PUGET SOUND ENERGY

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November 21, 2018

BY HAND DELIVERY AND EMAIL

Puget Sound Clean Air Agency
ATTN: Public Comment on DSEIS, Tacoma LNG Project
1904 Third Avenue, Suite 105
Seattle, WA 98101
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Re: Comments on Tacoma LNG Project Draft Supplemental Environmental Impact Statement

Dear Agency:

Puget Sound Energy, Inc. ("PSE") appreciates this opportunity to comment on the Draft Supplemental Environmental Impact Statement ("DSEIS") prepared by the Puget Sound Clean Air Agency ("PSCAA") and currently in the public notice process.

As the Northwest's largest utility, PSE has been a leader in developing and promoting clean energy and advancing efficiency programs and technologies. In the last decade, PSE has deployed over 770 megawatts of wind generation and other green energy projects and is currently the nation's third-largest utility producer of wind power.

In addition to developing renewables, we have gone above and beyond in our conservation efforts establishing award-winning programs in Energy Conservation and Green Power. PSE has one of our country's best and most comprehensive energy-efficiency programs for helping homes and businesses reduce their energy use. PSE offers our customers financial incentives and technical help to conserve energy, and PSE also promotes the growth of renewable electricity production in its service area through various customer programs. We are keenly aware of our customers' interest in reducing carbon emissions, and we share their concern and commitment to achieving meaningful carbon reduction. At the end of 2017, we announced our TOGETHER commitment to reduce carbon emissions 50 percent by 2040 and have developed a measurable plan with short- and long-term steps to reach this goal while continuing to meet our customers' needs.

If we are going to significantly reduce carbon emissions in our state, however, we have to address transportation. In Washington, nearly half of all carbon emissions come from transportation. PSE has been supporting the market growth of electric vehicles and is working to further expand our efforts through our alternative vehicle strategies and supporting charging stations the region needs to make electric vehicles a central part of our transportation future. At the same time, we have to think of the whole picture and consider commercial and industrial transportation uses.

We have the opportunity to significantly reduce emissions with cleaner alternatives to diesel and other fuels. PSE's partnership with TOTE Maritime will make just this kind of impact. When TOTE's first ship leaves Tacoma for Alaska fueled with LNG, it will result in material reductions of harmful air pollutants, including diesel particulate, sulfur dioxide, oxides of nitrogen and greenhouse gases. In concert with the vessel owners, the Tacoma LNG facility will create the greenest shipping fleet on the West Coast. In short, Tacoma LNG is a critical component of moving to lower carbon and cleaner energy infrastructure.

PSCAA's DSEIS is an integral step in moving this effort forward. As with any draft document, there are inevitably items that merit correction, which is why SEPA provides for public input and comment in the first instance. While the DSEIS text itself is succinct, the life-cycle analysis is broad in reach and quite dense. PSE has given the DSEIS and its referenced materials meticulous review, and we largely concur with its methodology, analysis and conclusions. Consequently, our comments are minor and carefully focused on accuracy and detail, so that the Final Supplemental Environmental Impact Statement ("FSEIS") sets the bar high for other greenhouse gas ("GHG") impacts analyses in the future across Washington. With these thoughts in mind, PSE respectfully submits the following comments to PSCAA for consideration in finalizing the Tacoma LNG DSEIS. We think that you have a quality product based on a reputable consultant that reaches the correct conclusion that the proposed project will result in a net reduction in GHG emissions. Nevertheless, there are specific improvements suggested below that, without changing the conclusion, will enhance the internal consistency and accuracy of the final product. These comments are not necessarily presented in order of importance.

Comment #1: PSE supports the inclusion of a condition in the Tacoma LNG air permit that requires that natural gas come exclusively from British Columbia.

Several commenters have wrongly criticized PSCAA for assuming that the natural gas to be used by the Tacoma LNG facility will come from British Columbia. This criticism is misplaced. PSE has identified from the outset of the PSCAA review process that the natural gas to be used by the Tacoma LNG facility will come from British Columbia. All gas delivered to PSE's gas system flows under firm pipeline capacity contracts on Williams' Northwest Pipeline, LLC ("NWP"). NWP is the only pipeline system for gas to get to PSE's system. NWP is fully contracted and has been since their last expansion in 2003. Each firm pipeline contract has a firm receipt point and a firm delivery point(s). Firm receipts from Sumas can only originate in British Columbia. The firm receipt point on contracts acquired to serve the Tacoma LNG facility is Sumas.

PSE has consistently stated that the gas delivered to Tacoma LNG for liquefaction, storage and subsequent use will originate in British Columbia. For that reason, PSE supports a condition in the air permit to memorialize this commitment and put to rest the factually inaccurate suggestion that natural gas from other regions will be used by the facility.

Comment #2: PSE supports the methodology employed by PSCAA to quantify upstream greenhouse gas emissions associated with extraction and transportation of natural gas.

Several commenters have wrongly criticized PSCAA for relying upon a British Columbia-specific analysis using the GHGenius model. We believe that the estimate of greenhouse gas emissions generated by GHGenius for British Columbia natural gas production is conservative and overstates the upstream greenhouse gas emissions. More accurate information can be obtained from the Canadian National Inventory Report ("NIR") in conjunction with provincial data on how the NIR value (which covers the oil and gas sector broadly) was developed. Both the GHGenius values and the NIR values are widely used and accepted. Although a small number of articles suggest that these values underreport fugitive emissions, general consensus has not been reached on this point and the values in the articles suggesting that underreporting has occurred are speculative. As explained further below, PSCAA must rely on the most recent widely accepted data and not arbitrarily base estimates on isolated studies.

The SEIS should be based on the Provincial data

On May 25, 2018, PSE submitted a Background Information Document ("BID") that assessed the life-cycle greenhouse gas emissions associated with the proposed facility. As part of that analysis, PSE determined emissions for natural gas production in British Columbia based on Province-specific data from the Canadian NIR and British Columbia natural gas production data as reported by the Province in its Natural Gas & Oil Statistics data series. PSE believes that this is the most accurate means of determining greenhouse gas emissions associated with natural gas production in British Columbia. PSE recognizes that there is not a substantial difference between using the Province-specific fugitive emission rate (estimated at 0.2%) and the GHGenius fugitive emission rate (estimated at 0.32%). However, the SEIS should represent the most accurate information available. For that reason, we recommend that PSCAA revise its analysis to use the current British Columbia-specific data presented in the BID rather than relying on the data generated by GHGenius.

The SEIS cannot inflate fugitive emissions based on incomplete studies

Comments that PSCAA should artificially inflate the upstream fugitive emission rates based on limited and problematic mobile studies should be rejected. The primary article that forms the basis for these comments (the Atherton study) was published in October 2017.[1] The Atherton study provided valuable information about the need for increased measures to identify and reduce fugitive methane emissions from specific emission points. As the authors conclude, "Our study highlights the need for emission reduction efforts in the Montney to be focused on the few higher-emitting active gas wells, as well as abandoned, and aging infrastructure."[2] PSE supports this conclusion and notes that, unlike many areas in the U.S., the Canadian and British Columbia governments have implemented extensive measures in the years following the time period when the data underlying the Atherton study were collected (8/14/2015-9/5/2015). For example, in 2016, British Columbia implemented new guidelines eliminating routine flaring.[3] On April 26, 2018, the Canadian national government adopted new regulations that require companies to control methane leaks from equipment and the release of methane from compressors starting on January 1, 2020.[4] The Atherton paper concluded that "compressor stations emitted most frequently" and so the 2018 regulations appropriately target a source that Atherton expressly called out.[5] The 2018 Canadian regulations also limit methane leaks associated with well completion with the requirements taking effect on January 1, 2020.[6] These Canadian regulations also impose limits on methane venting and the release of methane from pneumatic devices starting January 1, 2023.[7] In short, the Atherton study was an important data point about the state of methane fugitive emissions in 2015 and the need for more regulation. Consistent therewith, the Canadian and British Columbia governments have acted since that study was performed, implementing a broad swath of regulations targeting fugitive methane emissions from the oil and gas sector.

It is also important to note that there were significant limitations relating to the Atherton study that call its quantitative conclusions into question. PSE recognizes the value of the Atherton study for qualitatively focusing the provincial and national governments on the need for further regulation of fugitive methane sources. As explained above, however, that has already been

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[1] Atherton et al.; *Mobile measurement of methane emissions from natural gas developments in northeastern British Columbia*, Canada, Atmos. Chem. Phys., 17, 12405-12420, 2017.
[2] *Id.*
[3] https://www.bcogc.ca/node/5916/download.
[4] https://www.canada.ca/en/environment-climate-change/news/2018/04/federal-methane-regulations-for-the-upstream-oil-and-gas-sector.html.
[5] Atherton et al; *Mobile measurement of methane emissions from natural gas developments in northeastern British Columbia*, Canada, Atmos. Chem. Phys., 17, 12405-12420, 2017.
[6] https://www.canada.ca/en/environment-climate-change/news/2018/04/federal-methane-regulations-for-the-upstream-oil-and-gas-sector.html.
[7] *Id.*

accomplished. Nonetheless, there are serious questions regarding the representativeness of the quantitative estimates of methane emissions expressed in the Atherton paper and the limitations of using the study for quantifying methane emission rates. As discussed in the recent paper published by the National Academy of Sciences ("NAS"), methane emissions from gas wells peak during mid-afternoon hours.[8] As described by the NAS authors, "maintenance activities, such as manual liquid unloadings (MLUs) or depressurization of equipment ("blowdowns"), are often triggered by human operators during daytime work-week hours and may produce high emission rates for short durations."[9] As discussed in the 2018 NAS paper, daytime weekday measurements, such as the Atherton study relied upon, should not be used to estimate a methane emission rate as they typically will reflect the absolute peak of emitting activity and can greatly distort the overall inventory.[10] While Atherton's qualitative recommendation that the government focus on "the few higher-emitting active gas wells, as well as abandoned, and aging infrastructure" may have merit, the quantitative component of the paper is highly suspect.

In summary, studies such as the Atherton report help focus regulatory priorities, but cannot be used, nor are intended, to adjust accepted inventory values for methane emission rates. As the Atherton authors themselves stated in response to peer review comments, "The primary purpose of the paper was to determine emission frequencies, not to create a highly accurate volumetric inventory."[11] At this point in time, the most accurate estimate of the emission rate for natural gas production in British Columbia is the Province-specific data from the Canadian NIR and British Columbia natural gas production data previously provided to PSCAA by PSE.

Comment #3: The DSEIS has inconsistencies regarding the TOTE fuel oil terminology.

The DSEIS is internally inconsistent in describing the type of fuel that TOTE currently uses and would continue to use under the No Action Alternative. We suggest that the DSEIS be revised to use a consistent acronym to describe the fuel to be used by TOTE and other ships under the No Action Alternative, and accordingly the emission factors used in the spreadsheets need to reflect the correct fuel.

The DSEIS describes the Proposed Action as a terminal to supply LNG to vessels "replacing the use of marine diesel oil ("MDO") and diesel fuel."[12] Table 3-1 of the DSEIS states that under the No Action Alternative, MDO would continue to be used by TOTE and other potential future customers of the Tacoma LNG facility. This is further discussed in Section 3.3.3 of the DSEIS:

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[8] Vaughn et al.; *Temporal variability largely explains top-down/bottom-up difference in methane emission estimates from a natural gas production region*, Proceedings of the National Academy of Sciences (Nov. 2018) 115 (46) 11712-11717; DOI: 10.1073/pnas.1805687115; http://www.pnas.org/content/115/46/11712.
[9] *Id.*
[10] *Id.*
[11] https://www.atmos-chem-phys-discuss.net/acp-2017-109/acp-2017-109-AR1.pdf
[12] DSEIS Section 1.2.1.

> Under the No Action Alternative, marine engines would continue to operate on MDO. Under the 250,000 gpd scenario, the Proposed Action would displace 21.48 million gallons of MDO used by TOTE marine vessels, and would provide additional capacity to replace another 23.21 million gallons of MDO used by other marine vessels. Under the 500,000 gpd scenario, the expanded capacity would also displace 21.48 million gallons of MDO used by TOTE marine vessels, and would provide additional capacity to replace up to 69.32 million gallons of MDO used by other marine vessels.

As seen in the quote above, the DSEIS repeatedly states that under the No Action Alternative, TOTE will utilize MDO. However, in Appendix C to the DSEIS, LCA states that the fuel used by TOTE is Marine Gas Oil ("MGO"). We recognize that MGO and MDO are very similar distillate fuels that are both referred to in common maritime use as diesel. However, in order to avoid confusion the SEIS needs to consistently describe the fuel used by TOTE. In its May 3, 2018 response to PSCAA's information request, TOTE stated that if the LNG terminal is not constructed, "[t]he current engines would remain and utilize 0.1% Sulphur compliant marine fuel (MGO)."[13] Therefore, we recommend that the DSEIS text be revised to be consistent with the LCA report in Appendix C and identify the fuel that TOTE employs as MGO.

Comment #4: The DSEIS spreadsheets should use marine diesel factors instead of bunker fuel factors to calculate the upstream emissions associated with TOTE's fuel oil.

Comment #3 is about the use of a consistent term to describe the fuel that TOTE uses and would continue to use under the No Action Alternative. Separate from that issue, but related to TOTE's current fuel use, there are calculation issues with the spreadsheets because they are based on the assumption that TOTE burns bunker fuel when in actuality it burns distillate fuel (diesel). The DSEIS calculations rely in many places on assumptions that vary based on the type of fuel employed. Several emission calculation errors derive from the incorrect assumption that the fuel TOTE will utilize under the No Action Alternative is appropriately modeled as residual oil or "bunker fuel for marine vessels" in GREET. As explained above, the appropriate fuel under the No Action Alternative for TOTE vessels is MGO. The MGO fuel that TOTE currently uses and would use under the No Action Alternative is most closely approximated as low sulfur diesel fuel within the GREET model, not bunker fuel. Assuming that TOTE will employ bunker fuel leads to an over-estimation of emissions under both the Action and No Action Alternatives.

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[13] Response to Question 8, *Tacoma LNG SEIS Data and Information Request for TOTE Maritime* (May 3, 2018).

This confusion between MGO and bunker fuel does not change the DSEIS conclusions. In fact, the net impact of this misunderstanding, which includes both upstream and downstream inaccuracies, is that the DSEIS underestimates the total GHG benefit associated with the Action Alternative. Nevertheless, the factors should be corrected so the numbers provided in the analysis are accurate. In this Comment #4 and the following Comment #5 we describe specific corrections needed for the upstream and downstream emissions. These comments are made in reference to the Scenario A spreadsheet (250,000 gpd), but apply equally to the Scenario B spreadsheet (500,000 gpd).

The DSEIS spreadsheets contain an error relating to the calculation of the upstream GHG emissions associated with producing TOTE's fuel oil because they use the GREET bunker fuel emission factor instead of the GREET diesel fuel emission factor. This leads to the under-estimation of upstream emissions associated with TOTE's fuel under the No Action Alternative.

The upstream emissions related to TOTE marine diesel production (tonnes/year CO2e) are identified in cell H140 of the "Upstream" sheet. The individual constituent GHGs (CO2, CH4 and N2O) are calculated in cells E140:G140. Each of those three is calculated similarly; the formula for CO2 is as follows:

=$C140*C$87/1000

Where:

C140 = GBtu/year of diesel fuel consumed
C87 = CO2 emission rate for bunker fuel

As you can see from the defined terms, there is an error in the emission rate being used. The purpose of the calculation is to determine the CO2 emissions associated with producing and delivering marine diesel (MGO) and yet the emission rate used is for the less refined bunker fuel. Because the upstream emissions associated with refining an MMBtu of bunker are roughly half the emissions associated with refining an MMBtu of diesel, this error results in the upstream emissions associated with TOTE marine diesel being understated. Table 1 shows how the upstream TOTE marine diesel emissions increase by approximately 12,500 tonnes per year when the appropriate emissions rate is utilized.

Table 1. No Action Alternative: Upstream TOTE Marine Diesel Emissions

	GHG Emissions tonne/year (as proposed)	**GHG Emissions tonne/year** (corrected)
Upstream TOTE Marine Diesel (MGO) Emissions	52,448	64,775

Comment #5: The DSEIS spreadsheets should use diesel fuel factors as opposed to bunker fuel factors to calculate the downstream emissions.

As introduced in Comment #4, the confusion over distillate fuel versus bunker fuel also resulted in errors in the downstream emissions calculations for both LNG and oil-fired vessels. These errors all derive from the incorrect assumption that the fuel TOTE will utilize under the No Action Alternative is appropriately modeled as residual oil or "bunker fuel for marine vessels" in GREET. As explained above, the distillate fuel TOTE vessels use today and will continue to use under the No Action Alternative is most closely approximated as low sulfur diesel fuel within the GREET model. Assuming that TOTE employs bunker fuel leads to over-estimated emissions under both the Action and No Action Alternatives. An example of how this impacts the spreadsheets is presented below.

In response to an information request from PSCAA, PSE provided data on the grams per trip of CO2 and the estimated tonnes of fuel that would be consumed during each trip. The estimated fuel use is calculated from the modeled engine work required over the course of a trip using fuel consumption factors listed in cells C110:C112 of the "EF Marine Vessels spec. TOTE" sheet. These fuel consumption factors are themselves calculated from direct CO2 emission factors for the Main Engine, Auxiliary Engine and Boiler. The formula used for calculating the fuel consumption factor for the Main Engine (cell C110) was:

=Q13*(12/44)/Fuel_Specs!$F$18

Where:

Q13 = the gCO2/kWh for a medium speed diesel.
Fuel_Specs!$F$18 = Carbon percentage by weight <u>for 2.8% sulfur bunker fuel</u>

This generated a fuel consumption factor with reported units of gallons MDO/kWh.

However, the 2.8% sulfur bunker fuel used in the SEIS calculation shown above is both (a) illegal to be used in a TOTE (or equivalent) vessel and (b) not equivalent in carbon content to the correct MGO baseline fuel for TOTE. Thus, the carbon percentage by weight for 2.8% bunker fuel should not be used to generate a 0.1% sulfur MGO fuel consumption factor. This matters because the carbon percentage by weight is lower for low sulfur diesel than that for high sulfur bunker fuel. By using the wrong denominator value, the fuel consumption factor is slightly off. When the proper fuel consumption factor is applied, the amount of distillate fuel consumed per trip changes by 1.5 tonnes per trip for the Main Engine as shown in Table 2 below.

Table 2. Fuel Consumption Estimates

	Fuel Consumption Estimate in Spreadsheet Using Wrong Fuel Consumption Factor	Fuel Consumption Estimate Using Accurate Fuel Consumption Factor
	(MT MGO)	(MT MGO)
Fuel Consumed Within 200 nm	62.0	62.2
Fuel Consumed Outside 200 nm	386.5	387.9
Total Fuel Consumed	448.6	450.1

This technical error is then carried into the calculation of the g/tonne MGO emission rate used to calculate the ultimate g/MMBtu MGO, LHV emission rate that is the foundation of the calculations. For example, the emissions rate (g/tonne MGO) for CO2 is calculated in cell L48 of the "End use TOTE-Fuel Oil Vessel" sheet using the following formula:

=L47*1000000/SUM($D$59:$F$59)

Where:

L47 = total emissions
$D$59:$F$59 = fuel consumption as determined using the fuel consumption factors

With the fuel consumption factors corrected, the emission rates (g/tonne MGO) shown in cells L49:P49 in the "End use TOTE-Fuel Oil Vessel" sheet change as shown in Table 3 below.

Table 3. Emission Rates Under No Action Alternative (g/tonne MGO)

	Emission Rate Estimate in Spreadsheet Using Wrong Fuel Consumption Factor	Emission Rate Estimate Using Accurate Fuel Consumption Factor
	(g/tonne MGO)	(g/tonne MGO)
CO2	3,182,667	3,171,667
NO2	143	152
CH4	49	49
CO2c	3,198,951	3,187,895
CO2e	3,242,897	3,234,406

As you can see, this technical error results in the DSEIS overstating the GHG emission rates (g/tonne MGOe) associated with the No Action Alternative.

Similarly, with the fuel consumption factors corrected, the emission rates (g/tonne MGO) shown in cells L49:P49 in the "End use TOTE-LNG Vessel" change as shown in Table 4 below.

Table 4. Emission Rates Under Action Alternative (g/tonne MGO)

	Emission Rate Estimate in Spreadsheet Using Wrong Fuel Consumption Factor	**Emission Rate Estimate Using Accurate Fuel Consumption Factor**
	(g/tonne MGOe)	**(g/tonne MGOe)**
CO2	2,180,117	2,172,582
NO2	153	152
CH4	25,931	25,841
CO2c	2,194,855	2,187,269
CO2e	2,888,582	2,878,599

As you can see, this results in the DSEIS overstating the GHG emission rates (g/tonne MGOe) associated with the Action Alternative.

This technical error is further magnified when the emission rates are divided by the fuel-specific heating value in the "Fuel_Specs" sheet to convert the g/tonne MGO emission rate to a g/MMBtu basis. In cell L49 of the "End use TOTE-Fuel Oil Vessel" sheet, a g/MMBtu MGO emission rate is calculated using the following formula:

=L48/(lbperkg*Fuel_Specs!$P$18)*1000

Where:

L48 = the emission rate in g/tonne MGO
Fuel_Specs!$P$18 = the heating value for 2.8% sulfur bunker fuel

As you can see, cell L49 incorrectly imports the heating value for 2.8% sulfur bunker fuel (i.e., "Fuel_Specs" sheet cell P18) rather than the heating value for a fuel equivalent to MGO such as low sulfur diesel (e.g., "Fuel_Specs" sheet cell P14). Fuel with a 2.8% sulfur level is prohibited from use within an Emission Control Area ("ECA") and is prohibited from use anywhere after January 1, 2020 unless the vessel is operating scrubbers. Therefore, there is no basis for using the bunker fuel heating value. As a result of using the bunker fuel heating value rather than the diesel fuel heating value, the g/MMBtu emission rate calculation is incorrect. In order to calculate an accurate g/MMBtu emission factor, the denominator in cell L49 must be the heating value associated with a low-sulfur diesel (cell C14 in the "Fuel_Specs" sheet). The use of a heating value associated with an obviously wrong fuel type is clearly inappropriate. This same technical error affects both the Action Alternative ("End Use TOTE-LNG Vessel" sheet) and the No Action Alternative ("End Use TOTE-Fuel Oil Vessel" sheet). Comparisons of the erroneous emission rates and the accurate emission rates for each scenario are shown in Table 5 and Table 6 below.

Table 5. Emission Rates Under No Action Alternative (g/MMBtu MGO, LHV)

	Emission Rate Estimate in Spreadsheet Using Wrong Heating Value	**Emission Rate Estimate Using Accurate Heating Value**
	(g/MMBtu MGO, LHV)	**(g/MMBtu MGO, LHV)**
CO2	85,081	78,179
NO2	4	4
CH4	1	1
CO2c	85,517	78,579
CO2e	86,691	79,725

Table 6. Emission Rates Under Action Alternative (g/MMBtu MGO, LHV)

	Emission Rate Estimate in PSCAA Spreadsheet Using Wrong Heating Value	**Emission Rate Estimate Using Accurate Heating Value**
	(g/MMBtu MGO, LHV)	**(g/MMBtu MGO, LHV)**
CO2	58,280	53,552
NO2	4	4
CH4	693	637
CO2c	58,674	53,914
CO2e	77,220	70,995

Ultimately, the values in the two tables above are used to calculate the marine vessel emissions associated with the Action and No Action Alternatives. For example, in cell F59 of the "Direct End use" sheet, methane emissions from LNG combustion are calculated using the following formula:

=$F31*Factors!E$73/1000

Where:

F31 = the annual LNG consumption in GBtu/yr, LHV
Factors!E$73 = the methane emission rate in the table above (693 g/MMBtu LHV, uncorrected; 637 g/MMBtu LHV, corrected)

Because the emissions are calculated by multiplying the LNG consumption by a flawed emission rate, the ultimate result is inaccurate.

Correcting the errors is relatively straightforward and does not result in a material change in the overall conclusions expressed in the DSEIS. Once the emission rates are corrected, the GHG emissions attributable to the upstream and downstream marine use of LNG fuel and MGO decline. As shown in cell H59 of the “Direct End use” sheet, direct end use emissions from LNG drop from 529,859 tonnes/year CO2e to 490,443 tonnes/year CO2e. The GHG emissions attributable to the downstream marine use of MGO (i.e., the No Action Alternative) decrease from 609,291 tonnes/year CO2e to 558,611 tonnes/year CO2e. Tables 7 and 8 below summarize the changes under Scenario A (250,000 gpd) that result from the corrections outlined above.

Table 7. Action Alternative: End Use Emissions

	GHG Emissions tonne/year (as proposed)	**GHG Emissions tonne/year** (corrected)
End Use LNG	**529,859**	**490,443**
On-site Peak Shaving	43,854	43,854
TOTE Marine	225,993	207,659
TOTE Marine Diesel Pilot fuel	7611	7,000
Other Marine LNG (by Bunker Barge)	244,185	224,375
Other Marine Diesel Pilot Fuel	8,216	7,555

Table 8. No Action Alternative: End Use Emissions

	GHG Emissions tonne/year (as proposed)	**GHG Emissions tonne/year** (corrected)
Total End Use Diesel /Fuel Oil/LNG	**602,291**	**558,611**
Diesel Peak Shaving for Power	58,891	58,891
TOTE Marine Diesel	261,325	240,326
Other Marine Diesel (by Bunker Barge)	282,076	259,394

When these corrections are combined with the corrections to the upstream marine diesel emissions rates, total emissions under the No Action Alternative (“Results” sheet, cell E51) decline from 727,536 tonnes/year CO2e to 696,183 tonnes/year. Total emissions under the Action Alternative (“Results” sheet, cell E31) decline from 687,639 tonnes/year to 648,223 tonnes/year. The decline in emissions under the Action Alternative is slightly greater than the decline under the No Action Alternative, thereby modestly improving the GHG reductions for the Action Alternative.

The DSEIS and associated spreadsheets should be revised to correct the errors identified above. Although these corrections do not change the ultimate conclusion expressed in the DSEIS that the Action Alternative results in a net decrease in life cycle GHG emissions as compared to the No Action Alternative, the FSEIS should reflect the accurate fuel assumptions and resulting calculations. We have included as an attachment to this letter a set of revised spreadsheets that reflect the suggested changes discussed in comments 4 and 5. You will see that the revised spreadsheets include toggles ("Input" sheet; cells H32 and H33) that allow you to turn on and off the corrections so as to be able to see the impact of using the correct factors/values.

Comment #6: The DSEIS greenhouse gas calculations should be revised to reflect the greenhouse gas emissions associated with Tacoma LNG's electricity supplier rather than a Washington State average mix.

Section 2.2.3 of the DSEIS accurately describes the specific electric power generation mix serving the facility, but then does not use that mix to calculate the greenhouse gas emissions from the facility's consumption of electricity. Instead the DSEIS imputes to the Tacoma LNG facility GHGs associated with the Washington statewide average for electric generation into the GHG calculations thus overstating emissions. In addition, the text of the DSEIS misstates the greenhouse gas emission rate that is imputed to the facility, by taking into account only the upstream power generation emissions and not the emissions from the generating facility itself. This second error relates only to the text of the DSEIS and not the actual calculations performed in the supporting spreadsheets. Both errors appear to be oversights that should be corrected.

As accurately stated in section 2.2.3 of the DSEIS, the Tacoma LNG facility electricity load will be exclusively served by and sourced from Tacoma Power ("Power would be delivered to the Tacoma LNG facility through the Tacoma Power electrical system."). There is no option for the facility to be served by other suppliers. Section 2.2.3 of the DSEIS also accurately notes that the majority of Tacoma Power's electricity portfolio is generated by hydroelectric, nuclear and non-hydroelectric renewable energy sources. The spreadsheets supporting the PSCAA life cycle analysis identify the combined upstream and power plant emissions associated with the Tacoma Power grid mix as 29.9 g/kWh CO_2e.[14] The same spreadsheets identify the combined upstream and power plant emissions associated with the average Washington grid mix as 215 g/kWh

[14] "Upstream" sheet; sum of cells H29 and H30.

CO_2e.[15] The DSEIS then calculates the greenhouse gas emissions associated with construction and operation of the Tacoma LNG facility using the 215 g/kWh CO_2e emission factor.[16]

The electricity supply for the facility must come from Tacoma PUD, so it is not accurate to use a state-wide grid mix when specific information exists for Tacoma PUD. Tacoma Power generates all the electricity it distributes, including that provided to the facility and has a surplus of power. Tacoma Power has had decreasing load and is forecasting the continuing sale of surplus power to the grid in the future.[17] As a result, there is no basis to assume that the greenhouse gas emissions associated with the generation mix serving Tacoma LNG's load will increase above the current level. Calculating the greenhouse gas emissions associated with Tacoma LNG's electricity consumption based on the Washington average (215 g/kWh CO_2e) as opposed to the emission rate associated with Tacoma Power (29.9 g/kWh CO_2e) is not accurate and should be corrected in the SEIS.

In addition, we believe that the text of the DSEIS needs to be revised to accurately reflect the emission rates used in the spreadsheet calculations for calculating GHGs associated with upstream statewide average electricity generation GHG emissions. Section 2.2.3 of the DSEIS states that "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)." 18 g/kWh CO_2e comes from cell H27 of the "Upstream" sheet in the supporting spreadsheets. We believe that the wrong value was copied out of the "Upstream" sheet and that the sum of cells H27 and H28 (i.e., 215 g/kWh CO_2e) should be referenced for calculations where the Washington average electricity generation GHG emission rate is appropriately employed. As explained above, it is not appropriate to use the Washington average electricity generation GHG emission rate for the Tacoma LNG facility because all of its electricity will be obtained from Tacoma Power. However, to the extent that the Washington average electricity generation GHG emission rate is used for calculations such as upstream refining, the text should accurately reference the emission factors used in the calculations.

In summary, the emission rate associated with Tacoma Power's generation portfolio must be used to calculate greenhouse gases associated with constructing and operating the Tacoma LNG facility. This emission rate must then be reflected in the text of the SEIS. While not changing the conclusion in the DSEIS, accurately characterizing the GHG emissions attributable to the electricity used by the proposed facility will more fully recognize the benefits attributable to the Action Alternative. The spreadsheets placed on public comment as an attachment to the DSEIS include a toggle ("Input" sheet; cell H24) that allows one to correct the generation portfolio to reflect the Tacoma Power generation mix. It may simply have been an oversight that the toggle

[15] "Upstream" sheet; sum of cells H27 and H28.
[16] "Upstream" sheet; cells G42 and G47.
[17] Tacoma Power Integrated Resource Plan, 2017 Update https://www.mytpu.org/file_viewer.aspx?id=64787.

was switched to the state-wide mix given that the text of the DSEIS accurately reflects that electricity for the proposed project would come exclusively from Tacoma Power. This oversight should be corrected in the FSEIS.

Comment #7: The DSEIS should be revised to employ the correct CA_GREET value for liquefaction and storage of LNG and to remove the inaccurate statement that the proposed facility is not energy efficient.

On page 89 of Appendix C of the DSEIS (the LCA report) LCA incorrectly states that "[t]he power consumption of Tacoma LNG is considerably higher than the CA_GREET default value." This misstatement should be corrected because the Tacoma LNG facility is in fact highly energy efficient. The unnumbered table on page 89 of Appendix C states that the electricity consumption for Tacoma LNG is 1,348 kWh/1,000 gal LNG while the CA_GREET value is 43.89 kWh/1,000 gal LNG. Based on these values, LCA reaches the conclusion that the proposed facility is not energy efficient. This conclusion is wrong because LCA uses an incorrect CA_GREET energy consumption value to derive the kWh/1,000 gal LNG power consumption value. LCA employed a Total Energy/Unit LNG value from CA_GREET of 1,607 $Btu_{energy}/MMBtu_{LNG}$. When one performs the unit conversion with a 91 percent efficiency, you get 43.89 kWh/1,000 gal LNG--the figure in the unnumbered table on page 89 of Appendix C. The derivation of this value is shown below.

Incorrect Derivation
Assumes LNG Storage (As a Transportation Fuel)

A	Heating Value	84,820 BTU / gallon	HHV Fuel Spec GREET
B	Conversion BTU to kW-h	3412.14 BTU / kW-h	Constant
C	Total Energy / unit LNG	1,607 BTU_{energy} / $MMBTU_{LNG}$	GREET Value below for Energy Consumption
D	Convert to kW-h / MMBTU(LNG)	0.47 kWh_{energy} / $MMBTU_{LNG}$	= C / B
E	Convert to kW-h / (1) BTU(LNG)	4.71E-07 kWh_{energy} / BTU_{LNG}	= D / 1E6
F	Convert to kW-h / gallon(LNG)	0.04 kWh_{energy} / $gallon_{LNG}$	= E / A
G	Energy / 1000-gallons	**40 kWh_{energy} / 1000-$gallon_{LNG}$**	= F * 1000
	Assuming 91% LOSS	**43.89 kWh_{energy} / 1000-$gallon_{LNG}$**	= F / 0.91 ← Incorrect

However, 1,607 $Btu_{energy}/MMBtu_{LNG}$ is the CA_GREET default factor for the energy associated with storage of LNG. The CA_GREET default factor for the energy associated with both liquefaction and storage of LNG is 125,772 $Btu_{energy}/MMBtu_{LNG}$. When one performs the unit conversion from the correct energy consumption value, you get 3,623 kWh/1,000 gal LNG.

	Correct Derivation		
	Natural Gas to Liquefied Natural Gas (As a Transportation Fuel)		
A	Heating Value	84,820 BTU / gallon	HHV Fuel Spec GREET
B	Conversion BTU to kW-h	3412.14 BTU / kW-h	Constant
C	Total Energy / unit LNG	125,772 BTU_{energy} / $MMBTU_{LNG}$	GREET Value below for Energy Consumption
D	Convert to kW-h / MMBTU(LNG)	36.86 kWh_{energy} / $MMBTU_{LNG}$	= C / B
E	Convert to kW-h / (1) BTU(LNG)	3.69E-05 kWh_{energy} / BTU_{LNG}	= D / 1E6
F	Convert to kW-h / gallon(LNG)	3.13 kWh_{energy} / $gallon_{LNG}$	= E / A
G	Energy / 1000-gallons	**3,126 kWh_{energy} / 1000-$gallon_{LNG}$**	= F * 1000
	Assuming 91% LOSS	**3,623 kWh_{energy} / 1000-$gallon_{LNG}$**	= F / 0.91 ← Correct

As shown in Table 9 below, a comparison of Tacoma LNG's power consumption value of 1,348 kWh/1,000 gal LNG to the correct CA_GREET derived power consumption value of 3,623 kWh/1,000 gal LNG demonstrates how energy efficient the Tacoma LNG facility will be.

Table 9. Energy Efficiency of the Tacoma LNG Facility

Tacoma LNG (kWh/1,000 gal LNG)	CA_GREET (kWh/1,000 gal LNG)
1,348	3,623

The DSEIS should be revised to accurately reflect the CA_GREET figure for liquefaction and storage as well as to note the high energy efficiency of the proposed facility.

Comment #8: The carbon balance on page 92 of Appendix A to the LCA Report contains errors.

The "Annual Throughput" figure on page 92 (Appendix A) of the LCA Report, which is Appendix C of the DSEIS contains several minor technical errors. Specifically, we have identified the following corrections for PSCAA's consideration:

- The amount of natural gas exiting the LNG Pretreatment system annually should be corrected to 322,354 tonnes, not 315,523 tonnes as shown in the DSEIS mass balance figure. The mass balance shows 326,239 tonnes of natural gas entering LNG Pretreatment and 3,885 tonnes exiting as "Pretreatment fired NG." The difference is 322,354 tonnes, not 315,523 tonnes.
- The amount of LPG produced annually should be corrected to 8,910 tonnes, not 8,722 tonnes as calculated in the DSEIS mass balance figure. Because the mass of natural gas exiting the pretreatment increases by 6,831 tonnes natural gas (322,354 tonne NG –

315,523 tonne NG = 6,831 tonne NG), the amount of LPG production will increase by 188 tonnes.

- The CO_2 produced annually by flaring the LPG should be corrected to 24,083 tonnes, not 23,573 tonnes as calculated in the DSEIS. Using a value of 8,910 tonnes LPG, CO2 emissions will increase by 510 tonnes CO2.
- The CO_2 produced annually for the facility should be corrected to 95,164 tonnes, not 94,654 tonnes as calculated in the DSEIS. Adding 510 tonnes CO2 to the facility total brings the total emissions to 95,164 tonnes.

The corrected values are summarized in Table 10 below.

Table 10. Carbon Balance Corrections

DSEIS Calculated (Incorrect)	Correct Value
315,523 tonne NG	322,354 tonne NG
8,722 tonne LPG	8,910 tonne LPG
23,573 tonne CO2 from flared LPG	24,083 tonne CO2 from flared LPG
94,654 tonne CO2 Facility Total	95,164 tonne CO2 Facility Total

While these are not significant differences, the FSEIS should be revised to reflect accurate values.

Comment #9: Table C.1 in Appendix C incorrectly identifies natural gas data as "placeholder data."

Table C.1 in Appendix C of the LCA Report, which, in turn, is Appendix C of the DSEIS incorrectly suggests that natural gas carbon content, heating value and the CO_2 emission factor are interim "placeholder" values. Our understanding is that the emission factors stated in Table C.1 are never used in the analysis so perhaps this is an editing oversight because this table does not have to be included in the appendix. However, if the table is to be included, there are minor errors that should be corrected. For example, the higher heating value ("HHV") for natural gas stated in Table C.1 is 1,054 Btus/scf. However, the correct value (which is accurately shown in the "Input" sheet of the supporting spreadsheets at cell C90) is 1,090 Btus/scf. Again, if Table C.1 is to be included in the FSEIS, the values should be corrected to reflect the values used in the actual analysis. While not affecting the conclusions in the DSEIS, it is confusing for Table C.1 to inaccurately reference "placeholder data" and to reflect values inconsistent with the DSEIS spreadsheets.

Comment #10: Note "a" in Table C.2 of Appendix C incorrectly states that natural gas properties will be recalculated based on requested data.

Table C.2, Note "a" in Appendix C of the LCA Report, which, in turn, is Appendix C of the DSEIS incorrectly states that "Natural gas properties will be recalculated based on data that has been requested." Note "a" also indicates that the fuel properties in Table C.1 match those on the "Fuel_Specs" sheet in the supporting spreadsheets. However, PSE responded to the PSCAA information requests on May 25, 2018--over four months prior to completion of the LCA Report in Appendix C. Therefore, the language in Note "a" appears to be out of date and should be removed. We also note that the fuel values in Table C.2 should be amended to match the numbers in the "Fuel_Specs" sheet of the underlying spreadsheets.

Comment #11: The DSEIS misstates the amount of LNG that would be gasified during times of peak demand.

There are inconsistencies in the DSEIS about the amount of LNG that would be gasified during peak demand periods. Section ES.2 of DSEIS inaccurately states "During times of peak gas demand, 85,000 dekatherms of NG would be re-gasified and re-injected into PSE's distribution system." However, in Section 2.3.4 the DSEIS accurately states that the vaporization system would have the capacity to deliver 66 MMSCF/day (i.e., 66,000 Dth/day) of natural gas at standard distribution pipeline pressure. We believe that the confusion may stem from language in the FEIS which speaks of the Proposed Action being to "re-inject <u>and divert</u> approximately 85,000 Dth/day." (emphasis added). The FEIS was accurate in this description, but that does not mean the entire 85,000 Dth/day is from re-gasified natural gas. As described in Section 1.3.4.1 of the BID, the Tacoma LNG facility will have the capacity on a peak demand day to re-gasify up to 66,000 Dth/day of gas from storage, but can add additional supply by diverting up to 19,000 Dth of natural gas that would normally be delivered to the facility for liquefaction. Therefore, Section ES.2 of DSEIS should be revised to state "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."

Similar to our other comments, this is not a significant error that affects the overall DSEIS conclusions, but nonetheless should be corrected.

Comment #12: Table A.11 in the LCA Report contains values that should be corrected.

Table A.11 in Appendix C of the LCA Report, which, in turn, is Appendix C of the DSEIS includes incorrect values. For example, Table A.11 indicates that 2,299 gallons of LNG are lost per bunkering event. The sheet entitled "PSE_LNG_Operations" in the DSEIS spreadsheet contains the value of 114 gallons per event. The latter value reflects the assumptions built into the DSEIS spreadsheet and the 2,299 gallon value currently in Table A.11 is inconsistent with what is actually used in the DSEIS spreadsheets. Table A.11 appears to have had the wrong data populated into many of the cells in the table and should be corrected to avoid confusion. These corrections to the table do not alter the conclusions of the DSEIS because the spreadsheets are accurate.

Comment #13: Section 2.3.4 of the DSEIS incorrectly suggests that the LNG that is re-gasified and injected into the pipeline during peak demand periods would be used for electricity generation.

Section 2.3.4 of the DSEIS states "GHG emissions would also occur during the combustion of the natural gas in the power generation facility associated with peak shaving." This statement is incorrect. During a peak demand period when the immediately available gas supply is insufficient, PSE's priority is residential and commercial natural gas customers. At such a time, the Tacoma LNG facility would gasify LNG in storage and re-inject this natural gas into the pipeline for use by its residential and commercial natural gas customers. As explained in Section 1.3.6.3 of the BID:

> The Tacoma LNG Facility would also enable PSE to avoid repurposing firm gas transmission from peak period electricity generation to residential gas service. In the absence of the Tacoma LNG Facility, during peak periods PSE would have to use this firm gas transmission to supply gas customers and thus would be required to operate "peaker" dual-fuel combustion turbine electric generating units utilizing fuel oil rather than using natural gas. The additional GHG emissions attributable to use of fuel oil in dual-fuel combustion turbine electric generating units is not quantified in this analysis, but will occur if the Project is not built.

As this provision makes clear, one benefit of the project is that during peak demand periods, PSE has the ability to vaporize LNG and put that natural gas into the pipeline to supply residential and commercial gas service. None of the peak shaving natural gas would be supplied to electricity generation. The natural gas used for electricity generation is in a separate portfolio of gas resources designated for PSE's electricity generation. Tacoma LNG is an exclusively natural gas customer gas supply resource.

Comment #14: The SEIS must accurately calculate emissions of black carbon and organic carbon relative to the Action and No Action Alternatives.

As noted above, the 2018 IPCC Special Report recommended an increased focus on reduction of short-term climate forcers such as black carbon and organic carbon. Black carbon is a component of $PM_{2.5}$ generated primarily by the incomplete combustion of fossil fuels.[18] Black carbon emissions are estimated to be the second or third largest contributor to current warming, after CO_2 and methane. Black carbon influences climate by directly heating surrounding air when suspended in the atmosphere, by reducing the reflectivity of the earth's surface when deposited (an effect particularly strong over snow and ice), and through additional indirect effects related to interaction with clouds. Black carbon has a tremendous impact locally and along the Canadian and Alaska coastlines on snow and ice fields, not to mention on human health.

One of the critical benefits presented by the proposed project is that it will result in a substantial decrease in black carbon emissions from vessels. PSCAA has appropriately included black carbon and organic carbon calculations in the DSEIS spreadsheets. However, those calculations contain errors that we presume are due to incorrect fuel assumptions (in the absence of the Tacoma LNG project TOTE vessels will run on diesel and not bunker fuel).[19] Whatever the reason for the mistakes, the FSEIS should be corrected as outlined below:

1. The "End use TOTE - Fuel Oil Vessel" sheet references incorrect BC/OC ratios for transit, maneuvering and hoteling emissions in cells Q44:R44, Q45:R45 and Q46:R46, respectively. For example, the transit black carbon emissions for the <u>fuel oil vessel</u> are calculated in cell Q44 using the following formula:

   =H44*BC_OC Ratios'!$C$6/100

   Where:
   H44 = PM2.5 emissions
   BC_OC Ratios'!$C$6 = the black carbon percentage for a natural gas fired engine

   The correct "BC_OC Ratios" sheet reference should be to cell O6, for a diesel-fired engine. In other words, the spreadsheet is calculating black carbon emissions for a <u>fuel oil-fired vessel</u> using the black carbon percentage of PM2.5 specific to a <u>natural gas-fired engine</u>. The formula should reference BC_OC Ratios'!$O$6, the correct BC percentage for a diesel-fired engine and consistent with the PM2.5 emissions factors used for an MGO-fueled marine vessel engine.

2. The Emissions Factors tables in rows 63 through 90 of the "End use TOTE - Fuel Oil Vessel" sheet misapply the Fuel Correction Factors. The formulae in these cells use

[18] https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-4-4-3.html.
[19] See comments 4 and 5 above.

emission factors contained in Table B.2 (cells D8:K17 of the "EF Marine Vessels spec. TOTE" sheet), and reflect emissions of an ocean going vessel operating on 0.1% S MDO as reported in the 2016 Puget Sound Maritime Air Emissions Inventory.[20] The Emissions Factors tables in rows 63 through 90 of the "End use TOTE - Fuel Oil Vessel" sheet then apply Fuel Correction Factors to the 0.1% MGO emissions rates. The Fuel Correction Factors are shown in Table 3.22 (cells B96:L105 of the "EF Marine Vessels spec. TOTE" sheet). However, these Fuel Correction Factors are intended to adjust emissions factors from a baseline of 2.7%S HFO (the baseline in the 2011 Puget Sound Maritime Air Emissions Inventory), not the 0.1% MGO baseline used in the current analysis.[21] By applying these Fuel Correction Factors to the updated baseline emissions factors for 0.1% MGO shown in Table B.2, particulate emissions for the fuel oil-fired vessel are incorrectly reduced by 83%.

3. Cells Q44:Q46 and R44:R46 of the "End use TOTE - Fuel Oil Vessel" and "End use TOTE-LNG Vessel" sheets are intended to represent the tonnes per trip values for black carbon and organic carbon, respectively, for each of the three phases of transportation. The values in cells Q48 and R48 of these two sheets are intended to represent the sum of the values for each of the phases. However, the values in cells Q48 and R48 of both of these two sheets are hard-entered numbers and do not reflect the sum of values above them.

Correcting these errors results in a four-fold increase in black carbon emissions associated with the TOTE Fuel Oil Vessel and a halving of the organic carbon emissions.

It is also noted that Table B.12 (cells B58:K60 of "EF Marine Vessels spec. TOTE") contains an error for the PM10 emissions rate of a fuel oil auxiliary boiler. The listed value is 16 g/kW-hr. The correct value is 0.16 g/kW-hr, as reported in the 2016 Puget Sound Maritime Air Emissions Inventory. Because the PM10 emissions rates of auxiliary boilers are assumed to be the same for fuel oil and natural gas, this error doesn't create a relative emissions difference between the two fuels. However, the error should still be addressed so as to ensure that the SEIS is accurate.

Given the substantial climate forcing impacts of black carbon, PSCAA must accurately address these emissions in the analysis. Failure to do so would cause the FSEIS to understate the life cycle benefits of the Proposed Action. The errors in the spreadsheets identified above should be corrected and the black carbon and organic carbon impacts of the Action Alternative as

[20] htbtps://pugetsoundmaritimeairforum.files.wordpress.com/2018/10/final-2016-psei-report-19-oct-2018-scg.pdf

[21] See, Section 3.6.10, Table 3.22 of the 2011 Inventory ("emission factors were given for engines using residual fuel with an average 2.7% sulfur content.") https://pugetsoundmaritimeairforum.files.wordpress.com/2016/06/2011pseireportupdate_20130523.pdf

compared to the No Action Alternative should be identified. While more commonly considered in the context of the 20-year horizon, it is important that even this 100-year horizon assessment recognize the huge benefit achieved by reducing black carbon emissions and reducing the substantial effects that black carbon has on the glaciers and snow fields that lie in immediate proximity to Pacific Northwest maritime traffic.

We have included as an attachment to this letter a set of revised spreadsheets that include a toggle ("Input" sheet; cells H30 and H31) that allow you to consider the black carbon and organic carbon impacts ("Input" sheet; cell H30) as well as to correct the inaccurate black carbon and organic carbon computations ("Input" sheet; cell H31).

Comment #15: The DSEIS uses an appropriate methane emission rate for marine LNG-fired engines.

Recent data lend further support for the use of the methane emission rate for marine LNG-fired engines that is in the DSEIS. The DSEIS relies upon the June 13, 2017 SINTEF report (Table 7.2) for the methane emission rate value for an LNG-fired LPDF 4-stroke engines. The 5.3 g/kW-hr value was derived from actual tests on two ships equipped with Low Pressure Dual Fuel ("LPDF") engines. Since the time of that report and preparation of the DSEIS, MAN Energy Solutions ("MAN"), the company upgrading the TOTE propulsion system to LNG, has performed its own testing. As described in the attached October 26, 2018 letter, MAN has tested methane emissions for a converted MAN 58/64 engine as part of their engineering development program. This engine is the equivalent of those that will power the MV Midnight Sun and MV North Star on LNG once fully converted. When adjusted for density to match the conditions of the SINTEF report, the emission rate is 5.3 g/kW-hr. Note that MAN compares their tested value to the value reported in the SINTEF report reflecting the average of actual tests and manufacturer testbed data. MAN's value comes out at exactly the same rate (5.3 g/kW-hr) as the other *in situ* tests. This lends tremendous credibility to the value used in the DSEIS.

Comment #16: PSCAA is correct to employ the AR4/100-year assumptions in assessing life cycle GHG emissions under the Action and No Action Alternatives.

At the public hearing held on October 30, 2018, multiple commenters suggested that PSCAA should apply AR5, 20-year average Global Warming Potentials ("GWPs") instead of the AR4, 100-year average GWPs employed in the DSEIS. The stated justification for this shift, which several other commenters acknowledged would put the SEIS at odds with Washington's statutes, rules and policies, was the belief that because a recent IPCC study says significant action must be taken in the next 12 years, that the average GWPs must more closely match this period. This comment reflects a misunderstanding of the SEIS process, what the IPCC report says, and the policy underlying the 100-year GWP horizon.

Focusing on a 20-Year Average GWP as Opposed to a 100-Year GWP Inaccurately Minimizes the Long Term Effect of Carbon Dioxide on Climate Change

GWP is the ratio between the climate warming effect of 1 tonne of a non-CO2 GHG and the climate warming effect of 1 tonne of CO2 had each been emitted on the same day. The IPCC has estimated that the average relative GWP for methane over the first 20 years after it is emitted is 86 (without climate-carbon feedbacks).[22] This means that over 20 years (and with no consideration beyond 20 years) the average relative global warming potential of 1 ton of methane equals that of 86 tonnes of CO2.

Because GWP is a ratio (as opposed to an absolute number) the relative decline in CO2 and methane distort the 20-year average GWP value. Specifically, over the first 3.3 years, the fraction of a tonne of CO2 emitted that remains in the atmosphere declines faster than methane. Thus methane's GWP over the first three years goes up notwithstanding the fact that its levels are declining significantly over that time period. This artificially inflates the global warming effect of methane during that 3.3-year period.

More importantly, half of methane's global warming effect has occurred within 8.6 years of being emitted and 3/4 of its effect has occurred within 17.2 years of being emitted. By 100 years, the direct effect of methane on global warming drops to negligible levels, with the fraction of remaining methane decreasing to 0.000009 percent, while slightly less than 40 percent of the CO2 is still present.[23] As the IPCC has stated, "About half of a CO2 pulse to the atmosphere is removed over a timescale of 30 years; a further 30% is removed within a few centuries; and the remaining 20% will typically stay in the atmosphere for many thousands of years."[24] Climate researcher, David Archer, et al., concluded that "climate effects of CO2 releases to the atmosphere will persist for tens, if not hundreds, of thousands of years into the future."[25] The authors of that paper cautioned against even limiting consideration to the 100-year horizon given the longevity of CO2.

Because methane is reduced by roughly 98 percent within the first 50 years, but it takes tens of thousands of years to reach the same reduction in CO2 stocks, it is bad policy to focus on the 20-year average GWP values. This ignores the much greater long-term impact that an equivalent

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[22] IPCC; Anthropogenic and Natural Radiative Forcing (2013); https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf

[23] Fugitive Methane and the Role of Atmospheric Half-Life; *Geoinfor Geostat: An Overview 5:3.* https://www.scitechnol.com/peer-review/fugitive-methane-and-the-role-of-atmospheric-halflife-bu53c.php?article_id=6097

[24] IPCC Fourth Assessment Report; TS 2.1.1; https://www.ipcc.ch/publications_and_data/ar4/wg1/en/tssts-2-1-1.html

[25] Atmospheric Lifetime of Fossil Fuel Carbon Dioxide; Annu. Rev. Earth Planet. Sci. (2009); http://climatemodels.uchicago.edu/geocarb/archer.2009.ann_rev_tail.pdf.

amount of CO2 has for centuries into the future. As the IPCC noted, "Adoption of a fixed horizon of e.g., 20, 100 or 500 years will inevitably put no weight on the long-term effect of CO2 beyond the time horizon."[26] Simply ignoring the impacts of CO2 after 20 years, as the 20-year average GWP does, makes no sense from a policy point of view and is why all creditable policy making organizations rely upon the 100-year horizon. The 100-year average GWP still understates the long-term impact of CO2 as opposed to methane, but it gives a more accurate sense of the long-term impacts.

The 2018 IPCC Special Report on the Impacts of Global Warming Does Not Suggest That it is Necessary or Appropriate to Rely on the 20 Year Average GWP

In October 2018, the UN Intergovernmental Panel on Climate Change ("IPCC") released a Special Report on the impacts of global warming exceeding 1.5 degrees Celsius above preindustrial levels. The Paris Climate Accord commits to actions to stay below an increase in global temperatures of 2 degrees Celsius but to also pursue actions that would strive to keep increases in temperature to 1.5 degrees Celsius. The report concludes that to stay below an increase of 1.5 degrees Celsius, greenhouse gas emissions will need to be reduced by 45% from 2010 levels by 2030 and 100% (net zero) below 2010 levels by 2050. Nowhere does that report state that it is appropriate to use the 20-year average GWP in place of the 100-year average GWP as a policy tool. Doing so would mean that climate impacts are only considered for the first 20 years and effects after 20 years are not considered.

The 2018 IPCC Special Report does discuss the need for an increased focus on reduction of short-term climate forcers such as methane and black carbon. Methane reduction through industry and governmental efforts to reduce leakage in natural gas production such as those already underway in British Columbia is identified as a key tool that is highly achievable and has economic benefits as well. Reduction in black carbon emissions through reductions in diesel emissions is also identified as a pathway that not only has highly significant short-term climate reduction potential, but also has significant corollary public health benefits. However, the 2018 IPCC Special Report's focus on addressing short-term climate forcers is distinct from saying that policymakers should stop considering the long-term relative impacts of greenhouse gases. Some greenhouse gases, such as CO2, will be around for millennia, while others, such as methane, will essentially be gone in a few decades or less. There are benefits and tradeoffs related to each. However, governments must make decisions based on the long-term impacts to climate.

The 2018 IPCC Special Report does not specifically recommend a particular pathway or scenario to be followed. However, it does identify the consequences of inaction and identifies a number of methods that can be chosen by policy makers.

[26] IPCC; Anthropogenic and Natural Radiative Forcing (2013); https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf

In the context of the Tacoma LNG project, use of LNG as a marine fuel is consistent with a number of the identified alternative pathways in the report. Substituting LNG for oil in ship engines reduces climate emissions directly and also reduces black carbon, creating not only long- and short-term climate benefits, but improvements to public health through reduced exposure to diesel particulates. The use of British Columbia natural gas is also consistent with the identified pathways. As part of the Pan-Canadian Framework on Clean Growth and Climate Change, the Canadian government committed to reduce methane emissions from the oil and gas sector by 40 to 45 percent from 2012 levels by 2025. In April 2018, Environment and Climate Change Canada ("ECCC") adopted federal methane regulations to deliver on this commitment.[27] These regulations included the requirement that by January 1, 2020, well completions involving hydraulic fracturing must prevent fugitive releases. British Columbia has charted an even more aggressive course than the Canadian national government by setting its own aggressive targets of reducing Province-wide greenhouse gas emissions by 18 percent (relative to 2007 levels) by 2016, 33 percent by 2020 and 80 percent by 2050.[28] By committing to its natural gas feedstock coming exclusively from British Columbia, Tacoma LNG is supporting responsible development from a region that is aggressively pursuing greenhouse gas reductions. This pathway is consistent with the pathways outlined in the 2018 IPCC Special Report.

Use of AR4/100-year average GWPs is consistent with Washington, PSCAA, and U.S. EPA policy, in addition to that adopted by the Paris Accord

As noted by many commenters at the October 30 hearing, federal and state GHG reporting regulations and all major GHG policy considerations and goals, including those of the State of Washington, U.S. EPA, PSCAA, the Paris Accord and the Kyoto Protocol, are based on the AR4/100-year average GWPs. At page 4-5 of the DSEIS PSCAA states correctly that it is applying the GWP factors because it is the currently accepted international reporting standard and the methodology for State of Washington GHG reporting. Neither the State of Washington, U.S. EPA, PSCAA, the Paris Accord nor the Kyoto Protocol have adopted the AR5 GWPs and it would be inappropriate for PSCAA to adopt those standards here. Emissions are reported using these assumptions and goals are based on these assumptions. As explained above, the basis for this approach is that focusing on the 20-year average GWP eliminates consideration of the long-term impact of CO2 and other GHGs. Maintaining consistency when making policy considerations is key.[29] Also, compelling reasons exist for looking at the long-term impacts of emissions on climate change.

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[27] See, e.g., https://www.canada.ca/en/environment-climate-change/news/2018/04/federal-methane-regulations-for-the-upstream-oil-and-gas-sector.html.

[28] http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_07042_01.

[29] We note that even if 20 year average GWP values are assessed, a correct analysis incorporating the impacts of black carbon demonstrates that the Action Alternative results in a substantial net reduction in GHG emissions.

Comment #17: Although PSCAA has not been presented with a permit application for liquefaction of 500,000 gallons of LNG per day, there is no error in assessing that amount in the context of the SEIS.

There was confusion at the October 30 hearing about the end use contemplated for LNG in excess of the amount to be consumed by TOTE, peak shaving and truck transfers (the "unallocated LNG"). The primary purposes of the Tacoma LNG facility would be to provide LNG for marine vessel fuel and to PSE customers by re-gasification during times of peak demand (i.e., peak shaving). A small amount of LNG would be capable of transfer by truck. At either a 250,000 or 500,000 gallon per day production volume, there would be additional unallocated LNG available for maritime use.

PSE has only requested authority from PSCAA to build and operate a facility with the capacity to produce 250,000 gallons per day of LNG. This is based exclusively on the use of the infrastructure proposed in the Notice of Construction ("NOC") application. In order to perform a complete life cycle analysis of the greenhouse gas emissions associated with both a 250,000 and 500,000 gallon per day scenario, it was assumed that all remaining LNG not used by TOTE, for on-road heavy duty trucking or for peak shaving would be combusted in other marine vessels. All of this unallocated LNG was assumed to be transferred into barges on the Blair Waterway; no bunkering could occur in the Hylebos Waterway. Methane losses associated with the bunkering process and emissions associated with marine combustion were calculated and included in the spreadsheets on the "Direct End use" sheet. Different fuel transfer alternatives might be considered in the future if a market is identified. At that time, should modifications to the Tacoma LNG facility be necessary, all appropriate environmental review and permitting processes would be conducted.

As part of the original Proposed Action, the FEIS studied the Tacoma LNG Facility's ability to liquefy between 250,000 and 500,000 gallons per day. The DSEIS prepared by PSCAA to study GHG emissions consistently analyzes the facility's ability to generate up to 500,000 gallons of LNG per day. PSCAA's decision to review the environmental impacts of the Proposed Action at 500,000 gallons per day as studied in the original FEIS is appropriate. However, environmental review and environmental documents such as an FEIS or FSEIS do not constitute permits–they simply inform decision-makers when reviewing permit applications. Here, the NOC permit application submitted by PSE asks PSCAA to approve a facility that is limited to a daily average production capacity of 250,000 gallons. PSE would need to seek additional NOC permitting in the future to modify the 250,000 gallon per day amount of LNG sought by the NOC before PSCAA. There is no error in PSCAA's decision to review the Proposed Action at 500,000 gallons per day of capacity consistent with the FEIS, and there is no bar to PSE's ability to seek approval for a facility that is smaller than the maximum studied.

Comment #18: PSCAA is not reviewing a proposal for export of LNG to foreign markets.

At least one commenter at the October 30 hearing wrongly asserted that PSE is going to use Tacoma LNG for export of LNG to another country. This assertion is incorrect. The Tacoma LNG Project is not and cannot be operated as an LNG export facility. LNG import and export terminals are subject to the jurisdiction of the Federal Energy Regulatory Commission ("FERC"), which is the only agency in the United States that has authority to certify such facilities. The Tacoma LNG Facility is not a FERC-certificated export terminal.

Beyond the legal inability to operate the Tacoma LNG Facility as an export terminal, the proposal lacks the physical ability to perform as one. The Tacoma LNG Facility is sized only to serve the needs of natural gas customers and TOTE vessels: the project NOC is for authorization to "produce up to 250,000 gallons of fuel-grade (to satisfy PSE's supply agreement with TOTE) LNG per day, and store up to 8 million gallons of LNG on site." Even assuming all 250,000 gallons per day were diverted away from TOTE and natural gas customers (something PSE cannot do legally), it would take six months of round-the-clock daily production at 250,000 gallons per day just to produce enough LNG to fill one LNG export tanker. Beyond PSE's legal and physical inability to produce the volumes necessary for LNG export, there is no existing infrastructure at the Tacoma LNG Facility, and none proposed, that could fuel such a vessel.

PSE appreciates this opportunity to comment on the DSEIS relating to our proposed Tacoma LNG project. We recognize and appreciate the tremendous effort that PSCAA and its contractors have invested in this document. We hope that our comments are accepted in the constructive manner in which they are intended. We believe strongly that the best SEIS is one that is accurate and firmly rooted in established approaches. We recognize that some of our comments are complicated technically and may merit or be best addressed through real-time discussion. As you review our comments if additional information is needed from PSE, as the project applicant, we will make the PSE Team available at any time.

Ultimately, we believe that the DSEIS reached an accurate conclusion in determining that the Action Alternative will result in a net decrease in GHG emissions. This conclusion is reached based on an established approach that is consistent with the procedures adopted by PSCAA, the State of Washington, U.S. EPA and reflected in the Paris Accord and the Kyoto Protocol. We believe that the edits identified in this letter and addressed (in regards to comments 4, 5, 6 and 14) through revisions to the spreadsheets should be incorporated into the FSEIS.[30] These edits

[30] Again, we note that the changes in the spreadsheet needed to address comment #6 simply requires changing a toggle in the spreadsheet version released for public comment to be consistent with the text. There is no dispute that

will make the FSEIS more accurate, but they do not alter the fact that by building and operating the Tacoma LNG facility, PSE will be helping to reduce GHG emissions in addition to helping reduce NOx, SO2 and particulate emissions.

With the conclusion of the comment period, PSE looks forward to expeditious issuance of the Final SEIS so that we can proceed with the application for a minor source Notice of Construction from PSCAA. When it commences operation, the Tacoma LNG project will result in the reduction of criteria pollutants and greenhouse gases. We look forward to being able to recognize those benefits for the community as soon as possible.

Please do not hesitate to contact the PSE team if you have any questions or would like to set up a meeting. The team contact is Keith Faretra who can be reached at keith.faretra@pse.com or (425) 456-2561.

Sincerely,

Steve R. Secrist on behalf of David Mills
Senior Vice-President, Policy and Energy Supply

Attachments:

- October 25, 2018 letter from MAN to TOTE re emissions test results
- Spreadsheets reflecting changes in letter

cc: Craig Kenworthy

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the sole potential source of electricity for the proposed project is Tacoma Power and that Tacoma Power's generation portfolio is significantly greener than the state-wide average for Washington.

MAN Energy Solutions

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TOTE Maritime Alaska, Inc.
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Federal Way, WA 98063-4129

United States of America

Augsburg, October 26, 2018

Ref. 58/64DF

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MV Midnight Sun & MV North Star

Emission Information regaring Methane after the 58/64 conversion to Dual-Fuel operation.

Dear Ladies and Gentlemen,

Herewith we would like inform you about the requested values regarding the Methane values of the converted 58/64 engine to Dual-Fuel Operation for the vessels MV Midnight Sun and MV North Star.

The provided data from the SINTEF report dated 2017-06-13 have been used for a comparison with the values we have derived in the meantime.

Our provided values are only for information and not binding since we are in the development process according to schedule.

	E2-Cyclus Factor Methane [g/kWh]	Density [kg/m³]
SINTEF Report 2017-06-13	6,9	0,78
MAN Augsburg		
Preliminary 07/2018	4,7 @ 75% only	0,536
Comparable to SINTEF	5,3	0,78

As a result, we are at least 23% of CH4 below the SINTEF value at a comparable density which has been used as a reference value for the study. The overall GHG should be much better than the stated 13,5%.

We hope that we have provided the requested information. If you should have any questions, please do not hesitate to contact us any time.

Yours sincerely,
MAN Energy Solutions

i.V. Spindler
Dr. Thomas Spindler
Senior Manager
Head of Upgrades & Retrofits
PrimeServ Augsburg

i.V. A. Knafl
Dr. Alexander Knafl
Vice President
Head of Advanced Engineering
& Exhaust Aftertreatment
Engineering 4-Stroke

GENERAL INPUTS

Date: 21-Sep-18
Version: 17

Comments/Source

LNG Plant Operation

LNG Product - End use share

LNG Production	Scenario A End use share	gal/day	lb/day	Mgal/ year	tonne/ year	Scenario B Enduse share	gal/day	lb/day	Mgal/ year	tonne/ year	Check gal/year (365)	Source: PSE-BID	Scenario A Volume Data
Total	**100.0%**	**250,000**	**907,193**	**88.75**	**146,083**	**100.00%**	**500,000**	**1,814,384**	**177.50**	**292,165**	182,499,845		**250,000**
On-site Peak Shaving	11.0%	27,397	99,418	9.73	16,009	5.48%	27,397	99,418	9.73	16,009	10,000,000		27,397
Gig Harbor Peak Shaving	0.0%	0	0	-	0	1.00%	5,000	18,144	1.78	2,922	1,825,000		0
On-road Trucking	0.0%	0	0	-	0	2.00%	10,000	36,288	3.55	5,843	3,650,000		0
TOTE Marine	42.7%	106,849	387,732	37.93	62,435	21.37%	106,849	387,732	37.93	62,435	39,000,000		106,849
Truck-to-Ship Bunkering	0.0%	0	0	-	0	1.00%	5,000	18,144	1.78	2,922	1,825,000		0
Other Marine (by Bunker Barge)	46.3%	115,753	420,043	41.09	67,638	69.15%	345,753	1,254,659	122.74	202,034	126,199,845		115,753

Results	-6.89%	-47.96 ktonne/year

Scenario Selection for End use Mix

	Scenario	Comment
Enduse Scenario	A	Pull Down

EER for Marine		Range
1	Type in	1 to 1.015

	Sub- Scenario	Comment
LPG is flared	Yes	Pull Down

	Used GEN MIX		
Pwr Mix	**Washington**	WA	Pull Down
Natural Gas Upstream		GHGenius	Pull Down

Overall Operational Hours

Overall Operational Hours	hours/year	days/year
LNG Liquefaction Plant	8,520	355.0
LNG Pretreatment	8,520	355.0
LNG Flaring	8,760	365.0
LNG Vaporizer	240	10.0
Emergency Diesel Generator	500	20.8

GWP Basis			Comments/Source
AR Version	AR4	Pull Down	Source: LCA assumption 8760h/yr-240h/year (pipeline used by the vaporizer)
Timeframe	100	Pull Down	Source: LCA assumption 8760h/yr-240h/year (pipeline used by the vaporizer)
BC/OC	No	Pull Down	
Correct BC/OC Ratios	No	Pull Down	Source: Capacity, NG use 2018-05-25 PSE Submittal page 12
Correct FCFs	Yes	Pull Down	Source: Capacity, NG use 2018-05-25 PSE Submittal page 12
Correct Fuel Heating Value	Yes	Pull Down	

Energy/Electrcity Consumption LNG Plant

Scenario A Equipment Capacity/Consumption		PSE Estimate (mmBtu/hr)	Fuel	Calculated (mmBtu/hr)	Input for 250.000 gal /day	Comments/Source
LNG Pretreatment	NG WPG heater	9	NG		9	Source: Capacity, NG use 2018-05-25 PSE Submittal ATTACHMENT F page 118
LNG Pretreatment	NG Regenerator heater	1.6	NG		1.6	Source: Capacity, NG use 2018-05-25 PSE Submittal ATTACHMENT F page 119
Waste gas flaring	Waste Gas Heat Input	35.6		67.8	35.6	Source: Capacity, NG use 2018-05-25 PSE Submittal page 12
LPG in Waste Gas		77	LPG			
Waste Gas, Mass Balance		88	C2/C5+			
Vaporizer	LNG Heater Capacity	66			66	Source: Capacity, NG use 2018-05-25 PSE Submittal ATTACHMENT F page 120
		(gal/h)				
Emergency equipment	Diesel genrator	104.6	Diesel		104.6	Source: Capacity, NG use 2018-05-25 PSE Submittal page 12

WPG: Water Propylene Glycol

LNG pretreatment CO_2 seperation efficiency	**99.760%**	Actual result based on LNG composition

Power Consumption LNG plant	Baseline		Comments/Source
LNG Production	1,348	kWh/1000 gal	Source: page 13, PES response
Vaporizer	45	kWh/1000 gal	

Overall Mass Balance

Mass Input/Output: Based on 500,000 gal/day	NG Feed lb / Day	LNG Output lb / Day	Mass ratio NG/LNG	Density LNG g/gal	Density LNG lb/gal
	1,012,995	907,013	1.1168	1,646	3.629

Calculated specs for Feed Gas, Emissions and Products

Component	NG - fired NG	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 CO2/mmBtu)HHV	118.11	0.00	136.68	136.87	136.42	116.87
C factor (lb CO2/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 CO2/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, gCO2/MJ	56.2	0.0	65.1	65.2	65.0	55.6
g CO2/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/m3	36.7	0.0	67.5	57.5	89.4	35.6
SG	0.610	1.216	1.272	1.132	1.581	0.587
Density (g/ft3)	21.2	42.2	44.1	39.3	54.9	20.4
Density (g/m3)	747.9	1490.2	1558.8	1386.3	1937.1	719.3
	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

947.8171227

1646

75,574	77,156	81.40344129 MJ/gal

1.1075 0.902934537 0.902935

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, base LNG	1.0765	0.0106	0.0765	0.0467	0.0298	1.00	1.0000
	4,704	46	334	204	4,370		

Upstream inputs

Natural Gas upstream WA	Emissions (g/mmBtu), LHV			
Processing Step	**CO_2**	**CH_4**	**N_2O**	**CO_{2e}**
Natural Gas Extraction	2,356	8.91	0.02	2,876.19
Extraction Fugitive	0.00	135.74	0.00	3,691.60
Natural Gas Processing	1,845	4.37	0.01	2,252.37
Processing Fugtive	778	6.83	0.00	1,246.31
Transmission & Storage	377	13.68	0.30	1,017.00
Transmisison Fugitive	0.00	19.19	0.00	777.75
Total	**5,355**	**189**	**0**	**10,371**

Upstream Life Cycle Data. Source: GHGenius for BC, GREET NA Natural Gas, PSE FEIS for BC inventory

GHGenius			GREET			BC Inventory		
CO2	CH4	N2O	CO2	CH4	N2O	CO2	CH4	N2O
2355.558703	8.905180223	0.020759	2126.915308	8.040794784	0.018744431	6,030	46	0
	135.7439715			122.5679201		824	6	0
1845.075523	4.371853334	0.014211	1665.982414	3.947497367	0.012831328			
777.5358703	6.830768106		702.0639913	6.167736439				
377	13.68	0.295	1650.744077	17.69875777	1.253646641			
	19.19			40.36132186				

Natural Gas upstream BC FORTIS GIG HARBOR

Natural Gas upstream BC	Emissions g/mmBTU (LHV)			
	CO2	**CH4**	**N2O**	
Natural Gas Extraction	2,356	9	0	2876.188209
Fugitive Emissions	0	136	0	3691.599287
Natural Gas Processing	1,845	4	0	2252.371857
Transmission	778	7	0	1246.305073
Total	**4,978**	**156**	**0**	9172.464426
				298

Natural Gas upstream from PSE for Lower Sensitivity

				298
Natural Gas upstream BC	**Emissions g/mmBTU (LHV)**			#VALUE!
	CO2	**CH4**	**N2O**	#VALUE!
Natural Gas Extraction and processing	6,030	46	0.16	7465.5
Transmission	824	6	0.02	1269.5
				365.5
				298
Total	**6,854**	**51**	**0**	8437
Distribution	10	2	0.00	

Table 3. 2015 GHG Emissions Rates for Natural Gas Production, Transmission, and Distribution in British Columbia

BC Natural Gas GHG Emissions (grams/MMBTU)	CO_2	CH_4	N_2O	CO_2e
Natural Gas Production and Processing	6,030	45.5	0.16	7,216
Oil and Natural Gas Transmission	824	5.9	0.02	978
Natural Gas Distribution	10	2.3	0.00	67
Total	6,863	53.7	0.18	8,260
Total Ex-Distribution	6,853	51.5	0.18	**8,193**

Power generation			Emissions (g/kWh)		
Processing Step	**Code**		**CO_2**	**CH_4**	**N_2O**
Washington	WA	Upstream	8.2	0.3800	0.0010
		Power Plants	196.0	0.0100	0.0030
Tacoma	TA	Upstream	1	0.0454	0.0001
		Power Plants	27	0.0003	0.0003
Marginal	MA	Upstream	20	0.6462	0.0026
		Power Plants	212	0.0090	0.0014
eGRID NWPP	NW	Upstream	11	0.5569	0.0010
		Power Plants	297	0.0107	0.0047

Crude Oil Resource Mix	U.S. Average
API Gravity	31.2
Imported Oil	43.80%
Canadian Oil Sands	10.30%
Refinery Efficiency	
Residual Oil	94.83%
Diesel	90.92%
Product Transport	
% Marine Vessel	29%
Average Distance	8,373

	Emissions (g/mmBtu), LHV		
Processing Step	CO_2	CH_4	N_2O
U.S. Bunker Fuel			
Crude Oil Production	12,627		
Extraction Fugitive			
Crude Oil Refining	4,049	10.49	0.07
Processing Fugitive			
Transport	419	0.69	0.01
Transport Fugitive			
Total U.S. Bunker Fuel	**17,095**	**11**	**0**
U.S. Diesel Fuel			
Crude Oil Production	13,155		
Extraction Fugitive			
Crude Oil Refining	7,386	20.46	0.14
Processing Fugitive			
Transport	376	0.66	0.01
Transport Fugitive			
Total U.S. Diesel Fuel	**20,918**	**21**	**0**
U.S.Gasoline Fuel			
Crude Oil Production	11,533		
Extraction Fugitive			
Crude Oil Refining	13,232		
Processing Fugitive			
Transport	491		
Transport Fugitive			
Ethanol blending	-1,006		
Total WA. Gasoline Fuel	**24,251**	**0**	**0**

INPUTS - NO PROJECT

Diesel fuel storage pumping	Consumption, Estimate
Processing Step	**kWhel/mmBtu**
Pumping Diesel fuel from tank to vehi	0.01

Loss of LNG Peak Shaving - Boiler opera	Consumption, Estimate
Processing Step	**kWhel/mmBtu**
Pumping Diesel fuel from tank to boile	0.01

ENDUSE

Gig harbor Delivery

Distance for LNG delivery by Diesel Tru	miles
Project	17
No Project	175

Truck capacity	gallons/trip
Capacity per trip	10,000

Energy Consumption	BTU/mile
	17,738

Life Cycle Step	Mgal/ year	GBtu/ year	GHG Emissions tonne/year	GHG Emissions tonne/40 year	GHG Emissions kg/1000 gal
NEW LNG Plant					
Construction Emissions					
Total Construction			**1,581**	**63,232**	**18**
Direct (Equipment)			182	7,289	2.1
Upstream Life Cycle (Equipment)			20	812	0.2
Upstream Life Cycle (Power)			57	2,262	0.6
Upstream Life Cycle (Material)			1,322	52,869	14.9
Operational Emissions					
Upstream Life cycle			**103,949**	**4,157,958**	**1,171**
Natural Gas			77,208	3,088,319	870
Power LNG production			25,739	1,029,541	290
Diesel Emergency			143	5,730	2
Power LNG Vaporizer -Peak Shaving			859	34,369	10
Gig harbor Diesel truck fuel			0.0	0	0.00
Direct LNG Plant			**52,251**	**2,090,030**	**589**
LNG Production			46,714	1,868,553	526
Vaporizer -On-site Peak Shaving			942	37,674	11
Marine vessel bunkering, truck CH4			4,595	183,803	52
End Use LNG	**88.75**	**6,848**	**490,443**	**19,617,710**	**5,526**
On-site Peak Shaving	9.73	750	43,854	1,754,145	494
Gig harbor LNG	0.00	0	0.0	0	0
On-road Trucking	0.00	0	0	0	0
TOTE Marine	37.93	2,927	207,659	8,306,355	2,340
TOTE Marine Diesel Pilot fuel			7,000	279,992	79
Truck-to-Ship Bunkering	0.00	0	0	0	0
Truck-to-Ship Bunkering Pilot Fuel			0	0	0
Other Marine LNG (by Bunker Barge)	41.09	3,171	224,375	8,975,012	2,528
Other Marine Diesel Pilot Fuel			7,555	302,207	85
Total Emissions (Tacoma LNG)			**648,223**	**25,928,931**	**7,304**

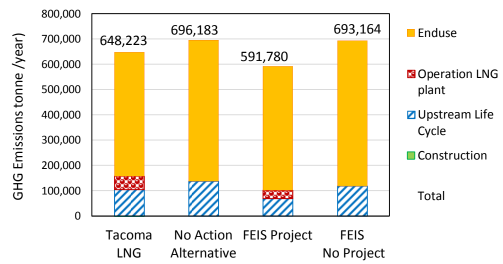
NO ACTION

Life Cycle Step	Mgal/ year	GBtu/ year	GHG Emissions tonne/year	GHG Emissions tonne/40 year	GHG Emissions kg/1000 gal
Upstream Displaced Emissions					
Total Upstream			**137,573**	**5,502,902**	**1,550.11**
No Peak Shaving - Diesel Dual Fuel		750	16,127	645,097	182
Upstream Gig harbor Peak Shaving		0	0	0	0.00
Upstream On-road trucking		0	0	0	0
Upstream TOTE Marine Diesel		3014	64,775	2,591,007	730
Upstream Truck-to-Ship Bunkering		0	0	0	0
Upstream Other Marine Diesel (by Bunker Barge)		3257	56,670	2,266,797	639
End Use Emissions					
Total End Use Diesel /Fuel Oil/LNG	**55.1**	**7,022**	**558,611**	**22,344,434**	**6,294**
Diesel Peak Shaving for Power	5.89	750	58,891	2,355,620	664
Gig harbor LNG	0.00	0	0	0	0.00
On-road Trucking	0.00	0	0	0	0
TOTE Marine Diesel	23.65	3,014	240,326	9,613,048	2,708
Truck-to-Ship Bunkering	0.00	0	0	0	0
Other Marine Diesel (by Bunker Barge)	25.55	3,257	259,394	10,375,765	2,923
Total Emission (No Action)			**696,183**	**27,847,335**	**7,844**
Net Emission reduction			**-47,960**	**-1,918,404**	**-540**
in percentage			-6.89%	-6.89%	-6.89%

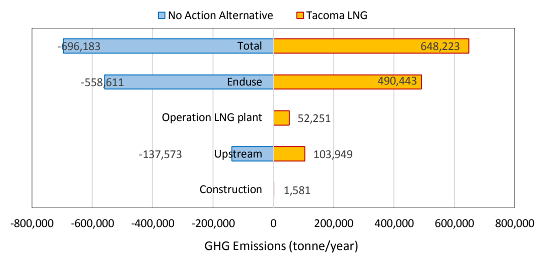
Short tables

Life Cycle Step	Mgal/ year	GBtu/ year	GHG Emissions tonne/year	GHG Emissions tonne/40 year	GHG Emissions kg/1000 gal
Tacoma LNG					
Construction			**1,581**	**63,232**	**18**
Upstream Life cycle			**103,949**	**4,157,958**	**1,171**
Direct LNG Plant			**52,251**	**2,090,030**	**589**
End Use LNG	**88.75**	**6,848**	**490,443**	**19,617,710**	**5,526**
On-site Peak Shaving	9.73	750	43,854		
Gig harbor LNG	0.00	0	0		
On-road Trucking	0.00	0	0		
TOTE Marine	37.93	2927	207,659		
TOTE Marine Diesel Pilot fuel	0.00	0	7,000		
Truck-to-Ship Bunkering	0.00	0	0		
Truck-to-Ship Bunkering Pilot Fuel			0		
Other Marine LNG (by Bunker Barge)	41.09	3171	224,375		
Other Marine Diesel Pilot Fuel			7,555		
Total	**88.75**	**6,848**	**648,223**	**25,928,931**	**7,304**
NO ACTION					
Upstream Life Cycle			**137,573**	**5,502,902**	**1,550**
Total End Use Diesel /Fuel Oil/LNG	**55.09**	**7,022**	**558,611**	**22,344,434**	**6,294**
Diesel Peak Shaving for Power	5.89	750	58,891		
Gig harbor LNG	0.00	0	0		
On-road Trucking	0.00	0	0		
TOTE Marine Diesel	23.65	3,014	240,326		
Truck-to-Ship Bunkering	0.00	0	0		
Other Marine Diesel (by Bunker Barge)	25.55	3,257	259,394		
Total	**55.09**	**7,022**	**696,183**	**27,847,335**	**7,844**
Net Emissions		-6.89%	**-47,960**	**-1,918,404**	**-540**
				-6.89%	-6.89%

GHG Emissions (tonne/year)	Tacoma LNG	No Action Alternative	FEIS Project	FEIS No Project
Construction	1,581			
Upstream Life Cycle	103,949	137,573	69,299	119,238
Operation LNG plant	52,251	0	33,539	0
Enduse	490,443	558,611	488,942	573,926
Total	648,223	696,183	591,780	693,164
Net Emissions	**-47,960**		-101,385	
	-0.068890041		-14.63%	



GHG Emissions (GBtu/ year)	No Action Alternative	Tacoma LNG	Net Emissions
Construction		1,581	
Upstream	-137,573	103,949	
Operation LNG plant	0	52,251	
Enduse	-558,611	490,443	
Total	-696,183	648,223	-47,960



Direct End Use Scenario: 250,000 gal/year

			Consumption					
Scenario A	**LNG Enduse**	**Equipment Type**	**Mgal/yr**	**GBtu, LHV/yr**	**EER**	**Btu/gal**		
	Power Peak Shaving							
	LNG	Dual Fuel Turbine	9.73	750	1	77,156	9.726027	
	Displaced Diesel	Dual Fuel Turbine	5.89	750		127,464	5.88731	
	Gig Harbor LNG							
	LNG	NG Boiler	0.00	0	1	77,156	1.775	
	LNG	NG Boiler	0.00	0		77,156	1.775	
	On-road Trucking							
	LNG	Truck Engine	0.00	0	0.9	77,156	3.55	ARB LNG Pathway document
	Diesel	Truck Engine	0.00	0		127,464	1.933981	
	TOTE Marine							
loss factor	LNG	Marine Engine	37.93	2,927	1	77,156	37.93151	
	Pilot diesel Fuel for LNG	Marine Engine	0.69	88	1	127,464	0.625559	
	Displaced MDO Fuel	Marine Engine	23.65	3,014		127,464	21.47753	
	Truck-to-Ship Bunkering							
loss facor	LNG	Marine Engine	0.00	0	1	77,156	1.775	
	Pilot Fuel for LNG	Marine Engine	0.00	0		127,464	0.029273	
	Displaced MDO Fuel	Marine Engine	0.00	0		127,464	1.005038	
	Other Marine (by Bunker Barge)							
	LNG	Marine Engine	41.09	3,162	1	77,156	122.7423	
	Pilot Fuel for LNG	Marine Engine	0.74	95	1	127,464	2.024243	
	Displaced MDO Fuel	Marine Engine	25.55	3,257		127,464	69.49901	
	Total LNG		88.750	6,839				

T 4.2

			Emissions (tonne/year)						
	Scenario A								
	GHG Emissions	**Equipment Type**	**CO_2c**	**CH_4**	**N_2O**	**CO_2e**		B	
	Power Peak Shaving								
	LNG	Duct Firing	43,755	1	0.26	43,854		43853.64	
	Diesel	Duct Firing	58,682	0	0.69	58,891		58890.5	
	Gig Harbor Delivery								
Diesel	LNG Tacoma	Truck Engine	0	0	0.00	0.0		4.200144	
Diesel	LNG	Truck Engine	0	0	0.00	0		43.17362	
	LNG Tacoma End Use	NG Boiler	0	0	0	0		8143.21	
	LNG End Use	NG Boiler	0	0	0	0		8143.21	
	On-road Trucking								
	LNG	Truck Engine	0	0	0.00	0		17862.04	
	Diesel	Truck Engine	0	0	0.00	0		19315.93	
	TOTE Marine								
	LNG	Marine Engine	157,787	1,864	11	207,659		226164.6	
	Pilot fuel	Marine Engine	6,899	0	0.33	7,000		7611.397	
	MDO Fuel	Marine Engine	236,870	4	11.29	240,326		261324.6	
	Truck-to-Ship Bunkering								
	LNG incl. Pilot fuel	Marine Engine	0	0	0.00	0		10575.31	
	Pilot fuel	Marine Engine	0	0	0.00	0		356.1743	
	Diesel Truck	Truck Engine	0	0	0.00	0	NET 0 difference	0	
	MDO Fuel	Marine Engine	0	0	0.00	0		12228.65	
	Other Marine (by Bunker Barge)								
	LNG	Marine Engine	170,489	2,014	12	224,375		70955.01	Marine Fuel + Operations losses
	Pilot fuel	Marine Engine	7,455	0	0.33	7,555		24399.05	
	MDO Fuel	Marine Engine	255,938	4	11.29	259,394		837700.8	

Assume barge delivers MDO for displaced emissions

Scenario A		
LNG Enduse	**Mgal/yr**	**GBtu, LHV/yr**
Power Peak Shaving	9.73	750
Gig Harbor LNG	0.00	0
On-road Trucking	0.00	0
TOTE Marine	37.93	2,927
Truck-to-Ship Bunkering	0.00	0
Other Marine (by Bunker Barge)	41.09	3,162
Total LNG	88.750	6,839

Tacoma LNG Emissions

Scenario A		Emissions (tonne/year)				
LNG Project	**Equipment Type**	**CO_2c**	**CH_4**	**N_2O**	**CO_2e**	
On-site Peak Shaving						
LNG	Dual Fuel Boiler	43,755	1	0	43,854	
Gig harbor Delivery						
LNG Tacoma	Truck Engine	0	0	0	0	
LNG Tacoma End Use	NG Boiler	0	0	0	0	
On-road Trucking						
LNG	Truck Engine	0	0	0	0	
TOTE Marine						
LNG	Marine Engine	157,787	1,864	11	207,659	
Pilot fuel	Marine Engine	6,899	0	0	7,000	
Truck-to-Ship Bunkering						
LNG incl. Pilot fuel	Marine Engine	0	0	0	0	
Pilot fuel	Marine Engine	0	0	0	0	
Diesel Truck	Truck Engine	0	0	0	0	NET 0
Other Marine (by Bunker Barge)						
LNG	Marine Engine	170,489	2,014	12	224,375	
Pilot fuel	Marine Engine	7,455	0	0	7,555	
Total End Use		**386,385**	**3,879**	**24**	**490,443**	

Non Action

Scenario A		Emissions (tonne/year)			
NO LNG Project	**Equipment Type**	**CO_2c**	**CH_4**	**N_2O**	**CO_2e**
On-site Peak Shaving					
Diesel - Upstream		15,697	15.8	0.1	16,125
Diesel - Power pumping		2	0.0	0.0	2
Diesel - End use	Dual Fuel Boiler	58,682	0.1	0.7	58,891
Gig harbor Delivery					
LNG	Truck Engine	0	0.0	0.0	0
LNG End Use	NG Boiler	0	0.0	0.0	0
On-road Trucking					
Diesel	Truck Engine	0	0.0	0.0	0
TOTE Marine					
MDO - Upstream		63,055	63.6	0.4	64,775
MDO fuel	Marine Engine	236,870	3.6	11.3	240,326
Truck-to-Ship Bunkering					
MDO Fuel	Marine Engine	0	0.0	0.0	0
Other Marine (by Bunker Barge)					
MDO - Upstream		55,679	36.4	0.3	56,670
MDO fuel	Marine Engine	255,938	3.6	11.3	259,394
Total End Use		**670,224**	**107**	**24**	**680,056**

Scenario A		Emissions (tonne/year), LHV			
NO LNG Project	**Equipment Type**	**CO_2c**	**CH_4**	**N_2O**	**CO_2e**
On-site Peak Shaving					
Diesel - Upstream		15,697	16	0	16,125
Diesel - Power pumping	Power	2	0	0	2
Diesel - End use	Dual Fuel Boiler	58,682	0	1	58,891
Total		**74,380**	**16**	**1**	**75,017**

LCA

Natural Gas upstream	Emissions (g/mmBtu), LHV			
Processing Step	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Natural Gas Extraction	2,356	8.9	0.021	2,584
Extraction Fugitive	0	135.7	0.000	3,394
Natural Gas Processing	1,845	4.4	0.014	1,959
Processing Fugtive	778	6.8	0.000	948
Transmission & Storage	377	13.7	0.295	807
Transmisison Fugitive	0.0	19.2	0.000	480
Total Natural Gas	**5,355**	**189**	**0.3**	**10,172**

Energy Input/Output: Based on 250,000 gal/day	NG Feed	LNG Output	ratio NG/LNG	NG Btu/gal LNG	
NG Feed (lb/day)	1,012,995	907,013	1.1168		with Loss Factor
LHV (based on mass ratio see INPUT	21,348	19,285	1.107	85,407	85,528
LHV, Btu/gal	21,074	21,262			

Natural Gas upstream LNG	GHG Emissions (kg/1000 gal LNG)				
	CO_2	**CH_4**	**N_2O**	**CO_2e**	just CH4
Natural Gas upstream	458.0	16.1	0.0	869.9	403.5
					35,813
					179,064

Power generation			Emissions (g/kWh)			
Processing Step	**Code**		**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Washington	WAUP	Upstream	8.2	0.3800	0.0010	18
	WAPP	Power Plants	196.0	0.0100	0.0030	197
Tacoma	TAUP	Upstream	1.3	0.0454	0.0001	2
	TAPP	Power Plants	27.4	0.0003	0.0003	27
Marginal	MAUP	Upstream	19.7	0.6462	0.0026	37
	MAPP	Power Plants	212.3	0.0090	0.0014	213
eGRID NWPP	NWUP	Upstream	11.5	0.5569	0.0010	26
	NWPP	Power Plants	297.2	0.0107	0.0047	299
Selected GEN MIX	**WA**					
Washington	**WAUP**	**Upstream**	**8.2**	**0.3800**	**0.0010**	**18**
	WAPP	**Power Plants**	**196.0**	**0.0100**	**0.0030**	**197**

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**

Power Consumption LNG Production	Baseline	GHG Emissions (kg/1000 gal LNG)			
Power (kWh/1000 gal)	1348	CO_2	CH_4	N_2O	CO_2e
Mix	**WA**	**275.3**	**0.5**	**0.0**	**290.0**

Power Consumption Vaporizer/ Peak Shaving	Baseline	GHG Emissions (kg/1000 gal LNG)			
Power (kWh/1000 gal)	45	CO_2	CH_4	N_2O	CO_2e
Mix	**WA**	**9.2**	**0.0**	**0.0**	**9.7**

Comparision to reported values

Provided BID Report page 4

Natural Gas upstream	Emissions (g/mmBtu), LHV			
Processing Step	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Natural Gas Production & Processing	6,030	45.5	0.160	7,215
Transmission & Storage	824	5.9	0.0	977
Natural Gas Distribution	10	2.3	0	68
Total	6,864	53.70	0.18	8,260
Total Ex-Distribution	**6,854**	**51.40**	**0.18**	**8,193**

Source: Provided Report BID page 14

Table 9. Tacoma Power Generating Mix (2016)

Fuel Type	Percentage Used
Hydro Power	84%
Nuclear*	6%
Coal*	2%
Natural Gas	1%
Wind	7%

*Represents a portion of the power Tacoma Power gets from the Bonneville Power Administration.

Table 10. Upstream GHG Emissions Associated With Facility Electrical Energy Use

Source: Provided Report BID page 14

Power Consumption LNG Production		Upstream Emissions from Tacoma Power Supply							
		VOC	CO	NOx	BC	OC	CH4	N2O	CO2
Emissions Rate	grams/mmBTUel	0.65	1.63	3.83	0.02	0.05	10.92	0.09	5942.00
per Power	g/kWhel	0.00	0.01	0.01	0.00	0.00	0.04	0.00	20.27
Emissions Rate	g/mmBTU LNG	0.04	0.101	0.237	0.001	0.003	0.674	0.006	367.1
of End product	**kg/ 1000 gal**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**27.99**

NO PROJECT

Diesel fuel storage pumping	Consumption, Estir	Emissions (g/mmBtu), LHV			
Processing Step	**kWhel/mmBtu**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Pumping Diesel fuel from tank to vehicle	0.01	2.042	0.004	0.000	2.151
Total		2.042	0.004	0.000	2.151

NO PROJECT

Loss of LNG Peak Shaving - Boiler operation with	Consumption, Estir	Emissions (g/mmBtu), LHV			
Processing Step	**kWhel/mmBtu**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Pumping Diesel fuel from tank to boiler	0.01	2.042	0.004	0.000	2.900
Total		2.042	0.004	0.000	2.900

Crude Oil Resource Mix	U.S. Average	WA
API Gravity	31.2	30.8
Imported Oil	43.80%	37.10%
Canadian Oil Sands	10.30%	13.20%
Refinery Efficiency		
Residual Oil	94.83%	94.80%
Diesel	90.92%	90.90%
Product Transport		
% Marine Vessel	29.02%	46.00%
Average Distance	8,373.0	2,470.0

	Emissions (g/mmBtu), LHV			
Processing Step	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
WA. Bunker Fuel				
Crude Oil Production	12,627	0	0	12,627
Extraction Fugitive	0	0	0	0
Crude Oil Refining	4,049	10.491	0.073	4,333
Processing Fugitive	0	0.000	0.000	0
Transport	419	0.692	0.009	439
Transport Fugitive	0	0.000	0.000	0
Total U.S. Bunker Fuel	**17,095**	**11.18**	**0.082**	**17,399**
WA Diesel Fuel				
Crude Oil Production	13,155	0	0.0	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 U.S. Diesel Fuel	**20,918**	**21.11**	**0.144**	**21,488**
WA.Gasoline Fuel				
Crude Oil Production	11,533	0.0	0.0	11,533
Extraction Fugitive	0	0.0	0.0	
Crude Oil Refining	13,232	0.0	0.0	13,232
Processing Fugitive	0	0.0	0.0	
Transport	491	0.0	0.0	491
Transport Fugitive	0	0.0	0.0	
Ethanol blending	-1,006	0.0	0.0	-1,006
Total WA. Gasoline Fuel	**24,251**	**0.0**	**0.0**	**24,251**

PROJECT

Diesel fuel for emergency genset	Consumption	Emissions (kg/1000 gal), LHV			
Processing Step	**mmBtu/ 1000 gal LNG**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Upstream Diesel production	0.0751137	1.57	0.00	0.00	1.6
Total		2	0	0	1.6

PROJECT

Gig Harbor Diesel Truck fuel

Upstream Diesel production	Consumption	Emissions (tonne/yr), LHV			
Processing Step	**mmBtu/year**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
LNG Project	0.00	0.00	0.00	0.00	0.00

Upstream GHG Emissions for Tacoma LNG

Pollutant	CO_2	CH_4	N_2O	CO_2e	Use Rate	
Emissions (kg/1000 gal), LHV						
Upstream Natural Gas	458.0	16.1	0.0	869.9	85,528	Btu/gal
Upstream Power LNG production	275.3	0.5	0.0	290.0	1.35	kWh/gal
Upstream Diesel Emergency	1.57	0.00	0.00	1.6	75.1	Btu/gal
Upstream Power LNG Vaporizer	9.2	0.0	0.0	9.7	0.045	kWh/gal
Total Upstream	**744.0**	**16.7**	**0.0**	**1171.3**		

NO PROJECT

	Upstream LNG/Diesel/Bunker fuel production	Consumption		Emissions (tonne/yr)			
	Processing Step	**GBtu/year**	**Fuel**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
D	No Peak Shaving - Diesel Boiler operation	750	Diesel	15,697	16	0.11	16,125
N	Gig harbor NG & LNG production	0	Natural Gas	0	0.0	0.0	0
D	Gig harbor Diesel truck fuel	0.00	Diesel	0.0	0.00	0.00	0.0
D	Diesel Storage On-road trucking	0	Diesel	0	0.0	0.00	0
B	TOTE Marine Diesel	3,014	MDO	63,055	64	0.43	64,775
B	Truck-to-Ship Bunkering	0	MDO	0	0.0	0.00	0
D	Other Marine Diesel	3,257	MDO	55,679	36	0.27	56,670
	Total			134,431	116	0.8	137,570
							137,573

DO NOT PRINT

Tacoma LNG Plant

Total NG end use	**6,839**	**GBtu, LHV/year**
On-site Peak Shaving	750	GBtu, LHV/year
LNG Output	6,089	GBtu, LHV/year

LNG Preatreatment

Operational hours	8,520	hr/yr
NG WPG heater	9	mmBtu/hr
	76,680	mmBtu/year
NG Regenerator heater	1.6	mmBtu/hr
	13,632	mmBtu/year
Total Annual Consumption	**90,312**	**mmBtu/year**
CO2 seperation efficiency	99.76%	

Waste gas Flare

Operational hours	8,760	hr/yr
Waste Gas Flow	40,417	scf/hr
Waste Gas Heat Capacity	35.6	mmBtu/hr
Total Heat Input	**311,856**	**mmBtu/yr**
Seperated CO2		

Vaporizer

Operational hours	240	hr/yr
LNGg Heater Capacity	66.00	mmBtu/hr
Total Consumption	15,840	mmBtu Fuel gas
Power requir. (Grid)	0.04500	kWh/gal
	0.00347	kWhel/mmBtu

(estimate need of 1830 Btu/gal LNG)

Emergency equipment

Diesel geneartor ULSD		
Operational hours	500	hr/yr
Capacity	1,500	kW
Electricity generation	750,000	kWh/yr
Diesel consumption	104.6	gal/h
	52,300	gal/year
	6,666	mmBtu/year
	164.3	tonne/year

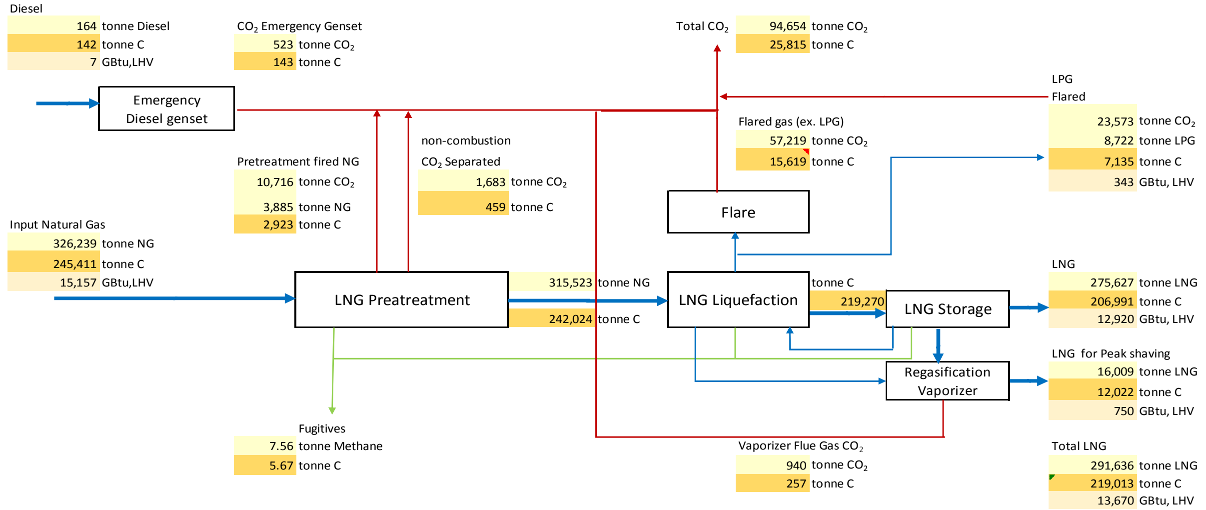
Liquefaction

Power require. (Grid)	1.35	kWh/galLNG
Operational hours Liqu.	8,520	hr/year

Fugitives - Refrigerant losses through Compressor Seals

	tonne/year
Methane	3.78

Annual throughput



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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.

This way ---->

Carbon Mass balance

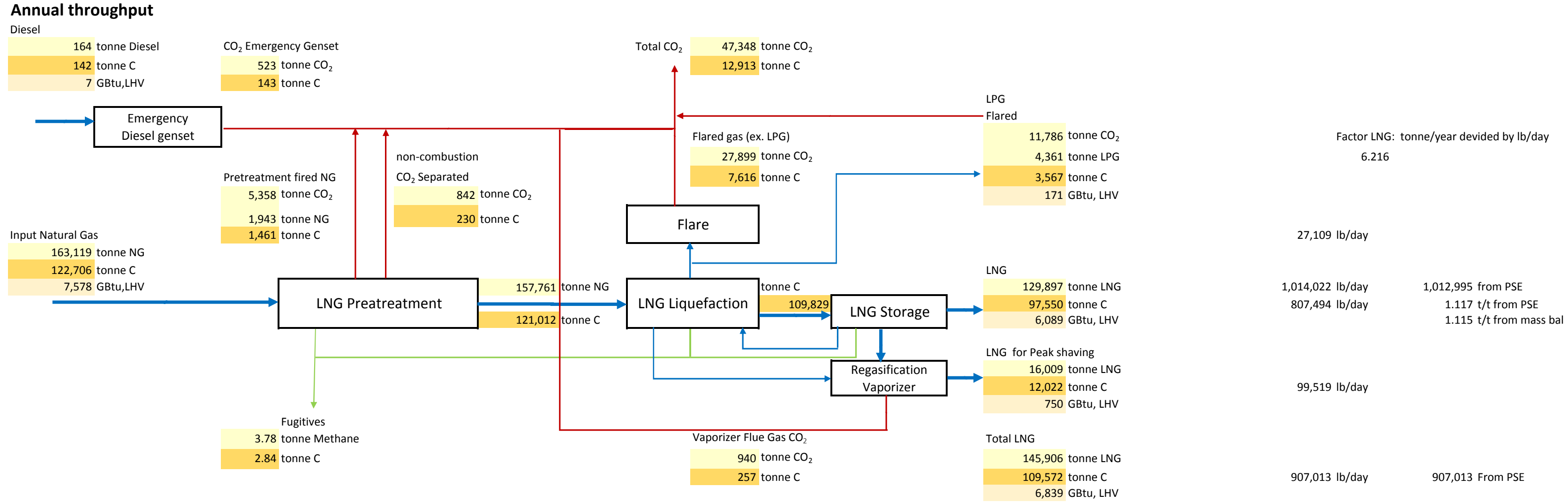
	Input,ouput		CO_2	Methane	**C content**		
	lb/day	tonne/yr	tonne/yr	tonne/yr	**tonne/yr**	**Comments**	**Source**
Input NG							
Natural gas	1,012,995	163,119			**122,706**		
Total NG Input	1,012,995	163,119			**122,706**		
Products							
LPG, estimated	0	0			**0**	A	
LNG	907,013	145,906			**109,572**		
Total Products	907,013	145,906			**109,572**		
Emissions							
Pretreatment			5,358		**1,461**		Heater fired by NG and boil off gas (BOG). BID response p8.- 9 page 12 PSE-BID
CO_2 Separated (non-combustion)			842		**230**	B	Using Gas composition and given separation efficiecy
Flaring (combustion)			27,057		**7,616**		Flaring is used to close C-Balance
Flaring from LPG (combustion)			11,786		**3,567**		Using gas composition calculation and EF of LPG boiler (no flar data)
Fugitives CH_4				3.78	**3**		Using given inventoru see Sheet Fugitives **95**
Vaporizing onside peak shaving			940		**257**		Boiler primary fuel is NG. However, the fuel gas mix can include compressed boil-off gas (BOG) . BID response p.9
Total Emissions			45,983	4	**13,133**		
Total Product + Emissions			45,983	4	**122,706**		
Total NG Input - Product + Emissions					**0**		

Comments:

A: How much LPG is produced as product? LPG production is not mentioned in the Response.

B: In the FEIS report page 103 the value is 10,703tonne/year. Could you clarify this?

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

LNG PLANT

Direct Combustion Emission Rate		Emission Factor (g/mmBtu), LHV			
Process	Equipment	CO_2	CH_4	N_2O	CO_2e
LNG Pretreatment	Boiler, NG	59,330	1.06	0.35	59,461
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
Vaporizer	Boiler, NG	1,252	0.02	0.01	1,255
Vaporizer	Pump Power	1	0.00	0.00	1.0

Flare Check

27,066

		Emissions (tonne/year)			
Process	Equipment	CO_2	CH_4	N_2O	CO_2e
LNG Pretreatment	Boiler, NG	5,358	0.10	0.03	5,370
Waste Gas Flaring	Flare	27,899	0.43	0.43	28,039
LPG flaring	Flare	11,786	0.18	0.18	11,846
Emergency Generator	Diesel Genset	521	0.03	0.00	523
Non-combustion C02 from pretrea	Vent/flare	842	0.00	0.00	842
Fugitives	Equip. Leaks	0	3.78	0.00	95
Sub - Total		**46,406**	**5**	**1**	**46,714**
Vaporizer	Boiler	940	0	0	942
Vaporizer	Pump - power	0.7	0.0	0.0	0.8
Fugitives					
Fugitives Ship/Barge Loading	Equip. Leaks	0.0	6.9	0.0	171.7
Fugitives - Bunker Vessel Storage	Equip. Leaks	0.0	176.9	0.0	4,423.4
Fugitives - Truck to Ship	Equip. Leaks	1.0	0.0	1.0	0.0
Total		**47,348**	**188**	**2**	**52,252**

Info for Table

	Specific Emission g/mmBtu (LNG product)			
Process	CO_2	CH_4	N_2O	CO_2e
LNG Pretreatment	783.4	0.0	0.0	785.2
Emission from flaring (co	4079.2	0.1	0.1	4099.7
Emission from LPG flaring	1723.4	0.0	0.0	1732.0
Emergency Generator	76.2	0.0	0.0	76.5
Non-combustion C02 fron	123.1	0.0	0.0	123.1
Fugitives	0.0	0.6	0.0	13.8
Sub - Total	**6785.3**	**0.7**	**0.1**	**6830.2**
Total	6,923	28	0	7,640

		Emissions (tonne/year)			
Process	Equipment	CO_2	CH_4	N_2O	CO_2e
Vaporizer	Boiler	940	0	0	942
Vaporizer	Pump - power	0.7	0.0	0.0	0.8

BUNKERING

LNG Bunkering and Vessel loading Emissions	CH_4 (g/mmBTU delivered)	CO_{2e} (g/mmBTU delivered)	Fraction of Gas Delivered by this Process
Ship/Barge Loading	2.4	58.82	100%
Bunker Vessel Storage	6.4	160	52%
Truck/Ship-to-Ship Transfer	0.0	0	0%
Total	8.8	142	
GREET			

Explain losses

10000 gal
0.5 L
0.2 g
0.00025

loss

Loss Factor	0.1413% Gas lost through the system
Net Delivered LNG	380,000 gallons per typical bunkering event

Bunker Barge Loading

Vapor Displaced	Recovery Rate	Loss per Bunkering Event	Volume per Bunkering Event (gallons)	Volume Lost per Bunkering Event (gallons)	CH_4 Emissions (g/mmBTU)	CO_{2e} Emissions (g/mmBTU)
0.22%	95.00%	0.011%	380,994	41.9	2.4	59

Bunker Vessel Storage

New ships have 0.1% loss

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 Emissions (g/mmBTU)	CO_{2e} Emissions (g/mmBTU)
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 Emissions (g/mmBTU)	CO_{2e} Emissions (g/mmBTU)
0.22%	0.00%	0.22%	380,838	838	47.0	1,176

Bunkering and Transfer Fugitives	Volume (LNG gallons/year)	Loss Factor	CH_4 Emissions (LNG Gallons/year)	CH_4 Emissions (tonne/ year)	CO_{2e} Emissions (tonne/year)	Check if exist
TOTE	37,931,507	0.0110%	4,173	7	172	1
Other Bunker Barge	41,092,466	0.2616%	107,493	177	4,423	1
Truck-to-Ship Bunkering	0	0.2205%	0	0	0	0
Total	**79,023,973**	**0.1413%**	**111,666**	**184**	**4,595**	

https://www.marad.dot.gov/wp-content/uploads/pdf/Methane-emissions-from-LNG-bunkering-20151124-final.pdf

Source: 2018-05-25 PSE Submittal page 78, table LNG Bunkering Emissions
see also https://www.marad.dot.gov/wp-content/uploads/pdf/Methane-emissions-from-LNG-bunkering-20151124-final.pdf

TOTAL

Total LNG plant emission	Emissions (tonne/year)					2 x	
	CO_2	**CH_4**	**N_2O**	**CO_2e**	**C**	**CO_2e FEIS**	See: BID p 12, and also BID REPORT, ATTACHMENT F (1 page)
LNG Pretreatment Boiler	5,358	0.10	0.03	5,370	1,464	9,860	uses EF of 53.06 kg/mmBtu for NG See EXCEL 2018 05-25 Tacoma L
Pretreatment CO2	842			842	230		
Flare waste Gas	27,899	0	0	28,039	7,617	56,262	FEIS uses EF provided by CB&I and flare vendor See EXCEL 2018 0!
Flare LPG	11,786	0	0	11,846	3,218	Included above	
Fugitives	0	3.78	0.00	95	5	190	
Emergency Generator	521	0.03	0.00	523	143	536	
Sub-Total	**46,406**	**4.52**	**0.65**	**46,714**	**12,677**	0.0	0 Waste gas for heater
Vaporizer	940	0.02	0.01	942	257		
Marine Vessel Bunkering, truck	0	183.80	0.00	4,595	185	1,684	
Total	**47,346**	**4.54**	**0.66**	**47,656**	**12,934**	68,532	

Source: BID REPORT, ATTACHMENT F (1 page)

LNG plant	Emissions (tonne CO2e/year)			
	CO_2	**CH_4**	**N_2O**	**CO_2e**
Flare	27,110	40.0	0.0	28,131
Vaporizer	841	0.0	0.0	842
WPG	4,183	0.1	0.0	4,186
Regen	744	0.0	0.0	744
Diesel Generator	534	0.0	0.0	536
Fugitives	--		--	95
Total	**33,411**	**41**	**0**	**34,533**

Propane Volume
12284 kg/day
6388 gal/day

Energy Efficiency

Input	Unit	Tacoma	CA_GREET
NG	lb/lb LNG	1.117	1.109
Electricity	kWh/1000 gal LNG	1,348.00	43.89

Adjust results to 355 days of operation instead of 365, 88.75 Mgal/year inestead of 91.25 Mgal/ 0.97260274

Scenario A	Project			No Project			Project			No Project		
	Fuel Throughput (MMBTU/year)	Loss Factor	GHG Emissions (MT CO2e/year)	Fuel Throughput (MMBTU/year)	Loss Factor	GHG Emissions (MT CO2e/year)	Fuel Throughput (MMBTU/year)	Loss Factor	GHG Emissions (MT CO2e/year)	Fuel Throughput (MMBTU/year)	Loss Factor	GHG Emissions (MT CO2e/year)
Extraction, processing, and transmission to Sumas hub	7,269,653	0.00%	59,563	748,262	0.00%	6,131	**7,070,485**	**0.00%**	**57,931**	**727,762**	**0.00%**	**5,963**
Transmission from Sumas Hub to PSE gate	7,266,233	0.05%	5,888	747,910	0.05%	606	**7,067,158**	**0.05%**	**5,727**	**727,419**	**0.05%**	**589**
Distribution via PSE System	7,259,336	0.095%	3,483	747,200	0.095%	359	**7,060,450**	**0.092%**	**3,388**	**726,729**	**0.092%**	**349**
Liquefaction	6,818,200	6.47%	36,800	0		0	**6,631,400**	**6.29%**	**35,792**	**0**	**0**	**0**
Direct Facility Emissions (includes Peak Shaving)	*6,818,200*		*34,483*	*0*		*0*	*6,631,400*	*0.00%*	*33,539*	*0*	*0*	*0*
Electricity Supply	*6,818,200*		*2,317*	*0*		*0*	*6,631,400*	*0.00%*	*2,253*	*0*	*0*	*0*
Vessel Loading of LNG	6,071,000		14,497	0		0	**5,904,671**	**0**	**14,100**	**0**	**0**	**0**
TOTE	*2,914,080*	0.011%	174	*0*		*0*	*2,834,242*	0.011%	169	*0*	*0*	*0*
Bunker Barge	*3,156,920*	0.837%	14,323	*0*		*0*	*3,070,429*	0.814%	13,930	*0*	*0*	*0*
Truck-to-Vessel	*0*	0.220%	0	*0*		*0*	*0*	0.214%	0	*0*	*0*	*0*
On-road Heavy-duty Truck Fuel	0		0	0		0	**0**	**0**	**0**	**0**	**0**	**0**
LNG (Plant-to-Tank Emissions)	*0*	*0.47%*	*0*	*0*		*0*	*0*	*0.46%*	*0*	*0*	*0*	*0*
LNG (Tank-to-Wheels Emissions)	*0*		*0*	*0*		*0*	*0*	*0.00%*	*0*	*0*	*0*	*0*
ULSD (Well-to-Wheels Emissions)	*0*		*0*	*0*		*0*	*0*	*0*	*0*	*0*	*0*	*0*
TOTE Vessel Operations	3,001,172		235,355	6,002,344		340,146	**2,918,948**	**0**	**228,907**	**5,837,897**	**0**	**330,827**
TOTE LNG (Direct Vessel Emissions)	*2,913,759*		*233,733*	*0*		*0*	*2,833,930*	*0*	*227,330*	*0*	*0*	*0*
TOTE Pilot Fuel Oil (Well-to-Tank Emissions)	*87,413*		*1,622*	*0*		*0*	*85,018*	*0*	*1,577*	*0*	*0*	*0*
TOTE Fuel Oil (Well-to-Tank Emissions)	*0*		*0*	*3,001,172*		*55,680*	*0*	*0*	*0*	*2,918,948*	*0*	*54,154*
TOTE Fuel Oil (Direct Vessel Emissions)	*0*		*0*	*3,001,172*		*284,466*	*0*	*0*	*0*	*2,918,948*	*0*	*276,672*
Other Vessel Operations	3,224,427		252,863	3,224,427		365,449	**3,136,086**	**0**	**245,935**	**3,136,086**	**0**	**355,437**
Other LNG (Direct Vessel Emissions)	*3,130,511*		*251,121*	*0*		*0*	*3,044,744*	*0*	*244,241*	*0*	*0*	*0*
Other Pilot Fuel Oil (Well-to-Tank Emissions)	*93,915*		*1,742*	*0*		*0*	*91,342*	*0*	*1,695*	*0*	*0*	*0*
Other Fuel Oil (Well-to-Tank Emissions)	*0*		*0*	*3,224,427*		*59,822*	*0*	*0*	*0*	*3,136,086*	*0*	*58,183*
Other Fuel Oil (Direct Vessel Emissions)	*0*		*0*	*3,224,427*		*305,627*	*0*	*0*	*0*	*3,136,086*	*0*	*297,254*
Total			**608,449**			**712,690**	**0**	**0**	**591,780**	**0**	**0**	**693,164**

Summary of Terminal Construction Emissions - GHG PSE LNG

Equipment (Direct + Upstream)	CO_2 (tonne/ year)	CH_4 (tonne/ year)	N_2O (tonne/ year)	CO_2e (tonne/ year)
1. Year - Construction Equipment	1,807	0.1	0.01	1,814
1. Year - Road Vehicles/Commuting	3	0.0	0.00	3
1. Year - Fugitive Dust				0
1. Year - Total Emissions	1,811	0.1	0.01	1,817
2. Year - Construction Equipment	3,638	0.3	0.03	3,654
2. Year - Road Vehicles/Commuting	298	0.0	0.00	298
2. Year - Fugitive Dust				0
2. Year - Total Emissions	3,936	0.3	0.03	3,953
3. Year - Construction Equipment	2,838	0.2	0.03	2,852
3. Year - Road Vehicles/Commuting	404	0.0	0.00	405
3. Year - Fugitive Dust				0
3. Year - Total Emissions	3,242	0.2	0.03	3,257
4. Year - Construction Equipment	1,655	0.1	0.02	1,664
4. Year - Road Vehicles/Commuting	2	0.0	0.00	2
4. Year - Fugitive Dust				0
4. Year - Total Emissions	1,657	0.1	0.02	1,666
Project TOTAL:	**10,646**	**0.8**	**0.09**	**10,692**

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
4. 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**

Equipment (Upstream)	CO_2 (tonne/ year)	CH_4 (tonne/ year)	N_2O (tonne/ year)	CO_2e (tonne/ year)
1. Year - Construction Equipment	104	0.1	0.00	107
1. Year - Road Vehicles/Commuting	1	0.0	0.00	1
1. Year - Fugitive Dust				0
1. Year - Total Emissions	105	0.1	0.00	108
2. Year - Construction Equipment	221	0.2	0.00	228
2. Year - Road Vehicles/Commuting	72	0.0	0.00	72
2. Year - Fugitive Dust				0
2. Year - Total Emissions	293	0.2	0.00	299
3. Year - Construction Equipment	189	0.2	0.00	195
3. Year - Road Vehicles/Commuting	97	0.0	0.00	97
3. Year - Fugitive Dust				0
3. Year - Total Emissions	286	0.2	0.00	292
4. Year - Construction Equipment	110	0.1	0.00	113
4. Year - Road Vehicles/Commuting	0	0.0	0.00	0
4. Year - Fugitive Dust				0
4. Year - Total Emissions	111	0.1	0.00	114
Project TOTAL:	**795**	**0.6**	**0.00**	**812**

Operation hours per month	205.44

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_2c 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 Tot	1,703	0.0178	0.0115	1707.1	4969	103.9	0.1	0.0	106.8	1,813.9

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 Tot	3,417	0.0486	0.0298	3427	10587.4376	221.4642	0.2235	0.0015	227.5070	3,654

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 Tota	2,649	0.0428	0.0260	2,658	9,052	189	0	0	195	2,852

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 Tota	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)

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**

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

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		26.6	0	0	0	0.00	0	0
Feb-1. Year	Winter 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		25.7	0	0	0	0.00	0	0
May-1. Year		26.6	0	0	0	0.00	0	0
Jun-1. Year	Summer 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		26.6	0	0	0	5.00	19	19
Nov-1. Year	Winter 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		26.6	0	0	0	0.00	0	0
Feb-2. Year	Winter 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		25.7	0	0	0	0.00	0	0
May-2. Year		26.6	0	0	0	0.00	0	0
Jun-2. Year	Summer 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		26.6	98	2,604	104,160	844.00	3,176	107,336
Nov-2. Year	Winter 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		26.6	98	2,604	104,160	888.00	3,342	107,502
Feb-3. Year	Winter 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		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	Summer 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		26.6	0	0	0	78.00	294	294
Nov-3. Year	Winter 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		26.6	0	0	0	39.00	147	147
Feb-4. Year	Winter 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		25.7	0	0	0	41.00	159	159
May-4. Year		26.6	0	0	0	39.00	147	147
Jun-4. Year	Summer 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		26.6	0	0	0	0.00	0	0
Nov-4. Year	Winter 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

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	38.00
	Summer	0	1225.00
2.Year	Winter	309,120	9999.00
	Summer	309,120	5789.00
3.Year	Winter	302,400	6356.00
	Summer	614,880	4160.00
4.Year	Winter	0	457.00
	Summer	0	306.00
Total		**1,535,520**	**28330.00**

Construction Material & Power- UPSTREAM Emissions -

Input	tonnes	Source
Steel	4,745	Response Tacoma LNG Supplementary SEIS Questions, July 07, 2018, page 5
Rebar	1666.0	
Stainless Steel	290.0	
Copper	26	
Asphalt	7570.0	
Paint	5.0	
Aggregate	80110.0	
Cement	1716.0	

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	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**	

Total power consumption during construction

Consumption	10,512,000	kWh

Source: Response Tacoma LNG Supplementary SEIS Questions, july 07, 2018, page 5

Upstream Emissions Power (see sheet Upstream, B40)

Gig Harbor Peak Shaving

General inputs		
Total LNG delivery to Gig Harbor per year	0	gal
Truck capacity	10,000	gal
Number of trips	0	

Calculation of Annual Diesel Truck Consumption	LNG Project	No project	
Distance to gig harbor	17	175	miles/trip
Annual miles for delivery	0	0	miles/year
Diesel consumption per mile	**17,738**	**17,738**	**Btu/mile**
Total Diesel Consumption	**0.00**	**0.00**	**mmBtu/year**

	Diesel Consumption	**Emissions (t/year)**			
Processing Step	**mmBtu/year**	**CO_2**	**CH_4**	**N_2O**	**CO_{2e}**
LNG Project	0.0	0.00	0.00000	0.00000	0.0
No project	0.00	0.00	0.00000	0.00000	0.0

On-road trucking

Annual Fuel delivery to tractors	Equipment	Consumption Mgal/year	GBtu/year
LNG	Tractor engine	0.00	0
Diesel	Tractor engine	0.00	0

Pathway Component	VOC	CO	NO_x	CH_4	N_2O	CO_2	CO_{2C}	Old value from BID CO_{2C}
	Emissions (g/MMBTU)							
Tank-to-Wheels LNG Combination Tractor	21.07	1,167	66.09	309.766737	0.03250653	55,559	57,459	57,458
Total LNG Tacoma -to-Wheels	**21.07**	**1,167**	**66.09**	**309.8**	**0.03**	**55,559**	**57,459**	**57,458**
Well-to-Wheels Diesel Combination Tractor	**31.52**	**94.58**	**228.4**	**4.75**	**0.18**	77,938	**78,186**	**78,185**
Plant-to-Tank LNG Combination Tractor	0.308	1.289	7.299	104.5	0.017	753	756	756

Processing Step	Consumption mmBtu/year	CO_2c	Emissions (t/year) CH_4	N_2O	CO_{2e}
LNG Project - LNG Tractor	0	0	0.00	0.00	0
Diesel tractor	0	0	0.00	0.00	0

Ship Emissions and Fuel Consumption Estimates

Source: 2018-05-25 PSE Submittal page 79, tables TOTE Vessel Emissions

Route Definition

Ship Type	Origin	Destination	Distance at Sea (nm)	Transit Speed (knots)	Transit Time (hours)	Maneuvering Time (hours)	Time at Berth (Origin - hours)	Time at Berth (Destination - hours)	Time within 200 nm: Transit	Time within 200 nm: Maneuvering	Time within 200 nm: Hotelling
RoRo	Anchorage	Tacoma	1450	22	65.9	2	10	10	14%	50%	50%

Use of extra pilot fuel for LNG Marine vessel	3%

Vessel Details

Service Speed (knots)	Max Speed (knots)	Installed Power (kW)	Main Engine Speed (RPM)	Aux Engine Speed (RPM)	Main Engine Type	Aux Engine Type	Boiler Type
24	25.5	52200	400	720	Low Pressure DF LNG All	Low Pressure DF LNG All	LNG Aux Boiler All

Outputs

Calculated Loads

Mode	Time (hours)	Main Engine Load (kW)	Aux Engine Load (kW)	Aux Boiler Load (kW)	Fuel - In ECA	Fuel - Outside ECA
Transit	65.9	33,396	132	0	LNG	LNG
Maneuvering	2.0	1,044	396	148	LNG	LNG
Hotelling	20.0	0	229	259	LNG	LNG

Emissions Calcs

Emissions Within 200nm (tonne per trip)

End Use Emissions Marine vessels	NO_x	VOC	CO	SO_2	PM10	PM2.5	DPM
	0.58	0.00	0.58	0.00	0.01	0.01	0.00
	0.01	0.00	0.02	0.00	0.00	0.00	0.00
	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Total Emissions (tonne)	0.60	0.00	0.60	0.00	0.01	0.01	0.00
Emissions Rate (g/tonne MGOe)	9,376	6	9,456	17	106	105	0
Emissions Rate (g/mmBtu MGOe, LHV)	251	0	253	0	3	3	0

Emissions Outside 200nm (tonne per trip)

End Use Emissions Marine vessels	NO_x	VOC	CO	SO_2	PM10	PM2.5	DPM
	3.62	0.00	3.62	0.01	0.04	0.04	0.00
	0.01	0.00	0.02	0.00	0.00	0.00	0.00
	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Total Emissions (tonne)	3.64	0.00	3.64	0.01	0.04	0.04	0.00
Emissions Rate (g/tonne MGOe)	9,310	3	9,323	17	99	99	0
Emissions Rate (g/mmBtu MGOe, LHV)	249	0	249	0	3	3	0

Total Emissions (tonne per trip)

End Use Emissions Marine vessels	NO_x	VOC	CO	SO_2	PM10	PM2.5	DPM
	4.20	0.00	4.20	0.01	0.04	0.04	0.00
	0.02	0.00	0.04	0.00	0.00	0.00	0.00
	0.02	0.00	0.01	0.00	0.00	0.00	0.00
Total Emissions (tonne)	4.24	0.00	4.25	0.01	0.05	0.05	0.00
Emissions Rate (g/tonne MGOe)	9,320	3	9,342	17	100	100	0
Emissions Rate (g/mmBtu MGOe, LHV)	230	0	230	0	2	2	0

Emissions Calcs

Emissions Within 200nm (tonne per trip)

End Use Emissions Marine vessels	CO_2	N_2O	CH_4	CO_2c	CO_2e
	135	0.01	1.62	136	179
	1	0.00	0.01	1	1
	3	0.00	0.01	3	3
Total Emissions (tonne)	139	0.01	1.64	140	183
Emissions Rate (g/tonne MGOe)	2,172,237	153	25,601	307,200	403,493
Emissions Rate (g/mmBtu MGOe, LHV)	58,070	4	684	58,467	76,794

Emissions Outside 200nm (tonne per trip)

End Use Emissions Marine vessels	CO_2	N_2O	CH_4	CO_2c	CO_2e
	846	0.06	10.10	851	1,121
	1	0.00	0.01	1	1
	3	0.00	0.01	3	3
Total Emissions (tonne)	849	0.06	10.12	855	1,126
Emissions Rate (g/tonne MGOe)	2,172,639	152	25,881	1,880,069	2,475,106
Emissions Rate (g/mmBtu MGOe, LHV)	58,080	4	692	58,472	76,979

Total Emissions (tonne per trip)

End Use Emissions Marine vessels	CO_2	N_2O	CH_4	CO_2c	CO_2e	BC	OC	Methane Slip
	981	0.07	11.71	988	1,301	0.01	0.00	0.43%
	1	0.00	0.02	2	2	0.00	0.00	0.36%
	5	0.00	0.02	5	6	0.00	0.00	0.16%
Total Emissions (tonne)	988	0.07	11.75	995	1,309	0.01	0.00	
Emissions Rate (g/tonne MGOe)	2,172,582	152	25,841	2,187,269	2,878,599	20	0	
Emissions Rate (g/mmBtu MGOe, LHV)	53,552	4	637	53,914	70,955	0	0	

Fuel Consumption Estimates

Geographic Region	Engine	Engine	Boiler
Fuel Consumed Within 200nm (MT MGOe)	62.2	0.8	0.8
Fuel Consumed Outside 200nm (MT MGOe)	387.9	2.2	0.8
Fuel Consumed (MT MGOe)	450.1	3.0	1.6

Within 200nm	Emissions Factors (g/kWh)									
Main Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Maneuvering	8.80	0.01	18.39	0.00	0.15	0.15	0.00	444	0.03	5.30
Hotelling	8.80	0.01	18.39	0.00	0.15	0.15	0.00	444	0.03	5.30
Aux Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Maneuvering	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Hotelling	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Aux Boiler	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00
Maneuvering	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00
Hotelling	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00

Outside 200nm	Emissions Factors (g/kWh)									
Main Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Maneuvering	8.80	0.01	18.39	0.00	0.15	0.15	0.00	444	0.03	5.30
Hotelling	8.80	0.01	18.39	0.00	0.15	0.15	0.00	444	0.03	5.30
Aux Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Maneuvering	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Hotelling	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Aux Boiler	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00
Maneuvering	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00
Hotelling	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00

Ship Emissions and Fuel Consumption Estimates

Route Definition

Ship Type	Origin	Destinatio n	Distance at Sea (nm)	Transit Speed (knots)	Transit Time (hours)	Maneuver ing Time (hours)	Time at Berth (Origin - hours)	Time at Berth (Destination - hours)	*Time within 200 nm* Transit	Maneuveri ng	Hotelling
RoRo	Anchorage	Tacoma	1450	22	65.9	2	10	10	14%	50%	50%

Vessel Details

Service Speed (knots)	Max Speed (knots)	Installed Power (kW)	Main Engine Speed (RPM)	Aux Engine Speed (RPM)	Main Engine Type	Aux Engine Type	Boiler Type
24	25.5	52200	400	720	Medium speed diesel 2000 - 2010	Medium speed diesel 2000 - 2010	Fuel Oil Aux Boiler All

Outputs

Calculated Loads

Mode	Time (hours)	Main Engine Load (kW)	Aux Engine Load (kW)	Aux Boiler Load (kW)	Fuel - In ECA	Fuel - Outside ECA
Transit	65.9	33,396	132	0	MGO (0.1	MGO (0.1% S)
Maneuvering	2.0	1,044	396	148	MGO (0.1	MGO (0.1% S)
Hotelling	20.0	0	229	259	MGO (0.1	MGO (0.1% S)

Emissions Calcs

End Use Emissions Marine vessels	*Emissions Within 200nm (tonne per trip)* NOx	VOC	CO	SO2	PM10	PM2.5	DPM
	3.72	0.15	0.34	0.13	0.07	0.07	0.07
	0.06	0.01	0.01	0.00	0.00	0.00	0.00
	0.03	0.00	0.00	0.02	0.00	0.00	0.00
Total Emissions (tonne)	3.82	0.16	0.35	0.15	0.08	0.07	0.08
Emissions Rate (g/tonne MGO)	59,739	2,578	5,478	2,287	1,191	1,141	1,184
Emissions Rate (g/mmBtu MGO, LHV)	1,597	69	146	61	32	31	32

End Use Emissions Marine vessels	*Emissions Within 200nm (tonne per trip)* CO2	N2O	CH4	CO2c	CO2e
	198	0.01	0.00	199	201
	1	0.00	0.00	1	1
	4	0.00	0.00	4	4
Total Emissions (tonne)	203	0.01	0.00	204	207
Emissions Rate (g/tonne MGO)	3,171,667	153	48	447,826	454,393
Emissions Rate (g/mmBtu MGO, LHV)	84,787	4	1	11,972	12,147

End Use Emissions Marine vessels	*Emissions Outside 200nm (tonne per trip)* NOx	VOC	CO	SO2	PM10	PM2.5	DPM
	23.24	0.95	2.10	0.80	0.46	0.44	0.46
	0.06	0.01	0.01	0.00	0.00	0.00	0.00
	0.03	0.00	0.00	0.02	0.00	0.00	0.00
Total Emissions (tonne)	23.34	0.96	2.11	0.82	0.46	0.44	0.46
Emissions Rate (g/tonne MGO)	59,707	2,467	5,398	2,093	1,177	1,128	1,176
Emissions Rate (g/mmBtu MGO, LHV)	1,596	66	144	56	31	30	31

End Use Emissions Marine vessels	*Emissions Outside 200nm (tonne per trip)* CO2	N2O	CH4	CO2c	CO2e
	1,235	0.06	0.02	1,241	1,259
	1	0.00	0.00	1	1
	4	0.00	0.00	4	4
Total Emissions (tonne)	1,240	0.06	0.02	1,246	1,264
Emissions Rate (g/tonne MGO)	3,171,667	152	49	2,740,069	2,780,013
Emissions Rate (g/mmBtu MGO, LHV)	84,787	4	1	73,249	74,317

End Use Emissions Marine vessels	*Total Emissions (tonne per trip)* NOx	VOC	CO	SO2	PM10	PM2.5	DPM
	26.96	1.10	2.43	0.93	0.53	0.51	0.53
	0.13	0.02	0.02	0.00	0.00	0.00	0.00
	0.07	0.00	0.01	0.03	0.00	0.00	0.00
Total Emissions (tonne)	27.15	1.13	2.46	0.96	0.54	0.51	0.54
Emissions Rate (g/tonne MGO)	59,711	2,482	5,410	2,121	1,179	1,130	1,177
Emissions Rate (g/mmBtu MGO, LHV)	1,472	61	133	52	29	28	29

End Use Emissions Marine vessels	*Total Emissions (tonne per trip)* CO2	N2O	CH4	CO2c	CO2e	BC	OC
	1,432	0.07	0.02	1,439	1,460	0.10	0.23
	2	0.00	0.00	2	2	0.00	0.00
	8	0.00	0.00	8	8	0.00	0.00
Total Emissions (tonne)	1,442	0.07	0.02	1,450	1,471	0.10	0.23
Emissions Rate (g/tonne MGO)	3,171,667	152	49	3,187,895	3,234,406	226	504
Emissions Rate (g/mmBtu MGO, LHV)	78,179	4	1	78,579	79,725	6	12

Fuel Consumption Estimates

Geographic Region	Engine	Engine	Aux Boiler
Fuel Consumed Within 200nm (MT MGOe)	62.2	0.8	0.8
Fuel Consumed Outside 200nm (MT MGOe)	387.9	2.2	0.8
Fuel Consumed (MT MGOe)	450.1	3.0	1.6

Looks like LNG

Within 200nm						Emissions Factors (g/kWh)				
Main Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	12.20	0.50	1.10	0.42	0.24	0.23	0.24	648	0.03	0.01
Maneuvering	56.49	10.59	10.65	0.42	1.75	1.68	1.75	648	0.03	0.01
Hotelling	56.49	10.59	10.65	0.42	1.75	1.68	1.75	648	0.03	0.01
Aux Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Maneuvering	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Hotelling	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Aux Boiler	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00
Maneuvering	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00
Hotelling	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00

Outside 200nm						Emissions Factors (g/kWh)				
Main Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	12.20	0.50	1.10	0.42	0.24	0.23	0.24	648	0.03	0.01
Maneuvering	56.49	10.59	10.65	0.42	1.75	1.68	1.75	648	0.03	0.01
Hotelling	56.49	10.59	10.65	0.42	1.75	1.68	1.75	648	0.03	0.01
Aux Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Maneuvering	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Hotelling	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Aux Boiler	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00
Maneuvering	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00
Hotelling	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00

Fugitive Emissions from Equipment Leaks

EQUIPMENT INFORMATION

Component	Phase	Fluid Serviced									Emission Factors[3] (lb/hr per component)	LDAR Control Efficiency[4]
		Amine Gas	Boil-Off Gas	Ethylene	Fuel Gas	Hydrocarbon Liquid	Liquefied Natural Gas	Mixed Refrigerant	Natural Gas	Untreated Natural Gas		
Valves	Gas/Vapor	39	9	12	36			112	185	30	0.001370	75%
	Light Liquid					33	244				0.005370	75%
	Heavy Liquid										0.000502	0%
Pump Seals	Light Liquid					1					0.049300	75%
	Heavy Liquid										0.009820	0%
Flanges/Connectors	Gas/Vapor	0	7	2	15			28	77	15	0.000559	30%
	Light Liquid					6	114				0.000559	30%
	Heavy Liquid										0.000559	30%
Compressor Seals	Gas/Vapor	0	2	0	0	0	0	1	1	0	0.016550	75%
Relief Valves	Gas/Vapor	3	0	1	3	1	19	8	9	2	0.022030	75%
Swivel Joints	Light Liquid						4				0.049300	75%

FLUID HAP/TAP CONTENT

Pollutant	CAS / ID	Fluid								
		Amine Gas	Boil-Off Gas	Ethylene	Fuel Gas	Hydrocarbon Liquid	Liquefied Natural Gas	Mixed Refrigerant	Natural Gas	Untreated Natural Gas
Methane Content (%wt)[1]	74-82-8	100%	100%	100%	100%	100%	100%	100%	100%	100%
n-Hexane (ppmw)[1]	110-54-3	70	5.7E-10	0	1,185	210,669	27	0	1,185	1,185
Hydrogen sulfide (ppmw)[1]	2148878	3,128	0.00035	0	22	0.010	0.21	0	22	166
Benzene (ppmw)[b, 2]	71-43-2	4.0	4.0	0	4.0	4.0	4.0	0	4.0	4.0
Ethylbenzene (ppmw)[b, 2]	100-41-4	0.20	0.20	0	0.20	0.20	0.20	0	0.20	0.20
m,p-Xylene (ppmw)[b, 2]	106-42-3	1.3	1.3	0	1.3	1.3	1.3	0	1.3	1.3
o-Xylene (ppmw)[b, 2]	95-47-6	0.22	0.22	0	0.22	0.22	0.22	0	0.22	0.22
Toluene (ppmw)[b, 2]	108-88-3	3.5	3.5	0	3.5	3.5	3.5	0	3.5	3.5

POTENTIAL EMISSIONS

Pollutant	CAS / ID	Amine Gas	Boil-Off Gas	Ethylene	Fuel Gas	Hydrocarbon Liquid	Liquefied Natural Gas	Mixed Refrigerant	Natural Gas	Untreated Natural Gas	Total	
					Hourly Emissions[a] (lb/hr)							
Methane[6]	74-82-8	0.02988000	0.01409660	0.01040010	0.03472200	0.06448280	0.52612070	0.09751390	0.14719760	0.02715950	0.95157320	
n-Hexane	110-54-3	0.00000208	0.00000000	0.00000000	0.00004113	0.01358456	0.00001441	0.00000000	0.00017437	0.00003217	0.01384873	
Hydrogen sulfide	2148878	0.00009345	0.00000000	0.00000000	0.00000075	0.00000000	0.00000011	0.00000000	0.00000319	0.00000451	0.00010202	
Benzene	71-43-2	0.00000012	0.00000006	0.00000000	0.00000014	0.00000026	0.00000212	0.00000000	0.00000059	0.00000011	0.00000341	
Ethylbenzene	100-41-4	0.00000001	0.00000000	0.00000000	0.00000001	0.00000001	0.00000010	0.00000000	0.00000003	0.00000001	0.00000016	
m,p-Xylene	106-42-3	0.00000004	0.00000002	0.00000000	0.00000005	0.00000009	0.00000070	0.00000000	0.00000020	0.00000004	0.00000113	
o-Xylene	95-47-6	0.00000001	0.00000000	0.00000000	0.00000001	0.00000001	0.00000012	0.00000000	0.00000003	0.00000001	0.00000019	
Toluene	108-88-3	0.00000010	0.00000005	0.00000000	0.00000012	0.00000022	0.00000183	0.00000000	0.00000051	0.00000009	0.00000294	
Total HAPs	HAP	0.00000028	0.00000013	0.00000000	0.00000032	0.00000060	0.00000488	0.00000000	0.00000136	0.00000025	0.00000782	
					Daily Emissions[a] (kg / day)							
Methane[6]	74-82-8	0.32528018	0.15345866	0.11321775	0.37799125	0.70197379	5.72746442	1.06155753	1.60242510	0.29566423	10.35903292	
n-Hexane	110-54-3	0.00002263	0.00000000	0.00000000	0.00044777	0.14788443	0.00015692	0.00000000	0.00189824	0.00035025	0.15076024	
Hydrogen sulfide	2148878	0.00101733	0.00000000	0.00000000	0.00000819	0.00000001	0.00000121	0.00000000	0.00003474	0.00004914	0.00111062	
Benzene	71-43-2	0.00000131	0.00000062	0.00000000	0.00000153	0.00000283	0.00002312	0.00000000	0.00000647	0.00000119	0.00003707	
Ethylbenzene	100-41-4	0.00000006	0.00000003	0.00000000	0.00000007	0.00000014	0.00000112	0.00000000	0.00000031	0.00000006	0.00000179	
m,p-Xylene	106-42-3	0.00000043	0.00000020	0.00000000	0.00000050	0.00000094	0.00000765	0.00000000	0.00000214	0.00000039	0.00001227	
o-Xylene	95-47-6	0.00000007	0.00000003	0.00000000	0.00000008	0.00000016	0.00000128	0.00000000	0.00000036	0.00000007	0.00000205	
Toluene	108-88-3	0.00000113	0.00000053	0.00000000	0.00000132	0.00000244	0.00001994	0.00000000	0.00000558	0.00000103	0.00003197	
Total HAPs	HAP	0.00000302	0.00000142	0.00000000	0.00000350	0.00000651	0.00005311	0.00000000	0.00001486	0.00000274	0.00008516	
												If Capacity is 500.000 gal/day
					Annual Emissions[a] (short ton per year)							a factor of 2 is applaie metric tonne&year
Methane[6]	74-82-8	0.13087440	0.06174311	0.04555244	0.15208236	0.28243466	2.30440867	0.42711088	0.64472549	0.11895861	4.16789062	3.781085563
n-Hexane	110-54-3	0.00000910	0.00000000	0.00000000	0.00018016	0.05950036	0.00006314	0.00000000	0.00076375	0.00014092	0.06065742	
Hydrogen sulfide	2148878	0.00040932	0.00000000	0.00000000	0.00000330	0.00000000	0.00000049	0.00000000	0.00001398	0.00001977	0.00044685	
Benzene	71-43-2	0.00000053	0.00000025	0.00000000	0.00000061	0.00000114	0.00000930	0.00000000	0.00000260	0.00000048	0.00001492	
Ethylbenzene	100-41-4	0.00000003	0.00000001	0.00000000	0.00000003	0.00000006	0.00000045	0.00000000	0.00000013	0.00000002	0.00000072	
m,p-Xylene	106-42-3	0.00000017	0.00000008	0.00000000	0.00000020	0.00000038	0.00000308	0.00000000	0.00000086	0.00000016	0.00000494	
o-Xylene	95-47-6	0.00000003	0.00000001	0.00000000	0.00000003	0.00000006	0.00000052	0.00000000	0.00000014	0.00000003	0.00000083	
Toluene	108-88-3	0.00000046	0.00000021	0.00000000	0.00000053	0.00000098	0.00000802	0.00000000	0.00000224	0.00000041	0.00001286	
Total HAPs	HAP	0.00000121	0.00000057	0.00000000	0.00000141	0.00000262	0.00002137	0.00000000	0.00000598	0.00000110	0.00003426	

Calculations:

[a] Hourly Emissions (lb/hr) = [Emission Factor (lb/hr per component)] x [Component Count] x [Pollutant Content (%wt)] x [1 - LDAR Control Efficiency (%)]

Annual Emissions (tpy) = [Emission Factor (lb/hr per component)] x [Component Count] x [Pollutant Content (%wt)] x [1 - LDAR Control Efficiency (%)] x [Hours of Operation (hrs/yr)] / [2,000 lb/ton]

Hours of Operation (hrs/yr) =	8,760	

[b] Pollutant Concentration (ppmw) = [Pollutant Concentration (μg/m^3)] / [453.6 g/lb] / [10^6 μg/g] / [35.31 ft^3/m^3] / [Gas Density (lb/cf)] x 10^6

Benzene Concentration (μg/m^3) =	2,980	5
Ethylbenzene Concentration (μg/m^3) =	144	5
m,p-Xylene Concentration (μg/m^3) =	986	5
o-Xylene Concentration (μg/m^3) =	165	5
Toluene Concentration (μg/m^3) =	2,570	5
Natural Gas Density (lb/scf) =	0.046	5

Notes:

[1] Provided by CB&I.

[2] From "Natural Gas Analysis"; Environmental Partners, Inc.; February 3, 2014. Most HAPs will go through with the heavy hydrocarbons, but the fraction is unknown. Therefore, we assume each fluid has the full concentration of HAP to provide a conservative emissions estimate.

[3] Terminal/Depot factors from South Coast Air Quality Management District's "Guidelines for Fugitive Emissions Calculations" (June 2003). In this guidance, the District updated emissions factors that were identified in the EPA's "Protocol for Equipment Leak Emission Estimates (November 1995).

[4] Control effectiveness from Texas Commission for Environmental Quality (TCEQ) "Control Efficiencies for TCEQ Leak Detection and Repair Programs" (July 2011) for its 28M fugitive leak detection program.

[5] See fuel characteristics in Table B-2.

[6] Assume all VOC is CH_4.

Life Cycle Associates, LLC

Fuel Life Cycle Factors Sheet -6.89%

Lookup Key	AR5_100	AR5_20	AR4_100	AR4_20
AR Edition	AR5	AR5	AR4	AR4
Time Horizon	100	20	100	20
CO_2	1	1	1	1
CH_4	30	85	25	72
N_2O	265	264	298	289
BC	900	3200	900	3200
OC	-69	-240	-69	-240

Global Warming Potential, Molecular Weight

Species	GWP	Mol Wt	Variable Name: GWP	Variable Name: MW
CO2	1.000	43.999	CO2_GWP	CO2_MW
CH4	25.000	16.042	CH4_GWP	CH4_MW
N2O	298.000	44.007	N2O_GWP	N2O_MW
VOC	3.117	10.209	VOC_GWP	VOC_MW
CO	1.571	28.005	CO_GWP	CO_MW
NO2	0.000	45.995	NO2_GWP	NO2_MW
BC	900.000			
OC	-69.000			
C		12.011		C_MW
H		1.008		H_MW
O		15.994		O_MW
N		14.007		N_MW
Ca		40.078		Ca_MW
Cl		35.453		Cl_MW
Na		22.990		Na_MW
S		32.065		S_MW
P		30.974		P_MW
K		39.098		K_MW

Carbon and Sulfur Ratios of Pollutants

	Ratio	Variable Name	CO_2/pollutant
Carbon ratio of VOC	0.85	VOC_C_Ratio	3.11
Carbon ratio of CO	0.43	CO_C_Ratio	1.57
Carbon ratio of CH4	0.75	CH4_C_Ratio	2.74
Carbon ratio of CO2	0.27	CO2_C_Ratio	1.00
Sulfur ratio of SO2	0.50	SO2_S_Ratio	

Conversion Factors

		Variable Name	
Energy			
J/Btu	1055.056	JperBtu	
Btu/MJ	947.82	BtuperMJ	
Btu/kWh	3412.1	BtuperkWh	
Mass			
g/lb	453.597	gperlb	
metric tonne/ton	0.907	tonneperton	907194.049
ton/metric tonne	1.102	shorttonpertonne	
lb/kg	2.205	lbperkg	
Volume			
scf/m3	35.3000	scfperm3	
L/gal	3.785	Lpergal	
Area			
acre/hectare	2.471	acreperhectare	
Distance			
cm/inch	2.54	cmperinch	
mi/naut mi	1.151	mipernaut	
ft/mi	5280		
km/mi	1.609	kmpermi	
scf/lb mol	379	scfperlbmol	
NL/g mol	22.414	Lpergmol	
Capacity			
kW/hr	1.341	kwperhp	

Emission Factors

Washington

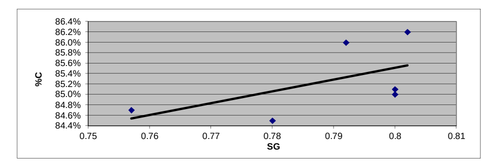
Fuel/ Application	Equipment Type	CO_2c	CH_4	N_2O	CO_2e
GREET WTT Emissions (g/mmBtu), LHV					
Diesel	Diesel Engine	78,187	4.2	0.6	78,472
Diesel	HD Truck	78,186	4.7	0.2	78,357
Diesel	Industrial Boiler	78,198	0.2	0.9	78,477
Gasoline, E10	Gasoline Engine	76,829	3.0	0.6	77,083
Bunker Fuel	**TOTE Marine Engine**	**78,579**	**1.2**	**3.7**	**79,725**
Bunker Fuel	**Residual Oil**	**85,003**	**4.2**		
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	**TOTE Marine Engine**	**53,914**	**637.0**	**3.7**	**70,955**
LNG	**IC Engine, GREET**	58,059	92		
LNG	**Marine Engine, This Study**	58,059			
LNG	Truck	57,459	309.8	0.0	65,213
LNG	NG Peak Shaving	58,308	1.1	0.4	58,439
LPG from Tacoma LNG	Boiler	68,058	1.1	1.1	68,403
LPG, conventional	Boiler	68,773	1.1	1.1	69,118
Waste Flare LPG - Tacoma LNG plant	Flare	68,773	1.1	1.1	69,118
Waste Flare gas - LNG plant	Flare	68,662	1.1	1.1	59,660
Fuel Gas	Boiler	59,410	1.1	0.8	59,660
Coal	Boiler	100,041	1.1	1.6	100,540

Specifications of Fuels, Global Warming Potentials of Greenhouse Gases, and Carbon and Sulfur Ratios of Pollutants

3.168747 0.925787

1) Specifications of Fuels

									10	11	12	13	14	15	16		18	19	20	21		
Fuel	Calculation: LHV	Heating Value LHV	HHV	Density Density	C ratio (% by wt)	S ratio (ppm by wt)	S ratio	SO_x	Carbon Factor Total C in Fuel LHV	Fossil C in Fuel LHV	Biogenic C in Fuel LHV		Heating Value LHV	Heating Value HHV	Heating Value LHV	Heating Value HHV		LHV/HHV ratio	Other Properties Density		Source	Citation
Use LHV or HHV in calculations?	1	1 -- LHV; 2 -- HHV																				
Liquid Fuels:	Btu/gal	Btu/gal	Btu/gal	g/gal			Ratio by Wt.	g/mmBtu	g CO2/mmBtu	g CO2/mmBtu	g CO2/mmBtu	g CO_2/MJ	MJ/kg	MJ/kg	Btu/lb	Btu/lb	MJ/unit		lb/gal	kg/L		
Crude oil	129,670	129,670	138,350	3,205	85.3%	16,000	0.016000	395	77,234	77,234	-	73.2	42.7	45.5	18,352	19,580	136.8	0.9373	7.07	0.847	CA_GREET	
Conventional gasoline	116,090	116,090	124,340	2,819	86.3%	26	0.000026	1	76,768	76,768	-	72.8	43.4	46.5	18,680	20,007	122.5	0.9336	6.21	0.745	GREET1_2012	Wang (2012)
Reformulated or low-sulfur gasoline	113,602	113,602	121,848	2,830	86.3%	26	0.000026	1	78,744	78,744	-	74.6	42.4	45.4	18,211	19,533	119.9	0.9323	6.24	0.747	Calculation	
CARBOB for CARFG	113,300	113,300	124,340	2,767	85.9%	15		0	76,850	76,850	-	72.8	43.2	47.4	18,573	20,383	119.5	0.9112	6.10	0.731	CA_GREET	Unnasch (2009)
CA reformulated gasoline	109,772	109,772	120,541	2,788	82.9%	11	0.000011	0	77,131	77,131	-	73.1	41.5	45.6	17,859	19,612	115.8	0.9107	6.15	0.737	CA_GREET	
U.S. conventional diesel	128,450	128,450	137,380	3,167	86.5%	200	0.000200	5	78,127	78,127	-	74.1	42.8	45.8	18,397	19,676	135.5	0.9350	6.98	0.837	CA_GREET	
Diesel for non-road engines	128,450	128,450	137,380	3,167	86.5%	163	0.000163	4	78,127	78,127	-	74.1	42.8	45.8	18,397	19,676	135.5	0.9350	6.98	0.837	CA_GREET	
Low-sulfur diesel	127,464	127,464	133,075	3,142	86.5%	11	0.000011	0.271	78,107	78,107	-	74.0	42.8	44.7	18,402	19,212	134.5	0.9578	6.93	0.830	CA_GREET	
Petroleum naphtha	116,920	116,920	125,080	2,745	85.0%	1	0.000001	0	73,104	73,104	-	69.3	44.9	48.1	19,320	20,669	123.4	0.9348	6.05	0.725	CA_GREET	
GTL naphtha	111,520	111,520	119,740	2,651	84.2%	0	0.000000	0	73,323	73,323	-	69.5	44.4	47.7	19,082	20,488	117.7	0.9314	5.84	0.700	CA_GREET	
Residual oil	140,353	140,353	150,110	3,752	86.8%	5,000	0.005000	134	85,003	85,003	-	80.6	39.5	42.2	16,968	18,148	148.1	0.9350	8.27	0.991	CA_GREET	
Bunker fuel for ocean tanker	140,353	140,353	150,110	3,752	86.8%	28,000	0.028000	749	85,003	85,003	-	80.6	39.5	42.2	16,968	18,148	148.1	0.9350	8.27	0.991	CA_GREET	
Methanol	57,250	57,250	65,200	3,006	37.5%	0	0.000000	0	72,130	72,130	-	68.4	20.1	22.9	8,639	9,838	60.4	0.8781	6.63	0.794	CA_GREET	
Ethanol	76,330	76,330	84,530	2,988	52.2%	1	0.000001	0	74,856	-	74,856	70.9	26.9519	29.8	11,587	12,832	80.5	0.9030	6.59	0.789	CA_GREET	
Butanol	99,837	99,837	108,458	3,065	64.9%	0	0.000000	0	72,944	-	72,944	69.1	34.4	37.3	14,775	16,051	105.3	0.9205	6.76	0.810	CA_GREET	
Acetone	83,127	83,127	89,511	2,964	62.0%	0	0.000000	0	80,958	-	80,958	76.7	29.6	31.9	12,721	13,698	87.7	0.9287	6.53	0.783	CA_GREET	
E-Diesel Additives	116,090	116,090	124,340	2,819	86.3%	26	0.000026	1	76,768	76,768	-	72.8	43.4	46.5	18,680	20,007	122.5	0.9336	6.21	0.745	CA_GREET	
LPG	75,574	75,574	83,698	1,923	81.8%		0.000000	0	76,254	76,254	-	72.3	41.5	45.9	17,826	19,743	79.7	0.9029	4.24	0.508	CA_GREET	
Liquefied natural gas (LNG)	77,156	77,156	84,331	1,646	75.1%	0	0.000000	0	58,690	58,690	-	55.6	49.5	54.1	21,262	23,240	81.4	0.9149	3.63	0.435	CA_GREET	
Dimethyl ether	68,930	68,930	75,610	2,518	52.2%	0	0.000000	0	69,854	69,854	-	66.2	28.9	31.7	12,417	13,621	72.7	0.9117	5.55	0.665	CA_GREET	
Dimethoxy methane (DMM)	72,200	72,200	79,197	3,255	47.4%	0	0.000000	0	78,282	78,282	-	74.2	23.4	25.7	10,061	11,036	76.2	0.9117	7.18	0.860	CA_GREET	
Algae Oil, TAG	124,316	124,316	138,129	3,444		0	0.000000	0		-	-	0.0	38.1	42.3	16,372	18,191	131.2	0.9000	7.59	0.910	CA_GREET	
Vegetable Oil (PVO)				3,400								0.0	37.5	0.0		0			7.50	0.898	Look something up.	
Methyl ester (biodiesel, BD)	119,550	119,550	127,960	3,361	77.6%	0	0.000000	0	79,919	3,873	76,046	75.7	37.5	40.2	16,134	17,269	126.1	0.9343	7.41	0.888	CA_GREET	
Ethyl ester (biodiesel, BD)	119,550	119,550	127,960	3,500	77.6%	0			83,225	-		78.9	36.0	38.6	16,941	16,584		1.0216	7.72	0.925	CA_GREET	
GTL Diesel	122,800	122,800	132,100	2,953	84.8%	0		0	74,702	-	74,702	70.8	43.9	47.2	18,863	20,291	129.6	0.9296	6.51	0.780	CA_GREET	
Renewable Diesel I (SuperCetane)	117,059	117,059	125,294	2,835	87.1%	0	0.000000	0	77,275	-	77,275	73.2	43.6	46.6	18,729	20,047	123.5	0.9343	6.25	0.749	CA_GREET	
Renewable Diesel II (UOP-HDO)	122,887	122,887	130,817	2,948	87.1%	0	0.000000	0	76,544	-	76,544	72.5	44.0	46.8	18,908	20,128	129.7	0.9394	6.50	0.779	CA_GREET	
Renewable Gasoline	115,983	115,983	124,230	2,830	84.0%	0	0.000000	0	75,083	-	75,083	71.2	43.2	46.3	18,590	19,912	122.4	0.9336	6.24	0.748	CA_GREET	
Liquid hydrogen	30,500	30,500	36,020	268	0.0%	0	0.000000	0		-	-	0.0	120.1	141.8	51,622	60,965	32.2	0.8468	0.59	0.071	CA_GREET	
Methyl tertiary butyl ether (MTBE)	93,540	93,540	101,130	2,811	68.1%	0	0.000000	0	74,969	74,969	-	71.1	35.1	38.0	15,094	16,319	98.7	0.9249	6.20	0.743	CA_GREET	
Ethyl tertiary butyl ether (ETBE)	96,720	96,720	104,530	2,810	70.6%	0	0.000000	0	75,139	75,139	-	71.2	36.3	39.2	15,613	16,873	102.0	0.9253	6.19	0.742	CA_GREET	
Tertiary amyl methyl ether (TAME)	100,480	100,480	108,570	2,913	70.6%	0	0.000000	0	74,979	74,979	-	71.1	36.4	39.3	15,646	16,906	106.0	0.9255	6.42	0.770	CA_GREET	
Butane	94,970	94,970	103,220	2,213	82.8%	0	0.000000	0	70,680	70,680	-	67.0	45.3	49.2	19,466	21,157	100.2	0.9201	4.88	0.585	CA_GREET	
Isobutane	90,060	90,060	98,560	2,118	82.8%	0	0.000000	0	71,334	71,334	-	67.6	44.9	49.1	19,288	21,108	95.0	0.9138	4.67	0.560	CA_GREET	
Isobutylene	95,720	95,720	103,010	2,253	85.7%	0	0.000000	0	73,894	73,894	-	70.0	44.8	48.2	19,271	20,739	101.0	0.9292	4.97	0.595	CA_GREET	
Propane	84,250	84,250	91,420	1,920	81.8%	0	0.000000	0	68,290	68,290	-	64.7	46.3	50.2	19,904	21,598	88.9	0.9216	4.23	0.507	CA_GREET	
Natural gas liquids	83,686	83,686	90,050			0	0.000000	0				0.0								0.000	CA_GREET	
Still gas (in refineries)	128,590	128,590	142,860			0	0.000000			-		0.0								0.000	CA_GREET	
Gaseous Fuels (at 32F and 1atm):	Btu/ft3	Btu/ft3	Btu/ft3	g/ft3			Ratio by Wt.	g/mmBtu	g CO2/mmBtu	g CO2/mmBtu		g CO_2/MJ	MJ/kg	MJ/kg	Btu/lb	Btu/lb	MJ/unit		lb/ft^3		CA_GREET	
Natural gas	984	984	1,090	21.18	75.2%	13.74	0.000014	0	59,314	59,314	-	56.2	49.0	54.3	21,074	23,339	1.0	0.9029	0.05		CA_GREET	15.34664142
Hydrogen	282	282	331	2.48	0.0%	0	0.000000	0	-			0.0	120.0	140.8	51,578	60,541	0.3	0.8520	0.01		CA_GREET	
Carbon Dioxide				55.98	27.3%	0	0.000000												0.12		CA_GREET	
Still gas (in refineries)	1,458	1,458	1,584	32.8	37.9%				31,259			29.6	46.9	51.0	20,163	21,905	2.6	0.9205	0.07		CA_GREET	
Landfill Gas	446	446	496	34.54	20.5%				58,017			55.0	13.6	15.2	5,857	6,514		0.8992	0.08		CA_GREET	
Fuel Gas (RD I)																					CA_GREET	
Shale Gas	930	930	1,030	20.40	72.4%	13.74	0.000014	0	58,178	58,178	-	55.1	48.1	53.3	20,679	22,902	1.0	0.9029	0.04		CA_GREET	
Flared Gas	930	930	1,030	20.40	72.4%	13.74	0.000014	0	58,178	58,178	-	55.1	48.1	53.3	20,679	22,902	1.0	0.9029	0.04		CA_GREET	
Propane Fuel Mix (RD II)																					CA_GREET	
Solid Fuels:	Btu/ton	Btu/ton	Btu/ton				Ratio by Wt.		g CO2/mmBtu	g CO2/mmBtu		g CO_2/MJ	MJ/kg	MJ/kg	Btu/lb	Btu/lb	MJ/unit				CA_GREET	
Coal	19,546,300	19,546,300	20,608,570		63.7%	11,100	0.011100		108,305	108,305	-	102.7	22.7	24.0	9773.2	10304.3	20,622	0.9485			CA_GREET	
Bituminous coal	22,460,600	22,460,600	23,445,900		75.5%	11,800	0.011800		111,711	111,711	-	105.9	26.1	27.3	11230.3	11723.0	23,697	0.9580			CA_GREET	
Coking coal	24,600,497	24,600,497	25,679,670		74.7%	11,800	0.011800		100,913	100,913	-	95.6	28.6	29.9	12300.2	12839.8	25,955	0.9580			CA_GREET	
Lignite																						
Farmed trees	16,811,000	16,811,000	17,703,170		51.7%	0	0.000000		102,204	-	102,204	96.9	19.6	20.6	8405.5	8851.6	17,737	0.9496			CA_GREET	
Herbaceous biomass	14,797,555	14,797,555	15,582,870		42.6%	0	0.000000		95,673	-	95,673	90.7	17.2	18.1	7398.8	7791.4	15,612	0.9496			CA_GREET	
Corn stover	14,075,990	14,075,990	14,974,460		44.5%	0	0.000000		105,064	-	105,064	99.6	16.4	17.4	7038.0	7487.2	14,851	0.9400			CA_GREET	
Forest residue	13,243,490	13,243,490	14,164,160		51.7%	0	0.000000		129,736	-	129,736	123.0	15.4	16.5	6621.7	7082.1	13,973	0.9350			CA_GREET	
Sugarcane straw					50.0%																?	
Sugarcane bagasse	12,947,318	12,947,318	14,062,678		46.3%				118,843	-	118,843	112.6	15.1	16.4	6473.7	7031.3	13,660	0.9207			?	
Pet Coke	25,370,000	25,370,000	26,920,000		79.9%	68,000	0.068000		104,664	104,664	-	99.2	29.5	31.3	12685.0	13460.0	26,767	0.9424			?	
Stillage solids																						
Lignin																					Jenny has something.	
Jet Fuel Properties	Btu/gal	Btu/gal	Btu/gal	g/gal			Ratio by Wt.	g/mmBtu	g CO2/mmBtu	g CO2/mmBtu	g CO2/mmBtu	g CO_2/MJ	MJ/kg	MJ/kg	Btu/lb		MJ/unit		lb/gal	kg/L		
Conventional Petroleum Jet Fuel	124,307	124,307	132,949	3,036	86.2%	700	0.000700	17	77,121	77,121	-	73.1	43.2	43.2	18,573		131.2		6.69	0.802	GREET1_2012	86.2%
Ultra Low Sulfur Petroleum Jet Fuel (ULSJ)	123,041	123,041	131,595	2,998	86.0%	11	0.000011	0	76,764	76,764	-	72.8	43.3	43.3	18,616		129.8		6.61	0.792	GREET1_2012	86.0%
GTL Aviation Fuel	119,777	119,777	128,103	2,866	84.7%	0	0.000000	0	74,232	74,232	-	70.4	44.1	44.1	18,960		126.4		6.32	0.757	GREET1_2012	84.7%
GTL Lubricant Base Oil	118,256	118,256	126,477	3,028	85.1%	0	0.000000	0	79,832	79,832	-	75.7	41.2	41.2	17,713		124.8		6.68	0.8	Sasol	85.1%
GTL Wax	126,293	126,293	135,073	3,028	85.0%	1	0.000001	0	74,664	74,664	-	70.8	44.0	44.0	18,917		133.2		6.68	0.8	Sasol	85.0%
Paraffin/Olefin	124,535	124,535	133,193	2,953	84.5%	2	0.000002	0	73,391	73,391	-	69.6	44.5	44.5	19,132		131.4		6.51	0.78	Sasol	84.5%



1) Emission Factors of Fuel Combustion for Stationary Applications (grams per mmBtu of fuel burned), GREET EF Tab

	Natural Gas							Residual Oil					
	Utility/ Industrial Boiler (>100 mmBtu/hr input)	Small Industrial Boiler (10-100 mmBtu/hr input)	Large Gas Turbine	CC Gas Turbine	Small Turbine	Stationary Reciprocating Engine	NG Flaring in Oil Field	Utility Boiler	Industrial Boiler	Commercial Boiler	Stationary Reciprocating Engine	Marine Vessel TOTE	Turbine
VOC	2.540	2.540	1.056	0.267	1.056	133.316	2.500	2.089	0.905	3.651	2.027	**61.187**	0.258
CO	22.210	24.970	41.286	14.533	41.286	705.993	26.000	16.209	36.017	16.153	657.005	**133.341**	1.560
NOx	36.400	41.050	31.969	17.425	31.969	832.952	48.900	433.518	137.081	177.688	2,076.988	**1,471.837**	256.412
PM10	3.507	3.507	3.575	0.133	3.575	7.197	3.700	17.379	35.345	35.345	54.608	**29.062**	25.944
PM2.5	3.507	3.507	3.575	0.133	3.575	7.197	3.700	13.492	16.173	16.173	54.043	**27.850**	6.574
SOx	0.269	0.269	0.269	0.269	0.269	0.269	0.269	739.297	683.325	667.785	267.327	**52.273**	267.327
BC	0.579	0.579	0.104	0.004	0.104	1.439	3.515	0.855	1.025	1.025	43.937	**5.570**	0.657
OC	1.501	1.501	2.431	0.090	2.431	3.080	0.185	0.594	0.712	0.712	9.782	**12.418**	1.644
CH4	1.060	1.060	1.056	1.142	1.056	392.354	49.000	3.182	3.231	1.535	4.221	**1.201**	3.024
N2O	0.750	0.350	0.102	0.119	0.102	0.111	1.100	0.638	1.712	1.712	0.600	**3.746**	0.603
CO2	59,366.9	59,282.8	59,341.6	59,385.9	59,341.6	56,808.8	59,229.3	85,040.5	85,012.9	85,040.2	84,030.9	**78,178.9**	85,069.7
CO2c	59,409.8	59,329.9	59,409.8	59,409.5	59,409.8	58,333.1	59,277.9	85,072.5	85,072.3	85,077.0	85,069.4	**78,578.9**	85,072.9

	Diesel Fuel					Gasoline		Crude	Coal		
	Industrial Boiler	Commercial Boiler	Stationary Reciprocating Engine	Turbine	Farming Tractor	Stationary Reciprocating Engine	Farming Tractor	Industrial Boiler	Utility Boiler	IGCC Turbine	Industrial Boiler
VOC	0.800	1.201	2.027	0.258	63.020	598.350	193.820	0.820	1.495	0.122	0.472
CO	20.867	25.115	657.005	1.560	349.150	1,520.438	6,907.000	23.740	12.417	2.235	23.955
NOx	53.860	66.543	2,076.988	256.412	628.010	98.588	267.620	181.600	116.035	11.902	121.631
PM10	8.122	8.404	54.608	25.944	55.970	52.558	7.840	29.712	28.841	251.841	2.663
PM2.5	5.473	7.522	54.043	6.574	54.291	52.558	7.605	19.313	20.278	73.411	2.521
SOx	0.542	0.542	0.542	0.542	0.542	1.238	1.238	395.465	325.406	4.110	544.401
BC	0.547	0.752	43.937	0.657	30.566	5.256	1.034	0.560	0.872	3.157	0.108
OC	1.368	1.881	9.782	1.644	18.948	16.819	6.571	0.406	1.643	5.946	0.204
CH4	0.198	0.763	4.221	3.024	0.630	3.000	3.575	0.360	1.058	1.050	1.246
N2O	0.918	0.918	0.600	0.603	0.920	0.600	1.104	2.000	1.586	1.581	0.857
CO2	78,163.2	78,153.7	77,148.7	78,187.5	77,452.2	72,576.8	65,371.4	77,264.4	100,017.1	100,037.4	100,001.6
CO2c	78,198.5	78,196.9	78,187.2	78,190.7	78,197.0	76,828.7	76,826.6	77,304.2	100,041.2	100,041.3	100,040.7

	Diesel	Diesel	Fuel Gas	Flare Gas	LNG	LPG	LPG	LNG	LNG	LNG
	Heavy Duty Truck	Locomotive	Industrial Boiler	Flare Gas	Heavy Duty Truck	Industrial Boiler	Flaring Tacoma	NG Peak shaving	Marine Engine TOTE CASE	Marine Engine
VOC	5.909	5.909	2.540	2.540	26.225	4.272	4.272	2.540	**0.076**	79.908
CO	57.875	57.875	22.210	22.210	1,452.359	3.531	3.531	24.970	**230.273**	90.798
NOx	53.121	53.121	36.400	36.400	82.257	69.413	69.413	41.050	**229.722**	2,085.241
PM10	10.052	10.052	3.507	3.507	7.416	3.738	3.738	3.507	**2.465**	18.121
PM2.5	4.619	4.619	3.507	3.507	3.616	3.738	3.738	3.507	**2.462**	16.675
SOx	0.545	0.545	0.269	0.269	0.000	0.000	0.000	0.000	**0.422**	0.000
BC	0.072	0.072	0.579	0.579	0.287	0.617	0.617	0.579	**0.492**	2.501
OC	0.125	0.125	1.501	1.501	0.521	1.600	1.600	1.501	**0.000**	6.503
CH4	4.750	4.750	1.060	1.060	309.767	1.068	1.068	1.060	**636.970**	91.620
N2O	0.175	0.175	0.750	0.750	0.033	4.806	4.806	0.350	**3.746**	2.000
CO2	78,076.6	78,076.6	57,408.9	68,662.0	55,095.9	68,039.6	68,754.6	58,261.1	**53,552.3**	57,667.7
CO2c	78,186.0	78,186.0	57,451.7	68,704.8	57,459.3	68,058.5	68,773.4	58,308.2	**53,914.3**	58,059.2

Biogenic CO2

59332.81
59332.81

Emissions Factors and Activity Assumptions

Source: UPDATED 2016 Puget Sound Maritime Air Emissions Inventory, Punlished Feb 2018 APPENDIX B: OGV EMISSIONS ESTIMATING METHODOLOGY (unless otherwise noted below table)

https://pugetsoundmaritimeairforum.org/2016-puget-sound-maritime-air-emissions-inventory/

The North American ECA introduced in 2015, requiring 0.1% sulfur content in diesel fuel compared to heavy fuel oil with high sulfur content (2.7%) used by the

Table B.2: Emission Factors for OGV Main Engines Using MDO, g/kW-hr

Engine	Model Year	Key	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
Slow speed diesel	< 1999	Slow speed diesel < 1999	17	0.6	1.4	0.38	0.24	0.23	0.24
Medium speed diesel	< 1999	Medium speed diesel < 1999	13.2	0.5	1.1	0.42	0.24	0.23	0.24
Slow speed diesel	2000 - 2010	Slow speed diesel 2000 - 2010	16	0.6	1.4	0.38	0.24	0.23	0.24
Medium speed diesel	2000 - 2010	Medium speed diesel 2000 - 2	12.2	0.5	1.1	0.42	0.24	0.23	0.24
Slow speed diesel	2011 - 2015	Slow speed diesel 2011 - 2015	14.4	0.6	1.4	0.38	0.24	0.23	0.24
Medium speed diesel	2011 - 2015	Medium speed diesel 2011 - 2	10.5	0.5	1.1	0.42	0.24	0.23	0.24
Lean Burn SI LNG	All	Lean Burn SI LNG All	0.9	0.0	1.7	0	0.02	0.02	0
Low Pressure DF LNG	All	Low Pressure DF LNG All	1.9	0.0	1.9	0.00	0.02	0.02	0
Gas turbine	All	Gas turbine All	6.1	0.1	0.2	0.6	0.1	0.04	0
Steamship	All	Steamship All	2.1	0.1	0.2	0.6	0.8	0.6	0

Medium speed means RPM>130

Table B.2: GHG Emission Factors for OGV Main Engines Using MDO, g/kW-hr

Engine Model Year	Model Year	Key	CO2	N2O	CH4
Slow speed diesel	< 1999	Slow speed diesel < 1999	589	0.0310	0.0120
Medium speed diesel	< 1999	Medium speed diesel < 1999	648	0.0310	0.0100
Slow speed diesel	2000 - 2010	Slow speed diesel 2000 - 2010	589	0.0310	0.0120
Medium speed diesel	2000 - 2010	Medium speed diesel 2000 - 2010	648	0.0310	0.0100
Slow speed diesel	2011 - 2015	Slow speed diesel 2011 - 2015	589	0.0310	0.0120
Medium speed diesel	2011 - 2015	Medium speed diesel 2011 - 2015	648	0.0310	0.0100
Gas turbine	All	Gas turbine All	922	0.0800	0.0020
Steamship	All	Steamship All	922	0.0800	0.0020
Lean Burn SI LNG	All	Lean Burn SI LNG All	472	0.0310	4.1000
Low Pressure DF LNG	All	Low Pressure DF LNG All	444	0.0310	5.3000 *Methane (CH4) slip*

N2O emissions factors for LNG engines assumed to be equal to medium speed diesel

LNG emissions factors from "GHG and NOx Emissions from Gas Fueled Engines", SINTEF, 2017. PM emissions based on EPA certification data of 2017 Wartsila DF engine (rated at 8MW)

VOC emissions for LNG engines are estimated as NMVOC, based on a typical ratio of 3.8% NMVOC/CH4 emissions, as described in "Methane Emissions from Natural Gas Bunkering Operations in the Marine Sector", MARAD, 201!

https://www.nho.no/siteassets/nhos-filer-og-bilder/filer-og-dokumenter/nox-fondet/dette-er-nox-fondet/presentasjoner-og-rapporter/methane-slip-from-gas-engines-mainreport-1492296.pdf

https://www.marad.dot.gov/wp-content/uploads/pdf/Methane-emissions-from-LNG-bunkering-20151124-final.pdf

Sulfur emissions rates for Low Pressure DF LNG engines based on SINEF report (Table 5.1) indicating 95-98% SOx reductions from LNG operation relative to MDO. Assume pilot fuel is MDO with a 0.5% sulfur content based on 2020 global sulfur ca

Table B.3: Low-Load Adjustment Multipliers for Emission Factors

Load	NOx	HC	CO	PM
2%	4.63	21.18	9.68	7.29
3%	2.92	11.68	6.46	4.33
4%	2.21	7.71	4.86	3.09
5%	1.83	5.61	3.89	2.44
6%	1.6	4.35	3.25	2.04
7%	1.45	3.52	2.79	1.79
8%	1.35	2.95	2.45	1.61
9%	1.27	2.52	2.18	1.48
10%	1.22	2.2	1.96	1.38
11%	1.17	1.96	1.79	1.3
12%	1.14	1.76	1.64	1.24
13%	1.11	1.6	1.52	1.19
14%	1.08	1.47	1.41	1.15
15%	1.06	1.36	1.32	1.11
16%	1.05	1.26	1.24	1.08
17%	1.03	1.6	1.17	1.06
18%	1.02	1.18	1.11	1.04
19%	1.01	1.11	1.05	1.02
20%	1	1	1.00	1.00

Source: 2012

Table 3.17: Composite Maneuvering Load Factors

Vessel Type	Load In	Load Out
Auto Carrier	0.04	0.06
Bulk	0.04	0.05
Containership	0.03	0.03
Cruise	0.03	0.04
General Cargo	0.03	0.04
ITB	0.04	0.06
Reefer	0.02	0.03
RoRo	0.02	0.02
Tanker	0.03	0.05

Table B.7: Auxiliary Engine Emission Factors, g/kW-hr

Engine	Model Year	Key	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
Medium speed diesel	≤ 1999	Medium speed diesel ≤ 1999	13.8	0.4	1.1	0.44	0.24	0.23	0.24
Medium speed diesel	2000 - 2010	Medium speed diesel 2000 - 2	12.2	0.4	1.1	0.44	0.24	0.23	0.24
Medium speed diesel	2011 - 2015	Medium speed diesel 2011 - 2	10.5	0.4	1.1	0.44	0.24	0.23	0.24
Lean Burn SI LNG	All	Lean Burn SI LNG All	0.9	0.0	1.7	0	0.02	0.02	0.00
Low Pressure DF LNG	All	Low Pressure DF LNG All	1.9	0.0	1.9	0.003515	0.02	0.02	0.00

LNG emissions factors for aux engines assumed to be equivalent to main engine emissions factors as both the main and aux engines are medium speec

Table B.7: Greenhouse Gas Emission Factors for Auxiliary Engines, g/kW-hr

Engine	Model Year	Key	CO2	N2O	CH4
Medium speed diesel	All	Medium speed diesel All	683	0.029	0.008
Medium speed diesel	2000 - 2010	Medium speed diesel 2000 - 2010	683	0.029	0.008
Medium speed diesel	2011 - 2015	Medium speed diesel 2011 - 2015	683	0.029	0.008
Lean Burn SI LNG	All	Lean Burn SI LNG All	472	0.029	4.1
Low Pressure DF LNG	All	Low Pressure DF LNG All	444	0.029	5.3

Table B.12: Auxiliary Boiler Emission Factors using MDO, g/kW-hr

Engine	Model Year	Key	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
Fuel Oil Aux Boiler	All	Fuel Oil Aux Boiler All	2	0.1	0.2	6	0.16	0.15	0
LNG Aux Boiler	All	LNG Aux Boiler All	2	0.1	0.2	0	0.16	0.15	0

Source: 2013 POLB Emissions Inventory

Table B.12: Auxiliary Boiler GHG Emission Factors using MDO, g/kW-hr

Engine	Model Year	Key	CO2	N2O	CH4
Fuel Oil Aux Boiler	All	Fuel Oil Aux Boiler All	922	0.075	0.002
LNG Aux Boiler	All	LNG Aux Boiler All	644	0.075	0.002

Source: 2013 POLB Emissions Inventory

CO2 emissions for LNG based on ratios of carbon-per-BTU for bunker fuel and natural gas, as given in ANL GREET's fuel properties worksheet
N2O emissions for LNG assumed to be equal to fuel oil. CH4 emissions for LNG scaled based on fuel oil emissions and ratios of CH4 emissions from medium speed FO and LNG engines.

Table B.18: 2016 Auxiliary Engine Power and Load Defaults, kW

Vessel Type	Sea	Maneuvering	Hotelling
Auto Carrier	590	1224	876
Bulk	266	384	157
Bulk - Self Discharging	462	807	258
Bulk - Heavy Load	305	1223	136
Bulk - Wood Chips	266	1275	157
Container - 1000	892	1275	536
Container - 2000	1280	1911	945
Container - 3000	888	1685	965
Container - 4000	1499	2528	1196
Container - 5000	1444	2458	1202
Container - 6000	1598	2665	1461
Container - 7000	1332	2675	1325
Container - 8000	1497	4769	1449
Container - 9000	1495	4551	1383
Container - 10000	1662	2617	887
Cruise	na	na	na
General Cargo	471	1096	829
ITB	79	208	102
Reefer	1247	1168	900
RoRo	132	396	229
Tanker - Aframax	556	628	909
Tanker - Chemical	417	583	1271
Tanker - Handysize	560	600	900
Tanker - Panamax	488	600	379
Tanker - Suezmax	858	1289	2902

Table B11 2016 Auxiliary Boiler Energy Defaults, kW

Vessel Type	Sea	Maneuvering	Hotelling *
Auto Carrier	0	184	314
Bulk	0	94	125
Bulk - Self Discharging	0	103	125
Bulk - Heavy Load	0	94	134
Bulk - Wood Chips	0	134	134
Container - 1000	0	213	273
Container - 2000	0	282	361
Container - 3000	0	328	420
Container - 4000	0	371	477
Container - 5000	0	473	579
Container - 6000	0	567	615
Container - 7000	0	470	623
Container - 8000	0	506	668
Container - 9000	0	613	677
Container - 10000	0	458	581
Cruise	0	361	306
General Cargo		124	134
ITB	0	0	0
Reefer	0	237	304
RoRo	0	148	259
Tanker - Aframax	0	438	5030
Tanker - Chemical	0	136	568
Tanker - Handysize	0	144	2586
Tanker - Panamax	0	351	3421
Tanker - Suezmax	0	191	5843

*using upper limit

Table 3.22: Fuel Correction Factors

Fuel Used	NOx	VOC	CO	SO2	PM10	PM2.5	DPM	CO2	N2O	CH4
HFO (2.7% S)	1	1	1	1	1	1	1	1	1	1
HFO (1.5% S)	1	1	1	0.555	0.82	0.82	0.82	1	1	1
MGO (0.5% S)	0.94	1	1	0.185	0.25	0.25	0.25	1	0.94	1
MDO (1.5% S)	0.94	1	1	0.555	0.47	0.47	0.47	1	0.94	1
MGO (0.1% S)	1	1	1	1	1	1	1	1	1	1
MGO (0.3% S)	0.94	1	1	0.111	0.21	0.21	0.21	1	0.94	1
MGO (0.4% S)	0.94	1	1	0.148	0.23	0.23	0.23	1	0.94	1
ULSD	1	1	1	1.2007	1.18	1.18	1.18	1	1	1
LNG	1	1	1	1	1	1	1	1	1	1

LNG fuel correction factors set to 1 as direct emissions factors already account for LNG engines meeting Tier 3 standards
ULSD factors based on scaling from 0.5%S to 0.1%S MGO and further scaling 0.1%S MGO to 0.0015%S

Fuel Consumption Factors	SFOC	Units	Source
Main Engine	204.31	gMDO/kWh	Implied by CO2 emissions factors, converted using CO2 emissions above
Aux Engine	215.34	gMDO/kWh	Implied by CO2 emissions factors, converted using CO2 emissions above
Boiler	290.70	gMDO/kWh	Implied by CO2 emissions factors, converted using CO2 emissions above

Parameters	Natural Gas[a]	Flared Waste Gas[a]									Diesel
		Liquefying Case 1	Liquefying Case 2	Liquefying Case 3	Liquefying Case 4	Liquefying Case 5	Holding	LNG Transfer A1	LNG Transfer A2/A3	LNG Transfer B	
Heat Content (Btu/scf)	1,093	346	466	1,644	864	1,825	1,144	506	506	223	138,000
Density (lb/scf)	0.046	0.101	0.091	0.088	0.097	0.087	0.049	0.058	0.059	0.067	
Sulfur Content (ppmw)[c]	25	337	912	524	250	587	17	0	0	0	15
VOC Content (wt%)	NA	9.6%	14%	51%	24%	58%	17%	0.10%	0.10%	0.10%	
Benzene Concentration (mg/m^3)[b]	2,980	2,980	2,980	2,980	2,980	2,980	2,980	2,980	2,980	2,980	
Ethylbenzene Concentration (mg/m	144	144	144	144	144	144	144	144	144	144	
m,p-Xylene Concentration (mg/m^3)[b]	986	986	986	986	986	986	986	986	986	986	
o-Xylene Concentration (mg/m^3)[b]	165	165	165	165	165	165	165	165	165	165	
Toluene Concentration (mg/m^3)[b]	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	

Notes:

[a] Provided by CB&I.

[c] Based on the Williams Gas Pipeline tariff of 0.25 grains per 100 cubic feet for H2S, the past 12-month maximum total sulfur (reported as H2S by Williams Gas Pipeline) of 0.603 grains per 100 cubic feet, and sulfur from odorant of 0.23 grains per 100 cubic feet (odorant injection rates provided by PSE).

[b] From "Natural Gas Analysis"; Environmental Partners, Inc.; February 3, 2014. Most hazardous air pollutants (HAPs) will go through with the heavy hydrocarbons, but the fraction is unknown. Therefore, we conservatively assume the waste gas has the full concentration of HAP.

Do not Print

4) Mass fractions of black carbon and organic carbon emissions of corresponding PM2.5 emission factors

4.1) Stationary, mobile, and open burning emission sources, %

	Natural gas						Coal		Biomass		
	Boiler	Engine	Combined	Simple cyc	Nonroad E	Flared	Boiler	IGCC	Industrial,	IGCC	Open burn
BC	16.5	20.0	2.9	2.9	9.8	95.0	4.3	4.3	13.8	13.8	12.1
OC	42.8	42.8	68.0	68.0	83.7	5.0	8.1	8.1	32.6	32.6	33.9

	Diesel							
	Industrial,	Simple cyc	Engine	Nonroad v	Nonroad E	Locomotiv	HDDT 8b	HDDT 6
BC	10.0	10.0	81.3	56.3	77.1	8.4	16.0	8.1
OC	25.0	25.0	18.1	34.9	21.1	88.6	66.0	88.0

	Gasoline			Residual fuel oil				Crude oil	Biochar	Jet fuel	
	Engine	Off-road ve	Nonroad E	Boiler	Engine	Simple cyc	Ocean tan	Boiler	Boiler	Cruise	Landing and take-offs
BC	10.0	13.6	9.8	6.3	15.0	6.0	15.0	2.9	6.2	31.3	35.8
OC	32.0	86.4	83.7	4.4	39.0	4.0	39.0	2.1	79.9	30.3	26.0

GENERAL INPUTS

Date: 21-Sep-18
Version: 17

Comments/Source

LNG Plant Operation

LNG Product - End use share

LNG Production	Scenario A End use share	gal/day	lb/day	Mgal/ year	tonne/ year	Scenario B Enduse share	gal/day	lb/day	Mgal/ year	tonne/ year	Check gal/year (365)	Comments/Source	Scenario A Volume Data
												Source: PSE-BID	
Total	**100.0%**	**250,000**	**907,193**	**88.75**	**146,083**	**100.00%**	**500,000**	**1,814,384**	**177.50**	**292,165**	**182,499,845**		**250,000**
On-site Peak Shaving	11.0%	27,397	99,418	9.73	16,009	5.48%	27,397	99,418	9.73	16,009	10,000,000		27,397
Gig Harbor Peak Shaving	0.0%	0	0	-	0	1.00%	5,000	18,144	1.78	2,922	1,825,000		0
On-road Trucking	0.0%	0	0	-	0	2.00%	10,000	36,288	3.55	5,843	3,650,000		0
TOTE Marine	42.7%	106,849	387,732	37.93	62,435	21.37%	106,849	387,732	37.93	62,435	39,000,000		106,849
Truck-to-Ship Bunkering	0.0%	0	0	-	0	1.00%	5,000	18,144	1.78	2,922	1,825,000		0
Other Marine (by Bunker Barge)	46.3%	115,753	420,043	41.09	67,638	69.15%	345,753	1,254,659	122.74	202,034	126,199,845		115,753

Results	-4.42%	-60.44	ktonne/year

Scenario Selection for End use Mix

	Scenario	Comment
Enduse Scenario	B	Pull Down

	Sub- Scenario	Comment
LPG is flared	Yes	Pull Down

EER for Marine		Range
1	Type in	1 to 1.015

	Used GEN MIX		
Pwr Mix	Washington	WA	Pull Down
Natural Gas Upstream		GHGenius	Pull Down

Overall Operational Hours

Overall Operational Hours	hours/year	days/year
LNG Liquefaction Plant	8,520	355.0
LNG Pretreatment	8,520	355.0
LNG Flaring	8,760	365.0
LNG Vaporizer	240	10.0
Emergency Diesel Generator	500	20.8

GWP Basis			Comments/Source
AR Version	AR4	Pull Down	Source: LCA assumption 8760h/yr-240h/year (pipeline used by the vaporizer)
Timeframe	100	Pull Down	Source: LCA assumption 8760h/yr-240h/year (pipeline used by the vaporizer)
BC/OC	No	Pull Down	
Correct BC/OC Ratios	No	Pull Down	Source: Capacity, NG use 2018-05-25 PSE Submittal page 12
Correct FCFs	Yes	Pull Down	Source: Capacity, NG use 2018-05-25 PSE Submittal page 12
Correct Fuel Heating Value	Yes	Pull Down	

Energy/Electrcity Consumption LNG Plant

Scenario B Equipment Capacity/Consumption		PSE Estimate (mmBtu/hr)	Fuel	Calculated (mmBtu/hr)	Input for 250.000 gal /day	Comments/Source
LNG Pretreatment	NG WPG heater	18	NG		9	Source: Capacity, NG use 2018-05-25 PSE Submittal ATTACHMENT F page 118
LNG Pretreatment	NG Regenerator heater	3.2	NG		1.6	Source: Capacity, NG use 2018-05-25 PSE Submittal ATTACHMENT F page 119
Waste gas flaring	Waste Gas Heat Input	71.2		138.0	35.6	Source: Capacity, NG use 2018-05-25 PSE Submittal page 12
LPG in Waste Gas		77	LPG			
Waste Gas, Mass Balance		88	C2/C5+			
Vaporizer	LNG Heater Capacity	66			66	Source: Capacity, NG use 2018-05-25 PSE Submittal ATTACHMENT F page 120
		(gal/h)				
Emergency equipment	Diesel genrator	104.6	Diesel		104.6	Source: Capacity, NG use 2018-05-25 PSE Submittal page 12

WPG: Water Propylene Glycol

LNG pretreatment CO_2 seperation efficiency	99.760%	Actual result based on LNG composition

Power Consumption LNG plant	Baseline		Comments/Source
LNG Production	1,348	kWh/1000 gal	Source: page 13, PES response
Vaporizer	45	kWh/1000 gal	

Overall Mass Balance

Mass Input/Output: Based on 500,000 gal/day	NG Feed lb / Day	LNG Output lb / Day	Mass ratio NG/LNG	Density LNG g/gal	Density LNG lb/gal
	2,025,990	1,814,026	1.1168	1,646	3.629

Calculated specs for Feed Gas, Emissions and Products

Component	NG - fired NG	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 CO2/mmBtu)HHV	118.11	0.00	136.68	136.87	136.42	116.87
C factor (lb CO2/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 CO2/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, gCO2/MJ	56.2	0.0	65.1	65.2	65.0	55.6
g CO2/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/m3	36.7	0.0	67.5	57.5	89.4	35.6
SG	0.610	1.216	1.272	1.132	1.581	0.587
Density (g/ft3)	21.2	42.2	44.1	39.3	54.9	20.4
Density (g/m3)	747.9	1490.2	1558.8	1386.3	1937.1	719.3
	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

947.8171

1646

75,574	77,156

81.40344129 MJ/gal

1.1075 0.902935 0.902935

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	
$i\text{-}C_4H_{10}$	13.5	0.0	7.6	0.4	7.2	5.8	
$n\text{-}C_4H_{10}$	14.5	0.0	9.3	0.5	8.9	5.2	
$i\text{-}C_5H_{12}$	3.6	0.0	2.7	2.5	0.3	0.8	
$n\text{-}C_5H_{12}$	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, base LNG	1.0765	0.0106	0.0765	0.0467	0.0298	1.00	1.0000
	9,372	93	666	407	8,706		

Upstream inputs

Natural Gas upstream WA	Emissions (g/mmBtu), LHV			
Processing Step	**CO_2**	**CH_4**	**N_2O**	**CO_{2e}**
Natural Gas Extraction	2,356	8.91	0.02	2,876.19
Extraction Fugitive	0.00	135.74	0.00	3,691.60
Natural Gas Processing	1,845	4.37	0.01	2,252.37
Processing Fugtive	778	6.83	0.00	1,246.31
Transmission & Storage	377	13.68	0.30	1,017.00
Transmisison Fugitive	0.00	19.19	0.00	777.75
Total	**5,355**	**189**	**0**	**10,371**

Upstream Life Cycle Data. Source: GHGenius for BC, GREET NA Natural Gas, PSE FEIS for BC inventory

GHGenius			GREET			BC Inventory		
CO2	CH4	N2O	CO2	CH4	N2O	CO2	CH4	N2O
2355.559	8.90518	0.020759	2126.915308	8.040794784	0.018744431	6,030	46	0
	135.744			122.5679201		824	6	0
1845.076	4.371853	0.014211	1665.982414	3.947497367	0.012831328			
777.5359	6.830768		702.0639913	6.167736439				
377	13.68	0.295	1650.744077	17.69875777	1.253646641			
	19.19			40.36132186				

Natural Gas upstream BC FORTIS GIG HARBOR

Natural Gas upstream BC	Emissions g/mmBTU (LHV)			
	CO2	**CH4**	**N2O**	
Natural Gas Extraction	2,356	9	0	2876.188209
Fugitive Emissions	0	136	0	3691.599287
Natural Gas Processing	1,845	4	0	2252.371857
Transmission	778	7	0	1246.305073
Total	**4,978**	**156**	**0**	9172.464426
				298

Natural Gas upstream from PSE for Lower Sensitivity

				298
Natural Gas upstream BC	**Emissions g/mmBTU (LHV)**			#VALUE!
	CO2	**CH4**	**N2O**	#VALUE!
Natural Gas Extraction and processing	6,030	46	0.16	7465.5
Transmission	824	6	0.02	1269.5
				365.5
				298
Total	**6,854**	**51**	**0**	8437
Distribution	10	2	0.00	

Table 3. 2015 GHG Emissions Rates for Natural Gas Production, Transmission, and Distribution in British Columbia

BC Natural Gas GHG Emissions (grams/MMBTU)	CO_2	CH_4	N_2O	CO_2e
Natural Gas Production and Processing	6,030	45.5	0.16	7,216
Oil and Natural Gas Transmission	824	5.9	0.02	978
Natural Gas Distribution	10	2.3	0.00	67
Total	6,863	53.7	0.18	8,260
Total Ex-Distribution	6,853	51.5	0.18	**8,193**

Power generation			Emissions (g/kWh)		
Processing Step	**Code**		**CO_2**	**CH_4**	**N_2O**
Washington	WA	Upstream	8.2	0.3800	0.0010
		Power Plants	196.0	0.0100	0.0030
Tacoma	TA	Upstream	1	0.0454	0.0001
		Power Plants	27	0.0003	0.0003
Marginal	MA	Upstream	20	0.6462	0.0026
		Power Plants	212	0.0090	0.0014
eGRID NWPP	NW	Upstream	11	0.5569	0.0010
		Power Plants	297	0.0107	0.0047

Crude Oil Resource Mix	U.S. Average
API Gravity	31.2
Imported Oil	43.80%
Canadian Oil Sands	10.30%
Refinery Efficiency	
Residual Oil	94.83%
Diesel	90.92%
Product Transport	
% Marine Vessel	29%
Average Distance	8,373

	Emissions (g/mmBtu), LHV		
Processing Step	CO_2	CH_4	N_2O
U.S. Bunker Fuel			
Crude Oil Production	12,627		
Extraction Fugitive			
Crude Oil Refining	4,049	10.49	0.07
Processing Fugitive			
Transport	419	0.69	0.01
Transport Fugitive			
Total U.S. Bunker Fuel	**17,095**	**11**	**0**
U.S. Diesel Fuel			
Crude Oil Production	13,155		
Extraction Fugitive			
Crude Oil Refining	7,386	20.46	0.14
Processing Fugitive			
Transport	376	0.66	0.01
Transport Fugitive			
Total U.S. Diesel Fuel	**20,918**	**21**	**0**
U.S.Gasoline Fuel			
Crude Oil Production	11,533		
Extraction Fugitive			
Crude Oil Refining	13,232		
Processing Fugitive			
Transport	491		
Transport Fugitive			
Ethanol blending	-1,006		
Total WA. Gasoline Fuel	**24,251**	**0**	**0**

INPUTS - NO PROJECT

Diesel fuel storage pumping	Consumption, Estimate
Processing Step	**kWhel/mmBtu**
Pumping Diesel fuel from tank to vehi	0.01

Loss of LNG Peak Shaving - Boiler opera	Consumption, Estimate
Processing Step	**kWhel/mmBtu**
Pumping Diesel fuel from tank to boile	0.01

ENDUSE

Gig harbor Delivery

Distance for LNG delivery by Diesel Tru	miles
Project	17
No Project	175

Truck capacity	gallons/trip
Capacity per trip	10,000

Energy Consumption	BTU/mile
	17,738

Life Cycle Step	Mgal/ year	GBtu/ year	GHG Emissions tonne/year	GHG Emissions tonne/40 year	GHG Emissions kg/1000 gal
NEW LNG Plant					
Construction Emissions					
Total Construction			**1,581**	**63,232**	**9**
Direct (Equipment)			182	7,289	1.0
Upstream Life Cycle (Equipment)			20	812	0.1
Upstream Life Cycle (Power)			57	2,262	0.3
Upstream Life Cycle (Material)			1,322	52,869	7.4
Operational Emissions					
Upstream Life cycle			**207,844**	**8,313,769**	**1,171**
Natural Gas			154,504	6,180,176	870
Power LNG production			51,477	2,059,079	290
Diesel Emergency			143	5,730	1
Power LNG Vaporizer -Peak Shaving			1,718	68,738	10
Gig harbor Diesel truck fuel			1.2	46	0.01
Direct LNG Plant			**108,997**	**4,359,871**	**614**
LNG Production			94,333	3,773,303	531
Vaporizer -On-site Peak Shaving			942	37,674	5
Marine vessel bunkering, truck CH4			13,722	548,893	77
End Use LNG	**177.50**	**13,695**	**987,120**	**39,484,803**	**5,561**
On-site Peak Shaving	9.73	750	43,854	1,754,145	247
Gig harbor LNG	1.78	137	8,129.5	325,180	46
On-road Trucking	3.55	274	17,862	714,482	101
TOTE Marine	37.93	2,927	207,659	8,306,355	1,170
TOTE Marine Diesel Pilot fuel			7,000	279,992	39
Truck-to-Ship Bunkering	1.78	137	9,717	388,695	55
Truck-to-Ship Bunkering Pilot Fuel			328	13,102	2
Other Marine LNG (by Bunker Barge)	122.74	9,470	670,204	26,808,168	3,776
Other Marine Diesel Pilot Fuel			22,367	894,685	126
Total Emissions (Tacoma LNG)			**1,305,542**	**52,221,676**	**7,355**

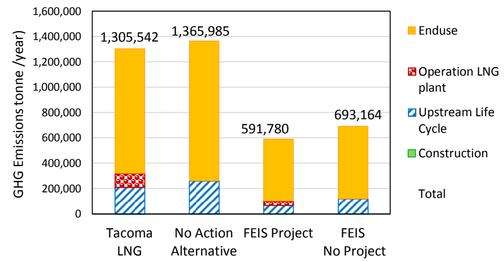
NO ACTION

Life Cycle Step	Mgal/ year	GBtu/ year	GHG Emissions tonne/year	GHG Emissions tonne/40 year	GHG Emissions kg/1000 gal
Upstream Displaced Emissions					
Total Upstream			**260,100**	**10,403,984**	**1,465.35**
No Peak Shaving - Diesel Dual Fuel		750	16,127	645,097	91
Upstream Gig harbor Peak Shaving		137	2,174	86,947	12.25
Upstream On-road trucking		247	5,297	211,886	30
Upstream TOTE Marine Diesel		3014	64,775	2,591,007	365
Upstream Truck-to-Ship Bunkering		141	2,454	98,172	14
Upstream Other Marine Diesel (by Bunker Barge)		9729	169,272	6,770,875	954
End Use Emissions					
Total End Use Diesel /Fuel Oil/LNG	**110.7**	**14,018**	**1,105,885**	**44,235,403**	**6,230**
Diesel Peak Shaving for Power	5.89	750	58,891	2,355,620	332
Gig harbor LNG	1.78	137	8,168	326,739	46.02
On-road Trucking	1.93	247	19,316	772,637	109
TOTE Marine Diesel	23.65	3,014	240,326	9,613,048	1,354
Truck-to-Ship Bunkering	1.11	141	11,246	449,841	63
Other Marine Diesel (by Bunker Barge)	76.33	9,729	767,938	30,717,517	4,326
Total Emission (No Action)			**1,365,985**	**54,639,386**	**7,696**
Net Emission reduction			**-60,443**	**-2,417,711**	**-341**
in percentage			-4.42%	-4.42%	-4.42%

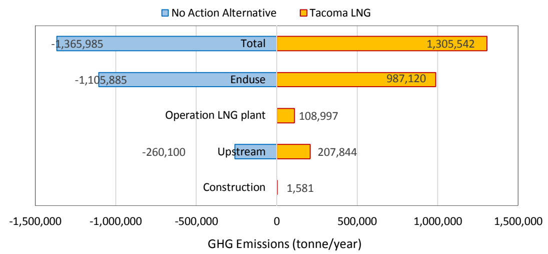
Short tables

Life Cycle Step	Mgal/ year	GBtu/ year	GHG Emissions tonne/year	GHG Emissions tonne/40 year	GHG Emissions kg/1000 gal
Tacoma LNG					
Construction			**1,581**	**63,232**	**9**
Upstream Life cycle			**207,844**	**8,313,769**	**1,171**
Direct LNG Plant			**108,997**	**4,359,871**	**614**
End Use LNG	**177.50**	**13,695**	**987,120**	**39,484,803**	**5,561**
On-site Peak Shaving	9.73	750	43,854		
Gig harbor LNG	1.78	137	8,129		
On-road Trucking	3.55	274	17,862		
TOTE Marine	37.93	2927	207,659		
TOTE Marine Diesel Pilot fuel	0.00	0	7,000		
Truck-to-Ship Bunkering	1.78	137	9,717		
Truck-to-Ship Bunkering Pilot Fuel			328		
Other Marine LNG (by Bunker Barge)	122.74	9470	670,204		
Other Marine Diesel Pilot Fuel			22,367		
Total	**177.50**	**13,695**	**1,305,542**	**52,221,676**	**7,355**
NO ACTION					
Upstream Life Cycle			**260,100**	**10,403,984**	**1,465**
Total End Use Diesel /Fuel Oil/LNG	**110.68**	**14,018**	**1,105,885**	**44,235,403**	**6,230**
Diesel Peak Shaving for Power	5.89	750	58,891		
Gig harbor LNG	1.78	137	8,168		
On-road Trucking	1.93	247	19,316		
TOTE Marine Diesel	23.65	3,014	240,326		
Truck-to-Ship Bunkering	1.11	141	11,246		
Other Marine Diesel (by Bunker Barge)	76.33	9,729	767,938		
Total	**110.68**	**14,018**	**1,365,985**	**54,639,386**	**7,696**
Net Emissions		-4.42%	**-60,443**	**-2,417,711**	**-341**
				-4.42%	-4.42%

GHG Emissions (tonne/year)	Tacoma LNG	No Action Alternative	FEIS Project	FEIS No Project
Construction	1,581			
Upstream Life Cycle	207,844	260,100	69,299	119,238
Operation LNG plant	108,997	0	33,539	0
Enduse	987,120	1,105,885	488,942	573,926
Total	1,305,542	1,365,985	591,780	693,164
Net Emissions	**-60,443**		-101,385	
	-0.0442485		-14.63%	



GHG Emissions (GBtu/ year)	No Action Alternative	Tacoma LNG	Net Emissions
Construction		1,581	
Upstream	-260,100	207,844	
Operation LNG plant	0	108,997	
Enduse	-1,105,885	987,120	
Total	-1,365,985	1,305,542	-60,443



Direct End Use Scenario: 500,000 gal/year

	LNG Enduse	Equipment Type	Consumption Mgal/yr	GBtu, LHV/yr	EER	Btu/gal		
Scenario B								
	Power Peak Shaving							
	LNG	Dual Fuel Turbine	9.73	750	1	77,156	9.726027	
	Displaced Diesel	Dual Fuel Turbine	5.89	750		127,464	5.88731	
	Gig Harbor LNG							
	LNG	NG Boiler	1.78	137	1	77,156	1.775	
	LNG	NG Boiler	1.78	137		77,156	1.775	
	On-road Trucking							
	LNG	Truck Engine	3.55	274	0.9	77,156	3.55	ARB LNG Pathway document
	Diesel	Truck Engine	1.93	247		127,464	1.933981	
	TOTE Marine							
loss factor	LNG	Marine Engine	37.93	2,927	1	77,156	37.93151	
	Pilot diesel Fuel for LNG	Marine Engine	0.69	88	1	127,464	0.625559	
	Displaced MDO Fuel	Marine Engine	23.65	3,014		127,464	21.47753	
	Truck-to-Ship Bunkering							
loss facor	LNG	Marine Engine	1.78	137	1	77,156	1.775	
	Pilot Fuel for LNG	Marine Engine	0.03	4		127,464	0.029273	
	Displaced MDO Fuel	Marine Engine	1.11	141		127,464	1.005038	
	Other Marine (by Bunker Barge)							
	LNG	Marine Engine	122.74	9,445	1	77,156	122.7423	
	Pilot Fuel for LNG	Marine Engine	2.22	283	1	127,464	2.024243	
	Displaced MDO Fuel	Marine Engine	76.33	9,729		127,464	69.49901	
	Total LNG		177.500	13,670				

T 4.2

	Scenario B GHG Emissions	Equipment Type	Emissions (tonne/year) CO_2c	CH_4	N_2O	CO_2e			
	Power Peak Shaving							B	
	LNG	Duct Firing	43,755	1	0.26	43,854		43853.64	
	Diesel	Duct Firing	58,682	0	0.69	58,891		58890.5	
	Gig Harbor Delivery								
Diesel	LNG Tacoma	Truck Engine	4	0	0.00	4.2		4.200144	
Diesel	LNG	Truck Engine	43	0	0.00	43		43.17362	
	LNG Tacoma End Use	NG Boiler	8,125	0	0	8,143		8143.21	
	LNG End Use	NG Boiler	8,125	0	0	8,143		8143.21	
	On-road Trucking								
	LNG	Truck Engine	15,738	85	0.01	17,862		17862.04	
	Diesel	Truck Engine	19,274	1	0.04	19,316		19315.93	
	TOTE Marine								
	LNG	Marine Engine	157,787	1,864	11	207,659		226164.6	
	Pilot fuel	Marine Engine	6,899	0	0.33	7,000		7611.397	
	MDO Fuel	Marine Engine	236,870	4	11.29	240,326		261324.6	
	Truck-to-Ship Bunkering								
	LNG incl. Pilot fuel	Marine Engine	7,384	87	0.51	9,717		10575.31	
	Pilot fuel	Marine Engine	323	0	0.02	328		356.1743	
	Diesel Truck	Truck Engine	0	0	0.00	0	NET 0 diffe	0	
	MDO Fuel	Marine Engine	11,084	0	0.53	11,246		12228.65	
	Other Marine (by Bunker Barge)								
	LNG	Marine Engine	509,247	6,016	35	670,204		70955.01	Marine Fuel + Operations losses
	Pilot fuel	Marine Engine	22,266	0	0.33	22,367		24399.05	
	MDO Fuel	Marine Engine	764,482	4	11.29	767,938		837700.8	

Assume barge delivers MDO for displaced emissions

Scenario B		
LNG Enduse	Mgal/yr	GBtu, LHV/yr
Power Peak Shaving	9.73	750
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)	122.74	9,445
Total LNG	177.500	13,670

Tacoma LNG Emissions

Scenario B		Emissions (tonne/year)				
LNG Project	Equipment Type	CO_2c	CH_4	N_2O	CO_2e	
On-site Peak Shaving						
LNG	Dual Fuel Boiler	43,755	1	0	43,854	
Gig harbor Delivery						
LNG Tacoma	Truck Engine	4	0	0	4	
LNG Tacoma End Use	NG Boiler	8,125	0	0	8,143	
On-road Trucking						
LNG	Truck Engine	15,738	85	0	17,862	
TOTE Marine						
LNG	Marine Engine	157,787	1,864	11	207,659	
Pilot fuel	Marine Engine	6,899	0	0	7,000	
Truck-to-Ship Bunkering						
LNG incl. Pilot fuel	Marine Engine	7,384	87	1	9,717	
Pilot fuel	Marine Engine	323	0	0	328	
Diesel Truck	Truck Engine	0	0	0	0	NET 0
Other Marine (by Bunker Barge)						
LNG	Marine Engine	509,247	6,016	35	670,204	
Pilot fuel	Marine Engine	22,266	0	0	22,367	
Total End Use		**771,529**	**8,054**	**48**	**987,138**	

Non Action

Scenario B		Emissions (tonne/year)			
NO LNG Project	Equipment Type	CO_2c	CH_4	N_2O	CO_2e
On-site Peak Shaving					
Diesel - Upstream		15,697	15.8	0.1	16,125
Diesel - Power pumping		2	0.0	0.0	2
Diesel - End use	Dual Fuel Boiler	58,682	0.1	0.7	58,891
Gig harbor Delivery					
LNG	Truck Engine	43	0.0	0.0	43
LNG End Use	NG Boiler	8,125	0.1	0.0	8,143
On-road Trucking					
Diesel	Truck Engine	19,274	1.2	0.0	19,316
TOTE Marine					
MDO - Upstream		63,055	63.6	0.4	64,775
MDO fuel	Marine Engine	236,870	3.6	11.3	240,326
Truck-to-Ship Bunkering					
MDO Fuel	Marine Engine	11,084	0.2	0.5	11,246
Other Marine (by Bunker Barge)					
MDO - Upstream		166,313	108.8	0.8	169,272
MDO fuel	Marine Engine	764,482	3.6	11.3	767,938
Total End Use		**1,327,928**	**181**	**25**	**1,339,950**

Scenario B		Emissions (tonne/year), LHV			
NO LNG Project	Equipment Type	CO_2c	CH_4	N_2O	CO_2e
On-site Peak Shaving					
Diesel - Upstream		15,697	16	0	16,125
Diesel - Power pumping	Power	2	0	0	2
Diesel - End use	Dual Fuel Boiler	58,682	0	1	58,891
Total		**74,380**	**16**	**1**	**75,017**

LCA

Natural Gas upstream	Emissions (g/mmBtu), LHV			
Processing Step	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Natural Gas Extraction	2,356	8.9	0.021	2,584
Extraction Fugitive	0	135.7	0.000	3,394
Natural Gas Processing	1,845	4.4	0.014	1,959
Processing Fugtive	778	6.8	0.000	948
Transmission & Storage	377	13.7	0.295	807
Transmisison Fugitive	0.0	19.2	0.000	480
Total Natural Gas	**5,355**	**189**	**0.3**	**10,172**

Energy Input/Output: Based on 250,000 gal/day	NG Feed	LNG Output	ratio NG/LNG	NG Btu/gal LNG	
NG Feed (lb/day)	2,025,990	1,814,026	1.1168		with Loss Factor
LHV (based on mass ratio see INPUT	42,695	38,570	1.107	85,407	85,577
LHV, Btu/gal	21,074	21,262			

Natural Gas upstream LNG	GHG Emissions (kg/1000 gal LNG)				
	CO_2	**CH_4**	**N_2O**	**CO_2e**	just CH4
Natural Gas upstream	458.3	16.2	0.0	870.4	403.8
					71,666
					358,332

Power generation			Emissions (g/kWh)			
Processing Step	**Code**		**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Washington	WAUP	Upstream	8.2	0.3800	0.0010	18
	WAPP	Power Plants	196.0	0.0100	0.0030	197
Tacoma	TAUP	Upstream	1.3	0.0454	0.0001	2
	TAPP	Power Plants	27.4	0.0003	0.0003	27
Marginal	MAUP	Upstream	19.7	0.6462	0.0026	37
	MAPP	Power Plants	212.3	0.0090	0.0014	213
eGRID NWPP	NWUP	Upstream	11.5	0.5569	0.0010	26
	NWPP	Power Plants	297.2	0.0107	0.0047	299
Selected GEN MIX	**WA**					
Washington	**WAUP**	**Upstream**	**8.2**	**0.3800**	**0.0010**	**18**
	WAPP	**Power Plants**	**196.0**	**0.0100**	**0.0030**	**197**

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**

Power Consumption LNG Production	Baseline	GHG Emissions (kg/1000 gal LNG)			
Power (kWh/1000 gal)	1348	CO_2	CH_4	N_2O	CO_2e
Mix	**WA**	**275.3**	**0.5**	**0.0**	**290.0**

Power Consumption Vaporizer/ Peak Shaving	Baseline	GHG Emissions (kg/1000 gal LNG)			
Power (kWh/1000 gal)	45	CO_2	CH_4	N_2O	CO_2e
Mix	**WA**	**9.2**	**0.0**	**0.0**	**9.7**

Comparision to reported values
Provided BID Report page 4

Natural Gas upstream	Emissions (g/mmBtu), LHV			
Processing Step	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Natural Gas Production & Processing	6,030	45.5	0.160	7,215
Transmission & Storage	824	5.9	0.0	977
Natural Gas Distribution	10	2.3	0	68
Total	6,864	53.70	0.18	8,260
Total Ex-Distribution	**6,854**	**51.40**	**0.18**	**8,193**

Source: Provided Report BID page 14

Table 9. Tacoma Power Generating Mix (2016)

Fuel Type	Percentage Used
Hydro Power	84%
Nuclear*	6%
Coal*	2%
Natural Gas	1%
Wind	7%

*Represents a portion of the power Tacoma Power gets from the Bonneville Power Administration.

Table 10. Upstream GHG Emissions Associated With Facility Electrical Energy Use

Source: Provided Report BID page 14

Power Consumption LNG Production		Upstream Emissions from Tacoma Power Supply							
		VOC	CO	NOx	BC	OC	CH4	N2O	CO2
Emissions Rate	grams/mmBTUel	0.65	1.63	3.83	0.02	0.05	10.92	0.09	5942.00
per Power	g/kWhel	0.00	0.01	0.01	0.00	0.00	0.04	0.00	20.27
Emissions Rate	g/mmBTU LNG	0.04	0.101	0.237	0.001	0.003	0.674	0.006	367.1
of End product	**kg/ 1000 gal**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**27.99**

NO PROJECT

Diesel fuel storage pumping	Consumption, Estir	Emissions (g/mmBtu), LHV			
Processing Step	**kWhel/mmBtu**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Pumping Diesel fuel from tank to vehicle	0.01	2.042	0.004	0.000	2.151
Total		2.042	0.004	0.000	2.151

NO PROJECT

Loss of LNG Peak Shaving - Boiler operation with	Consumption, Estir	Emissions (g/mmBtu), LHV			
Processing Step	**kWhel/mmBtu**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Pumping Diesel fuel from tank to boiler	0.01	2.042	0.004	0.000	2.900
Total		2.042	0.004	0.000	2.900

Crude Oil Resource Mix	U.S. Average	WA
API Gravity	31.2	30.8
Imported Oil	43.80%	37.10%
Canadian Oil Sands	10.30%	13.20%
Refinery Efficiency		
Residual Oil	94.83%	94.80%
Diesel	90.92%	90.90%
Product Transport		
% Marine Vessel	29.02%	46.00%
Average Distance	8,373.0	2,470.0

	Emissions (g/mmBtu), LHV			
Processing Step	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
WA. Bunker Fuel				
Crude Oil Production	12,627	0	0	12,627
Extraction Fugitive	0	0	0	0
Crude Oil Refining	4,049	10.491	0.073	4,333
Processing Fugitive	0	0.000	0.000	0
Transport	419	0.692	0.009	439
Transport Fugitive	0	0.000	0.000	0
Total U.S. Bunker Fuel	**17,095**	**11.18**	**0.082**	**17,399**
WA Diesel Fuel				
Crude Oil Production	13,155	0	0.0	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 U.S. Diesel Fuel	**20,918**	**21.11**	**0.144**	**21,488**
WA.Gasoline Fuel				
Crude Oil Production	11,533	0.0	0.0	11,533
Extraction Fugitive	0	0.0	0.0	
Crude Oil Refining	13,232	0.0	0.0	13,232
Processing Fugitive	0	0.0	0.0	
Transport	491	0.0	0.0	491
Transport Fugitive	0	0.0	0.0	
Ethanol blending	-1,006	0.0	0.0	-1,006
Total WA. Gasoline Fuel	**24,251**	**0.0**	**0.0**	**24,251**

PROJECT

Diesel fuel for emergency genset	Consumption	Emissions (kg/1000 gal), LHV			
Processing Step	**mmBtu/ 1000 gal LNG**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Upstream Diesel production	0.0375569	0.79	0.00	0.00	0.8
Total		1	0	0	0.8

PROJECT

Gig Harbor Diesel Truck fuel

Upstream Diesel production	Consumption	Emissions (tonne/yr), LHV			
Processing Step	**mmBtu/year**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
LNG Project	53.52	1.12	0.00	0.00	1.15

Upstream GHG Emissions for Tacoma LNG

Pollutant	CO_2	CH_4	N_2O	CO_2e	Use Rate	
Emissions (kg/1000 gal), LHV						
Upstream Natural Gas	458.3	16.2	0.0	870.4	85,577	Btu/gal
Upstream Power LNG production	275.3	0.5	0.0	290.0	1.35	kWh/gal
Upstream Diesel Emergency	0.79	0.00	0.00	0.8	37.6	Btu/gal
Upstream Power LNG Vaporizer	9.2	0.0	0.0	9.7	0.045	kWh/gal
Total Upstream	**743.5**	**16.7**	**0.0**	**1170.9**		

NO PROJECT

	Upstream LNG/Diesel/Bunker fuel production	Consumption		Emissions (tonne/yr)			
	Processing Step	**GBtu/year**	**Fuel**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
D	No Peak Shaving - Diesel Boiler operation	750	Diesel	15,697	16	0.11	16,125
N	Gig harbor NG & LNG production	137	Natural Gas	1,621	21.4	0.0	2,162
D	Gig harbor Diesel truck fuel	0.55	Diesel	11.5	0.01	0.00	11.8
D	Diesel Storage On-road trucking	247	Diesel	5,156	5.2	0.04	5,297
B	TOTE Marine Diesel	3,014	MDO	63,055	64	0.43	64,775
B	Truck-to-Ship Bunkering	141	MDO	2,411	1.6	0.01	2,454
D	Other Marine Diesel	9,729	MDO	166,313	109	0.80	169,272
	Total			254,265	217	1.4	260,097
							260,100

DO NOT PRINT

Tacoma LNG Plant

Total NG end use	**13,670**	**GBtu, LHV/year**
On-site Peak Shaving	750	GBtu, LHV/year
LNG Output	12,920	GBtu, LHV/year

LNG Preatreatment

Operational hours	8,520	hr/yr
NG WPG heater	18	mmBtu/hr
	153,360	mmBtu/year
NG Regenerator heater	3.2	mmBtu/hr
	27,264	mmBtu/year
Total Annual Consumption	**180,624**	**mmBtu/year**
CO2 seperation efficiency	99.76%	

Waste gas Flare

Operational hours	8,760	hr/yr
Waste Gas Flow	80,834	scf/hr
Waste Gas Heat Capacity	71.2	mmBtu/hr
Total Heat Input	**623,712**	**mmBtu/yr**
Seperated CO2		

Vaporizer

Operational hours	240	hr/yr
LNGg Heater Capacity	66.00	mmBtu/hr
Total Consumption	15,840	mmBtu Fuel gas
Power requir. (Grid)	0.04500	kWh/gal
	0.00347	kWhel/mmBtu
		(estimate need of 1830 Btu/gal LNG)

Emergency equipment

Diesel geneartor ULSD		
Operational hours	500	hr/yr
Capacity	1,500	kW
Electricity generation	750,000	kWh/yr
Diesel consumption	104.6	gal/h
	52,300	gal/year
	6,666	mmBtu/year
	164.3	tonne/year

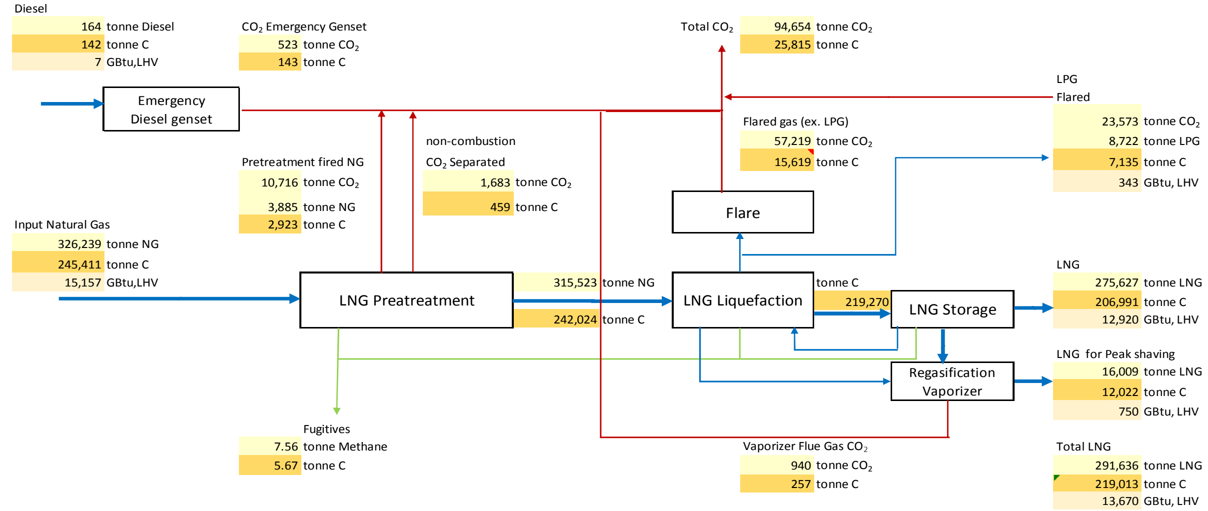
Liquefaction

Power require. (Grid)	1.35	kWh/galLNG
Operational hours Liqu.	8,520	hr/year

Fugitives - Refrigerant losses through Compressor Seals

	tonne/year
Methane	7.56

Annual throughput



eet on the right

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.

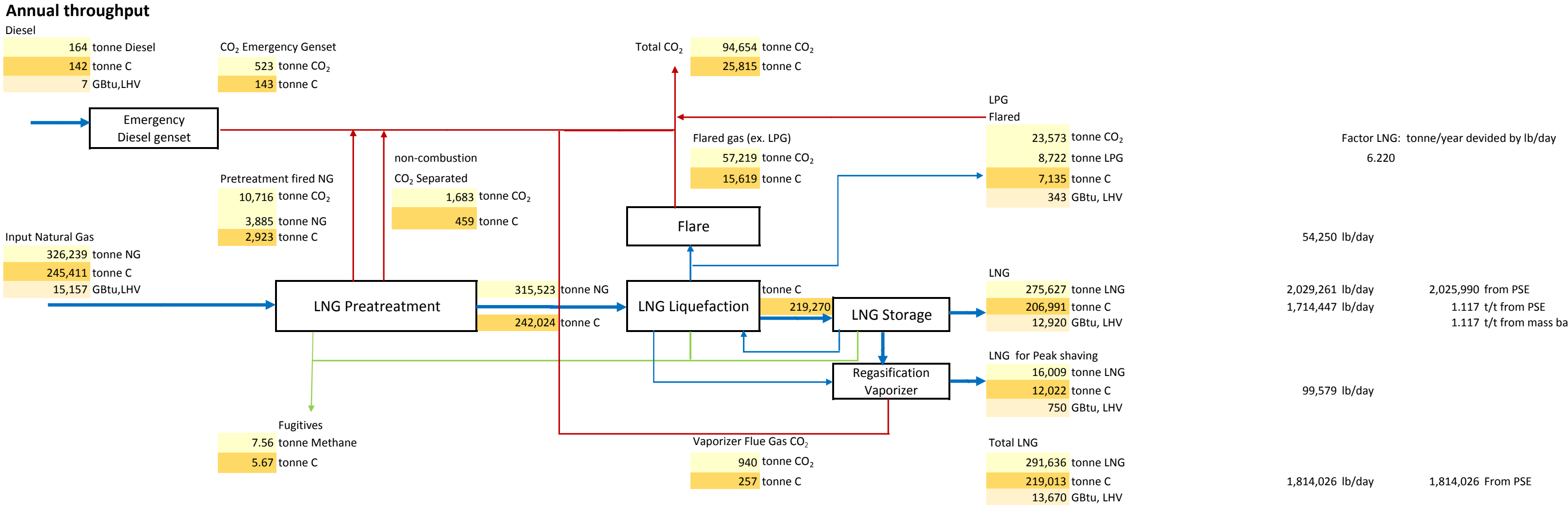
This way ---->

Carbon Mass balance

	Input,ouput		CO_2	Methane	**C content**			
	lb/day	tonne/yr	tonne/yr	tonne/yr	**tonne/yr**	**Comments**	**Source**	
Input NG								
Natural gas	2,025,990	326,239			**245,411**			
Total NG Input	2,025,990	326,239			**245,411**			
Products								
LPG, estimated	0	0			**0**	A		
LNG	1,814,026	291,636			**219,013**			
Total Products	1,814,026	291,636			**219,013**			
Emissions								
Pretreatment			10,716		**2,923**		Heater fired by NG and boil off gas (BOG). BID response p8.- 9 page 12 PSE-BID	
CO_2 Separated (non-combustion)			1,683		**459**	B	Using Gas composition and given separation efficiecy	
Flaring (combustion)			55,535		**15,619**		Flaring is used to close C-Balance	
Flaring from LPG (combustion)			23,573		**7,135**		Using gas composition calculation and EF of LPG boiler (no flar data)	
Fugitives CH_4				7.56	**6**		Using given inventoru see Sheet Fugitives	**95**
Vaporizing onside peak shaving			940		**257**		Boiler primary fuel is NG. However, the fuel gas mix can include compressed boil-off gas (BOG) . BID response p.9	
Total Emissions			92,448	8	**26,398**			
Total Product + Emissions			92,448	8	**245,411**			
Total NG Input - Product + Emissions					**0**			

Comments:
A: How much LPG is produced as product? LPG production is not mentioned in the Response.
B: In the FEIS report page 103 the value is 10,703tonne/year. Could you clarify this?

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

LNG PLANT

Direct Combustion Emission Rate		Emission Factor (g/mmBtu), LHV			
Process	**Equipment**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
LNG Pretreatment	Boiler, NG	59,330	1.06	0.35	59,461
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
Vaporizer	Boiler, NG	1,252	0.02	0.01	1,255
Vaporizer	Pump Power	1	0.00	0.00	1.0

		Emissions (tonne/year)			
Process	**Equipment**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
LNG Pretreatment	Boiler, NG	10,716	0.19	0.06	10,740
Waste Gas Flaring	Flare	57,219	0.88	0.89	57,506
LPG flaring	Flare	23,573	0.37	0.37	23,691
Emergency Generator	Diesel Genset	521	0.03	0.00	523
Non-combustion C02 from pretrea	Vent/flare	1,683	0.00	0.00	1,683
Fugitives	Equip. Leaks	0	7.56	0.00	189
Sub - Total		**93,712**	**9**	**1**	**94,333**
Vaporizer	Boiler	940	0	0	942
Vaporizer	Pump - power	0.7	0.0	0.0	0.8
Fugitives					
Fugitives Ship/Barge Loading	Equip. Leaks	0.0	7.5	0.0	187.8
Fugitives - Bunker Vessel Storage	Equip. Leaks	0.0	528.5	0.0	13,212.5
Fugitives - Truck to Ship	Equip. Leaks	1.0	12.9	1.0	322.1
Total		**94,654**	**558**	**2**	**108,998**

Info for Table

Flare Check

55,553

	Specific Emission g/mmBtu (LNG product)			
Process	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
LNG Pretreatment	783.9	0.0	0.0	785.6
Emission from flaring (co	4185.6	0.1	0.1	4206.6
Emission from LPG flaring	1724.4	0.0	0.0	1733.0
Emergency Generator	38.1	0.0	0.0	38.3
Non-combustion C02 fror	123.1	0.0	0.0	123.1
Fugitives	0.0	0.6	0.0	13.8
Sub - Total	**6855.2**	**0.7**	**0.1**	**6900.5**
Total	6,924	41	0	7,973

		Emissions (tonne/year)			
Process	**Equipment**	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Vaporizer	Boiler	940	0	0	942
Vaporizer	Pump - power	0.7	0.0	0.0	0.8

BUNKERING

LNG Bunkering and Vessel loading Emissions	**CH_4 (g/mmBTU delivered)**	**CO_{2e} (g/mmBTU delivered)**	**Fraction of Gas Delivered by this Process**
Ship/Barge Loading	2.4	58.82	98%
Bunker Vessel Storage	6.4	160	73%
Truck/Ship-to-Ship Transfer	47.0	1,176	75%
Total	55.8	1,060	
GREET			

Explain losses

10000 gal
0.5 L
0.2 g
0.00025

loss

Loss Factor	0.1988%	Gas lost through the system
Net Delivered LNG	380,000	gallons per typical bunkering event

Bunker Barge Loading

Vapor Displaced	Recovery Rate	Loss per Bunkering Event	Volume per Bunkering Event (gallons)	Volume Lost per Bunkering Event (gallons)	CH_4 Emissions (g/mmBTU)	CO_{2e} Emissions (g/mmBTU)
0.22%	95.00%	0.011%	380,994	41.9	2.4	59

Bunker Vessel Storage

New ships have 0.1% loss

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 Emissions (g/mmBTU)	CO_{2e} Emissions (g/mmBTU)
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 Emissions (g/mmBTU)	CO_{2e} Emissions (g/mmBTU)
0.22%	0.00%	0.22%	380,838	838	47.0	1,176

Bunkering and Transfer Fugitives	**Volume (LNG gallons/year)**	**Loss Factor**	**CH_4 Emissions (LNG Gallons/year)**	**CH_4 Emissions (tonne/ year)**	**CO_{2e} Emissions (tonne/year)**	Check if exist
TOTE	41,481,507	0.0110%	4,563	8	188	1
Other Bunker Barge	122,742,315	0.2616%	321,080	528	13,212	1
Truck-to-Ship Bunkering	3,550,000	0.2205%	7,827	13	322	1
Total	**167,773,822**	**0.1988%**	**333,471**	**549**	**13,722**	

https://www.marad.dot.gov/wp-content/uploads/pdf/Methane-emissions-from-LNG-bunkering-20151124-final.pdf

Source: 2018-05-25 PSE Submittal page 78, table LNG Bunkering Emissions
see also https://www.marad.dot.gov/wp-content/uploads/pdf/Methane-emissions-from-LNG-bunkering-20151124-final.pdf

TOTAL

Total LNG plant emission	Emissions (tonne/year)					2 x	
	CO_2	**CH_4**	**N_2O**	**CO_2e**	**C**	**CO_2e FEIS**	See: BID p 12, and also BID REPORT, ATTACHMENT F (1 page)
LNG Pretreatment Boiler	10,716	0.19	0.06	10,740	2,926	9,860	uses EF of 53.06 kg/mmBtu for NG See EXCEL 2018 05-25 Tacoma l
Pretreatment CO2	1,683			1,683	460		
Flare waste Gas	57,219	1	1	57,506	15,621	56,262	FEIS uses EF provided by CB&I and flare vendor See EXCEL 2018 0!
Flare LPG	23,573	0	0	23,691	6,436	Included above	
Fugitives	0	7.56	0.00	189	8	190	
Emergency Generator	521	0.03	0.00	523	143	536	
Sub-Total	**93,712**	**9.03**	**1.32**	**94,333**	**25,595**	0.0	0 Waste gas for heater
Vaporizer	940	0.02	0.01	942	257		
Marine Vessel Bunkering, truck	0	548.89	0.00	13,722	550	1,684	
Total	**94,652**	**9.05**	**1.33**	**95,274**	**25,852**	68,532	

Source: BID REPORT, ATTACHMENT F (1 page)

LNG plant	Emissions (tonne CO2e/year)			
	CO_2	**CH_4**	**N_2O**	**CO_2e**
Flare	27,110	40.0	0.0	28,131
Vaporizer	841	0.0	0.0	842
WPG	4,183	0.1	0.0	4,186
Regen	744	0.0	0.0	744
Diesel Generator	534	0.0	0.0	536
Fugitives	--		--	95
Total	**33,411**	**41**	**0**	**34,533**

Propane Volume

24568 kg/day
12776 gal/day

Energy Efficiency

Input	**Unit**	**Tacoma**	**CA_GREET**
NG	lb/lb LNG	1.117	1.109
Electricity	kWh/1000 gal LNG	1,348.00	43.89

Do Not Print

Adjust results to 355 days of operation instead of 365, 88.75 Mgal/year inestead of 91.2

0.97260274

Scenario A	Project			No Project			Project			No Project		
	Fuel Throughput (MMBTU/year)	Loss Factor	GHG Emissions (MT CO2e/yea	Fuel Throughput (MMBTU/year)	Loss Factor	GHG Emissions (MT CO2e/year)	Fuel Throughput (MMBTU/year)	Loss Factor	GHG Emissions (MT CO2e/year)	Fuel Throughput (MMBTU/year)	Loss Factor	GHG Emissions (MT CO2e/year)
Extraction, processing, and transmission to Sumas hub	7,269,653	0.00%	59,563	748,262	0.00%	6,131	**7,070,485**	**0.00%**	**57,931**	**727,762**	**0.00%**	**5,963**
Transmission from Sumas Hub to PSE gate	7,266,233	0.05%	5,888	747,910	0.05%	606	**7,067,158**	**0.05%**	**5,727**	**727,419**	**0.05%**	**589**
Distribution via PSE System	7,259,336	0.095%	3,483	747,200	0.095%	359	**7,060,450**	**0.092%**	**3,388**	**726,729**	**0.092%**	**349**
Liquefaction	6,818,200	6.47%	36,800	0		0	**6,631,400**	**6.29%**	**35,792**	**0**	**0**	**0**
Direct Facility Emissions (includes Peak Shaving,	*6,818,200*		*34,483*	*0*		*0*	*6,631,400*	*0.00%*	*33,539*	*0*	*0*	*0*
Electricity Supply	*6,818,200*		*2,317*	*0*		*0*	*6,631,400*	*0.00%*	*2,253*	*0*	*0*	*0*
Vessel Loading of LNG	6,071,000		14,497	0		0	**5,904,671**	**0**	**14,100**	**0**	**0**	**0**
TOTE	*2,914,080*	0.011%	174	*0*		*0*	*2,834,242*	0.011%	169	*0*	*0*	*0*
Bunker Barge	*3,156,920*	0.837%	14,323	*0*		*0*	*3,070,429*	0.814%	13,930	*0*	*0*	*0*
Truck-to-Vessel	*0*	0.220%	0	*0*		*0*	0	0.214%	0	*0*	*0*	*0*
On-road Heavy-duty Truck Fuel	0		0	0		0	**0**	**0**	**0**	**0**	**0**	**0**
LNG (Plant-to-Tank Emissions)	*0*	*0.47%*	*0*	*0*		*0*	*0*	*0.46%*	*0*	*0*	*0*	*0*
LNG (Tank-to-Wheels Emissions)	*0*		*0*	*0*		*0*	*0*	*0.00%*	*0*	*0*	*0*	*0*
ULSD (Well-to-Wheels Emissions)	*0*		*0*	*0*		*0*	*0*	*0*	*0*	*0*	*0*	*0*
TOTE Vessel Operations	3,001,172		235,355	6,002,344		340,146	**2,918,948**	**0**	**228,907**	**5,837,897**	**0**	**330,827**
TOTE LNG (Direct Vessel Emissions)	*2,913,759*		*233,733*	*0*		*0*	*2,833,930*	*0*	*227,330*	*0*	*0*	*0*
TOTE Pilot Fuel Oil (Well-to-Tank Emissions)	*87,413*		*1,622*	*0*		*0*	*85,018*	*0*	*1,577*	*0*	*0*	*0*
TOTE Fuel Oil (Well-to-Tank Emissions)	*0*		*0*	*3,001,172*		*55,680*	*0*	*0*	*0*	*2,918,948*	*0*	*54,154*
TOTE Fuel Oil (Direct Vessel Emissions)	*0*		*0*	*3,001,172*		*284,466*	*0*	*0*	*0*	*2,918,948*	*0*	*276,672*
Other Vessel Operations	3,224,427		252,863	3,224,427		365,449	**3,136,086**	**0**	**245,935**	**3,136,086**	**0**	**355,437**
Other LNG (Direct Vessel Emissions)	*3,130,511*		*251,121*	*0*		*0*	*3,044,744*	*0*	*244,241*	*0*	*0*	*0*
Other Pilot Fuel Oil (Well-to-Tank Emissions)	*93,915*		*1,742*	*0*		*0*	*91,342*	*0*	*1,695*	*0*	*0*	*0*
Other Fuel Oil (Well-to-Tank Emissions)	*0*		*0*	*3,224,427*		*59,822*	*0*	*0*	*0*	*3,136,086*	*0*	*58,183*
Other Fuel Oil (Direct Vessel Emissions)	*0*		*0*	*3,224,427*		*305,627*	*0*	*0*	*0*	*3,136,086*	*0*	*297,254*
Total			**608,449**			**712,690**	**0**	**0**	**591,780**	**0**	**0**	**693,164**

Summary of Terminal Construction Emissions - GHG PSE LNG

Equipment (Direct + Upstream)	CO_2 (tonne/ year)	CH_4 (tonne/ year)	N_2O (tonne/ year)	CO_2e (tonne/ year)
1. Year - Construction Equipment	1,807	0.1	0.01	1,814
1. Year - Road Vehicles/Commuting	3	0.0	0.00	3
1. Year - Fugitive Dust				0
1. Year - Total Emissions	1,811	0.1	0.01	1,817
2. Year - Construction Equipment	3,638	0.3	0.03	3,654
2. Year - Road Vehicles/Commuting	298	0.0	0.00	298
2. Year - Fugitive Dust				0
2. Year - Total Emissions	3,936	0.3	0.03	3,953
3. Year - Construction Equipment	2,838	0.2	0.03	2,852
3. Year - Road Vehicles/Commuting	404	0.0	0.00	405
3. Year - Fugitive Dust				0
3. Year - Total Emissions	3,242	0.2	0.03	3,257
4. Year - Construction Equipment	1,655	0.1	0.02	1,664
4. Year - Road Vehicles/Commuting	2	0.0	0.00	2
4. Year - Fugitive Dust				0
4. Year - Total Emissions	1,657	0.1	0.02	1,666
Project TOTAL:	**10,646**	**0.8**	**0.09**	**10,692**

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
4. 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**

Equipment (Upstream)	CO_2 (tonne/ year)	CH_4 (tonne/ year)	N_2O (tonne/ year)	CO_2e (tonne/ year)
1. Year - Construction Equipment	104	0.1	0.00	107
1. Year - Road Vehicles/Commuting	1	0.0	0.00	1
1. Year - Fugitive Dust				0
1. Year - Total Emissions	105	0.1	0.00	108
2. Year - Construction Equipment	221	0.2	0.00	228
2. Year - Road Vehicles/Commuting	72	0.0	0.00	72
2. Year - Fugitive Dust				0
2. Year - Total Emissions	293	0.2	0.00	299
3. Year - Construction Equipment	189	0.2	0.00	195
3. Year - Road Vehicles/Commuting	97	0.0	0.00	97
3. Year - Fugitive Dust				0
3. Year - Total Emissions	286	0.2	0.00	292
4. Year - Construction Equipment	110	0.1	0.00	113
4. Year - Road Vehicles/Commuting	0	0.0	0.00	0
4. Year - Fugitive Dust				0
4. Year - Total Emissions	111	0.1	0.00	114
Project TOTAL:	**795**	**0.6**	**0.00**	**812**

Operation hours per month	205.44

Construction Emission during 1. 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)	CO2c (tonne/ year)	CH4 (tonne/ year)	N2O (tonne/ year)	CO2e use (tonne/ year)	Fuel consumption (mmBtu/year)	Upstream Emission Diesel production: Upstream CO2 (tonne/ year)	Upstream CH4 (tonne/ year)	Upstream N2O (tonne/ year)	Upstream CO2e (tonne/ year)	Total: 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 Tot	1,703	0.0178	0.0115	1707.1	4969	103.9	0.1	0.0	106.8	1,813.9

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 Tot	3,417	0.0486	0.0298	3427	10587.4376	221.4642	0.2235	0.0015	227.5070	3,654

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 Tot	2,649	0.0428	0.0260	2,658	9,052	189	0	0	195	2,852

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 Tot	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)

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**

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

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		26.6	0	0	0	0.00	0	0
Feb-1. Year	Winter 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		25.7	0	0	0	0.00	0	0
May-1. Year		26.6	0	0	0	0.00	0	0
Jun-1. Year	Summer 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		26.6	0	0	0	5.00	19	19
Nov-1. Year	Winter 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		26.6	0	0	0	0.00	0	0
Feb-2. Year	Winter 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		25.7	0	0	0	0.00	0	0
May-2. Year		26.6	0	0	0	0.00	0	0
Jun-2. Year	Summer 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		26.6	98	2,604	104,160	844.00	3,176	107,336
Nov-2. Year	Winter 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		26.6	98	2,604	104,160	888.00	3,342	107,502
Feb-3. Year	Winter 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		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	Summer 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		26.6	0	0	0	78.00	294	294
Nov-3. Year	Winter 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		26.6	0	0	0	39.00	147	147
Feb-4. Year	Winter 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		25.7	0	0	0	41.00	159	159
May-4. Year		26.6	0	0	0	39.00	147	147
Jun-4. Year	Summer 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		26.6	0	0	0	0.00	0	0
Nov-4. Year	Winter 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

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	38.00
	Summer	0	1225.00
2.Year	Winter	309,120	9999.00
	Summer	309,120	5789.00
3.Year	Winter	302,400	6356.00
	Summer	614,880	4160.00
4.Year	Winter	0	457.00
	Summer	0	306.00
Total		**1,535,520**	**28330.00**

Construction Material & Power- UPSTREAM Emissions -

Input	tonnes	Source
Steel	4,745	Response Tacoma LNG Supplementary SEIS Questions, July 07, 2018, page 5
Rebar	1666.0	
Stainless Steel	290.0	
Copper	26	
Asphalt	7570.0	
Paint	5.0	
Aggregate	80110.0	
Cement	1716.0	

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	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**	

Total power consumption during construction

Consumption	10,512,000	kWh

Source: Response Tacoma LNG Supplementary SEIS Questions, july 07, 2018, page 5

Upstream Emissions Power (see sheet Upstream, B40)

Gig Harbor Peak Shaving

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	No project	
Distance to gig harbor	17	175	miles/trip
Annual miles for delivery	3,018	31,063	miles/year
Diesel consumption per mile	**17,738**	**17,738**	**Btu/mile**
Total Diesel Consumption	**53.52**	**550.99**	**mmBtu/year**

	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
No project	550.99	43.08	0.00262	0.00010	43.2

On-road trucking

Annual Fuel delivery to tractors		Consumption	
	Equipment	Mgal/year	GBtu/year
LNG	Tractor engine	3.55	274
Diesel	Tractor engine	1.93	247

	Emissions (g/MMBTU)							Old value from BID
Pathway Component	**VOC**	**CO**	**NO_x**	**CH_4**	**N_2O**	**CO_2**	**CO_{2C}**	**CO_{2C}**
Tank-to-Wheels LNG Combination Tractor	21.07	1,167	66.09	309.766737	0.03250653	55,559	57,459	57,458
Total LNG Tacoma -to-Wheels	**21.07**	**1,167**	**66.09**	**309.8**	**0.03**	**55,559**	**57,459**	**57,458**
Well-to-Wheels Diesel Combination Tractor	**31.52**	**94.58**	**228.4**	**4.75**	**0.18**	77,938	**78,186**	**78,185**
Plant-to-Tank LNG Combination Tractor	0.308	1.289	7.299	104.5	0.017	753	756	756

	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

Ship Emissions and Fuel Consumption Estimates

Source: 2018-05-25 PSE Submittal page 79, tables TOTE Vessel Emissions

Route Definition

Ship Type	Origin	Destination	Distance at Sea (nm)	Transit Speed (knots)	Transit Time (hours)	Maneuvering Time (hours)	Time at Berth (Origin - hours)	Time at Berth (Destination - hours)	*Time within 200 nm* Transit	Maneuvering	Hotelling
RoRo	Anchorage	Tacoma	1450	22	65.9	2	10	10	14%	50%	50%

Use of extra pilot fuel for LNG Marine vessel	3%

Vessel Details

Service Speed (knots)	Max Speed (knots)	Installed Power (kW)	Main Engine Speed (RPM)	Aux Engine Speed (RPM)	Main Engine Type	Aux Engine Type	Boiler Type
24	25.5	52200	400	720	Low Pressure DF LNG All	Low Pressure DF LNG All	LNG Aux Boiler All

Outputs

Calculated Loads

Mode	Time (hours)	Main Engine Load (kW)	Aux Engine Load (kW)	Aux Boiler Load (kW)	Fuel - In ECA	Fuel - Outside ECA
Transit	65.9	33,396	132	0	LNG	LNG
Maneuvering	2.0	1,044	396	148	LNG	LNG
Hotelling	20.0	0	229	259	LNG	LNG

Emissions Calcs

Emissions Within 200nm (tonne per trip)

End Use Emissions Marine vessels	NO_x	VOC	CO	SO_2	PM10	PM2.5	DPM
	0.58	0.00	0.58	0.00	0.01	0.01	0.00
	0.01	0.00	0.02	0.00	0.00	0.00	0.00
	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Total Emissions (tonne)	0.60	0.00	0.60	0.00	0.01	0.01	0.00
Emissions Rate (g/tonne MGOe)	9,376	6	9,456	17	106	105	0
Emissions Rate (g/mmBtu MGOe, LHV)	251	0	253	0	3	3	0

Emissions Outside 200nm (tonne per trip)

End Use Emissions Marine vessels	NO_x	VOC	CO	SO_2	PM10	PM2.5	DPM
	3.62	0.00	3.62	0.01	0.04	0.04	0.00
	0.01	0.00	0.02	0.00	0.00	0.00	0.00
	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Total Emissions (tonne)	3.64	0.00	3.64	0.01	0.04	0.04	0.00
Emissions Rate (g/tonne MGOe)	9,310	3	9,323	17	99	99	0
Emissions Rate (g/mmBtu MGOe, LHV)	249	0	249	0	3	3	0

Total Emissions (tonne per trip)

End Use Emissions Marine vessels	NO_x	VOC	CO	SO_2	PM10	PM2.5	DPM
	4.20	0.00	4.20	0.01	0.04	0.04	0.00
	0.02	0.00	0.04	0.00	0.00	0.00	0.00
	0.02	0.00	0.01	0.00	0.00	0.00	0.00
Total Emissions (tonne)	4.24	0.00	4.25	0.01	0.05	0.05	0.00
Emissions Rate (g/tonne MGOe)	9,320	3	9,342	17	100	100	0
Emissions Rate (g/mmBtu MGOe, LHV)	230	0	230	0	2	2	0

Emissions Calcs

Emissions Within 200nm (tonne per trip)

End Use Emissions Marine vessels	CO_2	N_2O	CH_4	CO_2c	CO_2e
	135	0.01	1.62	136	179
	1	0.00	0.01	1	1
	3	0.00	0.01	3	3
Total Emissions (tonne)	139	0.01	1.64	140	183
Emissions Rate (g/tonne MGOe)	2,172,237	153	25,601	307,200	403,493
Emissions Rate (g/mmBtu MGOe, LHV)	58,070	4	684	58,467	76,794

Emissions Outside 200nm (tonne per trip)

End Use Emissions Marine vessels	CO_2	N_2O	CH_4	CO_2c	CO_2e
	846	0.06	10.10	851	1,121
	1	0.00	0.01	1	1
	3	0.00	0.01	3	3
Total Emissions (tonne)	849	0.06	10.12	855	1,126
Emissions Rate (g/tonne MGOe)	2,172,639	152	25,881	1,880,069	2,475,106
Emissions Rate (g/mmBtu MGOe, LHV)	58,080	4	692	58,472	76,979

Total Emissions (tonne per trip)

End Use Emissions Marine vessels	CO_2	N_2O	CH_4	CO_2c	CO_2e	BC	OC	Methane Slip
	981	0.07	11.71	988	1,301	0.01	0.00	0.43%
	1	0.00	0.02	2	2	0.00	0.00	0.36%
	5	0.00	0.02	5	6	0.00	0.00	0.16%
Total Emissions (tonne)	988	0.07	11.75	995	1,309	0.01	0.02	
Emissions Rate (g/tonne MGOe)	2,172,582	152	25,841	2,187,269	2,878,599	22	46	
Emissions Rate (g/mmBtu MGOe, LHV)	53,552	4	637	53,914	70,955	1	1	

Fuel Consumption Estimates

Geographic Region	Engine	Engine	Boiler
Fuel Consumed Within 200nm (MT MGOe)	62.2	0.8	0.8
Fuel Consumed Outside 200nm (MT MGOe)	387.9	2.2	0.8
Fuel Consumed (MT MGOe)	450.1	3.0	1.6

Within 200nm						Emissions Factors (g/kWh)				
Main Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Maneuvering	8.80	0.01	18.39	0.00	0.15	0.15	0.00	444	0.03	5.30
Hotelling	8.80	0.01	18.39	0.00	0.15	0.15	0.00	444	0.03	5.30
Aux Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Maneuvering	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Hotelling	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Aux Boiler	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00
Maneuvering	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00
Hotelling	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00

Outside 200nm						Emissions Factors (g/kWh)				
Main Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Maneuvering	8.80	0.01	18.39	0.00	0.15	0.15	0.00	444	0.03	5.30
Hotelling	8.80	0.01	18.39	0.00	0.15	0.15	0.00	444	0.03	5.30
Aux Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Maneuvering	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Hotelling	1.90	0.00	1.90	0.00	0.02	0.02	0.00	444	0.03	5.30
Aux Boiler	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00
Maneuvering	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00
Hotelling	2.00	0.10	0.20	0.00	0.16	0.15	0.00	644	0.08	0.00

Ship Emissions and Fuel Consumption Estimates

Route Definition

Ship Type	Origin	Destination	Distance at Sea (nm)	Transit Speed (knots)	Transit Time (hours)	Maneuvering Time (hours)	Time at Berth (Origin - hours)	Time at Berth (Destination - hours)	*Time within 200 nm* Transit	Maneuvering	Hotelling
RoRo	Anchorage	Tacoma	1450	22	65.9	2	10	10	14%	50%	50%

Vessel Details

Service Speed (knots)	Max Speed (knots)	Installed Power (kW)	Main Engine Speed (RPM)	Aux Engine Speed (RPM)	Main Engine Type	Aux Engine Type	Boiler Type
24	25.5	52200	400	720	Medium speed diesel 2000 - 2010	Medium speed diesel 2000 - 2010	Fuel Oil Aux Boiler All

Outputs

Calculated Loads

Mode	Time (hours)	Main Engine Load (kW)	Aux Engine Load (kW)	Aux Boiler Load (kW)	Fuel - In ECA	Fuel - Outside ECA
Transit	65.9	33,396	132	0	MGO (0.1	MGO (0.1% S)
Maneuvering	2.0	1,044	396	148	MGO (0.1	MGO (0.1% S)
Hotelling	20.0	0	229	259	MGO (0.1	MGO (0.1% S)

Emissions Calcs

Emissions Within 200nm (tonne per trip)

End Use Emissions Marine vessels	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
	3.72	0.15	0.34	0.13	0.07	0.07	0.07
	0.06	0.01	0.01	0.00	0.00	0.00	0.00
	0.03	0.00	0.00	0.02	0.00	0.00	0.00
Total Emissions (tonne)	3.82	0.16	0.35	0.15	0.08	0.07	0.08
Emissions Rate (g/tonne MGO)	59,739	2,578	5,478	2,287	1,191	1,141	1,184
Emissions Rate (g/mmBtu MGO, LHV)	1,597	69	146	61	32	31	32

Emissions Within 200nm (tonne per trip)

End Use Emissions Marine vessels	CO2	N2O	CH4	CO2c	CO2e
	198	0.01	0.00	199	201
	1	0.00	0.00	1	1
	4	0.00	0.00	4	4
Total Emissions (tonne)	203	0.01	0.00	204	207
Emissions Rate (g/tonne MGO)	3,171,667	153	48	447,826	454,393
Emissions Rate (g/mmBtu MGO, LHV)	84,787	4	1	11,972	12,147

Emissions Outside 200nm (tonne per trip)

End Use Emissions Marine vessels	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
	23.24	0.95	2.10	0.80	0.46	0.44	0.46
	0.06	0.01	0.01	0.00	0.00	0.00	0.00
	0.03	0.00	0.00	0.02	0.00	0.00	0.00
Total Emissions (tonne)	23.34	0.96	2.11	0.82	0.46	0.44	0.46
Emissions Rate (g/tonne MGO)	59,707	2,467	5,398	2,093	1,177	1,128	1,176
Emissions Rate (g/mmBtu MGO, LHV)	1,596	66	144	56	31	30	31

Emissions Outside 200nm (tonne per trip)

End Use Emissions Marine vessels	CO2	N2O	CH4	CO2c	CO2e
	1,235	0.06	0.02	1,241	1,259
	1	0.00	0.00	1	1
	4	0.00	0.00	4	4
Total Emissions (tonne)	1,240	0.06	0.02	1,246	1,264
Emissions Rate (g/tonne MGO)	3,171,667	152	49	2,740,069	2,780,013
Emissions Rate (g/mmBtu MGO, LHV)	84,787	4	1	73,249	74,317

Total Emissions (tonne per trip)

End Use Emissions Marine vessels	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
	26.96	1.10	2.43	0.93	0.53	0.51	0.53
	0.13	0.02	0.02	0.00	0.00	0.00	0.00
	0.07	0.00	0.01	0.03	0.00	0.0018	0.00
Total Emissions (tonne)	27.15	1.13	2.46	0.96	0.54	0.51	0.54
Emissions Rate (g/tonne MGO)	59,711	2,482	5,410	2,121	1,179	1,130	1,177
Emissions Rate (g/mmBtu MGO, LHV)	1,472	61	133	52	29	28	29

Total Emissions (tonne per trip)

End Use Emissions Marine vessels	CO2	N2O	CH4	CO2c	CO2e	BC	OC
	1,432	0.07	0.02	1,439	1,460	0.10	0.23
	2	0.00	0.00	2	2	0.00	0.00
	8	0.00	0.00	8	8	0.00	0.00
Total Emissions (tonne)	1,442	0.07	0.02	1,450	1,471	0.10	0.20
Emissions Rate (g/tonne MGO)	3,171,667	152	49	3,187,895	3,234,406	226	433
Emissions Rate (g/mmBtu MGO, LHV)	78,179	4	1	78,579	79,725	6	11

Fuel Consumption Estimates

Geographic Region	Engine	Engine	Aux Boiler	
Fuel Consumed Within 200nm (MT MGOe)	62.2	0.8	0.8	
Fuel Consumed Outside 200nm (MT MGOe)	387.9	2.2	0.8	Looks like LNG
Fuel Consumed (MT MGOe)	450.1	3.0	1.6	

Within 200nm					Emissions Factors (g/kWh)				
Main Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	12.20	0.50	1.10	0.42	0.24	0.23	0.24	648	0.03	0.01
Maneuvering	56.49	10.59	10.65	0.42	1.75	1.68	1.75	648	0.03	0.01
Hotelling	56.49	10.59	10.65	0.42	1.75	1.68	1.75	648	0.03	0.01
Aux Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Maneuvering	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Hotelling	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Aux Boiler	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00
Maneuvering	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00
Hotelling	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00

Outside 200nm					Emissions Factors (g/kWh)				
Main Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	12.20	0.50	1.10	0.42	0.24	0.23	0.24	648	0.03	0.01
Maneuvering	56.49	10.59	10.65	0.42	1.75	1.68	1.75	648	0.03	0.01
Hotelling	56.49	10.59	10.65	0.42	1.75	1.68	1.75	648	0.03	0.01
Aux Engine	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Maneuvering	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Hotelling	12.20	0.40	1.10	0.44	0.24	0.23	0.24	683	0.03	0.01
Aux Boiler	**NO_x**	**VOC**	**CO**	**SO_2**	**PM10**	**PM2.5**	**DPM**	**CO_2**	**N_2O**	**CH_4**
Transit	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00
Maneuvering	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00
Hotelling	2.00	0.10	0.20	6.00	0.16	0.15	0.00	922	0.08	0.00

Fugitive Emissions from Equipment Leaks

EQUIPMENT INFORMATION

Component	Phase	Fluid Serviced									Emission Factors[3] (lb/hr per component)	LDAR Control Efficiency[4]
		Amine Gas	Boil-Off Gas	Ethylene	Fuel Gas	Hydrocarbon Liquid	Liquefied Natural Gas	Mixed Refrigerant	Natural Gas	Untreated Natural Gas		
Valves	Gas/Vapor	39	9	12	36			112	185	30	0.001370	75%
	Light Liquid					33	244				0.005370	75%
	Heavy Liquid										0.000502	0%
Pump Seals	Light Liquid					1					0.049300	75%
	Heavy Liquid										0.009820	0%
Flanges/Connectors	Gas/Vapor	0	7	2	15			28	77	15	0.000559	30%
	Light Liquid					6	114				0.000559	30%
	Heavy Liquid										0.000559	30%
Compressor Seals	Gas/Vapor	0	2	0	0	0	0	1	1	0	0.016550	75%
Relief Valves	Gas/Vapor	3	0	1	3	1	19	8	9	2	0.022030	75%
Swivel Joints	Light Liquid						4				0.049300	75%

FLUID HAP/TAP CONTENT

Pollutant	CAS / ID	Fluid								
		Amine Gas	Boil-Off Gas	Ethylene	Fuel Gas	Hydrocarbon Liquid	Liquefied Natural Gas	Mixed Refrigerant	Natural Gas	Untreated Natural Gas
Methane Content (%wt)[1]	74-82-8	100%	100%	100%	100%	100%	100%	100%	100%	100%
n-Hexane (ppmw)[1]	110-54-3	70	5.7E-10	0	1,185	210,669	27	0	1,185	1,185
Hydrogen sulfide (ppmw)[1]	2148878	3,128	0.00035	0	22	0.010	0.21	0	22	166
Benzene (ppmw)[b, 2]	71-43-2	4.0	4.0	0	4.0	4.0	4.0	0	4.0	4.0
Ethylbenzene (ppmw)[b, 2]	100-41-4	0.20	0.20	0	0.20	0.20	0.20	0	0.20	0.20
m,p-Xylene (ppmw)[b, 2]	106-42-3	1.3	1.3	0	1.3	1.3	1.3	0	1.3	1.3
o-Xylene (ppmw)[b, 2]	95-47-6	0.22	0.22	0	0.22	0.22	0.22	0	0.22	0.22
Toluene (ppmw)[b, 2]	108-88-3	3.5	3.5	0	3.5	3.5	3.5	0	3.5	3.5

POTENTIAL EMISSIONS

Pollutant	CAS / ID	Amine Gas	Boil-Off Gas	Ethylene	Fuel Gas	Hydrocarbon Liquid	Liquefied Natural Gas	Mixed Refrigerant	Natural Gas	Untreated Natural Gas	Total
Hourly Emissions[a] (lb/hr)											
Methane[6]	74-82-8	0.02988000	0.01409660	0.01040010	0.03472200	0.06448280	0.52612070	0.09751390	0.14719760	0.02715950	0.95157320
n-Hexane	110-54-3	0.00000208	0.00000000	0.00000000	0.00004113	0.01358456	0.00001441	0.00000000	0.00017437	0.00003217	0.01384873
Hydrogen sulfide	2148878	0.00009345	0.00000000	0.00000000	0.00000075	0.00000000	0.00000011	0.00000000	0.00000319	0.00000451	0.00010202
Benzene	71-43-2	0.00000012	0.00000006	0.00000000	0.00000014	0.00000026	0.00000212	0.00000000	0.00000059	0.00000011	0.00000341
Ethylbenzene	100-41-4	0.00000001	0.00000000	0.00000000	0.00000001	0.00000001	0.00000010	0.00000000	0.00000003	0.00000001	0.00000016
m,p-Xylene	106-42-3	0.00000004	0.00000002	0.00000000	0.00000005	0.00000009	0.00000070	0.00000000	0.00000020	0.00000004	0.00000113
o-Xylene	95-47-6	0.00000001	0.00000000	0.00000000	0.00000001	0.00000001	0.00000012	0.00000000	0.00000003	0.00000001	0.00000019
Toluene	108-88-3	0.00000010	0.00000005	0.00000000	0.00000012	0.00000022	0.00000183	0.00000000	0.00000051	0.00000009	0.00000294
Total HAPs	HAP	0.00000028	0.00000013	0.00000000	0.00000032	0.00000060	0.00000488	0.00000000	0.00000136	0.00000025	0.00000782
Daily Emissions[a] (kg / day)											
Methane[6]	74-82-8	0.32528018	0.15345866	0.11321775	0.37799125	0.70197379	5.72746442	1.06155753	1.60242510	0.29566423	10.35903292
n-Hexane	110-54-3	0.00002263	0.00000000	0.00000000	0.00044777	0.14788443	0.00015692	0.00000000	0.00189824	0.00035025	0.15076024
Hydrogen sulfide	2148878	0.00101733	0.00000000	0.00000000	0.00000819	0.00000001	0.00000121	0.00000000	0.00003474	0.00004914	0.00111062
Benzene	71-43-2	0.00000131	0.00000062	0.00000000	0.00000153	0.00000283	0.00002312	0.00000000	0.00000647	0.00000119	0.00003707
Ethylbenzene	100-41-4	0.00000006	0.00000003	0.00000000	0.00000007	0.00000014	0.00000112	0.00000000	0.00000031	0.00000006	0.00000179
m,p-Xylene	106-42-3	0.00000043	0.00000020	0.00000000	0.00000050	0.00000094	0.00000765	0.00000000	0.00000214	0.00000039	0.00001227
o-Xylene	95-47-6	0.00000007	0.00000003	0.00000000	0.00000008	0.00000016	0.00000128	0.00000000	0.00000036	0.00000007	0.00000205
Toluene	108-88-3	0.00000113	0.00000053	0.00000000	0.00000132	0.00000244	0.00001994	0.00000000	0.00000558	0.00000103	0.00003197
Total HAPs	HAP	0.00000302	0.00000142	0.00000000	0.00000350	0.00000651	0.00005311	0.00000000	0.00001486	0.00000274	0.00008516
Annual Emissions[a] (short ton per year)											
Methane[6]	74-82-8	0.13087440	0.06174311	0.04555244	0.15208236	0.28243466	2.30440867	0.42711088	0.64472549	0.11895861	4.16789062
n-Hexane	110-54-3	0.00000910	0.00000000	0.00000000	0.00018016	0.05950036	0.00006314	0.00000000	0.00076375	0.00014092	0.06065742
Hydrogen sulfide	2148878	0.00040932	0.00000000	0.00000000	0.00000330	0.00000000	0.00000049	0.00000000	0.00001398	0.00001977	0.00044685
Benzene	71-43-2	0.00000053	0.00000025	0.00000000	0.00000061	0.00000114	0.00000930	0.00000000	0.00000260	0.00000048	0.00001492
Ethylbenzene	100-41-4	0.00000003	0.00000001	0.00000000	0.00000003	0.00000006	0.00000045	0.00000000	0.00000013	0.00000002	0.00000072
m,p-Xylene	106-42-3	0.00000017	0.00000008	0.00000000	0.00000020	0.00000038	0.00000308	0.00000000	0.00000086	0.00000016	0.00000494
o-Xylene	95-47-6	0.00000003	0.00000001	0.00000000	0.00000003	0.00000006	0.00000052	0.00000000	0.00000014	0.00000003	0.00000083
Toluene	108-88-3	0.00000046	0.00000021	0.00000000	0.00000053	0.00000098	0.00000802	0.00000000	0.00000224	0.00000041	0.00001286
Total HAPs	HAP	0.00000121	0.00000057	0.00000000	0.00000141	0.00000262	0.00002137	0.00000000	0.00000598	0.00000110	0.00003426

If Capacity is
500.000 gal/day
a factor of 2 is
applied

metric tonne&year
7.562171126

Calculations:

[a] Hourly Emissions (lb/hr) = [Emission Factor (lb/hr per component)] x [Component Count] x [Pollutant Content (%wt)] x [1 - LDAR Control Efficiency (%)]

Annual Emissions (tpy) = [Emission Factor (lb/hr per component)] x [Component Count] x [Pollutant Content (%wt)] x [1 - LDAR Control Efficiency (%)] x [Hours of Operation (hrs/yr)] / [2,000 lb/ton]

Hours of Operation (hrs/yr) =	8,760	

[b] Pollutant Concentration (ppmw) = [Pollutant Concentration (μg/m^3)] / [453.6 g/lb] / [10^6 μg/g] / [35.31 ft^3/m^3] / [Gas Density (lb/cf)] x 10^6

Benzene Concentration (μg/m^3) =	2,980	5
Ethylbenzene Concentration (μg/m^3) =	144	5
m,p-Xylene Concentration (μg/m^3) =	986	5
o-Xylene Concentration (μg/m^3) =	165	5
Toluene Concentration (μg/m^3) =	2,570	5
Natural Gas Density (lb/scf) =	0.046	5

Notes:

[1] Provided by CB&I.

[2] From "Natural Gas Analysis"; Environmental Partners, Inc.; February 3, 2014. Most HAPs will go through with the heavy hydrocarbons, but the fraction is unknown. Therefore, we assume each fluid has the full concentration of HAP to provide a conservative emissions estimate.

[3] Terminal/Depot factors from South Coast Air Quality Management District's "Guidelines for Fugitive Emissions Calculations" (June 2003). In this guidance, the District updated emissions factors that were identified in the EPA's "Protocol for Equipment Leak Emission Estimates (November 1995).

[4] Control effectiveness from Texas Commission for Environmental Quality (TCEQ) "Control Efficiencies for TCEQ Leak Detection and Repair Programs" (July 2011) for its 28M fugitive leak detection program.

[5] See fuel characteristics in Table B-2.

[6] Assume all VOC is CH_4.

Life Cycle Associates, LLC

Fuel Life Cycle Factors Sheet

-4.42%

Global Warming Potential, Molecular Weight

Species	GWP	Mol Wt	Variable Name: GWP	Variable Name: MW
CO2	1.000	43.999	CO2_GWP	CO2_MW
CH4	25.000	16.042	CH4_GWP	CH4_MW
N2O	298.000	44.007	N2O_GWP	N2O_MW
VOC	3.117	10.209	VOC_GWP	VOC_MW
CO	1.571	28.005	CO_GWP	CO_MW
NO2	0.000	45.995	NO2_GWP	NO2_MW
BC	900.000			
OC	-69.000			
C		12.011		C_MW
H		1.008		H_MW
O		15.994		O_MW
N		14.007		N_MW
Ca		40.078		Ca_MW
Cl		35.453		Cl_MW
Na		22.990		Na_MW
S		32.065		S_MW
P		30.974		P_MW
K		39.098		K_MW

Lookup Key	AR5_100	AR5_20	AR4_100	AR4_20
AR Edition	AR5	AR5	AR4	AR4
Time Horizon	100	20	100	20
CO_2	1	1	1	1
CH_4	30	85	25	72
N_2O	265	264	298	289
BC	900	3200	900	3200
OC	-69	-240	-69	-240

Carbon and Sulfur Ratios of Pollutants

	Ratio	Variable Name	CO_2/pollutant
Carbon ratio of VOC	0.85	VOC_C_Ratio	3.11
Carbon ratio of CO	0.43	CO_C_Ratio	1.57
Carbon ratio of CH4	0.75	CH4_C_Ratio	2.74
Carbon ratio of CO2	0.27	CO2_C_Ratio	1.00
Sulfur ratio of SO2	0.50	SO2_S_Ratio	

Conversion Factors

		Variable Name	
Energy			
J/Btu	1055.056	JperBtu	
Btu/MJ	947.82	BtuperMJ	
Btu/kWh	3412.1	BtuperkWh	
Mass			
g/lb	453.597	gperlb	
metric tonne/ton	0.907	tonneperton	907194.049
ton/metric tonne	1.102	shorttonpertonne	
lb/kg	2.205	lbperkg	
Volume			
scf/m3	35.3000	scfperm3	
L/gal	3.785	Lpergal	
Area			
acre/hectare	2.471	acreperhectare	
Distance			
cm/inch	2.54	cmperinch	
mi/naut mi	1.151	mipernaut	
ft/mi	5280		
km/mi	1.609	kmpermi	
scf/lb mol	379	scfperlbmol	
NL/g mol	22.414	Lpergmol	
Capacity			
kW/hr	1.341	kwperhp	

Emission Factors

Washington

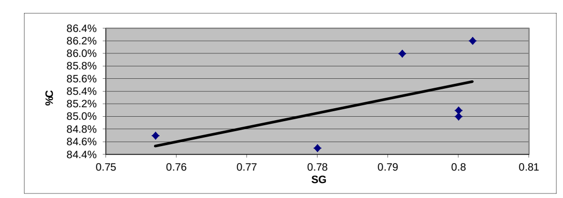
Fuel/ Application	Equipment Type	CO_2c	CH_4	N_2O	CO_2e
GREET WTT Emissions (g/mmBtu), LHV					
Diesel	Diesel Engine	78,187	4.2	0.6	78,472
Diesel	HD Truck	78,186	4.7	0.2	78,357
Diesel	Industrial Boiler	78,198	0.2	0.9	78,477
Gasoline, E10	Gasoline Engine	76,829	3.0	0.6	77,083
Bunker Fuel	**TOTE Marine Engine**	**78,579**	**1.2**	**3.7**	**79,725**
Bunker Fuel	**Residual Oil**	**85,003**	**4.2**		
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	**TOTE Marine Engine**	**53,914**	**637.0**	**3.7**	**70,955**
LNG	**IC Engine, GREET**	58,059	92		
LNG	**Marine Engine, This Study**	58,059			
LNG	Truck	57,459	309.8	0.0	65,213
LNG	NG Peak Shaving	58,308	1.1	0.4	58,439
LPG from Tacoma LNG	Boiler	68,058	1.1	1.1	68,403
LPG, conventional	Boiler	68,773	1.1	1.1	69,118
Waste Flare LPG - Tacoma LNG plant	Flare	68,773	1.1	1.1	69,118
Waste Flare gas - LNG plant	Flare	68,662	1.1	1.1	59,660
Fuel Gas	Boiler	59,410	1.1	0.8	59,660
Coal	Boiler	100,041	1.1	1.6	100,540

Specifications of Fuels, Global Warming Potentials of Greenhouse Gases, and Carbon and Sulfur Ratios of Pollutants

3.16875 0.92579

1) Specifications of Fuels

									10	11	12	13	14	15	16		18	19	20	21			
Fuel	Calculation: LHV	Heating Value LHV	HHV	Density Density	C ratio (% by wt)	S ratio (ppm by wt)	S ratio	SO_x	Carbon Factor Total C in Fuel LHV	Fossil C in Fuel LHV	Biogenic C in Fuel LHV		Heating Value LHV	Heating Value Heating Value HHV	Heating Value LHV	Heating Value HHV		LHV/HHV ratio	Other Properties Density		Source	Citation	
Use LHV or HHV in calculations?	1	1 -- LHV; 2 -- HHV																					
Liquid Fuels:	Btu/gal	Btu/gal	Btu/gal	g/gal			Ratio by Wt.	g/mmBtu	g CO2/mmBtu	g CO2/mmBtu	g CO2/mmBtu	g CO_2/MJ	MJ/kg	MJ/kg	Btu/lb	Btu/lb	MJ/unit		lb/gal	kg/L			
Crude oil	129,670	129,670	138,350	3,205	85.3%	16,000	0.016000	395	77,234	77,234	-	73.2	42.7	45.5	18,352	19,580	136.8	0.9373	7.07	0.847	CA_GREET		
Conventional gasoline	116,090	116,090	124,340	2,819	86.3%	26	0.000026	1	76,768	76,768	-	72.8	43.4	46.5	18,680	20,007	122.5	0.9336	6.21	0.745	GREET1_2012	Wang (2012)	
Reformulated or low-sulfur gasoline	113,602	113,602	121,848	2,830	86.3%	26	0.000026	1	78,744	78,744	-	74.6	42.4	45.4	18,211	19,533	119.9	0.9323	6.24	0.747	Calculation		
CARBOB for CARFG	113,300	113,300	124,340	2,767	85.9%	15		0	76,850	76,850	-	72.8	43.2	47.4	18,573	20,383	119.5	0.9112	6.10	0.731	CA_GREET	Unnasch (2009)	
CA reformulated gasoline	109,772	109,772	120,541	2,788	82.9%	11	0.000011	0	77,131	77,131	-	73.1	41.5	45.6	17,859	19,612	115.8	0.9107	6.15	0.737	CA_GREET		
U.S. conventional diese	128,450	128,450	137,380	3,167	86.5%	200	0.000200	5	78,127	78,127	-	74.1	42.8	45.8	18,397	19,676	135.5	0.9350	6.98	0.837	CA_GREET		
Diesel for non-road engines	128,450	128,450	137,380	3,167	86.5%	163	0.000163	4	78,127	78,127	-	74.1	42.8	45.8	18,397	19,676	135.5	0.9350	6.98	0.837	CA_GREET		
Low-sulfur diesel	127,464	127,464	133,075	3,142	86.5%	11	0.000011	0.271	78,107	78,107	-	74.0	42.8	44.7	18,402	19,212	134.5	0.9578	6.93	0.830	CA_GREET		
Petroleum naphtha	116,920	116,920	125,080	2,745	85.0%	1	0.000001	0	73,104	73,104	-	69.3	44.9	48.1	19,320	20,669	123.4	0.9348	6.05	0.725	CA_GREET		
GTL naphtha	111,520	111,520	119,740	2,651	84.2%	0	0.000000	0	73,323	73,323	-	69.5	44.4	47.7	19,082	20,488	117.7	0.9314	5.84	0.700	CA_GREET		
Residual oil	140,353	140,353	150,110	3,752	86.8%	5,000	0.005000	134	85,003	85,003	-	80.6	39.5	42.2	16,968	18,148	148.1	0.9350	8.27	0.991	CA_GREET		
Bunker fuel for ocean tanker	140,353	140,353	150,110	3,752	86.8%	28,000	0.028000	749	85,003	85,003	-	80.6	39.5	42.2	16,968	18,148	148.1	0.9350	8.27	0.991	CA_GREET		
Methanol	57,250	57,250	65,200	3,006	37.5%	0	0.000000	0	72,130	72,130	-	68.4	20.1	22.9	8,639	9,838	60.4	0.8781	6.63	0.794	CA_GREET		
Ethanol	76,330	76,330	84,530	2,988	52.2%	1	0.000001	0	74,856	-	74,856	70.9	26.9519	29.8	11,587	12,832	80.5	0.9030	6.59	0.789	CA_GREET		
Butanol	99,837	99,837	108,458	3,065	64.9%	0	0.000000	0	72,944	-	72,944	69.1	34.4	37.3	14,775	16,051	105.3	0.9205	6.76	0.810	CA_GREET		
Acetone	83,127	83,127	89,511	2,964	62.0%	0	0.000000	0	80,958	-	80,958	76.7	29.6	31.9	12,721	13,698	87.7	0.9287	6.53	0.783	CA_GREET		
E-Diesel Additives	116,090	116,090	124,340	2,819	86.3%	26	0.000026	1	76,768	76,768	-	72.8	43.4	46.5	18,680	20,007	122.5	0.9336	6.21	0.745	CA_GREET		
LPG	75,574	75,574	83,698	1,923	81.8%		0.000000	0	76,254	76,254	-	72.3	41.5	45.9	17,826	19,743	79.7	0.9029	4.24	0.508	CA_GREET		
Liquefied natural gas (LNG)	77,156	77,156	84,331	1,646	75.1%	0	0.000000	0	58,690	58,690	-	55.6	49.5	54.1	21,262	23,240	81.4	0.9149	3.63	0.435	CA_GREET		
Dimethyl ether	68,930	68,930	75,610	2,518	52.2%	0	0.000000	0	69,854	69,854	-	66.2	28.9	31.7	12,417	13,621	72.7	0.9117	5.55	0.665	CA_GREET		
Dimethoxy methane (DMM)	72,200	72,200	79,197	3,255	47.4%	0	0.000000	0	78,282	78,282	-	74.2	23.4	25.7	10,061	11,036	76.2	0.9117	7.18	0.860	CA_GREET		
Algae Oil, TAG	124,316	124,316	138,129	3,444		0	0.000000	0		-	-	0.0	38.1	42.3	16,372	18,191	131.2	0.9000	7.59	0.910	CA_GREET		
Vegetable Oil (PVO)				3,400								0.0	37.5	0.0		0			7.50	0.898	Look something up.		
Methyl ester (biodiesel, BD)	119,550	119,550	127,960	3,361	77.6%	0	0.000000	0	79,919	3,873	76,046	75.7	37.5	40.2	16,134	17,269	126.1	0.9343	7.41	0.888	CA_GREET		
Ethyl ester (biodiesel, BD)	119,550	119,550	127,960	3,500	77.6%	0			83,225	-		78.9	36.0	38.6	16,941	16,584		1.0216	7.72	0.925	CA_GREET		
GTL Diesel	122,800	122,800	132,100	2,953	84.8%	0	0.000000	0	74,702	-	74,702	70.8	43.9	47.2	18,863	20,291	129.6	0.9296	6.51	0.780	CA_GREET		
Renewable Diesel I (SuperCetane)	117,059	117,059	125,294	2,835	87.1%	0	0.000000	0	77,275	-	77,275	73.2	43.6	46.6	18,729	20,047	123.5	0.9343	6.25	0.749	CA_GREET		
Renewable Diesel II (UOP-HDO)	122,887	122,887	130,817	2,948	87.1%	0	0.000000	0	76,544	-	76,544	72.5	44.0	46.8	18,908	20,128	129.7	0.9394	6.50	0.779	CA_GREET		
Renewable Gasoline	115,983	115,983	124,230	2,830	84.0%	0	0.000000	0	75,083	-	75,083	71.2	43.2	46.3	18,590	19,912	122.4	0.9336	6.24	0.748	CA_GREET		
Liquid hydrogen	30,500	30,500	36,020	268	0.0%	0	0.000000	0		-	-	0.0	120.1	141.8	51,622	60,965	32.2	0.8468	0.59	0.071	CA_GREET		
Methyl tertiary butyl ether (MTBE)	93,540	93,540	101,130	2,811	68.1%	0	0.000000	0	74,969	74,969	-	71.1	35.1	38.0	15,094	16,319	98.7	0.9249	6.20	0.743	CA_GREET		
Ethyl tertiary butyl ether (ETBE)	96,720	96,720	104,530	2,810	70.6%	0	0.000000	0	75,139	75,139	-	71.2	36.3	39.2	15,613	16,873	102.0	0.9253	6.19	0.742	CA_GREET		
Tertiary amyl methyl ether (TAME)	100,480	100,480	108,570	2,913	70.6%	0	0.000000	0	74,979	74,979	-	71.1	36.4	39.3	15,646	16,906	106.0	0.9255	6.42	0.770	CA_GREET		
Butane	94,970	94,970	103,220	2,213	82.8%	0	0.000000	0	70,680	70,680	-	67.0	45.3	49.2	19,466	21,157	100.2	0.9201	4.88	0.585	CA_GREET		
Isobutane	90,060	90,060	98,560	2,118	82.8%	0	0.000000	0	71,334	71,334	-	67.6	44.9	49.1	19,288	21,108	95.0	0.9138	4.67	0.560	CA_GREET		
Isobutylene	95,720	95,720	103,010	2,253	85.7%	0	0.000000	0	73,894	73,894	-	70.0	44.8	48.2	19,271	20,739	101.0	0.9292	4.97	0.595	CA_GREET		
Propane	84,250	84,250	91,420	1,920	81.8%	0	0.000000	0	68,290	68,290	-	64.7	46.3	50.2	19,904	21,598	88.9	0.9216	4.23	0.507	CA_GREET		
Natural gas liquids	83,686	83,686	90,050			0	0.000000	0				0.0								0.000	CA_GREET		
Still gas (in refineries)	128,590	128,590	142,860			0	0.000000			-		0.0								0.000	CA_GREET		
Gaseous Fuels (at 32F and 1atm):	Btu/ft3	Btu/ft3	Btu/ft3	g/ft3			Ratio by Wt.	g/mmBtu	g CO2/mmBtu	g CO2/mmBtu		g CO_2/MJ	MJ/kg	MJ/kg	Btu/lb	Btu/lb	MJ/unit		lb/ft^3		CA_GREET		
Natural gas	984	984	1,090	21.18	75.2%	13.74	0.000014	0	59,314	59,314	-	56.2	49.0	54.3	21,074	23,339	1.0	0.9029	0.05		CA_GREET		15.34664142
Hydrogen	282	282	331	2.48	0.0%	0	0.000000	0	-			0.0	120.0	140.8	51,578	60,541	0.3	0.8520	0.01		CA_GREET		
Carbon Dioxide				55.98	27.3%	0	0.000000												0.12		CA_GREET		
Still gas (in refineries)	1,458	1,458	1,584	32.8	37.9%				31,259			29.6	46.9	51.0	20,163	21,905	2.6	0.9205	0.07		CA_GREET		
Landfill Gas	446	446	496	34.54	20.5%				58,017			55.0	13.6	15.2	5,857	6,514		0.8992	0.08		CA_GREET		
Fuel Gas (RD I)																					CA_GREET		
Shale Gas	930	930	1,030	20.40	72.4%	13.74	0.000014	0	58,178	58,178	-	55.1	48.1	53.3	20,679	22,902	1.0	0.9029	0.04		CA_GREET		
Flared Gas	930	930	1,030	20.40	72.4%	13.74	0.000014	0	58,178	58,178	-	55.1	48.1	53.3	20,679	22,902	1.0	0.9029	0.04		CA_GREET		
Propane Fuel Mix (RD II																					CA_GREET		
Solid Fuels:	Btu/ton	Btu/ton	Btu/ton				Ratio by Wt.		g CO2/mmBtu	g CO2/mmBtu		g CO_2/MJ	MJ/kg	MJ/kg	Btu/lb	Btu/lb	MJ/unit				CA_GREET		
Coal	19,546,300	19,546,300	20,608,570		63.7%	11,100	0.011100		108,305	108,305	-	102.7	22.7	24.0	9773.2	10304.3	20,622	0.9485			CA_GREET		
Bituminous coa	22,460,600	22,460,600	23,445,900		75.5%	11,800	0.011800		111,711	111,711	-	105.9	26.1	27.3	11230.3	11723.0	23,697	0.9580			CA_GREET		
Coking coal	24,600,497	24,600,497	25,679,670		74.7%	11,800	0.011800		100,913	100,913	-	95.6	28.6	29.9	12300.2	12839.8	25,955	0.9580			CA_GREET		
Lignite																							
Farmed trees	16,811,000	16,811,000	17,703,170		51.7%	0	0.000000		102,204	-	102,204	96.9	19.6	20.6	8405.5	8851.6	17,737	0.9496			CA_GREET		
Herbaceous biomass	14,797,555	14,797,555	15,582,870		42.6%	0	0.000000		95,673	-	95,673	90.7	17.2	18.1	7398.8	7791.4	15,612	0.9496			CA_GREET		
Corn stover	14,075,990	14,075,990	14,974,460		44.5%	0	0.000000		105,064	-	105,064	99.6	16.4	17.4	7038.0	7487.2	14,851	0.9400			CA_GREET		
Forest residue	13,243,490	13,243,490	14,164,160		51.7%	0	0.000000		129,736	-	129,736	123.0	15.4	16.5	6621.7	7082.1	13,973	0.9350			CA_GREET		
Sugarcane straw					50.0%																?		
Sugarcane bagasse	12,947,318	12,947,318	14,062,678		46.3%				118,843	-	118,843	112.6	15.1	16.4	6473.7	7031.3	13,660	0.9207			?		
Pet Coke	25,370,000	25,370,000	26,920,000		79.9%	68,000	0.068000		104,664	104,664	-	99.2	29.5	31.3	12685.0	13460.0	26,767	0.9424			?		
Stillage solids																							
Lignin																					Jenny has something.		
Jet Fuel Properties	Btu/gal	Btu/gal	Btu/gal	g/gal			Ratio by Wt.	g/mmBtu	g CO2/mmBtu	g CO2/mmBtu	g CO2/mmBtu	g CO_2/MJ	MJ/kg	MJ/kg	Btu/lb		MJ/unit		lb/gal	kg/L			
Conventional Petroleum Jet Fuel	124,307	124,307	132,949	3,036	86.2%	700	0.000700	17	77,121	77,121	-	73.1	43.2	43.2	18,573		131.2		6.69	0.802	GREET1_2012	86.2%	
Ultra Low Sulfur Petroleum Jet Fuel (ULSJ)	123,041	123,041	131,595	2,998	86.0%	11	0.000011	0	76,764	76,764	-	72.8	43.3	43.3	18,616		129.8		6.61	0.792	GREET1_2012	86.0%	
GTL Aviation Fue	119,777	119,777	128,103	2,866	84.7%	0	0.000000	0	74,232	74,232	-	70.4	44.1	44.1	18,960		126.4		6.32	0.757	GREET1_2012	84.7%	
GTL Lubricant Base Oil	118,256	118,256	126,477	3,028	85.1%	0	0.000000	0	79,832	79,832	-	75.7	41.2	41.2	17,713		124.8		6.68	0.8	Sasol	85.1%	
GTL Wax	126,293	126,293	135,073	3,028	85.0%	1	0.000001	0	74,664	74,664	-	70.8	44.0	44.0	18,917		133.2		6.68	0.8	Sasol	85.0%	
Paraffin/Olefin	124,535	124,535	133,193	2,953	84.5%	2	0.000002	0	73,391	73,391	-	69.6	44.5	44.5	19,132		131.4		6.51	0.78	Sasol	84.5%	



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1) Emission Factors of Fuel Combustion for Stationary Applications (grams per mmBtu of fuel burned), GREET EF Tab

	Natural Gas							Residual Oil					
	Utility/ Industrial Boiler (>100 mmBtu/hr input)	Small Industrial Boiler (10-100 mmBtu/hr input)	Large Gas Turbine	CC Gas Turbine	Small Turbine	Stationary Reciprocating Engine	NG Flaring in Oil Field	Utility Boiler	Industrial Boiler	Commercial Boiler	Stationary Reciprocating Engine	Marine Vessel TOTE	Turbine
VOC	2.540	2.540	1.056	0.267	1.056	133.316	2.500	2.089	0.905	3.651	2.027	**61.187**	0.258
CO	22.210	24.970	41.286	14.533	41.286	705.993	26.000	16.209	36.017	16.153	657.005	**133.341**	1.560
NOx	36.400	41.050	31.969	17.425	31.969	832.952	48.900	433.518	137.081	177.688	2,076.988	**1,471.837**	256.412
PM10	3.507	3.507	3.575	0.133	3.575	7.197	3.700	17.379	35.345	35.345	54.608	**29.062**	25.944
PM2.5	3.507	3.507	3.575	0.133	3.575	7.197	3.700	13.492	16.173	16.173	54.043	**27.850**	6.574
SOx	0.269	0.269	0.269	0.269	0.269	0.269	0.269	739.297	683.325	667.785	267.327	**52.273**	267.327
BC	0.579	0.579	0.104	0.004	0.104	1.439	3.515	0.855	1.025	1.025	43.937	**5.570**	0.657
OC	1.501	1.501	2.431	0.090	2.431	3.080	0.185	0.594	0.712	0.712	9.782	**10.677**	1.644
CH4	1.060	1.060	1.056	1.142	1.056	392.354	49.000	3.182	3.231	1.535	4.221	**1.201**	3.024
N2O	0.750	0.350	0.102	0.119	0.102	0.111	1.100	0.638	1.712	1.712	0.600	**3.746**	0.603
CO2	59,366.9	59,282.8	59,341.6	59,385.9	59,341.6	56,808.8	59,229.3	85,040.5	85,012.9	85,040.2	84,030.9	**78,178.9**	85,069.7
CO2c	59,409.8	59,329.9	59,409.8	59,409.5	59,409.8	58,333.1	59,277.9	85,072.5	85,072.3	85,077.0	85,069.4	**78,578.9**	85,072.9

	Diesel Fuel					Gasoline		Crude	Coal		
	Industrial Boiler	Commercial Boiler	Stationary Reciprocating Engine	Turbine	Farming Tractor	Stationary Reciprocating Engine	Farming Tractor	Industrial Boiler	Utility Boiler	IGCC Turbine	Industrial Boiler
VOC	0.800	1.201	2.027	0.258	63.020	598.350	193.820	0.820	1.495	0.122	0.472
CO	20.867	25.115	657.005	1.560	349.150	1,520.438	6,907.000	23.740	12.417	2.235	23.955
NOx	53.860	66.543	2,076.988	256.412	628.010	98.588	267.620	181.600	116.035	11.902	121.631
PM10	8.122	8.404	54.608	25.944	55.970	52.558	7.840	29.712	28.841	251.841	2.663
PM2.5	5.473	7.522	54.043	6.574	54.291	52.558	7.605	19.313	20.278	73.411	2.521
SOx	0.542	0.542	0.542	0.542	0.542	1.238	1.238	395.465	325.406	4.110	544.401
BC	0.547	0.752	43.937	0.657	30.566	5.256	1.034	0.560	0.872	3.157	0.108
OC	1.368	1.881	9.782	1.644	18.948	16.819	6.571	0.406	1.643	5.946	0.204
CH4	0.198	0.763	4.221	3.024	0.630	3.000	3.575	0.360	1.058	1.050	1.246
N2O	0.918	0.918	0.600	0.603	0.920	0.600	1.104	2.000	1.586	1.581	0.857
CO2	78,163.2	78,153.7	77,148.7	78,187.5	77,452.2	72,576.8	65,371.4	77,264.4	100,017.1	100,037.4	100,001.6
CO2c	78,198.5	78,196.9	78,187.2	78,190.7	78,197.0	76,828.7	76,826.6	77,304.2	100,041.2	100,041.3	100,040.7

	Diesel	Diesel	Fuel Gas	Flare Gas	LNG	LPG	LPG	LNG	LNG	LNG
	Heavy Duty Truck	Locomotive	Industrial Boiler	Flare Gas	Heavy Duty Truck	Industrial Boiler	Flaring Tacoma	NG Peak shaving	Marine Engine TOTE CASE	Marine Engine
VOC	5.909	5.909	2.540	2.540	26.225	4.272	4.272	2.540	**0.076**	79.908
CO	57.875	57.875	22.210	22.210	1,452.359	3.531	3.531	24.970	**230.273**	90.798
NOx	53.121	53.121	36.400	36.400	82.257	69.413	69.413	41.050	**229.722**	2,085.241
PM10	10.052	10.052	3.507	3.507	7.416	3.738	3.738	3.507	**2.465**	18.121
PM2.5	4.619	4.619	3.507	3.507	3.616	3.738	3.738	3.507	**2.462**	16.675
SOx	0.545	0.545	0.269	0.269	0.000	0.000	0.000	0.000	**0.422**	0.000
BC	0.072	0.072	0.579	0.579	0.287	0.617	0.617	0.579	**0.534**	2.501
OC	0.125	0.125	1.501	1.501	0.521	1.600	1.600	1.501	**1.144**	6.503
CH4	4.750	4.750	1.060	1.060	309.767	1.068	1.068	1.060	**636.970**	91.620
N2O	0.175	0.175	0.750	0.750	0.033	4.806	4.806	0.350	**3.746**	2.000
CO2	78,076.6	78,076.6	57,408.9	68,662.0	55,095.9	68,039.6	68,754.6	58,261.1	**53,552.3**	57,667.7
CO2c	78,186.0	78,186.0	57,451.7	68,704.8	57,459.3	68,058.5	68,773.4	58,308.2	**53,914.3**	58,059.2

Biogenic CO2

59332.81

59332.81

Emissions Factors and Activity Assumptions

Source: UPDATED 2016 Puget Sound Maritime Air Emissions Inventory, Punlished Feb 2018 APPENDIX B: OGV EMISSIONS ESTIMATING METHODOLOGY (unless otherwise noted below table)

https://pugetsoundmaritimeairforum.org/2016-puget-sound-maritime-air-emissions-inventory/

The North American ECA introduced in 2015, requiring 0.1% sulfur content in diesel fuel compared to heavy fuel oil with high sulfur content (2.7%) used by the

Table B.2: Emission Factors for OGV Main Engines Using MDO, g/kW-hr

Engine	Model Year	Key	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
Slow speed diesel	< 1999	Slow speed diesel < 1999	17	0.6	1.4	0.38	0.24	0.23	0.24
Medium speed diesel	< 1999	Medium speed diesel < 1999	13.2	0.5	1.1	0.42	0.24	0.23	0.24
Slow speed diesel	2000 - 2010	Slow speed diesel 2000 - 2010	16	0.6	1.4	0.38	0.24	0.23	0.24
Medium speed diesel	2000 - 2010	Medium speed diesel 2000 - 2	12.2	0.5	1.1	0.42	0.24	0.23	0.24
Slow speed diesel	2011 - 2015	Slow speed diesel 2011 - 2015	14.4	0.6	1.4	0.38	0.24	0.23	0.24
Medium speed diesel	2011 - 2015	Medium speed diesel 2011 - 2	10.5	0.5	1.1	0.42	0.24	0.23	0.24
Lean Burn SI LNG	All	Lean Burn SI LNG All	0.9	0.0	1.7	0	0.02	0.02	0
Low Pressure DF LNG	All	Low Pressure DF LNG All	1.9	0.0	1.9	0.00	0.02	0.02	0
Gas turbine	All	Gas turbine All	6.1	0.1	0.2	0.6	0.1	0.04	0
Steamship	All	Steamship All	2.1	0.1	0.2	0.6	0.8	0.6	0

Medium speed means RPM>130

Table B.2: GHG Emission Factors for OGV Main Engines Using MDO, g/kW-hr

Engine Model Year	Model Year	Key	CO2	N2O	CH4	
Slow speed diesel	< 1999	Slow speed diesel < 1999	589	0.0310	0.0120	
Medium speed diesel	< 1999	Medium speed diesel < 1999	648	0.0310	0.0100	
Slow speed diesel	2000 - 2010	Slow speed diesel 2000 - 2010	589	0.0310	0.0120	
Medium speed diesel	2000 - 2010	Medium speed diesel 2000 - 2010	648	0.0310	0.0100	
Slow speed diesel	2011 - 2015	Slow speed diesel 2011 - 2015	589	0.0310	0.0120	
Medium speed diesel	2011 - 2015	Medium speed diesel 2011 - 2015	648	0.0310	0.0100	
Gas turbine	All	Gas turbine All	922	0.0800	0.0020	
Steamship	All	Steamship All	922	0.0800	0.0020	
Lean Burn SI LNG	All	Lean Burn SI LNG All	472	0.0310	4.1000	
Low Pressure DF LNG	All	Low Pressure DF LNG All	444	0.0310	5.3000	*Methane (CH4) slip*

N2O emissions factors for LNG engines assumed to be equal to medium speed diesel

LNG emissions factors from "GHG and NOx Emissions from Gas Fueled Engines", SINTEF, 2017. PM emissions based on EPA certification data of 2017 Wartsila DF engine (rated at 8MW)

VOC emissions for LNG engines are estimated as NMVOC, based on a typical ratio of 3.8% NMVOC/CH4 emissions, as described in "Methane Emissions from Natural Gas Bunkering Operations in the Marine Sector", MARAD, 201

https://www.nho.no/siteassets/nhos-filer-og-bilder/filer-og-dokumenter/nox-fondet/dette-er-nox-fondet/presentasjoner-og-rapporter/methane-slip-from-gas-engines-mainreport-1492296.pdf

https://www.marad.dot.gov/wp-content/uploads/pdf/Methane-emissions-from-LNG-bunkering-20151124-final.pdf

Sulfur emissions rates for Low Pressure DF LNG engines based on SINEF report (Table 5.1) indicating 95-98% SOx reductions from LNG operation relative to MDO. Assume pilot fuel is MDO with a 0.5% sulfur content based on 2020 global sulfur ca

Table B.3: Low-Load Adjustment Multipliers for Emission Factors

Load	NOx	HC	CO	PM
2%	4.63	21.18	9.68	7.29
3%	2.92	11.68	6.46	4.33
4%	2.21	7.71	4.86	3.09
5%	1.83	5.61	3.89	2.44
6%	1.6	4.35	3.25	2.04
7%	1.45	3.52	2.79	1.79
8%	1.35	2.95	2.45	1.61
9%	1.27	2.52	2.18	1.48
10%	1.22	2.2	1.96	1.38
11%	1.17	1.96	1.79	1.3
12%	1.14	1.76	1.64	1.24
13%	1.11	1.6	1.52	1.19
14%	1.08	1.47	1.41	1.15
15%	1.06	1.36	1.32	1.11
16%	1.05	1.26	1.24	1.08
17%	1.03	1.6	1.17	1.06
18%	1.02	1.18	1.11	1.04
19%	1.01	1.11	1.05	1.02
20%	1	1	1.00	1.00

Source: 2012

Table 3.17: Composite Maneuvering Load Factors

Vessel Type	Load In	Load Out
Auto Carrier	0.04	0.06
Bulk	0.04	0.05
Containership	0.03	0.03
Cruise	0.03	0.04
General Cargo	0.03	0.04
ITB	0.04	0.06
Reefer	0.02	0.03
RoRo	0.02	0.02
Tanker	0.03	0.05

Table B.7: Auxiliary Engine Emission Factors, g/kW-hr

Engine	Model Year	Key	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
Medium speed diesel	≤ 1999	Medium speed diesel ≤ 1999	13.8	0.4	1.1	0.44	0.24	0.23	0.24
Medium speed diesel	2000 - 2010	Medium speed diesel 2000 - 2	12.2	0.4	1.1	0.44	0.24	0.23	0.24
Medium speed diesel	2011 - 2015	Medium speed diesel 2011 - 2	10.5	0.4	1.1	0.44	0.24	0.23	0.24
Lean Burn SI LNG	All	Lean Burn SI LNG All	0.9	0.0	1.7	0	0.02	0.02	0.00
Low Pressure DF LNG	All	Low Pressure DF LNG All	1.9	0.0	1.9	0.003515	0.02	0.02	0.00

LNG emissions factors for aux engines assumed to be equivalent to main engine emissions factors as both the main and aux engines are medium speec

Table B.7: Greenhouse Gas Emission Factors for Auxiliary Engines, g/kW-hr

Engine	Model Year	Key	CO2	N2O	CH4
Medium speed diesel	All	Medium speed diesel All	683	0.029	0.008
Medium speed diesel	2000 - 2010	Medium speed diesel 2000 - 2010	683	0.029	0.008
Medium speed diesel	2011 - 2015	Medium speed diesel 2011 - 2015	683	0.029	0.008
Lean Burn SI LNG	All	Lean Burn SI LNG All	472	0.029	4.1
Low Pressure DF LNG	All	Low Pressure DF LNG All	444	0.029	5.3

Table B.12: Auxiliary Boiler Emission Factors using MDO, g/kW-hr

Engine	Model Year	Key	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
Fuel Oil Aux Boiler	All	Fuel Oil Aux Boiler All	2	0.1	0.2	6	0.16	0.15	0
LNG Aux Boiler	All	LNG Aux Boiler All	2	0.1	0.2	0	0.16	0.15	0

Source: 2013 POLB Emissions Inventory

Table B.12: Auxiliary Boiler GHG Emission Factors using MDO, g/kW-hr

Engine	Model Year	Key	CO2	N2O	CH4
Fuel Oil Aux Boiler	All	Fuel Oil Aux Boiler All	922	0.075	0.002
LNG Aux Boiler	All	LNG Aux Boiler All	644	0.075	0.002

Source: 2013 POLB Emissions Inventory

CO2 emissions for LNG based on ratios of carbon-per-BTU for bunker fuel and natural gas, as given in ANL GREET's fuel properties worksheet
N2O emissions for LNG assumed to be equal to fuel oil. CH4 emissions for LNG scaled based on fuel oil emissions and ratios of CH4 emissions from medium speed FO and LNG engines.

Table B.18: 2016 Auxiliary Engine Power and Load Defaults, kW

Vessel Type	Sea	Maneuvering	Hotelling
Auto Carrier	590	1224	876
Bulk	266	384	157
Bulk - Self Discharging	462	807	258
Bulk - Heavy Load	305	1223	136
Bulk - Wood Chips	266	1275	157
Container - 1000	892	1275	536
Container - 2000	1280	1911	945
Container - 3000	888	1685	965
Container - 4000	1499	2528	1196
Container - 5000	1444	2458	1202
Container - 6000	1598	2665	1461
Container - 7000	1332	2675	1325
Container - 8000	1497	4769	1449
Container - 9000	1495	4551	1383
Container - 10000	1662	2617	887
Cruise	na	na	na
General Cargo	471	1096	829
ITB	79	208	102
Reefer	1247	1168	900
RoRo	132	396	229
Tanker - Aframax	556	628	909
Tanker - Chemical	417	583	1271
Tanker - Handysize	560	600	900
Tanker - Panamax	488	600	379
Tanker - Suezmax	858	1289	2902

Table B11 2016 Auxiliary Boiler Energy Defaults, kW

Vessel Type	Sea	Maneuvering	Hotelling *
Auto Carrier	0	184	314
Bulk	0	94	125
Bulk - Self Discharging	0	103	125
Bulk - Heavy Load	0	94	134
Bulk - Wood Chips	0	134	134
Container - 1000	0	213	273
Container - 2000	0	282	361
Container - 3000	0	328	420
Container - 4000	0	371	477
Container - 5000	0	473	579
Container - 6000	0	567	615
Container - 7000	0	470	623
Container - 8000	0	506	668
Container - 9000	0	613	677
Container - 10000	0	458	581
Cruise	0	361	306
General Cargo		124	134
ITB	0	0	0
Reefer	0	237	304
RoRo	0	148	259
Tanker - Aframax	0	438	5030
Tanker - Chemical	0	136	568
Tanker - Handysize	0	144	2586
Tanker - Panamax	0	351	3421
Tanker - Suezmax	0	191	5843

*using upper limit

Table 3.22: Fuel Correction Factors

Fuel Used	NOx	VOC	CO	SO2	PM10	PM2.5	DPM	CO2	N2O	CH4
HFO (2.7% S)	1	1	1	1	1	1	1	1	1	1
HFO (1.5% S)	1	1	1	0.555	0.82	0.82	0.82	1	1	1
MGO (0.5% S)	0.94	1	1	0.185	0.25	0.25	0.25	1	0.94	1
MDO (1.5% S)	0.94	1	1	0.555	0.47	0.47	0.47	1	0.94	1
MGO (0.1% S)	1	1	1	1	1	1	1	1	1	1
MGO (0.3% S)	0.94	1	1	0.111	0.21	0.21	0.21	1	0.94	1
MGO (0.4% S)	0.94	1	1	0.148	0.23	0.23	0.23	1	0.94	1
ULSD	1	1	1	1.2007	1.18	1.18	1.18	1	1	1
LNG	1	1	1	1	1	1	1	1	1	1

LNG fuel correction factors set to 1 as direct emissions factors already account for LNG engines meeting Tier 3 standards
ULSD factors based on scaling from 0.5%S to 0.1%S MGO and further scaling 0.1%S MGO to 0.0015%S

Fuel Consumption Factors	SFOC	Units	Source
Main Engine	204.31	gMDO/kWh	Implied by CO2 emissions factors, converted using CO2 emissions above
Aux Engine	215.34	gMDO/kWh	Implied by CO2 emissions factors, converted using CO2 emissions above
Boiler	290.70	gMDO/kWh	Implied by CO2 emissions factors, converted using CO2 emissions above

Combusted Gas Characteristics

0.799393301

Parameters	Natural Gas[a]	Flared Waste Gas[a]									Diesel
		Liquefying Case 1	Liquefying Case 2	Liquefying Case 3	Liquefying Case 4	Liquefying Case 5	Holding	LNG Transfer A1	LNG Transfer A2/A3	LNG Transfer B	
Heat Content (Btu/scf)	1,093	346	466	1,644	864	1,825	1,144	506	506	223	138,000
Density (lb/scf)	0.046	0.101	0.091	0.088	0.097	0.087	0.049	0.058	0.059	0.067	
Sulfur Content (ppmw)[c]	25	337	912	524	250	587	17	0	0	0	15
VOC Content (wt%)	NA	9.6%	14%	51%	24%	58%	17%	0.10%	0.10%	0.10%	
Benzene Concentration (mg/m^3)[b]	2,980	2,980	2,980	2,980	2,980	2,980	2,980	2,980	2,980	2,980	
Ethylbenzene Concentration (mg/m^3	144	144	144	144	144	144	144	144	144	144	
m,p-Xylene Concentration (mg/m^3)[b]	986	986	986	986	986	986	986	986	986	986	
o-Xylene Concentration (mg/m^3)[b]	165	165	165	165	165	165	165	165	165	165	
Toluene Concentration (mg/m^3)[b]	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	

Notes:

[a] Provided by CB&I.

[c] Based on the Williams Gas Pipeline tariff of 0.25 grains per 100 cubic feet for H2S, the past 12-month maximum total sulfur (reported as H2S by Williams Gas Pipeline) of 0.603 grains per 100 cubic feet, and sulfur from odorant of 0.23 grains per 100 cubic feet (odorant injection rates provided by PSE).

[b] From "Natural Gas Analysis"; Environmental Partners, Inc.; February 3, 2014. Most hazardous air pollutants (HAPs) will go through with the heavy hydrocarbons, but the fraction is unknown. Therefore, we conservatively assume the waste gas has the full concentration of HAP.

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4) Mass fractions of black carbon and organic carbon emissions of corresponding PM2.5 emission factors

4.1) Stationary, mobile, and open burning emission sources, %

	Natural gas						Coal		Biomass			Diesel							
	Boiler	Engine	Combined	Simple cy	Nonroad E	Flared	Boiler	IGCC	Industrial,	IGCC	Open burr	Industrial,	Simple cy	Engine	Nonroad v	Nonroad E	Locomoti	HDDT 8b	HDDT 6
BC	16.5	20.0	2.9	2.9	9.8	95.0	4.3	4.3	13.8	13.8	12.1	10.0	10.0	81.3	56.3	77.1	8.4	16.0	8.1
OC	42.8	42.8	68.0	68.0	83.7	5.0	8.1	8.1	32.6	32.6	33.9	25.0	25.0	18.1	34.9	21.1	88.6	66.0	88.0

	Gasoline			Residual fuel oil				Crude oil	Biochar	Jet fuel	
	Engine	Off-road v	Nonroad E	Boiler	Engine	Simple cy	Ocean tan	Boiler	Boiler	Cruise	Landing and take-offs
BC	10.0	13.6	9.8	6.3	15.0	6.0	15.0	2.9	6.2	31.3	35.8
OC	32.0	86.4	83.7	4.4	39.0	4.0	39.0	2.1	79.9	30.3	26.0