

US EPA ARCHIVE DOCUMENT

**Table A-1
GHG Emission Summary
Formosa Plastic Corporation, Texas
2012 Expansion Project: Gas Turbines
March 2014**

Source Name	Operating Scenario	EPN	Detailed Calculations in	GHG Mass Emissions (tpy)	CO ₂ e (tpy)
Gas Turbine 1	Firing 100% Natural Gas	7K	Table A-2	463,071	463,540
Gas Turbine 2		7L		463,071	463,540
Duct Firing, Unit 1 [1]	Firing 100% Natural Gas	7K	Table A-3	61,449	61,511
	Firing 100% OL Tail Gas		Table A-4	53,041	53,103
	Firing 100% Hydrogen [2]		N/A	0	0
Duct Firing, Unit 2 [1]	Firing 100% Natural Gas	7L	Table A-3	61,449	61,511
	Firing 100% OL Tail Gas		Table A-4	53,041	53,103
	Firing 100% Hydrogen [2]		N/A	0	0
Subtotal Total, Combined Cycle Units [3] =				1,049,040	1,050,103
Turbine Startup, Fuel Line Maintenance [4]	Startup, Maintenance	7K-NGVENT, 7L-NGVENT	Table A-5	1.24	29.9
Fugitive Components [4]	N/A	NG-FUG	Table A-6	20.90	506.1
SF ₆ Electrical Insulation [4]	N/A	SF6-FUG	Table A-7	<0.01	28.2
Total =				1,049,062	1,050,667

Notes:

[1] The duct burners may fire up to 100% heat input on any listed fuel or any combination thereof.

[2] Combustion of 100% hydrogen fuel stream in the duct burners does not result in any GHG emissions (carbon content is zero).

[3] Total GHG emissions are calculated as the maximum emissions from duct burner firing on any one of the three fuel types, plus GHG emission contributions from the Gas turbines.

[4] FPC TX Requests that No Emission Limit be established for this source.

Compliance will be assured with the design/work practice standard as specified in the permit.

Table A-2
GHG Emission Calculations - Natural Gas Combustion - Gas Turbines
Formosa Plastic Corporation, Texas
2012 Expansion Project: Gas Turbines
March 2014

GHG Emissions Contribution From Natural Gas Fired Combustion Turbines:

EPN	Average Heat Input (MMBtu/hr)	Annual Heat Input (MMBtu/yr)	Pollutant	Emission Factor (kg/MMBtu) ¹	GHG Mass Emissions ² (tpy)	Global Warming Potential ³	CO ₂ e (tpy)
7K	997	8,733,720	CO ₂	53.02	463,062	1	463,062
			CH ₄	1.0E-03	8.73	25	218.3
			N ₂ O	1.0E-04	0.87	298	260.3
			Totals		463,071		463,540
7L	997	8,733,720	CO ₂	53.02	463,062	1	463,062
			CH ₄	1.0E-03	8.73	25	218.3
			N ₂ O	1.0E-04	0.87	298	260.3
			Totals		463,071		463,540
Total for 2 Turbines					926,143		927,081

Notes:

1. CO₂ GHG factor from Table C-1 of 40 CFR 98 Mandatory Greenhouse Gas Reporting (GHG MRR).
CH₄ and N₂O GHG factors based on Table C-2 of GHG MRR.
2. CO₂ emissions based on 40 CFR Part 98, Subpart C, Equation C-1.
3. Global Warming Potential factors based on Table A-1 of 40 CFR 98 Mandatory Greenhouse Gas Reporting.

Sample Calculation, CO₂:

GHG Mass Emissions (metric ton/yr) = 0.001 x 8733720 (MMBtu/yr) x 53.02 kg/MMBtu = 463062

CO₂e (metric ton/yr) = 463062 (tpy) x 1 = 463062

Table A-3
GHG Emission Calculations - Duct Burners Natural Gas Combustion
Formosa Plastic Corporation, Texas
2012 Expansion Project: Gas Turbines
March 2014

GHG Emissions Contribution From Natural Gas Fired Combustion:					Emissions per Unit			
Source Type	Average Heat Input/Unit (MMBtu/hr)	Annual Avg Heat Input, Each Unit (MMBtu/yr)	Pollutant	Emission Factor (kg/MMBtu) ¹	GHG Mass Emissions ² (metric ton/yr)	Global Warming Potential ³	CO ₂ e (metric ton/yr)	CO ₂ e (tpy)
Turbine 1 Duct Burners	120	1,051,200	CO ₂	53.02	55,735	1	55,735	61,447
			CH ₄	1.0E-03	1.05	25	26.3	29.0
			N ₂ O	1.0E-04	0.11	298	31.3	34.5
				Totals	55,736		55,792	61,511
Turbine 2 Duct Burners	120	1,051,200	CO ₂	53.02	55,735	1	55,735	61,447
			CH ₄	1.0E-03	1.05	25	26.3	29.0
			N ₂ O	1.0E-04	0.11	298	31.3	34.5
				Totals	55,736		55,792	61,511
Total, All Natural Gas Duct Firing					111,472		111,584	123,022

Notes:

1. CO₂ GHG factor from Table C-1 of 40 CFR 98 Mandatory Greenhouse Gas Reporting (GHG MRR).
CH₄ and N₂O GHG factors based on Table C-2 of GHG MRR.
2. CO₂ emissions based on 40 CFR Part 98, Subpart C, Equation C-1.
3. Global Warming Potential factors based on Table A-1 of 40 CFR 98 Mandatory Greenhouse Gas Reporting.

Sample Calculation, CO₂:

GHG Mass Emissions (metric ton/yr) = 0.001 x 1051200 (MMBtu/yr) x 53.02 kg/MMBtu = 55735

CO₂e (metric ton/yr) = 55735 (metric ton/yr) x 1 = 55734.6

Table A-4
GHG Emission Calculations - OL Tail Gas Combustion
Formosa Plastic Corporation, Texas
2012 Expansion Project: Gas Turbines
March 2014

Olefins (OL) Tail Gas Data:

Variable	Value	Units	Reference
Net Heating Value (LHV)	624	Btu/scf	Formosa Design Specification
Carbon Content (Annual Avg)	0.677	kg C/kg	Formosa Design Specification
Molecular Weight (Annual Avg)	9.77	kg/kg-mol	Formosa Design Specification

GHG Emissions Contribution from OL Tail Gas Combustion:

Source Type	Average Heat Input/Unit (MMBtu/hr)	Annual Average Fuel Gas Usage/Unit ¹ (MMscf/hr)	Annual Average Fuel Use, Each Unit (scf/yr)	Annual Average Heat Input, Each Unit (MMBtu/yr)	Pollutant	Emission Factor (kg/MMBtu) ²	GHG Mass Emissions ³ (metric ton/yr)	Global Warming Potential ⁴	CO ₂ e (metric ton/yr)	CO ₂ e (tpy)
Turbine 1 Duct Burners	120	0.192	1.68E+09	1.05E+06	CO ₂		48,109	1	48,109	53,040
					CH ₄	1.0E-03	1.05	25	26.28	29
					N ₂ O	1.0E-04	0.11	298	31.33	35
					Totals		48,110		48,166	53,103
Turbine 2 Duct Burners	120	0.192	1.68E+09	1.05E+06	CO ₂		48,109	1	48,109	53,040
					CH ₄	1.0E-03	1.05	25	26.28	29
					N ₂ O	1.0E-04	0.11	298	31.33	35
					Totals		48,110		48,166	53,103
Total, All OL Tail Gas Combustion							96,220		96,333	106,207

Notes:

- Fuel use calculated as: $MMscf/hr = Firing\ rate\ (MMBtu/hr) / HHV\ (Btu/scf)$
- CH₄ and N₂O GHG factors based on Table C-2 of 40 CFR 98 Mandatory Greenhouse Gas Reporting.
- CH₄ and N₂O emissions based on 40 CFR Part 98, Subpart C, Equation C-8.
- CO₂ emissions based on 40 CFR Part 98, Subpart C, Equation C-5.
- Global Warming Potential factors based on Table A-1 of 40 CFR 98 Mandatory Greenhouse Gas Reporting.

Sample Calculation: Duct Burners Turbine 1 - CO₂:

GHG Mass Emissions (metric ton/yr) = $(44/12) \times 1.68E+09\ (scf/yr) \times 0.677\ kg\ C/kg \times 9.77\ kg/kg-mol / 849.5\ scf/kg-mole\ @\ std\ cond. \times 0.001 = 4.81E+04$
 CO₂e (metric ton/yr) = $4.81E+04\ (metric\ ton/yr) \times 1 = 4.81E+04$

Table A-4A
GHG Emission Calculations - Duct Burners OL Tail Gas Combustion
Formosa Plastic Corporation, Texas
2012 Expansion Project: Gas Turbines
March 2014

OL Tail Gas Composition

Compound	Molecular Weight (lb/lbmol)	Lower Heating Value, LHV (Btu/lb)	Lower Heating Value, LHV (Btu/scf)	Molar Composition (mol %) [1]	Component Lower Heating Value, LHV (Btu/scf)	Number of carbons	Component Carbon Mass (lbC/lbmol)	Fuel Carbon Mass (lbC/lbmol)	Component Mass per Lbmol Gas (lb)	carbon content (lbC/lb)
Hydrogen	2.016	51,571	274	45.00%	123.44	0	0	0.000	0.907	0.677
Methane	16.04	21,504	910	55.00%	500.55	1	12	6.600	8.822	
Ethane	30.07	20,429	1,621	0.000050%	0.00	2	24	0.000	0.000	
Propane	44.09	19,923	2,318	0.000010%	0.00	3	36	0.000	0.000	
Carbon Monoxide	28.01	321	323	0.1500%	0.485	1	12	0.018	0.042	
Carbon Dioxide	44.009	0	0	0.0050%	0.000	1	12	0.001	0.002	

Gross heating
value = 624
Btu/scf

MW = 9.77
lb/lbmol

Notes:

[1] Composition is representative and may vary. Estimated composition used for emission calculation purposes only.

Table A-5
GHG Emission Calculations -
Gaseous Fuel Venting During Turbine Startup and
Fuel Line Maintenance, EPNs 7K-NGVENT, 7L-NGVENT
Formosa Plastic Corporation, Texas
2012 Expansion Project: Gas Turbines
March 2014

Location	Initial Conditions			Final Conditions			Annual Frequency of Event	CO ₂ ³	CH ₄ ⁴	Total, both Turbines
	Volume ¹ (ft ³)	Press. (psig)	Temp. (°F)	Press. (psig)	Temp. (°F)	Volume ² (scf)		Annual (tpy)	Annual (tpy)	Annual (tpy)
Turbine Startup	75.0	300	90	0	68	1,635	30	0.0336	0.98	
Fuel Line Maintenance	20.0	300	90	0	68	436	24	0.00718	0.210	
GHG Mass-Based Emissions								0.0408	1.19	1.24
Global Warming Potential ⁵								1	25	
CO ₂ e Emissions								0.0408	29.9	29.9

Notes:

- Initial volume is calculated by multiplying the crosssectional area by the length of pipe using the following formula: $V_i = \pi [(diameter\ in\ inches/12)/2]^2 * length\ in\ feet = ft^3$
- Final volume calculated using ideal gas law $[(PV/ZT)_i = (PV/ZT)_f]$. $V_f = V_i (P_i/P_f) (T_f/T_i) (Z_i/Z_f)$, where Z is estimated using the following equation: $Z = 0.9994 - 0.0002P + 3E-08P^2$.
- CO₂ emissions based on vol% of CO₂ in natural gas 1.20% from natural gas analysis
- CH₄ emissions based on vol% of CH₄ in natural gas 96.6% from natural gas analysis
- Global Warming Potential factors based on Table A-1 of 40 CFR 98 Mandatory Greenhouse Gas Reporting.

Example calculation:

1635 scf Nat Gas	0.012 scf CO ₂	lbmole	44 lb CO ₂	ton =	=	0.0336	ton/yr CO ₂
yr	scf Nat Gas	385 scf	lbmole	2000 lb			

Table A-6
GHG Emission Calculations - Fugitive Component Emissions
Formosa Plastic Corporation, Texas
2012 Expansion Project: Gas Turbines
March 2014

GHG Emissions Contribution From Fugitive Piping Components:

EPN	Source Type	Fluid State	Count	Emission Factor ¹ scf/hr/comp	CO ₂ Content (vol %)	CH ₄ Content (vol %)	CO ₂ (tpy)	Methane (tpy)	Total (tpy)
NG-FUG	Valves	Gas/Vapor	600	0.121	1.20%	96.6%	0.436	12.80	
	Flanges	Gas/Vapor	2400	0.017			0.245	7.19	
	Relief Valves	Gas/Vapor	5	0.193			5.80E-03	1.70E-01	
	Sampling Connections	Gas/Vapor	10	0.031			1.86E-03	5.46E-02	
	Compressors	Gas/Vapor	3	0.002			3.60E-05	1.06E-03	
GHG Mass-Based Emissions							0.689	20.2	20.9
Global Warming Potential²							1	25	
CO₂e Emissions							0.69	505.4	506.1

Notes:

1. Emission factors from Table W-1A of 40 CFR 98 Mandatory Greenhouse Gas Reporting
2. Global Warming Potential factors based on Table A-1 of 40 CFR 98 Mandatory Greenhouse Gas Reporting.

Example calculation:

600 valves	0.121 scf gas	0.012 scf CO ₂	lbmol	44.01 lb CO ₂	8760 hr	ton	0.44	ton/yr
	hr * valve	scf gas	385 scf	lbmol	yr	2000 lb		

Table A-7
GHG Emission Calculations - Electrical Equipment Insulated with SF₆
Formosa Plastic Corporation, Texas
2012 Expansion Project: Gas Turbines
March 2014

EPN	Insulated SF₆ Circuit Breaker Capacity (pounds)	Annual Leak Rate, wt %	Annual Leak Rate (tpy)	Global Warming Potential¹	Estimated Annual CO₂e Emission Rate (tpy)
SF6-FUG	495	0.50%	1.24E-03	22,800	28.2

Notes:

1. Global Warming Potential factors based on Table A-1 of 40 CFR 98 Mandatory Greenhouse Gas Reporting.