

Appendix B: Emission Calculations

Otter Tail Power
Astoria, SD - Simple Cycle Combustion Turbine
Maximum Facility Emissions among Potential Turbine Vendors
Emissions Summary - Project Total

Controlled/limited PTE (ton/yr)

Pollutant	Combustion Turbine	Dewpoint Heater	Fire Pump	Facility Total
PM	8.7	0.22	0.02	9.0
PM ₁₀	20.5	0.22	0.02	20.7
PM _{2.5}	20.5	0.22	0.02	20.7
NO _x	247.0	1.47	0.25	248.7
SO ₂	6.3	0.03	0.0006	6.3
CO	246.0	2.47	0.31	248.8
VOC	64.0	0.16	0.25	64.4
H ₂ SO ₄	0.8	0.01		0.8
Greenhouse gases (GHG)				
CO ₂ e	547113.3	3513	67.7	550,694
CO ₂	546557.6	3509	67.5	550,134
CH ₄	10.1	0.07	0.003	10.21
N ₂ O	1.0	0.01	0.0005	1.02
Hazardous Air Pollutants (HAP)				
Lead		0.000		0.000
Acetaldehyde	0.18		0.000	0.184
Acrolein	0.03		0.000	0.029
Arsenic		0.000		0.000
Beryllium		0.000		0.000
Benzene	0.06	0.000	0.000	0.056
1,3-Butadiene	0.00			0.002
Cadmium		0.000		0.000
Chromium		0.000		0.000
Cobalt		0.000		0.000
Dichlorobenzene		0.000		0.000
Ethylbenzene	0.15			0.147
Formaldehyde	3.27	0.002	0.000	3.268
Hexane		0.053		0.053
Manganese		0.000		0.000
Mercury		0.000		0.000
Naphthalene	0.01	0.000	0.000	0.006
Nickel		0.000		0.000
POM (incl. PAH)	0.01	0.000	0.000	0.010
Propylene Oxide	0.13			0.133
Selenium		0.000		0.000
Toluene	0.60	0.000	0.000	0.598
Xylene	0.29		0.000	0.294
TOTAL HAP	4.73	0.000	0.000	4.726
Notes:				
1) Otter Tail is proposing a 12-month rolling emissions limit of 247 tons NOx and 246 tons CO, verified using CEMS.				
2) Otter Tail is proposing 12-month rolling operating hour limits of 4,000 hours per year for the dewpoint heater and 500 hours per year for the fire pump.				

Otter Tail Power
Astoria, SD - Simple Cycle Combustion Turbine
Maximum Emissions among Potential Turbine Vendors
Combustion Turbine, Normal Operation (non-SU/SD hours)

Heat Input Rating: 2788 MMBtu/hr (100% load @ avg. annual temp.)
 Gross Output: 263 MW (at avg. annual temp. = 43.7F)
 Operating Hours: 3300 hr/yr
 Number of Turbines: 1
 Fuel: Natural Gas

Pollutant	Emission Factor			Potential Emissions	
	Number	Units	Source	lb/hr	ton/yr
PM	0.0019	lb/MMBtu	AP-42	5.3	8.7
PM ₁₀	Vendor value at 100% load, avg. ann. temp.			12.4	20.5
PM _{2.5}	Vendor value at 100% load, avg. ann. temp.			12.4	20.5
NO _x	Vendor value at 100% load, avg. ann. temp.			164.7	247.0
SO ₂	Vendor value at 100% load, avg. ann. temp.			3.8	6.3
CO	Vendor value at 100% load, avg. ann. temp.			66.9	246.0
VOC	Vendor value at 100% load, avg. ann. temp.			38.8	64.0
Sulfuric Acid Mist	Vendor value at 100% load, avg. ann. temp.			0.5	0.8
Greenhouse gases (GHG)					
CO ₂ e				331,584	547,113
CO ₂	Vendor value at 100% load, avg. ann. temp.			331,247	546,558
CH ₄	0.001	kg/MMBtu	40 CFR Part 98	6.15	10.1
N ₂ O	0.0001	kg/MMBtu	40 CFR Part 98	0.61	1.0
Hazardous Air Pollutants (HAP)					
Acetaldehyde	4.0E-05	lb/MMBtu	AP-42	0.112	0.18
Acrolein	6.4E-06	lb/MMBtu	AP-42	0.018	0.03
Benzene	1.2E-05	lb/MMBtu	AP-42	0.033	0.06
1,3-Butadiene	< 4.3E-07	lb/MMBtu	AP-42	0.001	0.00
Ethylbenzene	3.2E-05	lb/MMBtu	AP-42	0.089	0.15
Formaldehyde	7.1E-04	lb/MMBtu	AP-42	1.979	3.27
Naphthalene	1.3E-06	lb/MMBtu	AP-42	0.004	0.01
PAH	2.2E-06	lb/MMBtu	AP-42	0.006	0.01
Propylene Oxide	< 2.9E-05	lb/MMBtu	AP-42	0.081	0.13
Toluene	1.3E-04	lb/MMBtu	AP-42	0.362	0.60
Xylenes	6.4E-05	lb/MMBtu	AP-42	0.178	0.29
TOTAL HAP				2.864	4.73

NOTES:

- Hourly emissions of NO_x and CO will vary substantially during startup and shutdown conditions. However, the overall annual emissions will be maintained at or below 247 tons NO_x and 246 tons CO, verified using CEMS.
- AP-42 emission factors obtained from Fifth Edition AP-42, Section 3.1 (4/00).
- The PM emission factor is filterable only. PM₁₀ and PM_{2.5} emission factors represent filterable plus condensable.
- The vendor-based data are expected emisissions for stated ambient operating conditions, exclusive of evaporative cooling or wet compression power augmentation.
- GHG emission factors for CH₄ and N₂O obtained from 40 CFR pt. 98 - Mandatory Greenhouse Gas Reporting, Table C - 1 and C -2, reflecting the update effective January 1, 2014.
- CO₂e values correspond to the sum of the individual GHG emissions times the following global warming potentials (GWP) obtained from 40 CFR 98, Table A-1.

Greenhouse Gas	GWP
CO ₂	1
CH ₄	25
N ₂ O	298

Otter Tail Power
Astoria, SD - Simple Cycle Combustion Turbine Facility
Dew Point Heater
PTE Calculation

Heat Input Rating: 15.00 MMBtu/hr
 Fuel Gas Heat Content: 1020.0 Btu/ft³
 Fuel Firing Rate: 0.0147 MMcf/hr
 Operating Hours: 4000 hr/yr (conserv. value, based on synthetic minor emission est. for CT)
 Fuel: Natural Gas

Pollutant	Emission Factor			Potential Emissions	
	Number	Units	Source	lb/hr	ton/yr
PM	7.6	lb/MMcf	AP-42	0.112	0.22
PM ₁₀	7.6	lb/MMcf	AP-42	0.112	0.22
PM _{2.5}	7.6	lb/MMcf	AP-42	0.112	0.22
NO _x	50	lb/MMcf	AP-42	0.735	1.47
SO ₂	0.00140	lb/MMBtu	Mass bal.	0.014	0.03
CO	84	lb/MMcf	AP-42	1.235	2.47
VOC	5.500	lb/MMcf	AP-42	0.081	0.16
Sulfuric Acid Mist	0.00021	lb/MMBtu	Mass bal.	0.003	0.01
CO _{2e}				1,756	3513
CO ₂	53.06	kg/MMBtu	40 CFR Part 98	1,755	3509
CH ₄	0.001	kg/MMBtu	40 CFR Part 98	0.033	0.07
N ₂ O	0.0001	kg/MMBtu	40 CFR Part 98	0.003	0.01
Lead	4.902E-07	lb/MMBtu	AP-42	0.0000	0.00
Arsenic	1.96E-07	lb/MMBtu	AP-42	0.0000	0.00
Beryllium	< 1.18E-08	lb/MMBtu	AP-42	0.0000	0.00
Benzene	2.06E-06	lb/MMBtu	AP-42	0.0000	0.00
Cadmium	1.08E-06	lb/MMBtu	AP-42	0.0000	0.00
Chromium	1.37E-06	lb/MMBtu	AP-42	0.0000	0.00
Cobalt	8.24E-08	lb/MMBtu	AP-42	0.0000	0.00
Dichlorobenzene	1.18E-06	lb/MMBtu	AP-42	0.0000	0.00
Formaldehyde	7.35E-05	lb/MMBtu	AP-42	0.0011	0.00
Hexane	1.76E-03	lb/MMBtu	AP-42	0.0265	0.05
Manganese	3.73E-07	lb/MMBtu	AP-42	0.0000	0.00
Mercury	2.55E-07	lb/MMBtu	AP-42	0.0000	0.00
Naphthalene	5.98E-07	lb/MMBtu	AP-42	0.0000	0.00
Nickel	2.06E-06	lb/MMBtu	AP-42	0.0000	0.00
POM	6.85E-07	lb/MMBtu	Sum	0.0000	0.00
2-Methylnaphthalene	2.35E-08	lb/MMBtu	AP-42		
3-Methylchloranthrene	< 1.76E-09	lb/MMBtu	AP-42		
7,12-Dimethylbenz(a)anthracene	< 1.57E-08	lb/MMBtu	AP-42		
Acenaphthene	< 1.76E-09	lb/MMBtu	AP-42		
Acenaphthylene	< 1.76E-09	lb/MMBtu	AP-42		
Anthracene	< 2.35E-09	lb/MMBtu	AP-42		
Benz(a)anthracene	< 1.76E-09	lb/MMBtu	AP-42		
Benzo(a)pyrene	< 1.18E-09	lb/MMBtu	AP-42		
Benzo(b)fluoranthene	< 1.76E-09	lb/MMBtu	AP-42		
Benzo(g,h,i)perylene	< 1.18E-09	lb/MMBtu	AP-42		
Benzo(k)fluoranthene	< 1.76E-09	lb/MMBtu	AP-42		
Chrysene	< 1.76E-09	lb/MMBtu	AP-42		
Dibenzo(a,h)anthracene	< 1.18E-09	lb/MMBtu	AP-42		
Fluoranthene	2.94E-09	lb/MMBtu	AP-42		
Fluorene	2.75E-09	lb/MMBtu	AP-42		
Indeno(1,2,3-cd)pyrene	< 1.76E-09	lb/MMBtu	AP-42		
Naphthalene	5.98E-07	lb/MMBtu	AP-42		
Phenanthrene	1.67E-08	lb/MMBtu	AP-42		
Pyrene	4.90E-09	lb/MMBtu	AP-42		
Selenium	< 2.35E-08	lb/MMBtu	AP-42	0.0000	0.00
Toluene	3.33E-06	lb/MMBtu	AP-42	0.0001	0.00
TOTAL HAP				0.0278	0.06

1. AP-42 emission factors, obtained from Fifth Edition AP-42, Section 1.4 (7/98), correspond to natural gas combustion.
2. GHG emission factors obtained from 40 CFR pt. 98 - Mandatory Greenhouse Gas Reporting, Table C -1 and C -2, reflecting the update effective January 1, 2014.
3. CO_{2e} values correspond to the sum of the individual GHG emissions times the following global warming potentials (GWP) obtained from 40 CFR 98, Table A-1.
4. Sulfuric acid mist emissions based on assumption of 10% fuel sulfur is converted to sulfuric acid mist.
5. SO₂ emission factor based on mass balance calculation, assuming 0.5 grains sulfur/100 scf of natural gas.

Greenhouse Gas	GWP
CO ₂	1
CH ₄	25
N ₂ O	298

**Otter Tail Power
Astoria, SD - Simple Cycle Combustion Turbine Facility
Fire Pump, Diesel
PTE Calculation**

Heat Input Rating: 1.66 MMBtu/hr
 Engine Output: 150 HP
 Diesel Sulfur Limit: 15 ppm
 Operating Hours: 500 hr/yr (conservative for emergency engine)

Pollutant	Emission Factor			Potential Emissions	
	Number	Units	Source	lb/hr	ton/yr
PM	0.22	g/HP-hr	vendor/typ.	0.07	0.02
PM ₁₀	0.22	g/HP-hr	vendor/typ.	0.07	0.02
PM _{2.5}	0.22	g/HP-hr	vendor/typ.	0.07	0.02
NO _x	3.0	g/HP-hr	vendor/typ.	0.99	0.25
SO ₂	0.00152	lb/MMBtu	mass bal.	0.003	0.0006
CO	3.70	g/HP-hr	vendor/typ.	1.22	0.31
VOC	3.0	g/HP-hr	vendor/typ.	0.99	0.25
Sulfuric Acid Mist	0.00025	lb/MMBtu	mass bal.	0.000	0.00
CO ₂ e				271	67.7
CO ₂	73.96	kg/MMBtu	40 CFR Part 98	270	67.5
CH ₄	0.003	kg/MMBtu	40 CFR Part 98	0.01	0.003
N ₂ O	0.0006	kg/MMBtu	40 CFR Part 98	0.002	0.0005
Acetaldehyde	2.52E-05	lb/MMBtu	AP-42	0.0000	0.0000
Acrolein	7.88E-06	lb/MMBtu	AP-42	0.0000	0.0000
Benzene	7.76E-04	lb/MMBtu	AP-42	0.0013	0.0003
Formaldehyde	7.89E-05	lb/MMBtu	AP-42	0.0001	0.0000
Naphthalene	1.30E-04	lb/MMBtu	AP-42	0.0002	0.0001
PAH	2.12E-04	lb/MMBtu	AP-42	0.0004	0.0001
Toluene	2.81E-04	lb/MMBtu	AP-42	0.0005	0.0001
Xylene	1.93E-04	lb/MMBtu	AP-42	0.0003	0.0001
TOTAL HAP				0.0028	0.0007

1. AP-42 emission factors obtained from Fifth Edition AP-42, Section 3.4 (10/96).
2. Sulfuric acid mist emissions based on assumption of 10% fuel sulfur is converted to sulfuric acid mist.
3. GHG emission factors obtained from 40 CFR pt. 98 - Mandatory Greenhouse Gas Reporting, Table C -1 and C - 2, reflecting the update effective January 1, 2014.
4. CO₂e values correspond to the sum of the individual GHG emissions times the following global warming potentials (GWP) obtained from 40 CFR 98, Table A-1.

Greenhouse Gas	GWP
CO ₂	1
CH ₄	25
N ₂ O	298