2019, which will be effective in January 2020. These provincial regulations are projected to meet or exceed the performance of the national standards.

Comments were received about facility lifespan used in the analysis (40 years), with specific requests for information about other LNG facility lifespans and how the construction and operation GHG emissions are accounted together. The supporting information is found in a reference that was included in the LCA report (Tronskar 2016). That information may be found at https://www.researchgate.net/publication/299274312.

With respect to the comment expressing concern that the four-year construction period would alter the life-cycle analysis for GHG, PSCAA disagrees with this suggestion. The methodology used relied on reasonable assumptions to support an evaluation of the proposed LNG GHG emissions with a No Action Alternative and life-cycle basis.

Some comments inquired if diesel fuel would be used at the LNG facility in the event of a power outage and why these emissions are included in Table 4-5 under "Peak Shaving." Diesel emergency fuel is the small amount of diesel fuel used at the Tacoma LNG plant to test the emergency backup equipment. It is also expected to operate to support a safe shutdown during power outages to maintain the facility until the power is restored. That is evidenced by the fact there was no difference in the projected emergency generator operation emissions in either the 250,000 gallons per day (gpd) or the 500,000 gpd scenario. The reference to peak shaving is an error in labeling (other comments on peak shaving references in the DSEIS have been addressed in other places). The label of these emission in Table 4-5 have been corrected. The diesel emissions from project emergency generator operations onsite have been included in the analysis. The labeling error discussed above will correct this confusion. The "Peak Shaving" emission values in Table 4-5 are identical to the emission values for "Diesel Emergency" in Table 4-3.

Comments asked for a reference supporting the statement in Appendix C of the LCA report that the LCA models listed produce the same life-cycle GHG results. Many studies show that LCA models achieve the same results with the same inputs. See Coordinating Research Council workshop information for Life Cycle

Analysis of Transportation Fuels, Argonne National Laboratory, October 26-28, 2015 as an example (Coordinating Research Council workshop information).

Comments suggested that the SEIS should recommend Best Available Control Technology (BACT) for GHGs as a permit condition. PSCAA will comply with the requirements of the Clean Air Act, Ch. 70.94. RCW and SEPA, Ch. 43.21C RCW in the review of the air permit application.

Comments indicated that the No Action Alternative life-cycle analysis should be based on the use of low sulfur diesel rather than bunker fuel to reflect the current situation. The calculations regarding the fuel indicated in the no action alternative have been modified to reflect the use of low sulfur fuel. Please refer to Appendix B (Section B.3) and Appendix C of the LCA report for the revised data. See also response #18 LCA Inputs and Assumptions – Marine Diesel Oil.

Comments noted that GHG emissions less than 1 percent of the total emissions are excluded from the analysis. The study team selected a cut off level of relevance of 1 percent of the life-cycle GHG emissions, which is less than the variability in most LCA studies on similar products. Table D.2 in Appendix LCA-D, Section D.2 describes the assumptions underlying those choices regarding the activities that were identified but excluded from the study. In many cases the alternative use of LNG would include similar activities. The exclusion of these activities is consistent with the International Organization for Standardization (ISO) 14040 standards. Please refer to Appendix LCA-D, Section D.2 for the assumptions made for excluding activities from the study.

A commenter asked about cumulative effects from the proposed facility with other existing industry at the Port of Tacoma. The identified scope for the SEIS was for a life-cycle analysis of the GHG emissions associated with the proposed LNG facility. The emissions from other sources that are not specifically related to the proposed facility are not consistent with the life-cycle analysis methodologies. The review was focused on the proposed facility in comparison with the No Action Alternative.

Some comments recommended that the SEIS employ different Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model values for gas liquefaction and LNG storage, and the power consumption assumed for the LNG facility was mischaracterized. The explanation of the comparison has been revised to include more details explaining this information and observation. Additionally, a more detailed breakdown of the values used in this comparison are also provided (see Appendix A, specifically Section A.2 and Table A.10) in the LCA report. A key distinction that the revised information explains is that some of the typical GREET model factors for LNG plant operations reflect systems that use natural gas and other waste fuel gases available to provide the energy needs for liquefaction. The proposed Tacoma LNG facility uses purchased electricity to meet these needs and does not identify any waste gas systems to supply energy needs for LNG operation. These distinctions are shown in the more detailed energy comparisons provided in Table A.10 of the LCA report. The impact of using purchased electricity to operate the proposed LNG facility shows up in the GHG life-cycle analysis, as referenced in other comment responses related to the electrical utility mix assumptions used in this analysis.

A commenter asked about the line item “Upstream Life-cycle Power LNG Production” in Table 4-3 and how it is used in the analysis. The line item “Upstream Life-cycle Power LNG Production” is the electrical power needed to run the LNG plant and it is listed as an upstream emission because the proposed facility would not generate its own electrical power.

A commenter suggested using the facility’s local electricity supplier rather than the statewide average mix for electricity generation assumptions in the life-cycle analysis. Washington GHG reporting guidelines indicate that the local utility mix is appropriate for GHG reporting. The Washington average is a conservative assumption because it includes more coal based power generation than the Tacoma Power mix. A marginal mix would result in similar GHG emissions since coal power is being decommissioned. By 2040, Washington requires a 15 percent RPS of new renewables. The requirement of the RPS will result in a growth in renewable power. Please see the discussion of marginal power in Appendix LCA-B, Section B.2.

The suggested change to the electric system mix to reflect the GHG emissions associated with Tacoma LNG's electricity supplier rather than the Washington State average mix would shift the baseline for this variable in the sensitivity analysis, indicating that any changes or uncertainty of future utility power supplies may result in increases to GHG life-cycle analysis. Even without making the changes in response to the comment on the utility mix, it does not change the overall conclusion for the analysis in the SEIS.

Please see the discussion of marginal power in Appendix LCA-B, Section B.2. The life-cycle analysis provided with the DSEIS provided a quantitative comparison of the utility mix assumptions (Tacoma vs. Washington vs. NWPP e-Grid) as shown in the sensitivity analysis provided in Section 5 (and Figure 5.5) of the LCA report. That information shows the range and effects of this assumption, including the utility variable this comment addresses.

Comments expressed concern regarding the completeness and accuracy of some of the information provided by PSE for the SEIS. It is reasonable and a common practice to obtain project-specific information from the project proponent to support the review. PSE provided the information requested for this review. However, the information provided by PSE was not the only information used in the analysis and the documents produced in the SEIS demonstrate that fact. Other information and reference material was also used and cited in the SEIS publication, which was completed as originally scoped, using a life-cycle analysis for GHG emissions.

# 12. LCA Inputs and Assumptions – Global Warming Potential Value

These comments address the GWP input values used for the GHGs in this analysis (methane and carbon dioxide). The GWP values are unrelated to the lifespan of the facility, and are only related to the cumulative effects of the GHG emissions in the atmosphere.

Evaluation of the GHG emissions using the 100-year GWP protocol is consistent with IPCC AR4 (IPCC 2007) and other policy directions and initiatives in Washington State as prescribed in WAC 173-441-040. It is also consistent with the long-term goals of the Paris Agreement. The comments regarding a 100-year analysis methodology as contrasted to the 20-year analysis relates to the differences in GWP for methane on a longer versus a shorter lifetime. The analysis has not been revised to adjust the results of the life-cycle analysis on a 20-year basis because most of the GHG emissions and warming effects from the emissions considered in this analysis are $CO_2$, not $CH_4$. A 20-year GWP based analysis would omit the warming effect of $CO_2$ after 20 years and the $CO_2$ has much longer cumulative effects. $CO_2$ has a persistent effect in the atmosphere for over 100 years. Please refer to the discussion in Appendix LCA-A, Section A.4.Greenhouse Gases and Global Warming Potential and the final report in Section 2.5.2 Greenhouse Gases.

The more recent assessment from the IPCC (AR5) includes a higher GWP for methane and a lower GWP for $N_2O$. The AR5 represents newer data on radiative forcing of methane and other gases, secondary effects and their lifetime in the atmosphere. The updated LCA report included an updated sensitivity analysis that considered AR5 GWP values. Refer to Section 1.5.2 (and Appendix A.4) of the LCA report. The results of that sensitivity analysis are shown in Section 5 (see Figure 5.5) of the LCA report. That analysis indicates that the use of the AR5 GWP values, by itself, would not change the conclusions identified in the DSEIS.

The comments related to the GWP values (AR4 vs AR5) and time horizon for the emissions lifespan (100-year vs. 20-year) have been addressed as described above. The methodology selected by PSCAA and the project team to follow a protocol based on AR4 values for a 100-year life remains a valid, reasonable approach. The GHG emission reporting requirements for the federal government (40 Code of Federal Regulations 98 - Mandatory Greenhouse Gas Reporting) and Washington State (see WAC 173-441 - Reporting of Emissions of Greenhouse Gases) follow these protocols. It is both appropriate and reasonable to evaluate the GHG emissions from this proposal in a life-cycle analysis on the same basis as those inventory values to support comparisons and understanding of the emissions as was done in the SEIS.

The AR4 values were used throughout the model.

Commenters requested more information on the sensitivity associated with the use of the 100-year GWP value. A sensitivity analysis is in Section 5 of the LCA report. The results of the sensitivity analysis are summarized in Figure 5.5 of the LCA report and the end of Section 5 of that report discusses that information. Much of this information was provided in the DSEIS and additional information has been provided in the FSEIS (see response for LCA Inputs and Assumption – Natural Gas Source).

# 13. LCA Inputs and Assumptions – Natural Gas Source

Comments noted and/or questioned the assumption of the Canadian source of natural gas for the life of the life-cycle analysis.

The assumption about the source of the natural gas was based on the technical input from PSE (PSE 2018). Before completing the analysis, PSCAA verified PSE's commitment and certainty regarding the source of the gas. Prior to the SEIS, there was no life-cycle analysis in the record adequately supporting the conclusion, on a quantitative basis, that GHG emissions may be reduced as a result of the proposed project. In Section 3.13 of the FEIS, a statement was made that the project would produce a reduction of GHG emissions and assigned an economic value to that reduction. However, no quantitative analysis was provided for that conclusion. The life-cycle analysis in the DSEIS provided that quantitative analysis and demonstrated a GHG emission reduction would result, in part, based upon the source of the natural gas for the process. This was primarily because the emission factors for fugitive methane leaks from Canadian natural gas production are lower than other sources of the gas. Some commenters suggest that the source of natural gas should be evaluated as a speculative, market-based option. PSCAA finds that is not necessary because the SEIS analysis recommends that the source of the natural gas (British Columbia) be included as an enforceable condition in a permit, if issued by PSCAA. PSCAA can write a sufficiently specific condition to ensure it is enforceable. Inclusion of the source of the gas as a permit condition was supported by PSE in their comments submitted on the DSEIS (see Comment #1328, PSE Comment Letter on DSEIS, November 21, 2018), thus, commenters' concerns that such a condition could present legal questions are inapplicable in these circumstances.

If the gas supply to the LNG plant were not demonstrated to come from the Canadian system, the plant would need to stop LNG production or it would violate its air permit. Commenters' concerns that such a condition if required could present legal questions inapplicable in these circumstances.

Comments noted or questioned what might happen if Canadian gas supply to the LNG facility were not available.

If PSE receives a permit from PSCAA, a condition as described above would be included based on the analysis and recommendation in the SEIS. As an air permit approval condition and with evidence that the specific terms of the permit related to this gas source had not been met, the issue would likely end up an enforcement matter with PSCAA. With this type of enforceable condition, any changes regarding the source of the gas would require a permit modification and could also trigger additional SEPA review.

Comments expressed concern regarding the certainty that all of the natural gas supply to the LNG facility is from Canada.

PSCAA was aware of the gas supply mix from different regions when we were preparing the DSEIS. That is why the verification of this issue with PSE was necessary. This comment points to a clarification included in the final SEIS documents. The gas source in our analysis specified that it would come from British Columbia or Alberta, but entering Washington through British Columbia. As seen in the map of the Canadian gas system, the Alberta portion of the gas PSE buys comes through British Columbia. Additional information on the British Columbia and Alberta natural gas system linkage may be found at the British Columbia provincial website information on pipelines (Province of British Columbia 2019). This clarification is consistent with our analysis of the methane leakage rate as discussed in another portion of this response. As stated previously, if a permit is issued, PSCAA can write a sufficiently specific condition defining the required source of gas. If the gas supply to the LNG plant were not demonstrated to come from the system shown in Figure 1 on Western gas supply, the LNG plant would need to stop LNG production or it would be in violation of its air permit, if issued.

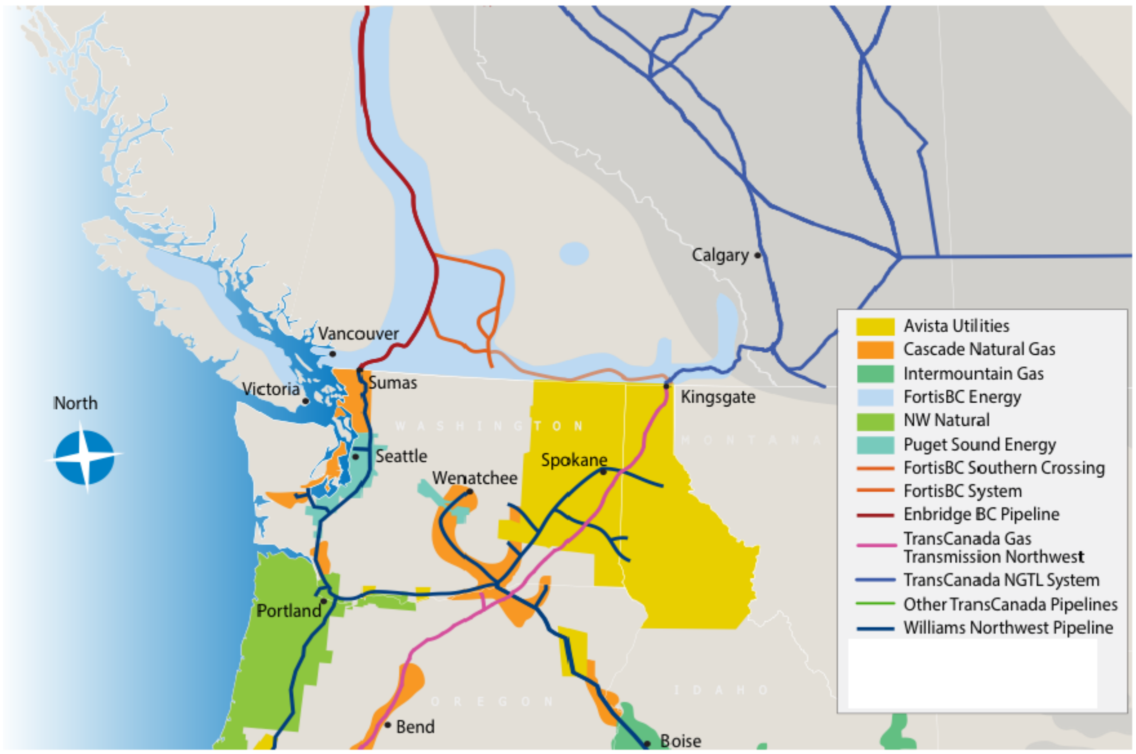


**Figure 1. Source: Puget Sound Energy**

Comments noted or questioned the enforceability of a Canadian natural gas supply requirement for the LNG facility.

When PSCAA reviewed the PSE input regarding the source of the natural gas and the pipeline systems that transport it to the area, we concluded that this was an important assumption that needed to be carried forward as an enforceable permit condition if a permit is issued. We believe that a sufficiently clear and demonstrable permit condition can be developed to ensure that outcome.

Before completing the analysis, PSCAA verified PSE's commitment and certainty regarding the source of the gas. In the DSEIS, the recommendation that the air permit include this gas source as a condition would lead to specific language in an NOC Order of Approval to make this effective. PSE submitted comments stating their support for this condition. If PSE receives an Order of Approval with this condition included, evidence that the specific terms of the permit related to this gas source had not been met would likely end up as an enforcement matter with PSCAA.

PSE does purchase gas from various locations (reportedly from British Columbia, Alberta, and the United States). Commenters suggested that all of the gas is commingled before delivery to a customer, which is inaccurate. PSE does take delivery of natural gas and stores some of it at the Jackson Prairie Underground Storage Facility in Lewis County. If various sources of gas are placed in that storage facility, then it would not be possible to determine the source of the gas for any drawn from that reservoir. That being said, natural gas from Canada does not suddenly merge with United States sourced gas once it crosses the border because the gas pipeline is conveying a supplied flow of gas under pressure that pushes the gas from north to south through western Washington. An example of this is illustrated by reported information related to the October 2018 pipeline rupture in British Columbia (US EIA 2018b). The U.S. Energy Information Agency reported that natural gas deliveries through the Sumas import point were averaging 1.1 billion cubic feet per day (bcfd). Any other gas supply coming to the Puget Sound region (be it from Canada through the Kingsgate import point in Idaho or from U.S. production fields) has to come by route of the Northwest Pipeline that parallels the Columbia River and merges with the pipeline from the north in Clark County at the compressor station north of Washougal. As the US EIA reported on the pipeline rupture, the flow at Sumas immediately went to zero and the incident affected natural gas supplies in Washington, Oregon, and Idaho. The recommendation for the source of gas as a continuing permit condition is based on the assumption that the north to south positive flow of natural gas in the Northwest Pipeline from Canada past the transfer point for gas to PSE feeding the LNG plant can be confirmed by information from both companies, which PSE as a customer for that gas could obtain. If the flow past that transfer point is from Canada whenever gas is being supplied to the LNG facility, it would demonstrate compliance with this condition.

Some comments expressed concern that the PSE response to the gas supply disruption due to a pipeline explosion in British Columbia demonstrated the limitations of a required Canadian source of gas for the LNG facility.

The comments regarding the British Columbia pipeline rupture and its effects on the gas PSE used appear to oversimplify the response to that emergency event. Even with use of natural gas from other places, it did not satisfy all of the immediate needs. PSCAA is aware of industrial sources that were curtailed on their natural gas supplies. Some responded to the situation by switching to diesel fuel options (if it was available and approved). Other sources shutdown as a result of that lost fuel supply. In the event of an emergency in the future, it would not alter the enforceable air permit condition that is recommended in the SEIS. As stated previously, if the gas supply to the LNG plant were not demonstrated to come from the system shown in Figure 1, the facility would need to stop LNG production or it may risk violating its air permit, if issued. As the recent curtailment experience illustrated, alternatives such as shutdown or idling operations were possible for other industrial sites.

Regarding the assumptions outlined in the DSEIS pertaining to the comparative emissions rates for natural gas production in British Columbia, a range of emission estimates for gas production in British Columbia has been published. Additional data has been presented in Appendix LCA-B. While there is some uncertainty in the range of GHG emissions associated with gas production in British Columbia, the values used in the life-cycle analysis are consistent with the British Columbia inventory and fall within the ranges of estimates of GHG emissions from gas production and transport. The information reviewed and summarized in Appendix LCA-B attributes some of the differences in gas leakage rates to geophysical factors and regulatory environments. The range of leak rate emission factors considered in this life-cycle analysis are identified in Table B-4 of the LCA report. The updated LCA report (see Section 2.4.1) provides more details on the regulatory actions in Canada and British Columbia that supports the information and conclusions provided in the SEIS. There are national regulations which apply to all of Canada (which will include Alberta produced natural gas supplied through British Columbia) that will become effective in 2020 or 2023, depending on specific applicability. The Canadian regulations have been established to support their commitments to the Paris Agreement. The provincial government in British Columbia announced additional regulations by the British Columbia Oil & Gas Commission in January 2019, which will be effective in January 2020. These provincial regulations are projected to meet or exceed the performance of the national standards.

Comments expressed concern regarding the practice of methane flaring in British Columbia natural gas production and requested the inclusion of resulting emissions in the upstream portion of the LCA. British Columbia has been working on reducing methane leaks for many years. As an example, the British Columbia Oil & Gas Commission's 2012 Flaring Summary stated: "In 2010, the BC Energy Plan target of eliminating all routine associated gas flaring was achieved. Routine associated gas flaring is defined as the continuous flaring of solution gas that is economical to conserve. Associated (solution) gas is gas produced from a well during oil production" (BC Oil & Gas Commission 2012). This information clarifies the original statement about flaring in British Columbia.

The updated LCA report (see Section 2.4.1) provides more details on the regulatory actions in Canada and British Columbia, which supports the information and conclusions provided in the SEIS. There are national regulations which apply to all of Canada (which will include Alberta produced natural gas supplied through British Columbia) that will become effective in 2020 or 2023, depending on specific applicability. The Canadian regulations have been established to support their commitments to the Paris Agreement. The provincial government in British Columbia announced additional regulations by the British Columbia Oil & Gas Commission in January 2019, which will be effective in January 2020. These provincial regulations are projected to meet or exceed the performance of the national standards.

Additional information regarding GHG emissions for natural gas production in British Columbia and Alberta has been included in Appendix B of the LCA report. Most of the discussion in that appendix relates to methane leakage rate information. Additionally, flaring represents emissions which have been collected and support emission controls (e.g., flaring). The entire GHG emission profile (e.g., $CO_2$, $CH_4$, $N_2O$) are included in the life-cycle analysis. Flaring emissions associated with natural gas production in Canada are included in the life-cycle analysis.

Comments expressed the concern that since 100 percent of the natural gas used for the Proposed Action would be sourced from Canada, this could result in a restructuring of the sourcing of natural gas for other projects, leading to an increased use of non-Canadian natural gas for other project. US EIA data show the flow of natural gas to Washington and surrounding states. Tracking gas flows from state to state in Appendix B reveals that the net gas flows to Washington are from Canada. In 2017, essentially all of the reported natural gas supply to Washington originated in Canada, either through the Sumas gate in northwestern Washington or the Eastport gate in Idaho. The gas transmission line from Sumas runs south through western Washington on its way to Oregon. The gas transmission line starting at Eastport runs through Idaho, Washington, and Oregon on its way to California. The US EIA report (US EIA 2017) identified that the western Washington pipeline (from Sumas) imported 406.5 billion cubic feet of natural in 2017. That is equivalent to 1.11 billion cubic feet per day (bcfd) of natural gas supply. The natural gas liquefaction rate of 500,000 gpd LNG facility is the equivalent of 0.039 bcfd of consumption, which is 3.5 percent of the 2017 import rate. The actual proposed facility production rate of 250,000 gpd LNG would be half of that rate (1.75 percent). Looking at the Province of British Columbia's Natural Gas Pipelines in B.C. map (Province of British Columbia n.d.), it is unlikely that this proposal would result in a lack of Canadian gas for any other project or future population growth. Nothing indicates that the supply of gas from Canada is limited nor is there any indication that the main gas supply pipeline is at or near capacity and any prediction of fuel shuffling in relation to the SEIS analysis for this proposal would be speculative.

# 14. LCA Inputs and Assumptions – Leakage/Slippage

These comments relate to fugitive methane leakage during extraction and transport of natural gas. The responses also address questions and concerns about fuel slippage from marine vessels, which occurs when a percentage of non-combusted fuel escapes from the vessel engine and through the exhaust system.

Comments expressed concern about accurate reporting of GHG fugitive emissions from natural gas production in British Columbia. A range of emission estimates for gas production in Canada has been published. Additional data has been presented in Appendix LCA-B. While there is some uncertainty in the range of GHG emissions associated with gas production in British Columbia, the values used in the life-cycle analysis are consistent with the British Columbia inventory and fall within the ranges of estimates of GHG emissions from gas production and transport. The information reviewed and summarized in Appendix LCA-B attributes some of the differences in gas leakage rates to geophysical factors and regulatory environments.

The range of leak rate emission factors considered in this life-cycle analysis are identified in Table B-4 of the LCA report. The updated LCA report (see Section 2.4.1) provides more details on the regulatory actions in Canada and British Columbia, which supports the information and conclusions provided in the SEIS. There are national regulations which apply to all of Canada (which will include Alberta produced natural gas supplied through British Columbia) that will become effective in 2020 or 2023, depending on specific applicability. The Canadian regulations have been established to support their commitments to the Paris Agreement. The provincial government in British Columbia announced additional regulations by the British Columbia Oil & Gas Commission in January 2019 which will be effective in January 2020. These provincial regulations are projected to meet or exceed the performance of the national standards.

Appendix LCA-B in the LCA report includes a more detailed description of natural gas production processes, including hydraulic fracturing (see Appendix B.1.2).

Some comments noted that an updated version of the GREET model was released on October 10, 2018. Additional discussion of the models used in the LCA was incorporated into Appendix LCA-B. The release of a new version of the GREET model after the DSEIS was published for comment was not considered a basis to revise the analysis and revise the documents. The GREET1_2018 model includes greater fugitive methane emissions but the amount of flared natural gas is lower and the net well to tank GHG emissions per million Btu of natural gas are lower than those in the GREET1_2017 model. No additional life-cycle analysis was performed in response to a new release of the GREET model.

Some comments made note of the values used for the methane slippage rates from TOTE vessels. Data on the methane slippage rate from marine vessels is variable. The most recent literature suggests a range of 5.3 to 6.9 grams per kilowatt hour (g/kWh). A sensitivity analysis has been completed using the higher value. Information is identified in Section 2.3 of the LCA report (and highlighted in Table 2.4) that addresses the consideration of methane slippage. The range of values were considered and included in the updated sensitivity analysis discussed in Section 5 of the LCA Report.

Comments asked if methane slippage was included in the analysis for both TOTE and non-TOTE vessels and if so, what rates were used. Methane slippage emissions were included for both groups of vessels in the life-cycle analysis. The slippage emission factor used was 5.3 g / kWh for all vessels. Since there is literature showing this slippage rate could vary (5.3 up to 6.9 g/kWh), the higher value was included in the sensitivity analysis. See Section 5 of the LCA report.

Commenters requested clarification on methane leakage rates from onboard LNG storage tanks and a statement in the LCA report that these data were pending from PSE. The data were available and were used in the DSEIS. The places where the DSEIS showed missing data were errors in the document. The revised GHG analysis has been updated to reflect the data or information that was used in the analysis. These inputs were reviewed and confirmed based on literature values. The information was used in the model and is discussed in Section 2.4.4 and Appendix A of the LCA report. It was also included in the sensitivity analysis included in the report (see Table 2.4 of the LCA report).

Commenters requested clarification on the LCA inputs for fugitive emissions associated with the transmission pipeline and delivery of LNG to Gig Harbor by truck and the classification of these fugitive emissions as net zero emissions. Data has been reviewed and clarified as follows: delivery of LNG to Gig Harbor would be by truck in both the case of the Tacoma LNG project as well as the No Action Alternative. Therefore, the fugitive emissions associated with delivery to Gig Harbor by truck are net zero between the No Action Alternative and the Proposed Action.

Some comments requested clarification on the proper quantification of fugitive emissions from components such as pump seals, valves, flanges, and other components when the project has not yet been fully constructed. Fugitive GHG emissions evaluated in the life-cycle analysis are estimated based on the information available. Additionally, potential non-GHG fugitive emissions from the proposed facility were evaluated in the FEIS and will be reviewed through the Notice of Construction air permit application process.

Commenters noted that the Draft LCA report stated that fugitive emissions would occur from "valves and piping associated with the transfer of LNG to TOTE's ships…" but then stated that LNG bunkering of ships at the TOTE terminal would not produce fugitive emissions. The language in the final LCA report was revised. Fugitive emissions were based on the factors in Appendix LCA-A.3. These emissions were identified in the Draft SEIS documents and included in the analysis at that time.

Commenters noted that the draft LCA report stated that the storage tank was characterized in the Draft LCA report as "vapor and liquid-tight" but also stated that GHG emissions would also occur from fugitive losses from valves associated with the tank. To clarify, the tank itself is vapor and liquid tight. Fugitive emissions occur from valves and fuel transfer interconnects as discussed in Appendix LCA-A. These emissions were identified in the Draft SEIS documents and included in the analysis.

# 15. LCA Inputs and Assumptions – Natural Gas Properties

These comments pertain to the specific properties and composition of the natural gas proposed for this project.

Some comments raised questions regarding the data used for natural gas properties. The analysis used actual fuel properties provided by the applicant. There were typographical artifacts that were erroneously left in some of the documents from earlier draft work products and these have been corrected. These changes do not affect the analysis because the correct fuel properties were available and were used in the DSEIS. The analysis in Appendix LCA-C describes the effect of fuel properties in greater detail.

Comments stated that the DSEIS uses outdated assumptions regarding the shale and non-shale gas contributions to the overall natural gas supply in the United States. PSCAA disagrees with this assessment. The comment discusses United States natural gas information. However, the DSEIS stated all of the natural gas for the proposed LNG facility would be delivered from Canada and concluded that should be an enforceable air permit condition recommendation. US EIA data shows the flow of natural gas to Washington and surrounding states. These data reveal that the net gas flows to Washington are from Canada (see LCA Report, Appendix B). In 2017, essentially all of the reported natural gas supply to Washington originated in Canada—either through the Sumas gate in northwestern Washington or the Eastport gate in Idaho. The gas transmission line from Sumas runs south, supplying western Washington on its way to Oregon. The gas transmission line starting at Eastport runs through Idaho, Washington, and Oregon on its way to California. More information on the gas supply and production methods are included Appendix B (Section B.1) of the LCA report.

Comments requested clarification on the content of DSEIS Section 2.4.1, Table 2.4 (page 41). Specifically, whether the data in the table show the composition of natural gas that is distributed on average via the gas transmission pipeline. PSCAA received the data on the composition of the natural gas from PSE and it is consistent with the gas distributed in the transmission pipeline.

A commenter suggested that liquid hydrocarbons produced in Canada by natural gas production should be accounted for in the GHG life-cycle analysis. On their own, these byproducts would not be classified as a GHG with an assigned GWP value. However, to the extent these byproducts are used as fuel in the natural gas production, they are included as combustion products in the GHG emission profile for the natural gas production.

# 16. LCA Inputs and Assumptions – Hydraulic Fracturing

Comments expressed concerns related to the LCA inputs and assumptions regarding hydraulic fracturing, including, but not limited to, the upstream emissions associated with hauling water or sand to support gas extraction.

The energy inputs for natural gas production methods including water hauling are a relatively small portion of the overall energy use for natural gas production. Appendix LCA-B includes a more detailed description of natural gas production processes, including hydraulic fracturing (see Appendix B.1.2) in the LCA report.

It is outside of the scope of this SEIS to evaluate the potential impacts of hydraulic fracturing to other environmental and socio-political implications, but the GHG emissions are included in the SEIS analysis. See also response #3 Outside of Scope.

# 17. LCA Inputs and Assumptions – Peak Shaving

These comments relate to the use of LNG for peak shaving. Peak shaving refers to the use of natural gas or other fuels during periods of high energy demand.

The description of peak shaving in the DSEIS and the calculations related to it have been corrected to reflect PSE's proposal of solely vaporizing LNG for distribution into the natural gas supply system for use by their natural gas customers during high demand periods. PSE is not proposing to generate electricity with natural gas from the LNG facility. The vaporized natural gas from the LNG facility would replace natural gas that in the no action alternative is supplied by additional purchase contracts, use of other natural gas storage resources, or other measures PSE could identify to meet its supply obligations. Additionally, the emissions from the re-vaporizing of natural gas are accounted for the analysis.

Some comments asked specific questions about the power generated and fuel used during peak shaving periods. Because the applicant is not proposing to generate power with vaporized LNG, these questions are not within the scope of this SEIS.

Comments submitted expressed concern about the 10-year timeframe for peak shaving presented in the DSEIS. Other commenters noted inconsistencies in the description of the purpose for peak shaving by the Applicant and others questioned the assumption that the displaced fuel used for peak shaving (described in the No Action Alternative) was entirely diesel, thereby overestimating GHG emissions in the No Action Alternative.

An analysis of peak shaving for 10 and 40 years was added as a sensitivity (see Section 5 of the LCA report).

A comment requested clarification on Table 4-3, Page 4-8: Upstream Life-Cycle (Direct LNG Plant Vaporizer). Specifically, whether the table refers to electricity used to operate the vaporizer for peak shaving or LNG emitted during peak shaving. The result of peak shaving is the upstream energy to provide natural gas to make LNG and fuel for regasification plus the combustion of pipeline gas based on LNG. In this table, the Upstream Life-Cycle LNG Vaporizer emissions relate to the electrical demands to operate the vaporizer. The Direct LNG Plant emissions for the LNG Vaporizer are from the boiler used to vaporize the liquid product. So, it takes pumping power (Upstream - Electricity) and heat (Direct - Natural Gas firing) to re-vaporize the LNG. Both are classified as operational emissions. The actual values in the FSEIS tables have been adjusted in response to other comments on the "peak shaving" scenarios.

A comment identified that the amount of LNG vaporized during a peak shaving event was incorrectly presented in the Executive Summary of the DSEIS. Section ES.2 of the SEIS has been updated to reflect the amount of LNG that would be vaporized.

# 18. LCA Inputs and Assumptions – Marine Diesel Oil

These comments relate to the assumption in the DSEIS that MDO is the primary petroleum fuel in marine vessels that would be displaced by LNG.

Comments were submitted regarding the description of MDO in the DSEIS. Commenters indicated that marine emissions comparisons of TOTE fuel should be to MGO, rather than MDO. PSCAA agrees with this assessment, and the analysis has been revised based on the properties of MGO rather than using the properties of MDO. The text and analysis now reflects that the fuel used by TOTE in the NAA is MGO with 0.1 percent sulfur, which is the sulfur limit within the North American Emission Control Area. Appendix C summarizes the properties of MGO compared with other distillate fuels. Please refer Appendix LCA-C Section C.2.2 for the revised analysis of the fuel properties and the upstream life-cycle emissions presented in Appendix LCA-B.3. The updated fuel information resulted in small changes to the GHG emissions in this analysis, but did not alter the overall conclusions. The upstream petroleum life-cycle emissions are discussed in Appendix B (Section B.3) and the properties of the MGO (compared to other liquid fuels used) are included in Appendix C (Section C.2.2) of the LCA report. The updated calculation values are found through the report and the supporting analyses.

The updated fuel information resulted in small changes to the GHG emissions in this analysis, but did not alter the overall conclusions. The changes to the report included both end use and upstream petroleum life-cycle emissions (see LCA report Appendix B, Section B.3). The properties of MGO compared to other liquid fuels used are included in Appendix C of the LCA report (see Section C.2.2).

Comments stated that the DSEIS assumed all vessel and truck traffic calling at the project site would be LNG-powered, which is incorrect and this was not the assumption made in the analysis. Rather, the report assumed that the LNG produced would be largely used in marine vessels and would displace MGO on a 1:1 Btu replacement basis. To the extent that some vessels will continue to operate on MGO, even if the Tacoma LNG facility is built, does not alter the effect of LNG used in marine vessels.

# 19. LCA Inputs and Assumptions – End Use

These comments relate to assumptions made about the end use of the facility's LNG under the Proposed Action and the end use petroleum-based fuels in the No Action Alternative.

Comments suggested that the characterization of end uses in the SEIS differs from the FEIS and that the SEIS includes LNG end-use customers that do not presently exist, therefore rendering the GHG emissions benefits of those customers' LNG use invalid. Reasonable assumptions were made on the end use of LNG at this capacity level and the SEIS end-use assumptions do not need to match the FEIS for this analysis; however, the FEIS stated that there would be a GHG emissions reduction resulting from the project without showing the analysis of how that could occur. That lack of detail was a factor in the determination to proceed with the SEIS for GHG emissions.

The DSEIS analyzes GHG emissions based on a proposed facility with a daily capacity of up to 500,000 gallons per day. The FEIS did contemplate trucking and barging of LNG from the proposed facility; see Section 2.2.1.1 of the FEIS. In addition, the FEIS project description stated a daily production range of 250,000 gallons to 500,000 gallons of LNG. The assumptions did not state that all on-road trucking would be fueled by LNG.

To complete the analysis for the SEIS, it was not necessary to know all of the customers that may buy the product. The assumptions about future marine fuel use have been the stated purpose for most of the produced LNG since the publication of the DEIS (November 9, 2015). Considering business options that speculate beyond the previously reviewed business use is not necessary for this analysis to be complete. The FEIS stated the number of truck trips to/from the site at two per day to transport LNG product and that the scenarios used for the DSEIS reflect that volume. (See FEIS Sections 3.10.4.2 Operations Impacts, and Response 21-5, Transportation / Traffic Volumes.)

A commenter asked for a reference to support a statement in the LCA report that this project would not lead to an expansion of power generation resources. Additional information has been included in the LCA report (see Appendix LCA-B.2) to discuss the power mix for completing the GHG life-cycle analysis. The capacity of the electrical supply system to support this proposed facility was not in the scope of this review. The electric supply capacity for the proposed project was addressed in the City of Tacoma FEIS (see 3.11 – 19

Electricity), which states "Tacoma Power… has sufficient capacity to serve the facility as an additional customer."

Commenter(s) suggested that TOTE and other maritime users of the project's LNG might need to use diesel back-up power on occasion, and these back-up diesel emissions should be included in the analysis. PSCAA based the GHG life-cycle analysis on facility production and LNG end-use operational parameters provided by PSE and TOTE as compared to the use of marine fuel. In order to complete the life-cycle analysis for GHG emissions, it was necessary to assume that any LNG produced would be sold and that would include TOTE as an early customer for this fuel stream. It was also necessary to assume that any LNG sold would be used to displace a liquid fuel. No changes to the end-use scenarios for LNG were made for the final SEIS.

A commenter noted that on-road trucking fuel options include biodiesel and renewable diesel sources, and this should be considered for the No Action Alternative emission estimates. PSCAA's choice in the methodology to complete the GHG life-cycle analysis used the identified baseline No Action Alternative to allow comparison with the project as proposed. PSCAA used reasonable judgement in deciding which variables to include in the analysis. Future fuel options beyond the identified proposed use of produced LNG are speculative and not included in this analysis.

A commenter requested clarification regarding the Gig Harbor diesel truck fuel line item in Table 4-3. –The Gig Harbor Diesel Truck Fuel entry in Table 4-3 is referring to the upstream life-cycle GHG emissions to produce the fuel for that transport. The same table includes Gig Harbor LNG which is referencing the actual diesel fuel used to transport the LNG to Gig Harbor. Linking peak shaving to this part of the analysis would be an error. We received comments on the "peak shaving" scenarios (see also response #17 LCA Inputs and Assumptions - Peak Shaving) in the analysis and adjustments have been made to correct the assumptions around peak shaving use and impacts associated with the proposed LNG production.

A commenter asked about LNG loading rate information for TOTE vessels and how that compared to non-TOTE LNG loading rates. The DSEIS identified loading for TOTE vessels in terms of "hours per week." That information was accurate for TOTE vessels. PSE clarified that the TOTE loading time is based on the capacity of the proposed LNG facility to transfer up to 2,640 gallons of LNG per minute. Other customers could receive LNG at a lower rate, but the facility is designed to transfer fuel to others up to the TOTE transfer rate.

A commenter suggested that nitrogen and other hydrocarbons emissions from ship-to-ship bunkering end uses of the LNG was not included in the analysis. The operations and emission related assumptions for ship-to-ship bunkering of LNG were discussed in the DSEIS (LCA Report in Section A.3) and included in the analysis and in sensitivity information provided in Section 5 (both in the LCA report included with the DSEIS). This information remains in the Final LCA report, with updated values identified through this comment review.

Comments indicated the SEIS should document the LNG end-use mix assumptions for scenarios A and B. The end uses for LNG were identified for both scenarios in the report. The stated purpose of the SEIS was to supplement the FEIS issued by the City of Tacoma on November 9, 2015, specifically to address GHG emissions through a life-cycle analysis. The FEIS repeatedly stated that the Proposed Action was to "produce approximately 250,000 to 500,000 gallons LNG daily" (for example, in the FEIS, see p. 2 of the SEPA Fact Sheet, p. 1 of the Executive Summary, and p. 1-1 of Chapter 1). The NOC application submitted by PSE to PSCAA on May 22, 2017 requested an approval for a plant with a proposed capacity of 250,000 gallons LNG per day. A project applicant may request a permit approval to install a smaller facility than that which was reviewed under SEPA.

When PSCAA began working on the SEIS for GHG emissions, technical information was requested from PSE to support the technical review. In addition to the specific information provided in response to questions, PSE submitted their own life-cycle analysis prepared by a separate consultant. That analysis was completed on a 250,000 gpd LNG production rate. PSCAA concluded that the analysis in the SEIS should be consistent with the stated proposal in the FEIS, since that is the document being supplemented. PSE provided technical input to distinguish the differences between the 250,000 and 500,000 gpd scenarios and included details on each in the SEIS analysis for clarity. The end uses for LNG were identified for both scenarios in the LCA report.

# 20. LCA Inputs and Assumptions – Facility Downtime

Comments related to the emissions that would occur during facility start-up, downtime, or upset conditions are included here, particularly those related to flaring.

The facility will need maintenance and generally equipment is shut down during this time making the emissions lower or zero from the equipment that is shutdown. It is possible the flare could be used just before, during, or just after a maintenance shutdown of a piece of equipment. If a NOC Order of Approval is issued, that order will include requirements to ensure the flare is operated properly and does not have open flames or black smoke. Expected GHG flare emissions (e.g., $CO_2$, $CH_4$, $N_2O$) are included in the DSEIS analysis.

# 21. LCA Inputs and Assumptions – Additional Air Pollutants

These comments addressed air pollutants that are not GHGs. The life-cycle analysis and SEIS relate only to GHGs.

Comments indicated that the analysis should have included particulate matter which contributes to global warming. Particulate matter and black carbon are pollutants that are considered in the GREET model and have potential climate change impacts. The impacts include both warming and cooling effects. Since the effect of particulate matter and black carbon (neither are a gas) have not been adopted by the U.S. Environmental Protection Agency or the State of Washington in its GHG reporting programs, they are not included in this study. Onsite emissions of particulate matter, as a criteria pollutant for the proposed project, were reviewed in Section 3.2 (Air Quality) of the FEIS.

Commenters asked about or suggested that toxic air pollutants, such as volatile organic compounds, ammonia, heavy metals, hydrogen sulfide, and other pollutants be included in the analysis. The SEIS did not address these air pollutants because it is focused solely on GHG emissions. The FEIS evaluated the impacts of other pollutants on air quality and public health.

# 22. General Opposition

Following a careful review of all comments submitted on the draft SEIS, PSCAA believes that the FSEIS includes and/or relies upon reasonable assumptions, data and analyses to adequately evaluate the GHG emissions from the applicant's proposal. PSCAA will consider the SEIS, and other application materials, in its evaluation of the applicant's NOC application and will make a decision regarding the application consistent with applicable legal authorities.

# 23. General Support

PSCAA will consider the SEIS, and other application materials, in its evaluation of the applicant's NOC application and will make a decision regarding the application consistent with applicable legal authorities.

# Response to Petition 4

On November 20, 2018, commenters Nanette Reetz and Desiree Douglass submitted in three formats (bound paper, e-mail, and thumb drive) a document entitled "63,819 People Say No to Puget Sound Energy's Fracked Gas LNG Project." The document contained a November 19, 2018 cover letter referencing at the bottom “Protect the People, Protect the Salish Sea, #NoLNG253, Water Warriors, Stand with Puyallup Tribe”; approximately 69 pages (paper copy) of “Petition Updates” and links to postings and media related to the Petition; undated copy of the Petition addressed to Washington State Attorney General Bob Ferguson referencing “change.org, Puyallup Water Warriors & Redefine Tacoma” at the top; and 517 pages of comments (paper copy) dated 9-30-17 to “9 hours ago.” PSCAA understands the time and date of “9 hours ago” to be early AM on November 21, 2018, based on the submission of the e-mail version of the materials on November 21, 2018 at 1:00 PM. Of the 517 pages of comments (paper copy), the last 12 pages of the comments were dated either between 10-10-18 to 11-14-18 or “four weeks ago” to “9 hours ago.” The DSEIS was published for public comment on October 8, 2018. Notwithstanding that all but the last 12 pages of the comments are dated before the DSEIS was available for public comment, PSCAA understands that the petition submitters request that all the petition comments be considered by PSCAA as comments on the DSEIS. PSCAA has reviewed all of the petition comments and responds as follows:

Many comments state: general support for the Puyallup Tribe and tribal treaties; general opposition to the PSE LNG proposal, including but not limited to, concerns regarding PSE’s construction activities on the PSE site; general support the PSE LNG proposal; general opposition to fracking; general opposition to the burning or production of LNG and/or fossil fuels or fossil fuel facilities; general opposition to impacts from the PSE proposal including, but not limited to, impacts such as air (including GHGs), traffic, construction, visual, cultural resources, land use, property value and health impacts; general opposition to risks of explosions, leaks, or releases from the PSE proposal ; general support for the protection of water quality, for a healthy environment in and around Tacoma, for the Salish Seas, for orcas, salmon and animals; general support for the application of laws to protect the environment and alternatives to use of fossil fuels; and general support for environmental issued or concerns not specifically related to the PSE proposal. In addition, the November 19, 2018 cover letter requests the DSEIS uses a “20-year horizon and most recent best science” and incorporates by reference the comments of the Puyallup Tribe on the DSEIS. PSCAA responds as follows: Thank you for the comments. In addition, see responses #1 through #22.

# Appendix C.3 Comment Summary Table

This comment summary table is a comprehensive list of all participants who submitted unique comments to PSCAA during the public commenting process and the issues associated with each comment. The comment summary table is organized in alphabetical order by name for Tribal, State, or Organizations. For groups of individuals, comments are organized by the last name and first initial of the first commenter. For individuals, comments are organized by last name and first initial. All comments are tagged with a unique comment identification number. Commenters who submitted multiple unique letters should refer to the comment number to locate their letters in Appendix C.4. Additionally, a summary of issues associated with each form comment and petition can also be found at the end of this comment summary table.

For the complete collection of unique comments, form letters/emails, and petitions, refer to Appendix C.4, which can be found via flash drive insert on a hard copy of the FSEIS or online at **http://www.pscleanair.org/460/Current-Permitting-Projects**.

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| ***Tribal*** | |
| Bryan, A_1106<br>on Behalf of Puyallup Tribal Council and Tribal members | 3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Sterud, B_0824<br>Puyallup Tribe of Indians | 5. Regulatory Framework |
| Sterud, B_0865<br>Puyallup Tribe of Indians | 1. Determination of SEIS Scope - Comparison to FEIS<br>10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>15. LCA Inputs and Assumptions - Natural Gas Properties<br>2. Determination of the SEIS Scope<br>5. Regulatory Framework<br>6. Purpose and Need<br>7. SEPA Alternatives<br>8. No Action Alternative<br>9. LCA Methodology<br>3. Outside of SEIS Scope<br>17. LCA Inputs and Assumptions - Peak Shaving<br>19. LCA Inputs and Assumptions - End Use<br>20. LCA Inputs and Assumptions - Facility Downtime |
| ***State*** | |
| Sherman, W_0863<br>Council for Environmental Protection, Washington State Attorney General's Office | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>8. No Action Alternative |
| Toteff, S_0864<br>Department of Ecology | 10. LCA Calculations<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>17. LCA Inputs and Assumptions - Peak Shaving<br>18. LCA Inputs and Assumptions - Marine Diesel Oil<br>5. Regulatory Framework |
| ***Local*** | |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Adrien, J_1151<br>Economic Development Board for Tacoma-Pierce County | 23. General Support |
| Kendall, B_1114<br>Economic Development Board for Tacoma-Pierce County | 23. General Support |
| Paulsen, L_1179<br>Commissioners of the Board of Tacoma | 23. General Support |
| Pierson, T_1230<br>Tacoma-Pierce County Chamber | 23. General Support |
| ***Organizations*** | |
| Royer, J_1158<br>Pacific Merchant Shipping Association | 23. General Support |
| Unruh, G_1141<br>Economic Development Board for Tacoma-Pierce County | 23. General Support |
| America Honda Motor Co._1960 | 23. General Support |
| Belarde, B_1261<br>Laborers' International Union of North America - Local No. 252 | 23. General Support |
| Berkowitz, R_1267<br>Transportation Institute (TI) | 23. General Support |
| Bohannon, B_0445<br>Sailor's Union of the Pacific | 23. General Support |
| Boulanger, J_1262<br>Patriot Fire Protection | 23. General Support |
| Climate First Responders_1586<br>Climate First Responders | 5. Regulatory Framework |
| Cornett, S_0960<br>Washington Physicians for Social Responsibility | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Dilworth, E_1095<br>Citizens for a Healthy Bay | 11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>15. LCA Inputs and Assumptions - Natural Gas Properties<br>17. LCA Inputs and Assumptions - Peak Shaving<br>18. LCA Inputs and Assumptions - Marine Diesel Oil<br>19. LCA Inputs and Assumptions - End Use<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>7. SEPA Alternatives |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Doty, A_0956<br>Washington Environmental Council | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>17. LCA Inputs and Assumptions - Peak Shaving<br>5. Regulatory Framework<br>6. Purpose and Need |
| Gamble, J_1954<br>Master Builders Association of Pierce County | 23. General Support |
| Gering, D_1129<br>Manufacturing Industrial Council of Seattle | 23. General Support |
| Gering, D_1948<br>Manufacturing Industrial Council of Seattle | 23. General Support |
| Gilbert, S_1223<br>Institute for Neurotoxicology and Neurologic Disorder | 22. General Opposition |
| Grant, N_0724<br>MLK Labor | 23. General Support |
| Green, G_0980<br>TOTE Maritime Alaska | 23. General Support |
| Griffith, E_0679<br>New Progressive Alliance | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| Grimaldi, P_1993<br>Lynden Transport, Inc. | 23. General Support |
| Hagey, J_1150<br>Association of Washington Business (AWB) | 23. General Support |
| Hartmann, S_1219<br>Lynden Transport, Inc. | 23. General Support |
| Hartmann, S_1946<br>Lynden Transport, Inc. | 23. General Support |
| Hay, T_1228<br>Advocates for Cleaner Tacoma | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>18. LCA Inputs and Assumptions - Marine Diesel Oil<br>19. LCA Inputs and Assumptions - End Use |
| Hay, T_1279<br>Advocates for Cleaner Tacoma | 11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>17. LCA Inputs and Assumptions - Peak Shaving<br>19. LCA Inputs and Assumptions - End Use<br>7. SEPA Alternatives |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Hay, T_1298<br>Advocates for Cleaner Tacoma | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>17. LCA Inputs and Assumptions - Peak Shaving<br>19. LCA Inputs and Assumptions - End Use<br>7. SEPA Alternatives |
| Hutchinson, M_0663<br>GeoEngineers, Inc. | 23. General Support |
| Iverson, T_1229<br>Longshoremen, Port of Tacoma | 23. General Support |
| Jennings, C_1980<br>Skagit Business Alliance | 23. General Support |
| Johnson, E_1137<br>Washington Public Ports Association | 23. General Support |
| Johnson, K_1973<br>Association of Washington Business (AWB) | 23. General Support |
| Kendig, C_0721<br>American Honda Motor Co., Inc. | 23. General Support |
| Kovacich, D_0344<br>Maxum Petroleum | 23. General Support |
| Larson, T_0655<br>Whatcom Business Alliance | 23. General Support |
| Lohr, V_1235<br>Citizen's Climate Lobby | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Malott, M_1190<br>Citizens for a Healthy Bay (CHB) | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>5. Regulatory Framework |
| Malott, M_1304<br>Citizens for a Healthy Bay (CHB) | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Martinez, M_1185<br>Pierce County Building and Construction Trades Council | 23. General Support |
| Mayer, A_2002<br>Mt. Vernon Chamber of Commerce | 23. General Support |
| Meyer, D_0734<br>Port of Tacoma | 23. General Support |
| Mills, D_1130<br>Puget Sound Energy | 23. General Support |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Neal, M_1947<br>Manufacturing Industrial Council for the South Sound | 23. General Support |
| O'Brien, M_1192<br>Sierra Club | 22. General Opposition |
| O'Donnell, T_1227<br>IBW Local 76 | 23. General Support |
| O'Halloran, V_1234<br>Sound Ports Council, Maritime Trades Dept, AFLCIO | 23. General Support<br>7. SEPA Alternatives |
| Occhiogrosso, G_1986<br>Bellingham Regional Chamber of Commerce | 23. General Support |
| Parrott, J_1296<br>Foss Maritime Company | 23. General Support |
| Pierson, T_2015<br>Tacoma-Pierce County Chamber | 23. General Support |
| Powell, T_1098<br>Sightline Institute | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>18. LCA Inputs and Assumptions - Marine Diesel Oil<br>19. LCA Inputs and Assumptions - End Use<br>20. LCA Inputs and Assumptions - Facility Downtime<br>4. Language<br>6. Purpose and Need<br>7. SEPA Alternatives |
| Puget Sound Energy_1328<br>Puget Sound Energy | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>17. LCA Inputs and Assumptions - Peak Shaving<br>18. LCA Inputs and Assumptions - Marine Diesel Oil<br>21. LCA Inputs and Assumptions - Additional Air Pollutants |
| Puyallup Sumner Chamber of Commerce_1972<br>Puyallup Sumner Chamber of Commerce | 23. General Support |
| Puyallup Sumner Chamber of Commerce_2010<br>Puyallup Sumner Chamber of Commerce | 23. General Support |
| Rose, P_0725<br>Pierce County Central Labor Council | 23. General Support |
| Rowe, et al., P_0866<br>NorthWest Research Associates | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use |
| Schaffert, D_1979<br>Thurston County Chamber | 23. General Support |
| Schrappen, P_2001<br>Washington Maritime Federation | 23. General Support |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Serres, D_0958<br>Columbia Riverkeeper | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Sewell, S_1221<br>Washington Maritime Federation | 23. General Support |
| Siffring, S_1288<br>Western Energy Alliance | 13. LCA Inputs and Assumptions - Natural Gas Source<br>5. Regulatory Framework |
| Stokes, C_1952<br>Alliance of Western Energy Consumers (AWEC) | 23. General Support |
| Swanson, M_1957<br>Potelco, Inc. | 23. General Support |
| TOTE Maritime Alaska_0983<br>TOTE Maritime Alaska | 11. LCA Inputs and Assumptions - General<br>18. LCA Inputs and Assumptions - Marine Diesel Oil |
| Vincenzo, J_1156<br>Seafarers' International Union | 23. General Support |
| Wells, M_0658<br>UA Local 26 Plumbers and Pipefitters | 23. General Support |
| Wells, M_1186<br>Western Washington Local Plumbers, Pipefitters, and Welders (Local 26) | 23. General Support |
| Whatcom Business Alliance_1964<br>Whatcom Business Alliance | 23. General Support |
| ***Individuals*** | |
| Allie_0738 | 22. General Opposition |
| Ann_2470 | 22. General Opposition |
| Anonymous_1293 | 22. General Opposition |
| Barbara Ann_2473 | 22. General Opposition |
| Christine_1605 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>19. LCA Inputs and Assumptions - End Use |
| Dalton_2475 | 22. General Opposition |
| Delila_2476 | 22. General Opposition |
| Ebonie_2477 | 22. General Opposition |
| Elijah_2478 | 22. General Opposition |
| Hailey_2479 | 22. General Opposition |
| Imyah_2480 | 22. General Opposition |
| Jalyna_2481 | 22. General Opposition |
| James_2482 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Jelina_2483 | 22. General Opposition |
| Jeremiah_2484 | 22. General Opposition |
| Joey_2485 | 22. General Opposition |
| Kailgh_2486 | 22. General Opposition |
| Kanai_2487 | 22. General Opposition |
| Kiana_2488 | 22. General Opposition |
| Kishon_2489 | 22. General Opposition |
| Kiuna_2490 | 22. General Opposition |
| Mateo_2493 | 22. General Opposition |
| Mhasiyah_2494 | 22. General Opposition |
| Nevae_2495 | 22. General Opposition |
| Polina_2497 | 22. General Opposition |
| Rumi_1300 | 22. General Opposition |
| Unknown_2471 | 22. General Opposition |
| Various_1959 | 23. General Support |
| Vincent_1301 | 22. General Opposition |
| Anonymous_0471 | 22. General Opposition |
| Anonymous_0583 | 3. Outside of SEIS Scope |
| Anonymous_0656 | 23. General Support |
| Anonymous_0740 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Anonymous_0742 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Anonymous_0744 | 22. General Opposition |
| Anonymous_0745 | 22. General Opposition |
| Anonymous_0747 | 22. General Opposition |
| Anonymous_1906 | 22. General Opposition |
| Anonymous_2133 | 3. Outside of SEIS Scope |
| Anonymous_2472 | 22. General Opposition |
| Prince_2498 | 22. General Opposition |
| Ruby_2499 | 22. General Opposition |
| Ruth_2500 | 22. General Opposition |
| Tia_2502 | 22. General Opposition |
| Winnie_2503 | 22. General Opposition |
| 2, C_1584 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Adams, B_1109 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing |
| Adams, B_1840 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Adkins, J_1159 | 22. General Opposition |
| Adkins, J_1559 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Adrien, J_1999 | 23. General Support |
| Albert, A_1489 | 22. General Opposition |
| Albert, A_1519 | 22. General Opposition |
| Albert, H_2200 | 22. General Opposition |
| Alic, M_2202 | 22. General Opposition |
| Allee, P_1508 | 5. Regulatory Framework |
| Allen, W_0368 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>5. Regulatory Framework |
| Allen, W_1887 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Almendariz, M_1723 | 22. General Opposition |
| Alvarez, T_1708 | 22. General Opposition |
| Amdahl, D_1824 | 3. Outside of SEIS Scope |
| Amor, D_2008 | 23. General Support |
| Annalee, L_0749 | 22. General Opposition |
| Anderson, G_1571 | 22. General Opposition<br>5. Regulatory Framework |
| Anderson, G_1572 | 22. General Opposition |
| Anderson, G_1645 | 22. General Opposition |
| Anderson, G_1664 | 22. General Opposition |
| Anderson, K_1987 | 23. General Support |
| Anderson, N_1197 | 22. General Opposition |
| Anderson, N_2071 | 22. General Opposition |
| Anderson, N_2079 | 3. Outside of SEIS Scope |
| Anderson, N_2087 | 3. Outside of SEIS Scope |
| Anderson, N_2088 | 3. Outside of SEIS Scope |
| Anderson, N_2089 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Ann, M_1616 | 3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Arent, S_1607 | 22. General Opposition |
| Arielle Fiestal, J_1671 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>5. Regulatory Framework |
| Armstrong, D_1372 | 22. General Opposition |
| Arnold, O_1200 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>5. Regulatory Framework |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Aspell, A_1768 | 22. General Opposition |
| Atly, E_0567 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Atly, E_0568 | 22. General Opposition |
| Atly, E_0569 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Atly, E_0570 | 22. General Opposition |
| Atly, E_0571 | 22. General Opposition |
| Atly, E_2029 | 22. General Opposition |
| Atly, E_2036 | 3. Outside of SEIS Scope |
| Atly, E_2039 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| Atly, E_2043 | 3. Outside of SEIS Scope |
| Atly, E_2045 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| Augustino, S_1546 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Averill, D_1869 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Averill, D_1870 | 22. General Opposition |
| Averill, D_1871 | 5. Regulatory Framework |
| Averill, E_1867 | 22. General Opposition |
| Averill, E_1868 | 22. General Opposition |
| Ayres, P_2542 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| B, M_1990 | 23. General Support |
| B, M_1991 | 23. General Support |
| B., M_1183 | 23. General Support |
| Baird, C_2239 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Ballantyne, D_1310 | 3. Outside of SEIS Scope |
| Barbee, S_1217 | 22. General Opposition |
| Barbee, S_1649 | 5. Regulatory Framework |
| Barcia, H_2196 | 3. Outside of SEIS Scope |
| Barnhart, C_1122 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Barrett, K_2231 | 10. LCA Calculations<br>22. General Opposition |
| Bates, K_2009 | 23. General Support |
| Bayliss, B_2229 | 22. General Opposition |
| Beal, L_1658 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>3. Outside of SEIS Scope |
| Beazley, A_1789 | 22. General Opposition |
| Becktel, C_1533 | 22. General Opposition |
| Belle, A_1689 | 3. Outside of SEIS Scope |
| Bender, T_1363 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition |
| Benedict, O_0435 | 22. General Opposition<br>5. Regulatory Framework |
| Benedict, O_1600 | 5. Regulatory Framework |
| Bentley, D_1949 | 23. General Support |
| Berkowitz, R_1207 | 23. General Support |
| Bernthal, J_1665 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| Bernthal, J_1666 | 3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Bernthal, J_1786 | 22. General Opposition |
| Bird, M_2222 | 3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Blackburn, L_1774 | 22. General Opposition |
| Blanchard, P_1820 | 22. General Opposition |
| Blankenship, L_1992 | 23. General Support |
| Blattler, B_0672 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>3. Outside of SEIS Scope |
| Blattler, B_1259 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Bluespruce, J_1163 | 22. General Opposition |
| Bluhm, D_1312 | 22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework<br>7. SEPA Alternatives |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Bluhm, D_1313 | 5. Regulatory Framework |
| Bodine, A_2544 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition |
| Boehm-Brady, L_2234 | 22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Bohannon, B_1985 | 23. General Support |
| Boudreau, D_1785 | 22. General Opposition |
| Bowen, D_1757 | 22. General Opposition |
| Bowen, E_1561 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Boyer, M_2241 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition |
| Braaten, C_1118 | 1. Determination of SEIS Scope - Comparison to FEIS<br>22. General Opposition |
| Braaten, C_1617 | 1. Determination of SEIS Scope - Comparison to FEIS<br>11. LCA Inputs and Assumptions - General |
| Bramble, R_1389 | 22. General Opposition |
| Bramble, R_1398 | 22. General Opposition |
| Bramble, R_1409 | 22. General Opposition |
| Bramble, R_1422 | 22. General Opposition |
| Bramble, R_1434 | 22. General Opposition |
| Breckenridge, S_0819 | 23. General Support |
| Brenner, S_1334 | 22. General Opposition |
| Bresky, R_1496 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Brewer, H_1144 | 13. LCA Inputs and Assumptions - Natural Gas Source |
| Brewer, K_1171 | 22. General Opposition |
| Briggs, R_1327 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>17. LCA Inputs and Assumptions - Peak Shaving<br>19. LCA Inputs and Assumptions - End Use<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Brignell, K_1450 | 22. General Opposition |
| Brignell, K_1451 | 22. General Opposition |
| Brilcher, S_1282 | 10. LCA Calculations<br>22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Brockway, A_1099 | 22. General Opposition |
| Brooke, C_1735 | 22. General Opposition |
| Brooke, P_0715 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Brooke, P_1569 | 5. Regulatory Framework |
| Brothers, S_1374 | 22. General Opposition |
| Brown, B_1620 | 22. General Opposition |
| Brown, G_2540 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Brown, L_1462 | 22. General Opposition |
| Brown Randles, M_0652 | 22. General Opposition |
| Bryant, A_1903 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Bryant, J_1470 | 22. General Opposition |
| Bryson, C_0360 | 23. General Support |
| Bunch, J_1803 | 22. General Opposition |
| Burke, S_1280 | 11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Burkhart, D_1636 | 22. General Opposition |
| Bustillo, M_0820 | 23. General Support |
| Butterfield, L_1984 | 23. General Support |
| Byrne, M_0359 | 22. General Opposition |
| Cadden, S_1956 | 23. General Support |
| Caddock, J_1161 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition<br>5. Regulatory Framework |
| Caddock, J_1610 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>5. Regulatory Framework |
| Calnan, C_1115 | 23. General Support |
| Camilleri, A_1648 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Cannon, C_2244 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Capan, C_1378 | 22. General Opposition |
| Carey, R_1679 | 22. General Opposition |
| Carlson, C_1619 | 3. Outside of SEIS Scope |
| Carlson, D_1384 | 22. General Opposition |
| Carlson, D_1393 | 22. General Opposition |
| Carlson, D_1405 | 22. General Opposition |
| Carlson, D_1424 | 22. General Opposition |
| Carlson, D_1430 | 22. General Opposition |
| Carlton, J_1331 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>17. LCA Inputs and Assumptions - Peak Shaving<br>18. LCA Inputs and Assumptions - Marine Diesel Oil<br>7. SEPA Alternatives |
| Carruthers, C_1120 | 19. LCA Inputs and Assumptions - End Use |
| Castle, E_1765 | 22. General Opposition |
| Catford, T_1713 | 3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Chaloff, A_1354 | 22. General Opposition |
| Chaloff, A_1449 | 22. General Opposition |
| Chalupnik, J_1846 | 22. General Opposition |
| Chaney, B_1549 | 22. General Opposition |
| Chapin, C_1123 | 22. General Opposition |
| ChapmanDutton, H_1753 | 11. LCA Inputs and Assumptions - General |
| Charles, F_1813 | 5. Regulatory Framework |
| Charles, F_1976 | 23. General Support |
| Charles, F_1998 | 23. General Support |
| Chavez, J_1162 | 22. General Opposition |
| Christensen, M_2183 | 22. General Opposition |
| Christopherson, R_1370 | 22. General Opposition |
| Church, B_2249 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Church, J_0449 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Church, J_0466 | 22. General Opposition |
| Cirigliano, L_1831 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Clark, J_1838 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Clark, W_1239 | 22. General Opposition |
| Clearman, J_0361 | 23. General Support |
| Clearman, J_1160 | 23. General Support |
| Cody, H_1683 | 3. Outside of SEIS Scope |
| Cohn, L_1567 | 22. General Opposition |
| Cole, B_2557 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use |
| Coleman, L_1711 | 22. General Opposition |
| Coleman, L_1730 | 22. General Opposition |
| Coleman, L_1775 | 22. General Opposition |
| Combes, J_2212 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Cooke, H_1464 | 22. General Opposition |
| Cooper, B_1782 | 22. General Opposition |
| Cordell, G_2221 | 22. General Opposition |
| Cornett, S_0632 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Cornett, S_0633 | 3. Outside of SEIS Scope |
| Cornett, S_0636 | 3. Outside of SEIS Scope |
| Cornett, S_0637 | 3. Outside of SEIS Scope |
| Cornett, S_0638 | 3. Outside of SEIS Scope |
| Cornett, S_0639 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Cornett, S_0641 | 11. LCA Inputs and Assumptions - General |
| Cornett, S_0643 | 3. Outside of SEIS Scope |
| Cornett, S_2143 | 3. Outside of SEIS Scope |
| Cornett, S_2145 | 3. Outside of SEIS Scope |
| Cornett, S_2147 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Cornett, S_2148 | 3. Outside of SEIS Scope |
| Cornett, S_2150 | 3. Outside of SEIS Scope |
| Cornett, S_2151 | 3. Outside of SEIS Scope |
| Cornett, S_2153 | 3. Outside of SEIS Scope |
| Cornett, S_2154 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Cornwell, L_1243 | 22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Cotter, S_2063 | 6. Purpose and Need |
| Cotter, S_2065 | 3. Outside of SEIS Scope |
| Cotter, S_2066 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Cotter, S_2067 | 3. Outside of SEIS Scope |
| Cotter, S_2068 | 3. Outside of SEIS Scope |
| Cox, M_1191 | 22. General Opposition |
| Craig, L_1894 | 22. General Opposition |
| Craighead, T_1626 | 3. Outside of SEIS Scope |
| Craven, M_2245 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Crawford, B_1110 | 23. General Support |
| Cron, H_1460 | 22. General Opposition |
| Crosby, K_2203 | 22. General Opposition |
| Cross, S_0348 | 22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Cruz, E_2237 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Culpepper, B_2474 | 22. General Opposition |
| Cummings, B_1703 | 5. Regulatory Framework |
| Currie, E_0455 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Currie, E_0456 | 22. General Opposition |
| Curtis, S_0654 | 22. General Opposition |
| Cutler Wilson, L_2187 | 3. Outside of SEIS Scope |
| Dachary, H_1769 | 3. Outside of SEIS Scope |
| Dahl, C_1746 | 3. Outside of SEIS Scope |
| Dambergs, S_1263 | 22. General Opposition |
| Dambergs, S_1264 | 22. General Opposition |
| Dambergs, S_1265 | 22. General Opposition |
| Danielson, E_1766 | 22. General Opposition |
| Danysh, I_1554 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Danysh, I_1555 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| Danysh, I_1828 | 22. General Opposition |
| Danysh, I_1829 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Darienzo, M_1875 | 22. General Opposition |
| Davis, A_1761 | 22. General Opposition |
| Davis, L_1390 | 22. General Opposition |
| Davis, L_1402 | 22. General Opposition |
| Davis, L_1412 | 22. General Opposition |
| Davis, L_1419 | 22. General Opposition |
| Davis, L_1435 | 22. General Opposition |
| Davis, N_1507 | 22. General Opposition |
| De, R_1609 | 3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Dea, M_1659 | 3. Outside of SEIS Scope |
| Dearinger, T_0353 | 22. General Opposition |
| Deavers, T_1495 | 22. General Opposition |
| Deavers, T_1506 | 22. General Opposition |
| DeHart, B_0572 | 3. Outside of SEIS Scope |
| DeHart, B_0573 | 22. General Opposition |
| DeHart, B_0574 | 3. Outside of SEIS Scope |
| DeHart, B_0575 | 3. Outside of SEIS Scope |
| DeHart, B_0576 | 22. General Opposition |
| DeHart, B_0577 | 3. Outside of SEIS Scope |
| DeHart, B_0581 | 22. General Opposition |
| DeHart, B_2098 | 22. General Opposition |
| DeHart, B_2099 | 22. General Opposition |
| DeHart, B_2135 | 3. Outside of SEIS Scope |
| DeHart, B_2139 | 3. Outside of SEIS Scope |
| DeHart, B_2140 | 3. Outside of SEIS Scope |
| DeHart, B_2141 | 3. Outside of SEIS Scope |
| Demian, D_2550 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>7. SEPA Alternatives |
| Demick, M_1303 | 3. Outside of SEIS Scope<br>5. Regulatory Framework<br>8. No Action Alternative |
| Denning, M_1694 | 5. Regulatory Framework |
| Derry, A_1810 | 4. Language |
| DeSouza, R_0352 | 22. General Opposition<br>5. Regulatory Framework |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| DeSouza, R_0347 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Deumling, S_1480 | 22. General Opposition |
| DeVane, C_1477 | 22. General Opposition |
| Devlin, F_1589 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition |
| Dilworth, E_1138 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition |
| Dimasi, S_2181 | 22. General Opposition |
| DiNino, L_0349 | 22. General Opposition<br>8. No Action Alternative |
| Dlugonski, M_1388 | 22. General Opposition |
| Dlugonski, M_1401 | 22. General Opposition |
| Dlugonski, M_1413 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition |
| Dlugonski, M_1416 | 22. General Opposition |
| Dlugonski, M_1438 | 22. General Opposition |
| Donaldson, S_0458 | 22. General Opposition |
| Donohoe, S_1476 | 22. General Opposition |
| Donohoe, S_1512 | 22. General Opposition |
| Douglass, D_1722 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Douglass, D_1728 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Douglass, D_1781 | 22. General Opposition |
| Douglass, D_1908 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>5. Regulatory Framework<br>8. No Action Alternative |
| Dow, B_1904 | 13. LCA Inputs and Assumptions - Natural Gas Source |
| Dow, B_1905 | 5. Regulatory Framework |
| Downie, A_0751 | 22. General Opposition |
| Doyle, D_1968 | 23. General Support |
| Doyle-Enneking, T_1225 | 23. General Support |
| Doyle-Enneking, T_1962 | 23. General Support |
| Driscoll, M_1832 | 22. General Opposition |
| Duggan, R_2208 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Durham, J_1714 | 22. General Opposition |
| Durr, R_2180 | 3. Outside of SEIS Scope |
| Ebaugh, D_1895 | 22. General Opposition |
| Ebaugh, E_1893 | 22. General Opposition |
| Eckert, C_1539 | 22. General Opposition |
| Eckrich, M_1341 | 22. General Opposition |
| Edain, M_2545 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Edison, S_1792 | 22. General Opposition |
| Edmark, K_1668 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Edward Oaks III, L_0752 | 22. General Opposition |
| Eggerneiler, S_0561 | 22. General Opposition |
| Eggerneiler, S_0562 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Eggerneiler, S_0563 | 3. Outside of SEIS Scope |
| Eggerneiler, S_0564 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition |
| Eggerneiler, S_0565 | 11. LCA Inputs and Assumptions - General |
| Eggerneiler, S_2052 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Eggerneiler, S_2053 | 3. Outside of SEIS Scope |
| Eggerneiler, S_2057 | 22. General Opposition |
| Eggerneiler, S_2059 | 3. Outside of SEIS Scope |
| Eggerneiler, S_2060 | 22. General Opposition |
| Ein, F_2210 | 22. General Opposition |
| Elam, R_2549 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Elton, W_2535 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Erickson, P_1278 | 21. LCA Inputs and Assumptions - Additional Air Pollutants<br>9. LCA Methodology |
| Esperanza, D_1801 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Falzarano, B_1295 | 22. General Opposition |
| Falzarano, M_1257 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition |
| Farren, M_1565 | 22. General Opposition |
| Farwell, T_1902 | 22. General Opposition |
| Feist, C_1289 | 22. General Opposition |
| Feldman, G_1484 | 22. General Opposition |
| Felt, M_1961 | 23. General Support |
| Ferguson, J_1290 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>20. LCA Inputs and Assumptions - Facility Downtime |
| Ferguson, J_1741 | 10. LCA Calculations |
| Fergusson, P_1615 | 22. General Opposition |
| Fielding Lopez, E_1825 | 22. General Opposition |
| Fields, M_1688 | 22. General Opposition |
| Fields, M_1770 | 22. General Opposition |
| Finnie, B_1958 | 23. General Support |
| Fisher, I_1339 | 22. General Opposition |
| Fisher Walkins, I_1876 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Fitz Hugh, L_1180 | 5. Regulatory Framework |
| Flanagan, V_1710 | 22. General Opposition |
| Forbes, C_1978 | 23. General Support |
| Ford, B_1864 | 22. General Opposition |
| Ford, T_2186 | 22. General Opposition |
| Fortune, L_0440 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Fortune, L_2246 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>15. LCA Inputs and Assumptions - Natural Gas Properties |
| Fox, M_1580 | 22. General Opposition |
| Frank, L_1329 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Frankel, M_1193 | 22. General Opposition |
| Franzen, K_1467 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Friedman, W_1478 | 22. General Opposition |
| Frisch, D_1534 | 10. LCA Calculations<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Frisch, D_1662 | 10. LCA Calculations<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Fromer, E_1901 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Fuentes, C_2250 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Funderburk, L_1475 | 22. General Opposition |
| Funsch, B_1335 | 22. General Opposition<br>5. Regulatory Framework |
| Gabbay, D_2567 | 1. Determination of SEIS Scope - Comparison to FEIS<br>10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Gabbay, D_1719 | 3. Outside of SEIS Scope |
| Gale, J_1637 | 22. General Opposition<br>5. Regulatory Framework |
| Gale, M_1854 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>19. LCA Inputs and Assumptions - End Use |
| Galloway, C_0675 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>3. Outside of SEIS Scope |
| Galvin, K_2094 | 3. Outside of SEIS Scope |
| Galvin, K_2095 | 3. Outside of SEIS Scope |
| Galvin, K_2096 | 3. Outside of SEIS Scope |
| Galvin, K_2097 | 3. Outside of SEIS Scope |
| Garrity, M_1845 | 22. General Opposition |
| Genung, A_1418 | 22. General Opposition |
| Gere, S_1910 | 22. General Opposition |
| Gernez, C_0610 | 3. Outside of SEIS Scope |
| Gernez, C_0611 | 22. General Opposition |
| Gernez, C_0612 | 3. Outside of SEIS Scope |
| Gernez, C_0613 | 3. Outside of SEIS Scope |
| Gernez, C_1121 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Gernez, C_2173 | 3. Outside of SEIS Scope |
| Gernez, C_2174 | 3. Outside of SEIS Scope |
| Gernez, C_2175 | 22. General Opposition |
| Gernez, C_2176 | 3. Outside of SEIS Scope |
| Giddings, A_1371 | 22. General Opposition |
| Giddings, R_1297 | 22. General Opposition |
| Gilbert, V_1712 | 22. General Opposition |
| Gill, H_1545 | 22. General Opposition |
| Gilman, C_1345 | 22. General Opposition |
| Glans, C_0306 | 22. General Opposition |
| Golding, W_1805 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework<br>7. SEPA Alternatives<br>8. No Action Alternative |
| Goldman, H_1515 | 22. General Opposition |
| Goldsmith, D_1527 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>5. Regulatory Framework |
| Gomez, A_2192 | 22. General Opposition |
| Gottfried, J_1379 | 22. General Opposition |
| Gottfried, J_1380 | 22. General Opposition |
| Goulet, G_1704 | 5. Regulatory Framework |
| Gramentz, S_2207 | 22. General Opposition |
| Green, A_0817 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Greenberg, S_1224 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>5. Regulatory Framework |
| Greene, G_1140 | 23. General Support |
| Griffiths, E_2556 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Grossman, D_1442 | 5. Regulatory Framework |
| Grossman, L_2198 | 22. General Opposition |
| Gulick, M_1189 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Gunn, J_1524 | 3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Hagberg, S_1988 | 23. General Support |
| Hagedorn, L_2031 | 3. Outside of SEIS Scope |
| Hagedorn, L_2034 | 3. Outside of SEIS Scope |
| Hagedorn, L_2037 | 3. Outside of SEIS Scope |
| Hagedorn, L_2038 | 3. Outside of SEIS Scope |
| Hakimian, A_1593 | 3. Outside of SEIS Scope |
| Hale, A_2228 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>6. Purpose and Need |
| Haley, M_1530 | 22. General Opposition |
| Hall, C_1447 | 22. General Opposition |
| Hall, F_1743 | 22. General Opposition |
| Hall, M_1877 | 22. General Opposition |
| Hall, M_1878 | 3. Outside of SEIS Scope |
| Hall, M_1879 | 3. Outside of SEIS Scope |
| Halliburton, M_1791 | 22. General Opposition |
| Hallman, H_2570 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition<br>7. SEPA Alternatives |
| Hanks, L_1522 | 22. General Opposition |
| Hapoke, R_0812 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Harman, K_1445 | 22. General Opposition |
| Harria, B_1471 | 22. General Opposition |
| Harris, C_1342 | 22. General Opposition |
| Harris, J_1955 | 23. General Support |
| Hartt, C_1119 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| Harvey, A_1821 | 5. Regulatory Framework |
| Hayden, L_1385 | 22. General Opposition |
| Hayden, L_1395 | 22. General Opposition |
| Hayden, L_1411 | 22. General Opposition |
| Hayden, L_1421 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Hayden, L_1432 | 22. General Opposition |
| Haynes, B_1966 | 23. General Support |
| Heffernan, D_1841 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Heller, G_1733 | 22. General Opposition |
| Helmbold, J_2188 | 22. General Opposition |
| Henderson, B_1575 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Hendrickson, A_2469 | 22. General Opposition |
| Hendrickson, J_2227 | 22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Hendrickson, T_1678 | 22. General Opposition |
| Hendrickson, W_1597 | 22. General Opposition |
| Henry, D_2197 | 3. Outside of SEIS Scope |
| Herbert, E_1843 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Hewitt, K_1647 | 5. Regulatory Framework |
| Hewitt, K_1751 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Hewitt, K_1167 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Hibbard, R_1347 | 22. General Opposition |
| Hickman, E_0365 | 22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Higbee-Robinson, J_2531 | 3. Outside of SEIS Scope |
| Higley, R_1210 | 9. LCA Methodology |
| Hillman, S_1218 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Hiser, L_2561 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>3. Outside of SEIS Scope |
| Hiss, J_2562 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition |
| Hodge, R_1479 | 22. General Opposition |
| Hofeling, A_1100 | 23. General Support |
| Hofer, S_1254 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Hoff, L_1439 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Hoff, L_1531 | 22. General Opposition |
| Hoffman, S_1220 | 5. Regulatory Framework |
| Hogan, R_0582 | 5. Regulatory Framework |
| Hogan, R_0584 | 22. General Opposition |
| Hogan, R_0585 | 22. General Opposition |
| Hogan, R_0586 | 22. General Opposition |
| Hogan, R_1204 | 22. General Opposition |
| Hogan, R_2130 | 3. Outside of SEIS Scope |
| Hogan, R_2131 | 3. Outside of SEIS Scope |
| Hogan, R_2132 | 3. Outside of SEIS Scope |
| Hogan, R_2134 | 5. Regulatory Framework |
| Holmes, J_1897 | 22. General Opposition |
| Holtz, R_0307 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Holtz, R_0444 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Holtz, R_1206 | 3. Outside of SEIS Scope |
| Holtz, R_1319 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| Horky, S_1461 | 22. General Opposition |
| Horoitz, M_0587 | 22. General Opposition |
| Horoitz, M_2129 | 22. General Opposition |
| Horton, R_1989 | 23. General Support |
| Horton, T_1459 | 22. General Opposition |
| Horton, T_1510 | 22. General Opposition |
| Horvat, S_1528 | 22. General Opposition |
| Hotchkiss, D_1726 | 22. General Opposition |
| Houston, J_1503 | 22. General Opposition |
| Howe, J_1699 | 5. Regulatory Framework |
| Howell, D_1136 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>3. Outside of SEIS Scope |
| Hoyle, L_1338 | 22. General Opposition |
| Hrachovec, J_1705 | 5. Regulatory Framework |
| Hrachovec, J_1707 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Hulette, t_1346 | 22. General Opposition |
| Hume, K_0462 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Hume, K_0463 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Hume, M_0464 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Hume, M_0465 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Hunter, R_2571 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition<br>7. SEPA Alternatives |
| Hutchinson, M_2005 | 23. General Support |
| Idzerda, R_0634 | 3. Outside of SEIS Scope |
| Idzerda, R_0635 | 3. Outside of SEIS Scope |
| Idzerda, R_0640 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Idzerda, R_0642 | 3. Outside of SEIS Scope |
| Idzerda, R_0644 | 11. LCA Inputs and Assumptions - General |
| Idzerda, R_2142 | 3. Outside of SEIS Scope |
| Idzerda, R_2144 | 3. Outside of SEIS Scope |
| Idzerda, R_2146 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Idzerda, R_2149 | 3. Outside of SEIS Scope |
| Idzerda, R_2152 | 3. Outside of SEIS Scope |
| Idzerda, R_1822 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| Ilem, E_1509 | 23. General Support |
| Inclan, E_1356 | 22. General Opposition |
| Ingelsson, K_2199 | 22. General Opposition |
| Iverson, C_1795 | 22. General Opposition |
| James, I_1721 | 22. General Opposition |
| Jarvis_1598 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>3. Outside of SEIS Scope<br>5. Regulatory Framework<br>6. Purpose and Need |
| Jeglum, J_2190 | 3. Outside of SEIS Scope |
| Johanna, L_0614 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Johanna, L_0615 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Johanna, L_0616 | 3. Outside of SEIS Scope |
| Johanna, L_0617 | 3. Outside of SEIS Scope |
| Johanna, L_0618 | 3. Outside of SEIS Scope |
| Johanna, L_2168 | 3. Outside of SEIS Scope |
| Johanna, L_2169 | 3. Outside of SEIS Scope |
| Johanna, L_2170 | 3. Outside of SEIS Scope |
| Johanna, L_2171 | 3. Outside of SEIS Scope |
| Johanna, L_2172 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Johnson, B_1538 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Johnson, C_2191 | 22. General Opposition |
| Johnson, C_1587 | 19. LCA Inputs and Assumptions - End Use |
| Johnson, C_1646 | 17. LCA Inputs and Assumptions - Peak Shaving |
| Johnson, L_1176 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| Johnson-Deal, D_2193 | 3. Outside of SEIS Scope |
| Jolibois, K_1173 | 22. General Opposition |
| Jones, B_1535 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>19. LCA Inputs and Assumptions - End Use |
| Jones, E_1608 | 22. General Opposition |
| Jones, J_1862 | 22. General Opposition |
| Jones, J_1909 | 21. LCA Inputs and Assumptions - Additional Air Pollutants |
| Jones, J_1682 | 22. General Opposition |
| Jones, K_1172 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>5. Regulatory Framework |
| Jones, K_1308 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| Jordan, J_2216 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Kane, E_2554 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use |
| Karp, M_2209 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Karras, G_1368 | 22. General Opposition |
| Kavanagh, B_1880 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Kavanagh, B_1881 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Kavanagh, B_1882 | 13. LCA Inputs and Assumptions - Natural Gas Source |
| Kavanagh, K_1883 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Keely, M_1529 | 3. Outside of SEIS Scope |
| Kegel, E_1367 | 22. General Opposition |
| Kelly, L_2233 | 22. General Opposition |
| Kemena, N_1481 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Kendig, C_1945 | 23. General Support |
| Kennedy, J_1563 | 22. General Opposition |
| Kepford, P_0343 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Ketilsson, L_1767 | 22. General Opposition |
| Khaled, M_1674 | 23. General Support |
| Kibiger, L_1762 | 22. General Opposition |
| Kimmerling, M_1184 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>5. Regulatory Framework |
| Kindt, C_0467 | 11. LCA Inputs and Assumptions - General<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>22. General Opposition |
| Kindt, C_0468 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Kindt, C_0469 | 22. General Opposition<br>5. Regulatory Framework |
| Kindt, C_0760 | 11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>19. LCA Inputs and Assumptions - End Use<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Kindt, C_1117 | 22. General Opposition |
| Kindt, C_1568 | 6. Purpose and Need |
| Kindt, C_1677 | 19. LCA Inputs and Assumptions - End Use<br>22. General Opposition |
| Kindt, C_1744 | 1. Determination of SEIS Scope - Comparison to FEIS |
| Kindt, C_1752 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Kindt, C_1771 | 1. Determination of SEIS Scope - Comparison to FEIS |
| Kirchhoff, J_1383 | 5. Regulatory Framework |
| Kirchhoff, J_1396 | 22. General Opposition |
| Kirchhoff, J_1404 | 22. General Opposition |
| Kirchhoff, J_1423 | 22. General Opposition |
| Kirchhoff, J_1429 | 22. General Opposition |
| Kirk, K_2215 | 22. General Opposition<br>7. SEPA Alternatives |
| Kirkpatrick, C_1969 | 23. General Support |
| Klein, J_1516 | 22. General Opposition |
| Klob, M_2016 | 23. General Support |
| Knutzen, D_2022 | 23. General Support |
| Kochanowski, E_1525 | 3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Koelle, S_2184 | 3. Outside of SEIS Scope |
| Kopec, C_2539 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>7. SEPA Alternatives |
| Kovacich, D_1974 | 23. General Support |
| Krafft, E_1907 | 22. General Opposition |
| Kroeker, A_1836 | 22. General Opposition |
| Kroeker, A_2236 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Krueger, J_1758 | 3. Outside of SEIS Scope |
| Krupnik-Goldman, B_1842 | 22. General Opposition |
| Kuhlman, J_1574 | 3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Kuhlman, J_1578 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| Kuljis, R_1661 | 3. Outside of SEIS Scope |
| Kuperberg, Y_2224 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| Kupinse, W_0472 | 22. General Opposition |
| Kupinse, W_0475 | 10. LCA Calculations<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>22. General Opposition |
| Kupinse, W_0477 | 10. LCA Calculations<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Kupinse, W_1238 | 22. General Opposition |
| Kurz, J_1292 | 22. General Opposition |
| Kurz, J_1492 | 22. General Opposition |
| Lambert, D_1541 | 22. General Opposition |
| Lambert, D_1579 | 22. General Opposition |
| Lambert, M_0303 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Lane, F_2182 | 3. Outside of SEIS Scope |
| Langager, S_1982 | 23. General Support |
| Larco, D_1511 | 22. General Opposition |
| Latierra, C_1526 | 5. Regulatory Framework |
| Lawhon, K_1168 | 3. Outside of SEIS Scope |
| Lawrence, L_1517 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition |
| Lea, L_1653 | 23. General Support |
| Lee, K_1747 | 3. Outside of SEIS Scope |
| Lee, M_1472 | 22. General Opposition<br>5. Regulatory Framework |
| Lefeber, L_1977 | 23. General Support |
| Leffler, M_1796 | 22. General Opposition |
| Leistman, V_1233 | 22. General Opposition |
| Lemke, H_1650 | 10. LCA Calculations |
| Lenas, D_2195 | 22. General Opposition |
| Lewandowsky, K_1166 | 22. General Opposition |
| Lewis, H_2232 | 22. General Opposition |
| Lewis, P_1469 | 22. General Opposition |
| Leyritz, F_1139 | 23. General Support |
| Likkel, R_2013 | 23. General Support |
| Lindberg, J_0815 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Linder, D_2211 | 22. General Opposition |
| Lindey, J_1537 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition |
| Lindley, J_1148 | 22. General Opposition |
| Lindsey, M_1369 | 22. General Opposition |
| Littlewood, A_1358 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Lloyd, D_2536 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>7. SEPA Alternatives |
| Lloyd, L_0304 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Lombardi, S_1376 | 22. General Opposition |
| Lombardo, D_1798 | 22. General Opposition |
| Lopez, J_1381 | 22. General Opposition |
| Lopez, J_1830 | 22. General Opposition |
| Lord, S_1819 | 22. General Opposition |
| Low, S_1215 | 11. LCA Inputs and Assumptions - General<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition |
| Lucky, L_2251 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Lund, B_1542 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Lundahl, J_1611 | 10. LCA Calculations |
| Lundahl, J_1612 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Lynn, S_1742 | 22. General Opposition |
| MacBain, T_0446 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| MacBain, T_1547 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| Mack, C_1818 | 22. General Opposition |
| Mackie, C_1485 | 22. General Opposition |
| Madden, L_1178 | 22. General Opposition |
| Maddox, W_1971 | 23. General Support |
| Mager, S_0450 | 22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework<br>8. No Action Alternative |
| Magner, M_2062 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Magner, M_2064 | 3. Outside of SEIS Scope |
| Mallari, M_2194 | 22. General Opposition |
| Mallory, M_0818 | 13. LCA Inputs and Assumptions - Natural Gas Source |
| Mallory, M_0309 | 22. General Opposition<br>3. Outside of SEIS Scope |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Maloney, C_2546 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Manning, E_1970 | 23. General Support |
| Manning, S_1644 | 3. Outside of SEIS Scope |
| Manuel, J_1350 | 22. General Opposition |
| Marcantonio, J_1965 | 23. General Support |
| Margolin, J_1146 | 22. General Opposition |
| Marinkovich, D_1736 | 3. Outside of SEIS Scope |
| Marsh, D_2074 | 3. Outside of SEIS Scope |
| Marsh, D_2075 | 3. Outside of SEIS Scope |
| Marsh, D_2076 | 3. Outside of SEIS Scope |
| Marsh, D_2077 | 3. Outside of SEIS Scope |
| Marsh, D_2078 | 3. Outside of SEIS Scope |
| Marsh, R_2061 | 6. Purpose and Need |
| Marsh, R_2072 | 3. Outside of SEIS Scope |
| Marsh, R_2080 | 3. Outside of SEIS Scope |
| Marshall, D_1718 | 3. Outside of SEIS Scope |
| Marshall, E_1532 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition<br>6. Purpose and Need |
| Martin, D_1134 | 5. Regulatory Framework |
| Martin, D_1307 | 3. Outside of SEIS Scope<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Martin, R_1281 | 10. LCA Calculations<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Martin, R_1806 | 5. Regulatory Framework |
| Martinsen, J_0811 | 16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Martinson, K_1892 | 22. General Opposition |
| Massie, D_1951 | 23. General Support |
| Matheney, C_1684 | 22. General Opposition |
| Matsumoto, R_1366 | 22. General Opposition |
| Mcallister, R_1759 | 3. Outside of SEIS Scope |
| Mcconnell, K_1513 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| McCormack, R_0821 | 23. General Support |
| McCurtain, N_1196 | 19. LCA Inputs and Assumptions - End Use<br>5. Regulatory Framework |
| McFadden, K_1362 | 22. General Opposition |
| McFadden, K_1468 | 22. General Opposition |
| McFall, K_1602 | 3. Outside of SEIS Scope |
| McFarlane, B_0362 | 22. General Opposition<br>3. Outside of SEIS Scope |
| McGahan, E_1560 | 3. Outside of SEIS Scope<br>5. Regulatory Framework |
| McKinlay, B_1536 | 5. Regulatory Framework |
| McKinlay, B_1562 | 10. LCA Calculations<br>22. General Opposition |
| McKinlay, B_1808 | 5. Regulatory Framework |
| Mcleod, R_1487 | 22. General Opposition |
| McMinn, P_1817 | 22. General Opposition |
| McNeil, M_1482 | 22. General Opposition |
| Medford, D_1448 | 22. General Opposition |
| Medrano, M_1799 | 22. General Opposition |
| Melchior, A_1663 | 10. LCA Calculations<br>3. Outside of SEIS Scope |
| Melchior, A_1716 | 10. LCA Calculations |
| Melnichenko, K_1599 | 22. General Opposition |
| Metildi, N_1499 | 22. General Opposition |
| Metildi, N_1780 | 22. General Opposition |
| Meyerhoff, J_1352 | 22. General Opposition |
| Michelle Myers, R_1847 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Mickle, E_1337 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Miller, S_1443 | 22. General Opposition |
| Miner, M_1553 | 3. Outside of SEIS Scope |
| Mintz, E_1465 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Mogielnicki, N_1884 | 22. General Opposition |
| Mogielnicki, N_1886 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Mogielnicki, P_1885 | 22. General Opposition |
| Monk, J_1544 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Monroe, D_2014 | 23. General Support |
| Monroe, J_1154 | 23. General Support |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Monroe, J_1963 | 23. General Support |
| Montgomery, A_1729 | 22. General Opposition |
| Moor, M_1583 | 3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Moore, B_1112 | 22. General Opposition |
| Moore, D_1128 | 5. Regulatory Framework |
| Moore, R_1994 | 23. General Support |
| Morford, M_0460 | 22. General Opposition |
| Morford, M_0461 | 22. General Opposition |
| Morford, M_0473 | 22. General Opposition |
| Morford, M_0474 | 22. General Opposition |
| Morgana, L_1588 | 3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Morin, D_2541 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Morken, S_1651 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Morris, E_0305 | 22. General Opposition |
| Morris, R_0281 | 22. General Opposition |
| Morrison, A_0357 | 22. General Opposition |
| Morrison, D_1725 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Morrison, R_0666 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>3. Outside of SEIS Scope |
| Morrison, R_0727 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Mosher, D_1849 | 22. General Opposition |
| Mosher, D_1697 | 22. General Opposition |
| Mueller, N_1695 | 5. Regulatory Framework |
| Muir, G_0566 | 3. Outside of SEIS Scope |
| Muir, G_0590 | 22. General Opposition |
| Muir, G_0591 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Muir, G_0592 | 3. Outside of SEIS Scope |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Muir, G_0593 | 22. General Opposition |
| Muir, G_0594 | 3. Outside of SEIS Scope |
| Muir, G_0595 | 3. Outside of SEIS Scope |
| Muir, G_0627 | 22. General Opposition |
| Muir, G_0628 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Muir, G_0629 | 7. SEPA Alternatives |
| Muir, G_0630 | 3. Outside of SEIS Scope |
| Muir, G_0661 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Muir, G_1543 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| Muir, G_2048 | 3. Outside of SEIS Scope |
| Muir, G_2121 | 3. Outside of SEIS Scope |
| Muir, G_2122 | 3. Outside of SEIS Scope |
| Muir, G_2123 | 3. Outside of SEIS Scope |
| Muir, G_2124 | 3. Outside of SEIS Scope |
| Muir, G_2125 | 3. Outside of SEIS Scope |
| Muir, G_2126 | 3. Outside of SEIS Scope |
| Muir, G_2156 | 3. Outside of SEIS Scope |
| Muir, G_2157 | 22. General Opposition |
| Muir, G_2158 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Muir, G_2159 | 22. General Opposition |
| Muller, K_1330 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Muller, K_1333 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use |
| Muller, K_1360 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Muller, K_1891 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Munivrana, S_1802 | 22. General Opposition |
| Munter, J_1823 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Murdock, S_1779 | 22. General Opposition |
| Murphy, C_0354 | 22. General Opposition<br>5. Regulatory Framework<br>7. SEPA Alternatives<br>8. No Action Alternative |
| Murphy, C_2564 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>7. SEPA Alternatives |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Murphy, D_1863 | 22. General Opposition |
| Murphy, D_1888 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Murphy, D_1889 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Murphy, S_1898 | 22. General Opposition |
| Murray, R_0438 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>8. No Action Alternative |
| Murray, R_1493 | 5. Regulatory Framework |
| Murray, R_1576 | 22. General Opposition |
| Murray, R_1577 | 21. LCA Inputs and Assumptions - Additional Air Pollutants |
| Murray, R_1585 | 3. Outside of SEIS Scope |
| Murray, R_1811 | 3. Outside of SEIS Scope |
| Murray, R_1812 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Murray, R_1816 | 22. General Opposition |
| Murray, R_1582 | 16. LCA Inputs and Assumptions - Hydraulic Fracturing |
| Naidus, B_1852 | 22. General Opposition |
| Naidus, B_1853 | 22. General Opposition |
| Neal, M_1242 | 23. General Support |
| Nedderman, E_1772 | 22. General Opposition |
| Nelson, B_1107 | 23. General Support |
| New, B_1473 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| New, B_2217 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Nez, D_1521 | 3. Outside of SEIS Scope |
| Ng, P_0367 | 3. Outside of SEIS Scope |
| Ng, P_1201 | 22. General Opposition |
| Nock, L_1336 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Nowak, M_1595 | 22. General Opposition |
| O'Brien, B_1764 | 3. Outside of SEIS Scope |
| O'Hanley, K_0623 | 3. Outside of SEIS Scope |
| O'Hanley, K_0624 | 22. General Opposition |
| O'Hanley, K_0625 | 22. General Opposition |
| O'Hanley, K_0626 | 22. General Opposition |
| O'Hanley, K_1169 | 22. General Opposition |
| O'Hanley, K_1486 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| O'Hanley, K_2160 | 3. Outside of SEIS Scope |
| O'Hanley, K_2161 | 22. General Opposition |
| O'Hanley, K_2162 | 3. Outside of SEIS Scope |
| O'Hanley, K_2163 | 3. Outside of SEIS Scope |
| O'Hara, K_1340 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition |
| O'Neal, M_1391 | 22. General Opposition |
| O'Neal, M_1403 | 22. General Opposition |
| O'Neal, M_1415 | 22. General Opposition |
| O'Neal, M_1417 | 22. General Opposition |
| O'Neal, M_1437 | 22. General Opposition |
| O'Renick, J_1351 | 21. LCA Inputs and Assumptions - Additional Air Pollutants<br>22. General Opposition |
| O'Sullivan, B_2205 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Oakley, T_1912 | 22. General Opposition |
| Oaks, S_0588 | 11. LCA Inputs and Assumptions - General<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing |
| Oaks, S_0589 | 5. Regulatory Framework |
| Oaks, S_1216 | 22. General Opposition |
| Oaks, S_1731 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Oaks, S_2127 | 5. Regulatory Framework |
| Oaks, S_2128 | 16. LCA Inputs and Assumptions - Hydraulic Fracturing |
| Oaks, S_1680 | 22. General Opposition |
| Oaks, S_1681 | 3. Outside of SEIS Scope |
| Oaks, S_1702 | 22. General Opposition |
| Oaks, S_1709 | 22. General Opposition |
| Ogilvy, H_2566 | 1. Determination of SEIS Scope - Comparison to FEIS<br>10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Ohaus, T_2024 | 23. General Support |
| Olsen, D_1652 | 22. General Opposition<br>5. Regulatory Framework |
| Olson, A_2056 | 3. Outside of SEIS Scope |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Olson, A_2101 | 3. Outside of SEIS Scope |
| Olson, A_2103 | 3. Outside of SEIS Scope |
| Olson, L_2058 | 22. General Opposition |
| Olson, L_2100 | 3. Outside of SEIS Scope |
| Olson, L_2102 | 22. General Opposition |
| Olson, L_2104 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Olson, L_2105 | 11. LCA Inputs and Assumptions - General |
| Osborne, A_0822 | 23. General Support |
| Palmer, C_1890 | 22. General Opposition |
| Palmer, J_2021 | 23. General Support |
| Palmer, L_1834 | 3. Outside of SEIS Scope |
| Palmer, P_1357 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition |
| Pantastico, H_1814 | 22. General Opposition |
| Pantoja Castillo, W_1236 | 22. General Opposition |
| Paravagna, L_2563 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use |
| Parker, E_0363 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Parker, T_1344 | 22. General Opposition |
| Parker III, R_0712 | 23. General Support |
| Parson, B_1551 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Partridge, C_2537 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>7. SEPA Alternatives<br>8. No Action Alternative |
| Partridge, C_1490 | 22. General Opposition |
| Patches, D_1133 | 23. General Support |
| Patches, D_1975 | 23. General Support |
| Paterson, M_1311 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| Paterson, M_1316 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Paterson, M_1317 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>3. Outside of SEIS Scope |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Paterson, M_1318 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Patterson, M_1187 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>7. SEPA Alternatives |
| Paulsen, E_0351 | 22. General Opposition |
| Paynter, M_1188 | 22. General Opposition |
| Paynter, M_2219 | 22. General Opposition |
| Paynter, M_2240 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition |
| Peaphon, V_1291 | 13. LCA Inputs and Assumptions - Natural Gas Source |
| Peaphon, V_1809 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Peaphon, V_1826 | 11. LCA Inputs and Assumptions - General<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Peaphon, V_1232 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Pearlman, S_2548 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Pemberton, A_1866 | 22. General Opposition |
| Pennington, M_0651 | 22. General Opposition |
| Peppers, R_1873 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Peppers, R_1874 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Perk, D_1131 | 22. General Opposition |
| Perkins, S_1212 | 3. Outside of SEIS Scope |
| Peskin, N_1763 | 22. General Opposition |
| Peterson, M_1444 | 22. General Opposition |
| Petoud, D_1135 | 22. General Opposition |
| Phillips, D_1132 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Phillips, D_1332 | 22. General Opposition |
| Phoenix, Z_1621 | 3. Outside of SEIS Scope |
| Pickett, H_1523 | 5. Regulatory Framework |
| Piran, M_1299 | 22. General Opposition |
| Plant, M_1896 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Plaut, M_0596 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Plaut, M_0597 | 22. General Opposition |
| Plaut, M_0598 | 22. General Opposition |
| Plaut, M_0599 | 22. General Opposition |
| Plaut, M_2117 | 3. Outside of SEIS Scope |
| Plaut, M_2118 | 22. General Opposition |
| Plaut, M_2119 | 3. Outside of SEIS Scope |
| Plaut, M_2120 | 3. Outside of SEIS Scope |
| Playing, N_1573 | 7. SEPA Alternatives |
| Pledger, J_2011 | 23. General Support |
| Plunkett, J_2106 | 5. Regulatory Framework |
| Pogue, L_0452 | 22. General Opposition |
| Pogue, L_0453 | 22. General Opposition |
| Pogue, L_1175 | 3. Outside of SEIS Scope |
| Polishuk, S_1466 | 5. Regulatory Framework |
| Polishuk, S_1911 | 22. General Opposition |
| Pollack, K_1500 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition |
| Pollak, B_1463 | 22. General Opposition<br>5. Regulatory Framework |
| Potts, N_2020 | 23. General Support |
| Powell, E_2054 | 3. Outside of SEIS Scope |
| Powell, E_2055 | 3. Outside of SEIS Scope |
| Powell, E_2090 | 3. Outside of SEIS Scope |
| Powell, E_2091 | 3. Outside of SEIS Scope |
| Powell, E_2092 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Powell, E_2093 | 3. Outside of SEIS Scope |
| Prado, O_1776 | 22. General Opposition |
| Praskovich, A_2000 | 23. General Support |
| Prendergast, C_0764 | 22. General Opposition |
| Price, H_1142 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Price, H_1321 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use |
| Provenzano, A_1103 | 22. General Opposition |
| Provenzano, A_1701 | 22. General Opposition |
| Quester, N_1833 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Quigy, B_2046 | 3. Outside of SEIS Scope |
| Quigy, B_2047 | 3. Outside of SEIS Scope |
| Quigy, B_2049 | 3. Outside of SEIS Scope |
| Quigy, B_2050 | 3. Outside of SEIS Scope |
| Quisenberry, R_1454 | 22. General Opposition |
| Rack, S_0302 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Ramirez, N_1657 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Ramirez, N_1672 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Ramirez, N_1673 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| Rammel, A_1101 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>7. SEPA Alternatives |
| Raper, P_2003 | 23. General Support |
| Rarctrone, R_1900 | 22. General Opposition |
| Rasmussen, P_1624 | 5. Regulatory Framework |
| Rasmussen, P_1634 | 3. Outside of SEIS Scope |
| Rasmussen, P_1638 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| Rasmussen, P_1639 | 21. LCA Inputs and Assumptions - Additional Air Pollutants<br>3. Outside of SEIS Scope |
| Rasmussen, P_1640 | 5. Regulatory Framework |
| Rasmussen, P_1641 | 3. Outside of SEIS Scope |
| Rasmussen, P_1642 | 22. General Opposition |
| Rasmussen, P_1643 | 16. LCA Inputs and Assumptions - Hydraulic Fracturing |
| Ratermann, M_1944 | 22. General Opposition |
| Ray, D_1498 | 22. General Opposition |
| Ream, A_2555 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use |
| Reed, J_1794 | 22. General Opposition |
| Reetz, N_1195 | 22. General Opposition |
| Reetz, N_1686 | 3. Outside of SEIS Scope |
| Reetz, N_1717 | 13. LCA Inputs and Assumptions - Natural Gas Source |
| Reetz, N_1734 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Reetz, N_1737 | 22. General Opposition |
| Reetz, N_1783 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Reilly, K_0735 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Reilly, M_1353 | 21. LCA Inputs and Assumptions - Additional Air Pollutants<br>22. General Opposition<br>5. Regulatory Framework |
| Rekart, T_1773 | 22. General Opposition |
| Reuter, L_1603 | 5. Regulatory Framework |
| Reynolds, J_1997 | 23. General Support |
| Ricard, J_1556 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>17. LCA Inputs and Assumptions - Peak Shaving<br>3. Outside of SEIS Scope |
| Rickman, S_2220 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Riechel, K_1387 | 22. General Opposition |
| Riechel, K_1400 | 22. General Opposition |
| Riechel, K_1414 | 22. General Opposition |
| Riechel, K_1420 | 22. General Opposition |
| Riechel, K_1433 | 22. General Opposition |
| Riedener, C_1245 | 10. LCA Calculations<br>22. General Opposition<br>5. Regulatory Framework |
| Riedener, C_1246 | 1. Determination of SEIS Scope - Comparison to FEIS<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>19. LCA Inputs and Assumptions - End Use<br>3. Outside of SEIS Scope |
| Riedener, C_1247 | 1. Determination of SEIS Scope - Comparison to FEIS<br>19. LCA Inputs and Assumptions - End Use |
| Riedener, C_1248 | 1. Determination of SEIS Scope - Comparison to FEIS<br>17. LCA Inputs and Assumptions - Peak Shaving |
| Riedener, C_1249 | 5. Regulatory Framework |
| Riedener, C_1250 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>3. Outside of SEIS Scope |
| Riedener, C_1251 | 11. LCA Inputs and Assumptions - General<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>7. SEPA Alternatives |
| Riedener, C_1252 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Riley, D_1126 | 23. General Support |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Riley, D_2017 | 23. General Support |
| Ritter, M_2030 | 3. Outside of SEIS Scope |
| Ritter, M_2035 | 22. General Opposition |
| Ritter, M_2041 | 22. General Opposition |
| Ritter, P_1590 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope<br>6. Purpose and Need |
| Ritter, P_2027 | 3. Outside of SEIS Scope |
| Ritter, P_2028 | 3. Outside of SEIS Scope |
| Ritter, P_2032 | 3. Outside of SEIS Scope |
| Ritter, P_2033 | 3. Outside of SEIS Scope |
| Ritter, P_2040 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Ritter, P_2042 | 16. LCA Inputs and Assumptions - Hydraulic Fracturing |
| Ritter, P_2051 | 22. General Opposition |
| Robertson, L_1804 | 11. LCA Inputs and Assumptions - General<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Robertson, L_2235 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>5. Regulatory Framework<br>6. Purpose and Need |
| Robinson, M_1386 | 22. General Opposition |
| Robinson, M_1399 | 22. General Opposition |
| Robinson, M_1410 | 22. General Opposition |
| Robinson, M_1426 | 22. General Opposition |
| Robinson, M_1431 | 22. General Opposition |
| Rolf, M_1182 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| Rolf, M_1837 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Roman, L_2547 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Rose, M_1755 | 22. General Opposition |
| Roth, D_1855 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Roth, D_1856 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Roth, D_1857 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Rousseau, C_2189 | 3. Outside of SEIS Scope |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Rowe, J_2223 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Rowe, P_0345 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>15. LCA Inputs and Assumptions - Natural Gas Properties<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>17. LCA Inputs and Assumptions - Peak Shaving<br>19. LCA Inputs and Assumptions - End Use<br>2. Determination of the SEIS Scope<br>9. LCA Methodology |
| Rowe, P_1203 | 10. LCA Calculations<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>9. LCA Methodology |
| Rubardt, M_1540 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| Rudnick, D_1548 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope |
| Ruha, C_1452 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Russel, M_0350 | 23. General Support |
| Russell, D_1835 | 22. General Opposition |
| Ryan, S_1255 | 22. General Opposition |
| Rydel Kelly, H_1145 | 3. Outside of SEIS Scope |
| Sailer, D_1592 | 3. Outside of SEIS Scope |
| Saiyare, R_1211 | 22. General Opposition |
| Salgado, S_1213 | 23. General Support |
| Salgado, S_1953 | 23. General Support |
| Salomon, S_1440 | 22. General Opposition |
| Sampson, B_0619 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Sampson, B_0620 | 3. Outside of SEIS Scope |
| Sampson, B_0621 | 3. Outside of SEIS Scope |
| Sampson, B_0631 | 3. Outside of SEIS Scope |
| Sampson, B_1111 | 22. General Opposition |
| Sampson, B_1294 | 22. General Opposition |
| Sampson, B_2155 | 22. General Opposition |
| Sampson, B_2165 | 3. Outside of SEIS Scope |
| Sampson, B_2166 | 3. Outside of SEIS Scope |
| Sampson, B_2167 | 3. Outside of SEIS Scope |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Samstag, R_1601 | 22. General Opposition |
| Sanders, H_0346 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Sanders, H_0447 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Sanders, H_1143 | 22. General Opposition<br>5. Regulatory Framework |
| Sanders, H_1676 | 3. Outside of SEIS Scope |
| Sanders, H_1687 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Santerre, G_1456 | 22. General Opposition |
| Satiacum, E_1696 | 22. General Opposition |
| Sayegh, J_1750 | 10. LCA Calculations |
| Scharff, B_1458 | 22. General Opposition |
| Schramm, J_1865 | 22. General Opposition |
| Schurman, A_1256 | 22. General Opposition |
| Scott, J_2185 | 22. General Opposition |
| Scott, K_1170 | 23. General Support |
| Scott-Murray, A_1104 | 22. General Opposition |
| Seeberger, E_2501 | 22. General Opposition |
| Segelquust, K_1715 | 22. General Opposition |
| Sekiguchi, T_2214 | 22. General Opposition |
| Selle, T_2179 | 3. Outside of SEIS Scope |
| Shanstrom, J_1967 | 23. General Support |
| Shapiro, B_1453 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Shaughnesey, D_0364 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Shaughnessy, D_1591 | 3. Outside of SEIS Scope |
| Shaughnessy, D_1698 | 22. General Opposition |
| Shaughnessy, D_1732 | 22. General Opposition |
| Sherrod, B_1654 | 3. Outside of SEIS Scope |
| Shimeall, N_0355 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition |
| Shimeall, N_0454 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition |
| Shimeall, N_1194 | 16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>5. Regulatory Framework |
| Shimeall, N_1778 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Shimeall, N_2073 | 3. Outside of SEIS Scope |
| Shimeall, N_2081 | 3. Outside of SEIS Scope |
| Shimeall, N_2082 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Shimeall, N_2083 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Shimeall, N_2084 | 3. Outside of SEIS Scope |
| Shimeall, N_2085 | 3. Outside of SEIS Scope |
| Shimeall, N_2086 | 3. Outside of SEIS Scope |
| Shinaburger, R_0459 | 22. General Opposition |
| Shinaburger, R_1205 | 22. General Opposition |
| Shinya, N_1727 | 22. General Opposition |
| Shiple, M_1446 | 22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Shoetler, J_1155 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Shriner, M_1622 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Shriner, M_1850 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Shriner, W_1667 | 10. LCA Calculations<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>6. Purpose and Need |
| Shriner, W_1655 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope<br>6. Purpose and Need |
| Shriner, W_1872 | 5. Regulatory Framework |
| Shriner, W_1899 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Shurman, Z_1241 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>22. General Opposition |
| Sibelman, B_1108 | 3. Outside of SEIS Scope |
| Sibelman, J_1441 | 22. General Opposition |
| Sibley, C_2206 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Sierra, J_1520 | 22. General Opposition |
| Sigler, D_1382 | 22. General Opposition |
| Sigler, D_1394 | 22. General Opposition |
| Sigler, D_1406 | 22. General Opposition |
| Sigler, D_1427 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Sigler, D_1428 | 22. General Opposition |
| Sigler, D_1491 | 3. Outside of SEIS Scope |
| Silver, P_2213 | 22. General Opposition |
| Simmons, L_1177 | 23. General Support |
| Skelton, L_1174 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Smitch, C_2023 | 23. General Support |
| Smith, A_2551 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Smith, F_1787 | 22. General Opposition |
| Smith, J_1494 | 22. General Opposition |
| Smith, K_1656 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Smith, K_1756 | 10. LCA Calculations |
| Smith, S_1754 | 10. LCA Calculations |
| Smith, S_1777 | 22. General Opposition |
| Smith, S_0451 | 22. General Opposition |
| Smith, Z_1240 | 22. General Opposition |
| Smith, Z_1851 | 5. Regulatory Framework |
| Snell, R_0443 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition<br>3. Outside of SEIS Scope<br>8. No Action Alternative |
| Snell, R_1209 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Soeldner, W_2573 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition<br>7. SEPA Alternatives |
| Soltess, R_0736 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Soni, P_2018 | 23. General Support |
| Soni, R_2019 | 23. General Support |
| Spindel, P_1348 | 22. General Opposition |
| Stackhouse, J_1858 | 3. Outside of SEIS Scope |
| Stackhouse, J_1859 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Stackhouse, J_1860 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Stackhouse, J_1861 | 5. Regulatory Framework |
| Stagliano, N_1983 | 23. General Support |
| Stahre, G_2553 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>7. SEPA Alternatives |
| Steel, A_2230 | 22. General Opposition |
| Stegman, C_1827 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>6. Purpose and Need |
| Steidle, D_2201 | 22. General Opposition |
| Stein, B_0356 | 22. General Opposition<br>5. Regulatory Framework |
| Steitz, J_2538 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>7. SEPA Alternatives |
| Stemple, R_1550 | 3. Outside of SEIS Scope |
| Stenger, J_1844 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>5. Regulatory Framework |
| Stenger, J_2559 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>22. General Opposition<br>5. Regulatory Framework |
| Stewart, M_1457 | 22. General Opposition |
| Stewart, P_1497 | 22. General Opposition |
| Stewart, S_0358 | 22. General Opposition |
| Stewart, V_2543 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Stocker, K_1164 | 22. General Opposition |
| Stone, T_2558 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Stonington, L_2569 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition<br>7. SEPA Alternatives |
| Storey, T_2226 | 22. General Opposition |
| Storms, S_0976 | 17. LCA Inputs and Assumptions - Peak Shaving<br>3. Outside of SEIS Scope |
| Storms, S_1096 | 1. Determination of SEIS Scope - Comparison to FEIS<br>3. Outside of SEIS Scope |
| Storms, S_1097 | 1. Determination of SEIS Scope - Comparison to FEIS<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives<br>8. No Action Alternative |
| Storms, S_1807 | 5. Regulatory Framework |
| Storset, S_1214 | 23. General Support |
| Streiffert, D_1127 | 22. General Opposition |
| Stroud, L_1693 | 3. Outside of SEIS Scope |
| Stubbs, G_1359 | 22. General Opposition |
| Stubbs, G_1361 | 22. General Opposition |
| Studley, L_0813 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Stuth, A_2012 | 23. General Support |
| Styer, S_0369 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition |
| Subra, W_1314 | 11. LCA Inputs and Assumptions - General<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>19. LCA Inputs and Assumptions - End Use<br>3. Outside of SEIS Scope |
| Sullivan, G_1581 | 10. LCA Calculations<br>22. General Opposition<br>5. Regulatory Framework |
| Sullivan, G_2574 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition<br>7. SEPA Alternatives |
| Sullivan, G_1749 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Sullivan, G_1760 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Sullivan, T_0441 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Sullivan, T_1226 | 3. Outside of SEIS Scope |
| Sullvan, T_1266 | 22. General Opposition |
| Sundermann, C_1502 | 22. General Opposition |
| Sweetwater, S_2560 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition |
| Sweidel, K_1614 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Syfers, M_1181 | 3. Outside of SEIS Scope |
| Syfers, M_1309 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Syfers, M_1625 | 3. Outside of SEIS Scope |
| Syfers, M_1660 | 22. General Opposition |
| Sykes, H_1685 | 22. General Opposition |
| Symer, K_2238 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition |
| Szumlas, N_1720 | 22. General Opposition |
| T, L_2491 | 22. General Opposition |
| T, L_2492 | 22. General Opposition |
| Tail, A_0448 | 22. General Opposition |
| Takacs, L_0308 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Tenenberg, J_0755 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope |
| TenHoopen, K_1373 | 22. General Opposition |
| Terrano, J_1149 | 23. General Support |
| Terrano, J_1995 | 23. General Support |
| Thirsk, D_0653 | 22. General Opposition |
| Thomas, S_2006 | 23. General Support |
| Thompson, B_1113 | 22. General Opposition |
| Thompson, B_1623 | 13. LCA Inputs and Assumptions - Natural Gas Source |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Thompson, B_1627 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>6. Purpose and Need |
| Thompson, B_1628 | 13. LCA Inputs and Assumptions - Natural Gas Source |
| Thompson, B_1629 | 17. LCA Inputs and Assumptions - Peak Shaving<br>18. LCA Inputs and Assumptions - Marine Diesel Oil<br>7. SEPA Alternatives<br>8. No Action Alternative |
| Thompson, B_1630 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>7. SEPA Alternatives |
| Thompson, B_1631 | 1. Determination of SEIS Scope - Comparison to FEIS |
| Thompson, B_1632 | 3. Outside of SEIS Scope |
| Thompson, B_1633 | 3. Outside of SEIS Scope |
| Thompson, B_1635 | 3. Outside of SEIS Scope |
| Thompson, T_2007 | 23. General Support |
| Tilstra, D_2247 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Torres, A_2565 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>19. LCA Inputs and Assumptions - End Use |
| Torres, A_1788 | 22. General Opposition |
| Tosta, N_1552 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition |
| Tourje, D_1675 | 22. General Opposition |
| Townsell, P_0816 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Treadway, C_1604 | 22. General Opposition |
| Trejo, C_1700 | 5. Regulatory Framework |
| Trickey, M_0600 | 3. Outside of SEIS Scope |
| Trickey, M_0601 | 3. Outside of SEIS Scope |
| Trickey, M_0602 | 3. Outside of SEIS Scope |
| Trickey, M_0603 | 3. Outside of SEIS Scope |
| Trickey, M_0604 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Trickey, M_0605 | 9. LCA Methodology |
| Trickey, M_0606 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Trickey, M_0607 | 3. Outside of SEIS Scope |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Trickey, M_0608 | 3. Outside of SEIS Scope |
| Trickey, M_0609 | 3. Outside of SEIS Scope |
| Trickey, M_2109 | 3. Outside of SEIS Scope |
| Trickey, M_2110 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Trickey, M_2111 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Trickey, M_2112 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Trickey, M_2113 | 3. Outside of SEIS Scope |
| Trickey, M_2114 | 3. Outside of SEIS Scope |
| Trickey, M_2115 | 3. Outside of SEIS Scope |
| Trickey, M_2116 | 3. Outside of SEIS Scope |
| Trickey, M_2177 | 3. Outside of SEIS Scope |
| Trickey, M_2178 | 3. Outside of SEIS Scope |
| Trosper, M_1518 | 22. General Opposition |
| Tsien, W_2552 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope<br>7. SEPA Alternatives |
| Tucker, O_2496 | 22. General Opposition |
| Tuckiupay, A_1102 | 3. Outside of SEIS Scope |
| Tuepker, A_1407 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition |
| Turner, D_1483 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>22. General Opposition |
| Utigard, C_0945 | 11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>18. LCA Inputs and Assumptions - Marine Diesel Oil<br>3. Outside of SEIS Scope |
| Valdez, C_1125 | 22. General Opposition |
| VanderMalle, R_1474 | 3. Outside of SEIS Scope |
| Vartanian, J_2243 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Vasquez, J_0823 | 23. General Support |
| Velasco, T_1950 | 23. General Support |
| Velasquez, T_0366 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Villa, D_1269 | 17. LCA Inputs and Assumptions - Peak Shaving |
| Villa, D_1270 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage |
| Villa, D_1271 | 7. SEPA Alternatives |
| Villa, D_1272 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>9. LCA Methodology |
| Villa, D_1273 | 15. LCA Inputs and Assumptions - Natural Gas Properties<br>3. Outside of SEIS Scope |
| Villa, D_1274 | 1. Determination of SEIS Scope - Comparison to FEIS |
| Villa, D_1275 | 5. Regulatory Framework |
| Villa, D_1276 | 11. LCA Inputs and Assumptions - General |
| Villa, D_1277 | 17. LCA Inputs and Assumptions - Peak Shaving<br>7. SEPA Alternatives |
| Villa, P_1323 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Villa, P_1724 | 22. General Opposition |
| Villa, P_1738 | 22. General Opposition |
| Villa, P_1740 | 22. General Opposition |
| Villa, P_1748 | 3. Outside of SEIS Scope |
| Villa, P_1793 | 22. General Opposition |
| Villa, P_1797 | 22. General Opposition |
| Villa, P_2225 | 22. General Opposition |
| Voboril, E_2218 | 22. General Opposition |
| Voget, R_1557 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>7. SEPA Alternatives |
| Voget, R_0578 | 3. Outside of SEIS Scope |
| Voget, R_0579 | 22. General Opposition |
| Voget, R_0580 | 22. General Opposition |
| Voget, R_1208 | 22. General Opposition |
| Voget, R_2136 | 3. Outside of SEIS Scope |
| Voget, R_2137 | 3. Outside of SEIS Scope |
| Voget, R_2138 | 3. Outside of SEIS Scope |
| Voli, C_1116 | 5. Regulatory Framework |
| Volkmann, S_1784 | 22. General Opposition |
| Wacker, D_0457 | 22. General Opposition |
| Wade, S_1455 | 22. General Opposition |
| Wagner, P_1202 | 22. General Opposition |
| Walalch, J_1706 | 5. Regulatory Framework |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Walimaki, L_0711 | 23. General Support |
| Walker, L_0470 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing |
| Walker, L_0480 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Walker, L_0560 | 5. Regulatory Framework |
| Wall, J_2025 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Wall, J_2026 | 3. Outside of SEIS Scope |
| Wall, J_2044 | 3. Outside of SEIS Scope |
| Wallace, C_0814 | 5. Regulatory Framework |
| Wallach, J_1152 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition |
| Wallmak, L_1392 | 22. General Opposition |
| Wallmak, L_1397 | 22. General Opposition |
| Wallmak, L_1408 | 22. General Opposition |
| Wallmak, L_1425 | 22. General Opposition |
| Wallmak, L_1436 | 22. General Opposition |
| Walters, J_1365 | 22. General Opposition |
| Walters, N_1198 | 22. General Opposition |
| Walters, N_1199 | 22. General Opposition |
| Walters, N_1322 | 22. General Opposition |
| Walters, N_1558 | 3. Outside of SEIS Scope |
| Walters, N_1564 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Walters, N_1566 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Walters, N_1570 | 3. Outside of SEIS Scope |
| Walters, N_1594 | 3. Outside of SEIS Scope |
| Walters, N_1606 | 3. Outside of SEIS Scope<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Walters, N_1613 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Walters, N_1815 | 3. Outside of SEIS Scope |
| Walters, N_1848 | 3. Outside of SEIS Scope |
| Wappler, A_1105 | 23. General Support |
| Warner, M_1377 | 22. General Opposition |
| Warren, C_1596 | 14. LCA Inputs and Assumptions - Leakage/Slippage |
| Washburn, B_1343 | 22. General Opposition |
| Way, S_0476 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Way, S_0478 | 22. General Opposition |
| Way, S_0479 | 22. General Opposition |
| Way, S_0559 | 22. General Opposition<br>8. No Action Alternative |
| Way, S_1222 | 5. Regulatory Framework |
| Webber, L_1355 | 22. General Opposition |
| Weintraub, D_1504 | 22. General Opposition |
| Weir, K_2069 | 3. Outside of SEIS Scope |
| Weir, K_2070 | 12. LCA Inputs and Assumptions - Global Warming Potential Value |
| Weir, K_2107 | 3. Outside of SEIS Scope |
| Weir, K_2108 | 3. Outside of SEIS Scope |
| Weir, S_1839 | 22. General Opposition |
| Westling, T_1320 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>19. LCA Inputs and Assumptions - End Use<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Westre, W_0442 | 22. General Opposition<br>3. Outside of SEIS Scope |
| Westre, W_1237 | 22. General Opposition |
| Whipps, J_1364 | 22. General Opposition |
| White, K_1739 | 22. General Opposition |
| White, L_1800 | 22. General Opposition |
| Wicks, J_2572 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition<br>7. SEPA Alternatives |
| Wiederhold, J_1488 | 22. General Opposition |
| Wiegman, T_1231 | 22. General Opposition |
| Wiegman, T_1268 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>3. Outside of SEIS Scope<br>4. Language<br>7. SEPA Alternatives |
| Wight, P_1505 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>5. Regulatory Framework |
| Willard, C_2528 | 3. Outside of SEIS Scope |
| Williams, B_1349 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Williams, E_0970 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>19. LCA Inputs and Assumptions - End Use |
| Williams, E_1326 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>19. LCA Inputs and Assumptions - End Use |
| Williams, J_1691 | 22. General Opposition |
| Williams, N_1302 | 22. General Opposition |
| Wilmering, K_2568 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>19. LCA Inputs and Assumptions - End Use<br>22. General Opposition<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Winer, D_1375 | 22. General Opposition |
| Winkler, J_1157 | 23. General Support |
| Winkler, J_1996 | 23. General Support |
| Winters, C_1124 | 22. General Opposition |
| Wood, K_1165 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>7. SEPA Alternatives |
| Wood, S_2242 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Woodlock, G_0737 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>8. No Action Alternative |
| Wooten, C_2248 | 10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source |
| Wooten, R_2204 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>7. SEPA Alternatives |
| Wright, S_1790 | 22. General Opposition |
| Wulling, J_1501 | 22. General Opposition |
| Wynn, R_1690 | 22. General Opposition |
| Wynn, R_1745 | 22. General Opposition |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Yoos, S_0432 | 22. General Opposition<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Young, J_1670 | 22. General Opposition |
| Zastovnik, R_1692 | 22. General Opposition |
| Zeigler, B_1305 | 14. LCA Inputs and Assumptions - Leakage/Slippage<br>3. Outside of SEIS Scope<br>5. Regulatory Framework |
| Zender, K_1981 | 23. General Support |
| Zigrang, T_1514 | 22. General Opposition |
| Zimmerle, J_1153 | 13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>8. No Action Alternative |
| Zimmerman, S_2004 | 23. General Support |
| Zuckerman, J_0622 | 3. Outside of SEIS Scope |
| Zuckerman, J_1147 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>22. General Opposition |
| Zuckerman, J_2164 | 3. Outside of SEIS Scope |
| Zwicker, N_1669 | 22. General Opposition |
| Form Letter 1_2621 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Form Letter 2_2622 | 23. General Support |
| Form Letter 3_2623 | 22. General Opposition |
| Form Letter 4_2624 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Form Letter 6_2625 | 10. LCA Calculations<br>22. General Opposition<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Form Email 1_2532 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Form Email 2_2533 | 10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>6. Purpose and Need |

**Table C.3-1 Comprehensive List of Comments and Responses to Comments**

| Commenter Number | Response Title/Code |
|---|---|
| Form Email 3_2534 | 1. Determination of SEIS Scope - Comparison to FEIS<br>10. LCA Calculations<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>5. Regulatory Framework<br>7. SEPA Alternatives |
| Petition 1 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Petition 2 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Petition 3 | 12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>22. General Opposition<br>3. Outside of SEIS Scope |
| Petition 4 | 1. Determination of SEIS Scope - Comparison to FEIS<br>2. Determination of the SEIS Scope<br>3. Outside of SEIS Scope<br>4. Language<br>5. Regulatory Framework<br>6. Purpose and Need<br>7. SEPA Alternatives<br>8. No Action Alternative<br>9. LCA Methodology<br>10. LCA Calculations<br>11. LCA Inputs and Assumptions - General<br>12. LCA Inputs and Assumptions - Global Warming Potential Value<br>13. LCA Inputs and Assumptions - Natural Gas Source<br>14. LCA Inputs and Assumptions - Leakage/Slippage<br>15. LCA Inputs and Assumptions - Natural Gas Properties<br>16. LCA Inputs and Assumptions - Hydraulic Fracturing<br>17. LCA Inputs and Assumptions - Peak Shaving<br>18. LCA Inputs and Assumptions - Marine Diesel Oil<br>19. LCA Inputs and Assumptions - End Use<br>20. LCA Inputs and Assumptions - Facility Downtime<br>21. LCA Inputs and Assumptions - Additional Air Pollutants<br>22. General Opposition |