

GENERAL INPUTS

Date: 21-Sep-18
Version: 17

Comments/Source

LNG Plant Operation

LNG Product - End use share

LNG Production	Scenario A					Scenario B					Check	Scenario A Volume Data
	End use share	gal/day	lb/day	Mgal/year	tonne/year	Enduse share	gal/day	lb/day	Mgal/year	tonne/year	gal/year (365)	
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

Source: PSE-BID

Scenario Selection for End use Mix

Results -5.48% -39.90 ktonne/year

Scenario	Comment	EER for Marine	Range
Enduse Scenario A	Pull Down	1 Type in	1 to 1.015
Sub- Scenario	Comment	Used GEN MIX	
LPG is flared Yes	Pull Down	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

Source: LCA assumption 8760h/yr-240h/year (pipeline used by the vaporizer)
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Source: Capacity, NG use 2018-05-25 PSE Submittal page 12
Source: Capacity, NG use 2018-05-25 PSE Submittal page 12

Energy/Electricity Consumption LNG Plant

Scenario A		PSE Estimate	Calculated	
Equipment	Capacity/Consumption	(mmBtu/hr)	Fuel	(mmBtu/hr) Input for 250,000 gal /day
LNG Pretreatment	NG WPG heater	9	NG	9
LNG Pretreatment	NG Regenerator heater	1.6	NG	1.6
Waste gas flaring	Waste Gas Heat Input	35.6		67.8
LPG in Waste Gas		77	LPG	
Waste Gas, Mass Balance		88	C2/CS+	
Vaporizer	LNG Heater Capacity	66		66
		(gal/h)		
Emergency equipment	Diesel generator	104.6	Diesel	104.6

Source: Capacity, NG use 2018-05-25 PSE Submittal ATTACHMENT F page 118
Source: Capacity, NG use 2018-05-25 PSE Submittal ATTACHMENT F page 119
Source: Capacity, NG use 2018-05-25 PSE Submittal page 12

Source: Capacity, NG use 2018-05-25 PSE Submittal ATTACHMENT F page 120

Source: Capacity, NG use 2018-05-25 PSE Submittal page 12

LNG pretreatment CO₂ seperation efficiency **99.760%** Actual result based on LNG composition

Power Consumption LNG plant		Baseline
LNG Production	1,348	kWh/1000 gal
Vaporizer	45	kWh/1000 gal

Source: page 13, PES response

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 mol%	Pretreatment Vent mol%	To LNG mol%	Waste Gas mol%	LPG mol%	Tacoma LNG 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/l)	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
CH4	94.536	0.000	0.181	0.121	0.059	94.356
C2H6	6.284	0.000	1.967	1.935	0.032	4.317
C3H8	1.598	0.000	0.771	0.039	0.732	0.828
i-C4H10	0.232	0.000	0.131	0.007	0.125	0.101
n-C4H10	0.250	0.000	0.160	0.008	0.152	0.090
i-C5H12	0.049	0.000	0.038	0.034	0.004	0.011
n-C5H12	0.035	0.000	0.029	0.029	0.000	0.007
C6+	0.031	0.000	0.030	0.030	0.000	0.001
N2	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
H2	0.000	0.000	0.000	0.000	0.000	0.000
H2S	0.000	0.000	0.000	0.000	0.000	0.000
O2	0.000	0.000	0.000	0.000	0.000	0.000
He						
CO2	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 ₂ H ₆	188.9	0.0	59.1	58.2	1.0	129.8
	0.0	0.0	0.0	0.0	0.0	
C ₃ H ₈	70.5	0.0	34.0	1.7	32.3	36.5
i-C ₄ H ₁₀	13.5	0.0	7.6	0.4	7.2	5.8
n-C ₄ H ₁₀	14.5	0.0	9.3	0.5	8.9	5.2
i-C ₅ H ₁₂	3.6	0.0	2.7	2.5	0.3	0.8
n-C ₅ H 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 ₂ S	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

Processing Step	Emissions (g/mmBTU), LHV			
	CO ₂	CH ₄	N ₂ O	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 Fugitive	778	6.83	0.00	1,246.31
Transmission & Storage	377	13.68	0.30	1,017.00
Transmission Fugitive	0.00	19.19	0.00	777.75
Total	5,355	189	0	10,371

Natural Gas upstream BC FORTIS GIG HARBOR

Natural Gas upstream BC	Emissions g/mmBTU (LHV)			
	CO ₂	CH ₄	N ₂ O	
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

Natural Gas upstream from PSE for Lower Sensitivity

Natural Gas upstream BC	Emissions g/mmBTU (LHV)			#VALUE!
	CO ₂	CH ₄	N ₂ O	
Natural Gas Extraction and processing	6,030	46	0.16	7465.5
Transmission	824	6	0.02	1269.5
Total	6,854	51	0	8437
Distribution	10	2	0.00	

Power generation

Processing Step	Code	Emissions (g/kWh)			
		CO ₂	CH ₄	N ₂ O	
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

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

GHGenius			GREET			BC Inventory		
CO ₂	CH ₄	N ₂ O	CO ₂	CH ₄	N ₂ O	CO ₂	CH ₄	N ₂ O
2355.559	8.90518	0.020759	2126.915308	8.040794784		0.018744431	6,030	46
	135.744			122.5679201			824	6
1845.076	4.371853	0.014211	1665.982414	3.947497367		0.012831328		
777.5359	6.830768		702.0639913	6.167736439				
	377	13.68	1650.744077	17.69875777		1.253646641		
	19.19	0.295		40.36132186				

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 ₂ O	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

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

Processing Step	Emissions (g/mmBtu), LHV		
	CO ₂	CH ₄	N ₂ O
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 veh	0.01

Loss of LNG Peak Shaving - Boiler opera Consumption, Estimate	
Processing Step	kWhel/mmBtu
Pumping Diesel fuel from tank to boi	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					
<u>Construction Emissions</u>					
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
<u>Operational Emissions</u>					
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	529,859	21,194,356	5,970
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	225,993	9,039,715	2,546
TOTE Marine Diesel Pilot fuel			7,611	304,456	86
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	244,185	9,767,407	2,751
Other Marine Diesel Pilot Fuel			8,216	328,632	93
Total Emissions (Tacoma LNG)			687,639	27,505,576	7,748

NO ACTION

Life Cycle Step	Mgal/ year	GBtu/ year	GHG Emissions tonne/year	GHG Emissions tonne/40 year	GHG Emissions kg/1000 gal
<u>Upstream Displaced Emissions</u>					
Total Upstream			125,245	5,009,811	1,411.21
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	52,448	2,097,916	591
Upstream Truck-to-Ship Bunkering		0	0	0	0
Upstream Other Marine Diesel (by Bunker Barge)		3257	56,670	2,266,797	639
<u>End Use Emissions</u>					
Total End Use Diesel /Fuel Oil/LNG	50.6	7,022	602,291	24,091,647	6,786
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	21.48	3,014	261,325	10,452,985	2,945
Truck-to-Ship Bunkering	0.00	0	0	0	0
Other Marine Diesel (by Bunker Barge)	23.21	3,257	282,076	11,283,042	3,178
Total Emission (No Action)			727,536	29,101,458	8,198
Net Emission reduction			-39,897	-1,595,881	-450
in percentage			-5.48%	-5.48%	-5.48%

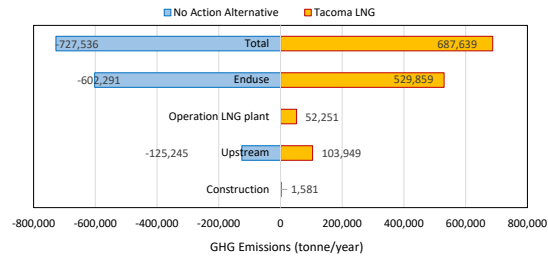
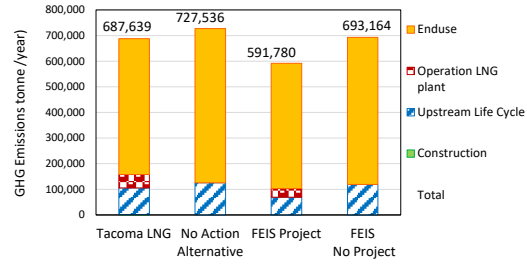
Short tables

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	529,859	21,194,356	5,970
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	225,993		
TOTE Marine Diesel Pilot fuel	0.00	0	7,611		
Truck-to-Ship Bunkering	0.00	0	0		
Truck-to-Ship Bunkering Pilot Fuel			0		
Other Marine LNG (by Bunker Barge)	41.09	3171	244,185		
Other Marine Diesel Pilot Fuel			8,216		
Total	88.75	6,848	687,639	27,505,576	7,748
NO ACTION					
Upstream Life Cycle			125,245	5,009,811	1,411
Total End Use Diesel /Fuel Oil/LNG	50.57	7,022	602,291	24,091,647	6,786
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	21.48	3,014	261,325		
Truck-to-Ship Bunkering	0.00	0	0		
Other Marine Diesel (by Bunker Barge)	23.21	3,257	282,076		
Total	50.57	7,022	727,536	29,101,458	8,198
Net Emissions		-5.48%	-39,897	-1,595,881	-450
				-5.48%	-5.48%

GHG Emissions (tonne/year)	Tacoma LNG	No Action Alternative	FEIS Project	FEIS No Project
Construction	1,581			
Upstream Life Cycle	103,949	125,245	69,299	119,238
Operation LNG plant	52,251	0	33,539	0
Enduse	529,859	602,291	488,942	573,926
Total	687,639	727,536	591,780	693,164
Net Emissions	-39,897			
	-0.05483854		-101,385	-14.63%

GHG Emissions (GBtu/year)	No Action Alternative	Tacoma LNG	Net Emissions
Construction		1,581	
Upstream	-125,245	103,949	
Operation LNG plant	0	52,251	
Enduse	-602,291	529,859	
Total	-727,536	687,639	-39,897



Direct End Use
Scenario: 250,000 gal/year

LNG Enduse	Equipment Type	Consumption		EER	Btu/gal
		Mgal/yr	GBtu, LHV/yr		
Power Peak Shaving					
LNG	Dual Fuel Turbine	9.73	750	1	77,156
Displaced Diesel	Dual Fuel Turbine	5.89	750		127,464
Gig Harbor LNG					
LNG	NG Boiler	0.00	0	1	77,156
LNG	NG Boiler	0.00	0		77,156
On-road Trucking					
LNG	Truck Engine	0.00	0	0.9	77,156
Diesel	Truck Engine	0.00	0		127,464
TOTE Marine					
LNG	Marine Engine	37.93	2,927	1	77,156
Pilot diesel Fuel for LNG	Marine Engine	0.63	88	1	140,353
Displaced MDO Fuel	Marine Engine	21.48	3,014		140,353
Truck-to-Ship Bunkering					
LNG	Marine Engine	0.00	0	1	77,156
Pilot Fuel for LNG	Marine Engine	0.00	0		140,353
Displaced MDO Fuel	Marine Engine	0.00	0		140,353
Other Marine (by Bunker Barge)					
LNG	Marine Engine	41.09	3,162	1	77,156
Pilot Fuel for LNG	Marine Engine	0.68	95	1	140,353
Displaced MDO Fuel	Marine Engine	23.21	3,257		140,353
Total LNG		88.750	6,839		

T 4.2

Scenario A		Emissions (tonne/year)			
GHG Emissions	Equipment Type	CO ₂ c	CH ₄	N ₂ O	CO ₂ e
Power Peak Shaving					
LNG	Duct Firing	43,755	1	0.26	43,854
Diesel	Duct Firing	58,682	0	0.69	58,891
Gig Harbor Delivery					
LNG Tacoma	Truck Engine	0	0	0.00	0.0
LNG	Truck Engine	0	0	0.00	0
LNG Tacoma End Use	NG Boiler	0	0	0	0
LNG End Use	NG Boiler	0	0	0	0
On-road Trucking					
LNG	Truck Engine	0	0	0.00	0
Diesel	Truck Engine	0	0	0.00	0
TOTE Marine					
LNG	Marine Engine	171,718	2,029	12	225,993
Pilot fuel	Marine Engine	7,508	0	0.34	7,611
MDO Fuel	Marine Engine	257,783	4	11.55	261,325
Truck-to-Ship Bunkering					
LNG incl. Pilot fuel	Marine Engine	0	0	0.00	0
Pilot fuel	Marine Engine	0	0	0.00	0
Diesel Truck	Truck Engine	0	0	0.00	0
MDO Fuel	Marine Engine	0	0	0.00	0
Other Marine (by Bunker Barge)					
LNG	Marine Engine	185,541	2,192	13	244,185
Pilot fuel	Marine Engine	8,113	0	0.34	8,216
MDO Fuel	Marine Engine	278,535	4	11.55	282,076

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

LNG Project	Equipment Type	Emissions (tonne/year)			
		CO ₂ c	CH ₄	N ₂ O	CO ₂ e
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	171,718	2,029	12	225,993
Pilot fuel	Marine Engine	7,508	0	0	7,611
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
Other Marine (by Bunker Barge)					
LNG	Marine Engine	185,541	2,192	13	244,185
Pilot fuel	Marine Engine	8,113	0	0	8,216
Total End Use		416,636	4,222	26	529,859

Non Action

NO LNG Project	Equipment Type	Emissions (tonne/year)			
		CO ₂ c	CH ₄	N ₂ O	CO ₂ e
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		51,531	33.7	0.2	52,448
MDO fuel	Marine Engine	257,783	3.9	11.6	261,325
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	278,535	3.9	11.6	282,076
Total End Use		702,210	78	24	711,409

Scenario A

NO LNG Project	Equipment Type	Emissions (tonne/year), LHV			
		CO ₂ c	CH ₄	N ₂ O	CO ₂ e
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

Processing Step	Emissions (g/mmBtu), LHV			
	CO ₂	CH ₄	N ₂ O	CO ₂ e
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 Fugitive	778	6.8	0.000	948
Transmission & Storage	377	13.7	0.295	807
Transmission 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
LHV, Btu/gal	21,074	21,262		85,528

Natural Gas upstream LNG	GHG Emissions (kg/1000 gal LNG)				
	CO ₂	CH ₄	N ₂ O	CO ₂ e	just CH4
Natural Gas upstream	458.0	16.1	0.0	869.9	403.5
					35,813
					179,064

Processing Step	Code	Upstream	Emissions (g/kWh)				Fuel Type	Percentage Used
			CO ₂	CH ₄	N ₂ O	CO ₂ e		
Washington	WAUP	Upstream	8.2	0.3800	0.0010	18	Hydro Power	84%
	WAPP	Power Plants	196.0	0.0100	0.0030	197	Nuclear*	6%
Tacoma	TAUP	Upstream	1.3	0.0454	0.0001	2	Coal*	2%
	TAPP	Power Plants	27.4	0.0003	0.0003	27	Natural Gas	1%
Marginal	MAUP	Upstream	19.7	0.6462	0.0026	37	Wind	7%
	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		

Comparison to reported values
Provided BID Report page 4

Processing Step	Emissions (g/mmBtu), LHV			
	CO ₂	CH ₄	N ₂ O	CO ₂ e
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)

Power Consumption LNG Construction	Baseline	GHG Emissions (tonnes)			
		CO ₂	CH ₄	N ₂ O	CO ₂ e
Power Total during construction (kWh)	10,512,000				
Mix	WAUP	2,146.6	4.1	0.0	2,261.6

Power Consumption LNG Production	Baseline	GHG Emissions (kg/1000 gal LNG)			
		CO ₂	CH ₄	N ₂ O	CO ₂ e
Power (kWh/1000 gal)	1348				
Mix	WA	275.3	0.5	0.0	290.0

Power Consumption Vaporizer/ Peak Shaving	Baseline	GHG Emissions (kg/1000 gal LNG)			
		CO ₂	CH ₄	N ₂ O	CO ₂ e
Power (kWh/1000 gal)	45				
Mix	WA	9.2	0.0	0.0	9.7

NO PROJECT					
Processing Step	Consumption, Estin kWhel/mmBtu	Emissions (g/mmBtu), LHV			
		CO ₂	CH ₄	N ₂ O	CO ₂ e
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					
Processing Step	Consumption, Estin kWhel/mmBtu	Emissions (g/mmBtu), LHV			
		CO ₂	CH ₄	N ₂ O	CO ₂ e
Pumping Diesel fuel from tank to boiler	0.01	2.042	0.004	0.000	2.900

*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	VOC	CO	NOx	BC	OC	CH4	N2O	CO2	Upstream Emissions from Tacoma Power Supply	
									grams/mmBTUel	g/kWhel
Emissions Rate	0.65	1.63	3.83	0.02	0.05	10.92	0.09	5942.00		
per Power	0.00	0.01	0.01	0.00	0.00	0.04	0.00	20.27		
Emissions Rate	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	27.99		

Total	2.042	0.004	0.000	2.900
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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

Processing Step	Emissions (g/mmBtu), LHV			
	CO₂	CH₄	N₂O	CO₂e
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	0
Crude Oil Refining	13,232	0.0	0.0	13,232
Processing Fugitive	0	0.0	0.0	0
Transport	491	0.0	0.0	491
Transport Fugitive	0	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

Processing Step	Consumption	Emissions (kg/1000 gal), LHV			
	mmBtu/ 1000 gal LNG	CO₂	CH₄	N₂O	CO₂e
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**

Processing Step	Consumption	Emissions (tonne/yr), LHV			
	mmBtu/year	CO₂	CH₄	N₂O	CO₂e
LNG Project	0.00	0.00	0.00	0.00	0.00

Upstream GHG Emissions for Tacoma LNG

Pollutant	CO₂	CH₄	N₂O	CO₂e	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)		
			GBtu/year	Fuel	CO ₂	CH ₄	N ₂ O
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	51,531	34	0.25	52,448
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				122,907	86	0.6	125,243
							125,245

Summary of Terminal Construction Emissions - GHG PSE LNG

Equipment (Direct + Upstream)	CO ₂ (tonne/ year)	CH ₄ (tonne/ year)	N ₂ O (tonne/ year)	CO ₂ e (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 ₂ O (tonne/ year)	CO ₂ e (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 ₂ O (tonne/ year)	CO ₂ e (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 ₂ O Emission Factor (g/gal)	CO _{2c} (tonne/ year)	CH ₄ (tonne/ year)	N ₂ O (tonne/ year)	CO _{2e} use (tonne/ year)	Fuel consumption (mmBtu/year)	Upstream Emission Diesel production				Total CO _{2e} (tonne/ year)
																		Upstream CO ₂ (tonne/ year)	Upstream CH ₄ (tonne/ year)	Upstream N ₂ O (tonne/ year)	Upstream CO _{2e} (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 ₂ c Emission Factor (g/hp-hr)	CH ₄ Emission Factor (g/gal)	N ₂ O Emission Factor (g/gal)	CO ₂ c (tonne/year)	CH ₄ (tonne/year)	N ₂ O (tonne/year)	CO ₂ e use (tonne/year)	Fuel consumption (mmBtu/year)	Upstream CO ₂ (tonne/year)	Upstream CH ₄ (tonne/year)	Upstream N ₂ O (tonne/year)	Upstream CO ₂ e (tonne/year)	Total CO ₂ e (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 ₂ O 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 ₂ O 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 ₂ O (g/VMT)	CO (g/VMT)	VOCs (g/VMT)	CO ₂ c (g/VMT)	CO ₂ (tonne/year)	CH ₄ (tonne/year)	N ₂ O (tonne/year)	CO ₂ e (tonne/year)	Fuel consumption (mmBtu/year)	Upstream CO ₂ (tonne/year)	Upstream CH ₄ (tonne/year)	Upstream N ₂ O (tonne/year)	Upstream CO ₂ e (tonne/year)	Total CO ₂ e (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 ₂ O (g/VMT)	CO (g/VMT)	VOCs (g/VMT)	CO ₂ c (g/VMT)	CO ₂ (tonne/year)	CH ₄ (tonne/year)	N ₂ O (tonne/year)	CO ₂ e (tonne/year)	Fuel consumption (mmBtu/year)	Upstream CO ₂ (tonne/year)	Upstream CH ₄ (tonne/year)	Upstream N ₂ O (tonne/year)	Upstream CO ₂ e (tonne/year)	Total CO ₂ e (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	3,250.51
								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 ₂ O (g/VMT)	CO (g/VMT)	VOCs (g/VMT)	CO ₂ c (g/VMT)	CO ₂ (tonne/year)	CH ₄ (tonne/year)	N ₂ O (tonne/year)	CO ₂ e (tonne/year)	Fuel consumption (mmBtu/year)	Upstream CO ₂ (tonne/year)	Upstream CH ₄ (tonne/year)	Upstream N ₂ O (tonne/year)	Upstream CO ₂ e (tonne/year)	Total CO ₂ e (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 ₂ O (g/VMT)	CO (g/VMT)	VOCs (g/VMT)	CO ₂ c (g/VMT)	CO ₂ (tonne/year)	CH ₄ (tonne/year)	N ₂ O (tonne/year)	CO ₂ e (tonne/year)	Fuel consumption (mmBtu/year)	Upstream CO ₂ (tonne/year)	Upstream CH ₄ (tonne/year)	Upstream N ₂ O (tonne/year)	Upstream CO ₂ e (tonne/year)	Total CO ₂ e (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 ₂ O (g/VMT)	CO (g/VMT)	VOCs (g/VMT)	CO ₂ c (g/VMT)	CO ₂ (tonne/year)	CH ₄ (tonne/year)	N ₂ O (tonne/year)	CO ₂ e (tonne/year)	Fuel consumption (mmBtu/year)	Upstream CO ₂ (tonne/year)	Upstream CH ₄ (tonne/year)	Upstream N ₂ O (tonne/year)	Upstream CO ₂ e (tonne/year)	Total CO ₂ e (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 ₂ O (g/VMT)	CO (g/VMT)	VOCs (g/VMT)	CO ₂ c (g/VMT)	CO ₂ (tonne/year)	CH ₄ (tonne/year)	N ₂ O (tonne/year)	CO ₂ e (tonne/year)	Fuel consumption (mmBtu/year)	Upstream CO ₂ (tonne/year)	Upstream CH ₄ (tonne/year)	Upstream N ₂ O (tonne/year)	Upstream CO ₂ e (tonne/year)	Total CO ₂ e (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 ₂ O (g/VMT)	CO (g/VMT)	VOCs (g/VMT)	CO ₂ c (g/VMT)	CO ₂ (tonne/year)	CH ₄ (tonne/year)	N ₂ O (tonne/year)	CO ₂ e (tonne/year)	Fuel consumption (mmBtu/year)	Upstream CO ₂ (tonne/year)	Upstream CH ₄ (tonne/year)	Upstream N ₂ O (tonne/year)	Upstream CO ₂ e (tonne/year)	Total CO ₂ e (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 ₂ O (g/VMT)	CO (g/VMT)	VOCs (g/VMT)	CO ₂ c (g/VMT)	CO ₂ (tonne/year)	CH ₄ (tonne/year)	N ₂ O (tonne/year)	CO ₂ e (tonne/year)	Fuel consumption (mmBtu/year)	Upstream CO ₂ (tonne/year)	Upstream CH ₄ (tonne/year)	Upstream N ₂ O (tonne/year)	Upstream CO ₂ e (tonne/year)	Total CO ₂ e (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	Winter 1. Year	26.6	0	0	0	0.00	0	0
Feb-1. Year		24	0	0	0	0.00	0	0
Mar-1. Year		26.6	0	0	0	0.00	0	0
Apr-1. Year	Summer 1. Year	25.7	0	0	0	0.00	0	0
May-1. Year		26.6	0	0	0	0.00	0	0
Jun-1. Year		25.7	0	0	0	85.00	331	331
Jul-1. Year		26.6	0	0	0	85.00	320	320
Aug-1. Year		26.6	0	0	0	75.00	282	282
Sep-1. Year	25.7	0	0	0	75.00	292	292	
Oct-1. Year	Winter 1. Year	26.6	0	0	0	5.00	19	19
Nov-1. Year		25.7	0	0	0	5.00	19	19
Dec-1. Year		26.6	0	0	0	0.00	0	0
Jan-2. Year	Winter 2. Year	26.6	0	0	0	0.00	0	0
Feb-2. Year		24.9	0	0	0	0.00	0	0
Mar-2. Year		26.6	0	0	0	0.00	0	0
Apr-2. Year	Summer 2. Year	25.7	0	0	0	0.00	0	0
May-2. Year		26.6	0	0	0	0.00	0	0
Jun-2. Year		25.7	0	0	0	174.00	677	677
Jul-2. Year		26.6	98	2,604	104,160	244.00	918	105,078
Aug-2. Year		26.6	98	2,604	104,160	294.00	1,106	105,266
Sep-2. Year	25.7	98	2,520	100,800	794.00	3,088	103,888	
Oct-2. Year	Winter 2. Year	26.6	98	2,604	104,160	844.00	3,176	107,336
Nov-2. Year		25.7	98	2,520	100,800	894.00	3,477	104,277
Dec-2. Year		26.6	98	2,604	104,160	889.00	3,346	107,506
Jan-3. Year	Winter 3. Year	26.6	98	2,604	104,160	888.00	3,342	107,502
Feb-3. Year		24	98	2,352	94,080	329.00	1,371	95,451
Mar-3. Year		26.6	98	2,604	104,160	279.00	1,050	105,210
Apr-3. Year	Summer 3. Year	25.7	98	2,520	100,800	279.00	1,085	101,885
May-3. Year		26.6	98	2,604	104,160	252.00	948	105,108
Jun-3. Year		25.7	98	2,520	100,800	189.00	735	101,535
Jul-3. Year		26.6	98	2,604	104,160	139.00	523	104,683
Aug-3. Year		26.6	98	2,604	104,160	139.00	523	104,683
Sep-3. Year	25.7	98	2,520	100,800	89.00	346	101,146	
Oct-3. Year	Winter 3. Year	26.6	0	0	0	78.00	294	294
Nov-3. Year		25.7	0	0	0	39.00	152	152
Dec-3. Year		26.6	0	0	0	39.00	147	147
Jan-4. Year	Winter 4. Year	26.6	0	0	0	39.00	147	147
Feb-4. Year		24	0	0	0	39.00	163	163
Mar-4. Year		26.6	0	0	0	39.00	147	147
Apr-4. Year	Summer 4. Year	25.7	0	0	0	41.00	159	159
May-4. Year		26.6	0	0	0	39.00	147	147
Jun-4. Year		25.7	0	0	0	0.00	0	0
Jul-4. Year		26.6	0	0	0	0.00	0	0
Aug-4. Year		26.6	0	0	0	0.00	0	0
Sep-4. Year	25.7	0	0	0	0.00	0	0	
Oct-4. Year	Winter 4. Year	26.6	0	0	0	0.00	0	0
Nov-4. Year		25.7	0	0	0	0.00	0	0
Dec-4. Year		26.6	0	0	0	0.00	0	0
Total					1,535,520		28,330	

Note: Commute round-trip distance was assumed

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
1. Year Summer	0	1225.00
2. Year Winter	309,120	9999.00
2. Year Summer	309,120	5789.00
3. Year Winter	302,400	6356.00
3. Year Summer	614,880	4160.00
4. Year Winter	0	457.00
4. Year 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 ₂ O	CO ₂ e	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
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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

Processing Step	Diesel Consumption mmBtu/year	Emissions (t/year)			
		CO ₂	CH ₄	N ₂ O	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		Consumption							
	Equipment	Mgal/year	GBtu/year						
LNG	Tractor engine	0.00	0						
Diesel	Tractor engine	0.00	0						

										Old value from BID
Emissions (g/MMBTU)										
Pathway Component	VOC	CO	NO _x	CH ₄	N ₂ O	CO ₂	CO _{2c}	CO _{2c}	CO _{2c}	
Tank-to-Wheels LNG Combination Tractor	21.07	1,167	66.09	309.766737	0.03250653	55,559	57,459	57,459	57,458	
Total LNG Tacoma -to-Wheels	21.07	1,167	66.09	309.8	0.03	55,559	57,459	57,459	57,458	
Well-to-Wheels Diesel Combination Tractor	31.52	94.58	228.4	4.75	0.18	77,938	78,186	78,186	78,185	
Plant-to-Tank LNG Combination Tractor	0.308	1.289	7.299	104.5	0.017	753	756	756	756	

Processing Step	Consumption mmbtu/year	CO _{2c}	Emissions (t/year)		CO _{2e}
			CH ₄	N ₂ O	
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

Route Definition

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

Time within 200 nm

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)	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	Aux Engine	Main Engine	Aux Engine	Boiler Type
			Speed (RPM)	Speed (RPM)	Type	Type	
24	25.5	52200	400	720	All	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

End Use Emissions Marine vessels	Emissions Within 200nm (tonne per trip)						
	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	0.04	0.00	0.00
Total Emissions (tonne)	0.60	0.00	0.60	0.00	0.05	0.01	0.00
Emissions Rate (g/tonne MGOe)	9,408	6	9,488	17	787	105	0
Emissions Rate (g/mmBtu MGOe, LHV)	252	0	254	0	21	3	0

End Use Emissions Marine vessels	Emissions Outside 200nm (tonne per trip)					
	NO _x	VOC	CO	SO ₂	PM10	PM2.5
	3.62	0.00	3.62	0.01	0.04	0.04
	0.01	0.00	0.02	0.00	0.00	0.00
	0.01	0.00	0.00	0.00	0.04	0.00
Total Emissions (tonne)	3.64	0.00	3.64	0.01	0.08	0.04
Emissions Rate (g/tonne MGOe)	9,343	3	9,356	17	211	99
Emissions Rate (g/mmBtu MGOe, LHV)	250	0	250	0	6	3

End Use Emissions Marine vessels	Total Emissions (tonne per trip)						
	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	0.01	0.00	0.00
	0.02	0.00	0.01	0.00	0.08	0.00	0.00
Total Emissions (tonne)	4.24	0.00	4.25	0.01	0.13	0.05	0.00
Emissions Rate (g/tonne MGOe)	9,352	3	9,374	17	292	100	0
Emissions Rate (g/mmBtu MGOe, LHV)	250	0	251	0	8	3	0

Emissions Calcs

End Use Emissions Marine vessels	Emissions Within 200nm (tonne per trip)				
	CO ₂	N ₂ O	CH ₄	CO ₂ c	CO ₂ e
	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)	2,179,771	153	25,689	308,266	404,892
Emissions Rate (g/mmBtu MGOe, LHV)	58,271	4	687	58,670	77,061

End Use Emissions Marine vessels	Emissions Outside 200nm (tonne per trip)				
	CO ₂	N ₂ O	CH ₄	CO ₂ c	CO ₂ e
	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)	2,180,174	152	25,971	1,886,590	2,483,690
Emissions Rate (g/mmBtu MGOe, LHV)	58,282	4	694	58,675	77,246

End Use Emissions Marine vessels	Total Emissions (tonne per trip)						
	CO ₂	N ₂ O	CH ₄	CO ₂ c	CO ₂ e	BC	OC
	981	0.07	11.71	988	1,301	0.01	0.00
	1	0.00	0.02	2	2	0.00	0.00
	5	0.00	0.02	5	6	0.00	0.00
Total Emissions (tonne)	988	0.07	11.75	995	1,309	0.01	0.02
Emissions Rate (g/tonne MGOe)	2,180,117	153	25,931	2,194,855	2,888,582	22	47
Emissions Rate (g/mmBtu MGOe, LHV)	58,280	4	693	58,674	77,220	1	1

Methane Slip
0.43%
0.36%
0.16%

Fuel Consumption Estimates

Geographic Region	Engine	Engine	Boiler
Fuel Consumed Within 200nm (MT MGOe)	62.0	0.8	0.8
Fuel Consumed Outside 200nm (MT MGOe)	386.5	2.2	0.8
Fuel Consumed (MT MGOe)	448.6	3.0	1.6

<i>Within 200nm</i>		Emissions Factors (g/kWh)								
Main Engine	NO _x	VOC	CO	SO ₂	PM10	PM2.5	DPM	CO ₂	N ₂ O	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 ₂ O	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 ₂ O	CH ₄
Transit	2.00	0.10	0.20	0.00	16.00	0.15	0.00	644	0.08	0.00
Maneuvering	2.00	0.10	0.20	0.00	16.00	0.15	0.00	644	0.08	0.00
Hotelling	2.00	0.10	0.20	0.00	16.00	0.15	0.00	644	0.08	0.00

<i>Outside 200nm</i>		Emissions Factors (g/kWh)								
Main Engine	NO _x	VOC	CO	SO ₂	PM10	PM2.5	DPM	CO ₂	N ₂ O	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 ₂ O	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 ₂ O	CH ₄
Transit	2.00	0.10	0.20	0.00	16.00	0.15	0.00	644	0.08	0.00
Maneuvering	2.00	0.10	0.20	0.00	16.00	0.15	0.00	644	0.08	0.00
Hotelling	2.00	0.10	0.20	0.00	16.00	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 - Destination - hours)		Transit	Maneuvering	
							Time at Berth (hours)	Time at Berth (hours)		g	Hotelling
RoRo	Anchorage	Tacoma	1450	22	65.9	2	10	10	14%	50%	50%

Time within 200 nm

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	MGO (0.1% S)
Maneuvering	2.0	1,044	396	148	MGO (0	MGO (0.1% S)
Hotelling	20.0	0	229	259	MGO (0	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
	3.50	0.15	0.34	0.00	0.01	0.01	0.01
	0.06	0.01	0.01	0.00	0.00	0.00	0.00
	0.03	0.00	0.00	0.00	0.01	0.00	0.00
Total Emissions (tonne)	3.59	0.16	0.35	0.01	0.02	0.01	0.01
Emissions Rate (g/tonne MGO)	56,349	2,587	5,497	85	319	195	202
Emissions Rate (g/mmBtu MGO, LHV)	1,506	69	147	2	9	5	5

End Use Emissions Marine vessels	Emissions Outside 200nm (tonne per trip)						
	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
	21.85	0.95	2.10	0.03	0.08	0.07	0.08
	0.06	0.01	0.01	0.00	0.00	0.00	0.00
	0.03	0.00	0.00	0.00	0.01	0.00	0.00
Total Emissions (tonne)	21.94	0.96	2.11	0.03	0.09	0.07	0.08
Emissions Rate (g/tonne MGO)	56,319	2,475	5,417	78	220	192	201
Emissions Rate (g/mmBtu MGO, LHV)	1,506	66	145	2	6	5	5

End Use Emissions Marine vessels	Total Emissions (tonne per trip)						
	NOx	VOC	CO	SO2	PM10	PM2.5	DPM
	25.34	1.10	2.43	0.03	0.09	0.09	0.09
	0.12	0.02	0.02	0.00	0.00	0.00	0.00
	0.06	0.00	0.01	0.00	0.01	0.00	0.00
Total Emissions (tonne)	25.52	1.13	2.46	0.04	0.11	0.09	0.09
Emissions Rate (g/tonne MGO)	56,323	2,491	5,428	79	234	193	201
Emissions Rate (g/mmBtu MGO, LHV)	1,506	67	145	2	6	5	5

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	206
Emissions Rate (g/tonne MGO)	3,182,667	144	48	449,379	455,584
Emissions Rate (g/mmBtu MGO, LHV)	85,081	4	1	12,013	12,179

End Use Emissions Marine vessels	Emissions Outside 200nm (tonne per trip)				
	CO2	N2O	CH4	CO2c	CO2e
	1,235	0.06	0.02	1,241	1,258
	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	1,263
Emissions Rate (g/tonne MGO)	3,182,667	143	49	2,749,572	2,787,313
Emissions Rate (g/mmBtu MGO, LHV)	85,081	4	1	73,503	74,512

End Use Emissions Marine vessels	Total Emissions (tonne per trip)							
	CO2	N2O	CH4	CO2c	CO2e	BC	OC	
	1,432	0.06	0.02	1,439	1,459	0.02	0.04	
	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	0.06	0.02	1,450	1,470	0.09	0.20	
Emissions Rate (g/tonne MGO)	3,182,667	143	49	3,198,951	3,242,897	203	435	
Emissions Rate (g/mmBtu MGO, LHV)	85,081	4	1	85,517	86,691	5	12	

Fuel Consumption Estimates

Geographic Region	Engine	Engine	Aux Boiler
Fuel Consumed Within 200nm (MT MGOe)	62.0	0.8	0.8
Fuel Consumed Outside 200nm (MT MGOe)	386.5	2.2	0.8
Fuel Consumed (MT MGOe)	448.6	3.0	1.6

Looks like LNG

<i>Within 200nm</i>										
Main Engine	NO _x	VOC	CO	SO ₂	PM10	PM2.5	DPM	CO ₂	N ₂ O	CH ₄
Transit	11.47	0.50	1.10	0.02	0.04	0.04	0.04	648	0.03	0.01
Maneuvering	53.10	10.59	10.65	0.02	0.30	0.29	0.30	648	0.03	0.01
Hotelling	53.10	10.59	10.65	0.02	0.30	0.29	0.30	648	0.03	0.01
Aux Engine	NO _x	VOC	CO	SO ₂	PM10	PM2.5	DPM	CO ₂	N ₂ O	CH ₄
Transit	11.47	0.40	1.10	0.02	0.04	0.04	0.04	683	0.03	0.01
Maneuvering	11.47	0.40	1.10	0.02	0.04	0.04	0.04	683	0.03	0.01
Hotelling	11.47	0.40	1.10	0.02	0.04	0.04	0.04	683	0.03	0.01
Aux Boiler	NO _x	VOC	CO	SO ₂	PM10	PM2.5	DPM	CO ₂	N ₂ O	CH ₄
Transit	1.88	0.10	0.20	0.22	2.72	0.03	0.00	922	0.07	0.00
Maneuvering	1.88	0.10	0.20	0.22	2.72	0.03	0.00	922	0.07	0.00
Hotelling	1.88	0.10	0.20	0.22	2.72	0.03	0.00	922	0.07	0.00

<i>Outside 200nm</i>										
Main Engine	NO _x	VOC	CO	SO ₂	PM10	PM2.5	DPM	CO ₂	N ₂ O	CH ₄
Transit	11.47	0.50	1.10	0.02	0.04	0.04	0.04	648	0.03	0.01
Maneuvering	53.10	10.59	10.65	0.02	0.30	0.29	0.30	648	0.03	0.01
Hotelling	53.10	10.59	10.65	0.02	0.30	0.29	0.30	648	0.03	0.01
Aux Engine	NO _x	VOC	CO	SO ₂	PM10	PM2.5	DPM	CO ₂	N ₂ O	CH ₄
Transit	11.47	0.40	1.10	0.02	0.04	0.04	0.04	683	0.03	0.01
Maneuvering	11.47	0.40	1.10	0.02	0.04	0.04	0.04	683	0.03	0.01
Hotelling	11.47	0.40	1.10	0.02	0.04	0.04	0.04	683	0.03	0.01
Aux Boiler	NO _x	VOC	CO	SO ₂	PM10	PM2.5	DPM	CO ₂	N ₂ O	CH ₄
Transit	1.88	0.10	0.20	0.22	2.72	0.03	0.00	922	0.07	0.00
Maneuvering	1.88	0.10	0.20	0.22	2.72	0.03	0.00	922	0.07	0.00
Hotelling	1.88	0.10	0.20	0.22	2.72	0.03	0.00	922	0.07	0.00

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						0.001370	75%
	Light Liquid					33	244	112	185	30	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						0.000559	30%
	Light Liquid					6	114	28	77	15	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	0.00002028	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.C
a factor of 2 is app
metric tonne&yea
3.781085563

Calculations:

$$^a \text{ Hourly Emissions (lb/hr)} = [\text{Emission Factor (lb/hr per component)}] \times [\text{Component Count}] \times [\text{Pollutant Content (\%wt)}] \times [1 - \text{LDAR Control Efficiency (\%)}]$$

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

$$\text{Hours of Operation (hrs/yr)} = 8,760$$

$$^b \text{ Pollutant Concentration (ppmw)} = [\text{Pollutant Concentration } (\mu\text{g}/\text{m}^3)] / [453.6 \text{ g/lb}] / [10^6 \mu\text{g/g}] / [35.31 \text{ ft}^3/\text{m}^3] / [\text{Gas Density (lb/cf)}] \times 10^6$$

$$\text{Benzene Concentration } (\mu\text{g}/\text{m}^3) = 2,980^5$$

$$\text{Ethylbenzene Concentration } (\mu\text{g}/\text{m}^3) = 144^5$$

$$\text{m,p-Xylene Concentration } (\mu\text{g}/\text{m}^3) = 986^5$$

$$\text{o-Xylene Concentration } (\mu\text{g}/\text{m}^3) = 165^5$$

$$\text{Toluene Concentration } (\mu\text{g}/\text{m}^3) = 2,570^5$$

$$\text{Natural Gas Density (lb/scf)} = 0.046^5$$

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 CH₄.

Life Cycle Associates, LLC

Fuel Life Cycle Factors Sheet -5.48%

Global Warming Potential, Molecular Weight		Variable Name			
Species	GWP	Mol Wt	GWP	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	
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	

AR Edition	AR5		AR4	
Time Horizon	100	20	100	20
CO ₂	1	1	1	1
CH ₄	30	85	25	72
N ₂ O	265	264	288	289

Carbon and Sulfur Ratios of Pollutants		Variable Name	
	Ratio		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 ₂ c	CH ₄	N ₂ O	CO ₂ e
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	85,517	1.3	3.8	86,691
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	58,674	693.2	4.1	77,220
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

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

	Natural Gas							Residual Oil					Diesel Fuel					Gasoline		Crude	
	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	Industrial Boiler	Commercial Boiler	Stationary Reciprocating Engine	Turbine	Farming Tractor	Stationary Reciprocating Engine	Farming Tractor	Industrial Boiler
VOC	2.540	2.540	1.056	0.267	1.056	133.316	2.500	2.089	0.905	3.651	2.027	66.589	0.258	0.800	1.201	2.027	0.258	63.020	598.350	193.820	0.820
CO	22.210	24.970	41.286	14.533	41.286	705.993	26.000	16.209	36.017	16.153	657.005	145.114	1.560	20.867	25.115	657.005	1.560	349.150	1,520.438	6,907.000	23.740
NOx	36.400	41.050	31.969	17.425	31.969	832.952	48.900	433.518	137.081	177.688	2,076.988	1,505.677	256.412	53.860	66.543	2,076.988	256.412	628.010	98.588	267.620	181.600
PM10	3.507	3.507	3.575	0.133	3.575	7.197	3.700	17.379	35.345	35.345	54.608	6.247	25.944	8.122	8.404	54.608	25.944	55.970	52.558	7.840	29.712
PM2.5	3.507	3.507	3.575	0.133	3.575	7.197	3.700	13.492	16.173	16.173	54.043	5.153	6.574	5.473	7.522	54.043	6.574	54.291	52.558	7.605	19.313
SOx	0.269	0.269	0.269	0.269	0.269	0.269	739.297	683.325	667.785	267.327	2.105	267.327	0.542	0.542	0.542	0.542	0.542	0.542	1.238	1.238	395.465
BC	0.579	0.579	0.104	0.004	0.104	1.439	3.515	0.855	1.025	1.025	43.937	5.430	0.657	0.547	0.752	43.937	0.657	30.566	5.256	1.034	0.560
OC	1.501	1.501	2.431	0.090	2.431	3.080	0.185	0.594	0.712	0.712	9.782	11.620	1.644	1.368	1.881	9.782	1.644	18.948	16.819	6.571	0.406
CH4	1.060	1.060	1.056	1.142	1.056	392.354	49.000	3.182	3.231	1.535	4.221	1.307	3.024	0.198	0.763	4.221	3.024	0.630	3.000	3.575	0.360
N2O	0.750	0.350	0.102	0.119	0.102	0.111	1.100	0.638	1.712	1.712	0.600	3.833	0.603	0.918	0.918	0.600	0.603	0.920	0.600	1.104	2.000
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	85,081.2	85,069.7	78,163.2	78,153.7	77,148.7	78,187.5	77,452.2	72,576.8	65,371.4	77,264.4
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	85,516.6	85,072.9	78,198.5	78,196.9	78,187.2	78,190.7	78,197.0	76,828.7	76,826.6	77,304.2

Biogenic CO2

59332.81
59332.81

Coal			Diesel	Diesel	Fuel Gas	Flare Gas	LNG	LPG	LPG	LNG	LNG	LNG
Utility Boiler	IGCC Turbine	Industrial Boiler	Heavy Duty Truck	Locomotive	Industrial Boiler	Flare Gas	Heavy Duty Truck	Industrial Boiler	Flaring Tacoma	NG Peak shaving	Marine Engine TOTE CASE	Marine Engine
1.495	0.122	0.472	5.909	5.909	2.540	2.540	26.225	4.272	4.272	2.540	0.083	79.908
12.417	2.235	23.955	57.875	57.875	22.210	22.210	1,452.359	3.531	3.531	24.970	250.604	90.798
116.035	11.902	121.631	53.121	53.121	36.400	36.400	82.257	69.413	69.413	41.050	250.004	2,085.241
28.841	251.841	2.663	10.052	10.052	3.507	3.507	7.416	3.738	3.738	3.507	7.800	18.121
20.278	73.411	2.521	4.619	4.619	3.507	3.507	3.616	3.738	3.738	3.507	2.680	16.675
325.406	4.110	544.401	0.545	0.545	0.269	0.269	0.000	0.000	0.000	0.000	0.460	0.000
0.872	3.157	0.108	0.072	0.072	0.579	0.579	0.287	0.617	0.617	0.579	0.582	2.501
1.643	5.946	0.204	0.125	0.125	1.501	1.501	0.521	1.600	1.600	1.501	1.245	6.503
1.058	1.050	1.246	4.750	4.750	1.060	1.060	309.767	1.068	1.068	1.060	693.207	91.620
1.586	1.581	0.857	0.175	0.175	0.750	0.750	0.033	4.806	4.806	0.350	4.077	2.000
100,017.1	100,037.4	100,001.6	78,076.6	78,076.6	57,408.9	68,662.0	55,095.9	68,039.6	68,754.6	58,261.1	58,280.4	57,667.7
100,041.2	100,041.3	100,040.7	78,186.0	78,186.0	57,451.7	68,704.8	57,459.3	68,058.5	68,773.4	58,308.2	58,674.4	58,059.2

Emissions Factors and Activity Assumptions

Source: **UPDATED** 2016 Puget Sound Maritime Air Emissions Inventory, Published 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 - 2010	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 - 2015	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

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, 2015

<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 cap

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

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 - 2010	12.2	0.4	1.1	0.44	0.24	0.23	0.24
Medium speed diesel	2011 - 2015	Medium speed diesel 2011 - 2015	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 speed

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

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

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: 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	16	0.15	0
LNG Aux Boiler	All	LNG Aux Boiler All	2	0.1	0.2	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)	0.94	1	1	0.037	0.17	0.17	0.17	1	0.94	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	0.94	1	1	0.0006	0.15	0.15	0.15	1	0.94	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	203.60	gMDO/kWh	Implied by CO2 emissions factors, converted using CO2 emissions above
Aux Engine	214.60	gMDO/kWh	Implied by CO2 emissions factors, converted using CO2 emissions above
Boiler	289.69	gMDO/kWh	Implied by CO2 emissions factors, converted using CO2 emissions above

Parameters	Natural Gas ^a	Flared Waste Gas ^a								
		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
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
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) ^b	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.