

**DRAFT ENVIRONMENTAL IMPACT REPORT
GRAYSON REPOWERING PROJECT**

Appendix F Greenhouse (GHG) Emission Inventory
September 15, 2017

Appendix F GREENHOUSE (GHG) EMISSION INVENTORY

APPENDIX F
GREENHOUSE GASES (GHG) EMISSIONS

**GREENHOUSE GASES EMISSION INVENTORY
GRAYSON REPOWERING PROJECT**

CALEEMOD RESULT - FACILITY OCCUPANCY

Category	CO ₂ e, MT/yr	CO ₂ , MT/yr	CH ₄ , MT/yr	N ₂ O, MT/yr
Area	6.90E-04	6.00E-04	0	0
Energy	153.6481	153.221	3.83E-03	1.11E-03
Mobile	59.7193	59.6474	2.88E-03	0
Waste	14.2824	0.3407	0.3407	0
Water	42.1712	0.1735	0.1735	4.26E-03
Total:	269.82	213.38	0.52	0.01

**GREENHOUSE GASES EMISSION INVENTORY
GRAYSON REPOWERING PROJECT**

SF6 Release from the New Circuit Breakers (Fairmont Switchyard):

	GWP ¹
SF6	22,800

NOTES:

¹GWP = Global Warming Potential. [Source: IPCC, 4th Assessment Report, 2007]

Kellogg: 42 circuit breakers (*existing*)

Fairmont: 21 circuit breakers (*new*)

Ratio: 0.5 Fairmont to Kellogg

Kellogg SF6 Releases

Year	SF6, lbs
2013	11
2014	2.6
2015	42.3
	18.63

Fairmont Estimated Annual SF6 Releases:

9.32 lbs

Fairmont Estimated Annual CO2e Releases:

212,420 lbs

96.35 MT

**GREENHOUSE GASES EMISSION INVENTORY
GRAYSON REPOWERING PROJECT**

Greenhouse Gases	GWP ¹	Natural gas emission factor ² , kg/mmcf
CO ₂	1	54400
CH ₄	25	1.03
N ₂ O	298	0.1

NOTES:

¹GWP = Global Warming Potential. [Source: IPCC, 4th Assessment Report, 2007]

²Source: https://www.epa.gov/sites/production/files/2015-11/documents/emission-factors_nov_2015.pdf

³Natural gas heating value of 1026 mmBtu/mmscf

Baseline GHG Emissions - Replaced Equipment and Facility Occupancy

Device/Activity	Actual Fuel consumption, MMcf/year	CO ₂ , MT/year	CH ₄ , MT/year	N ₂ O, MT/year	Total CO ₂ e, MT/year
Boiler 3 (Natural Gas)	88	4789.039	0.090675	0.00880338	4,794
Boiler 3 (Landfill Gas)*	341	18564.98	0.351506	0.0341268	18,584
Boiler 4 (Natural Gas)	327	17783.01	0.3367	0.03268936	17,801
Boiler 4 (Landfill Gas)*	1215	66097.41	1.251477	0.1215026	66,165
Boiler 5 (Natural Gas)	505	27461.65	0.519954	0.05048098	27,490
Boiler 5 (Landfill Gas)*	1429	77759.58	1.472286	0.1429404	77,839
Gas Turbine 8A	85	4607.158	0.087231	0.00846904	4,612
Gas Turbine 8B/C	103	5601.612	0.10606	0.01029708	5,607
Facility Occupants (Operational)		213.38	0.52091	0.00537	270
Total Project GHG Emissions:					223,162

**GREENHOUSE GASES EMISSION INVENTORY
GRAYSON REPOWERING PROJECT**

Greenhouse Gases	GWP ¹	Natural gas emission factor ² , kg/mmBtu
CO ₂	1	53.06
CH ₄	25	0.001
N ₂ O	298	0.0001

NOTES:

¹GWP = Global Warming Potential. [Source: IPCC, 4th Assessment Report, 2007]

²Source: https://www.epa.gov/sites/production/files/2015-11/documents/emission-factors_nov_2015.pdf

³Natural gas heating value of 1026 mmBtu/mmscf

GHG Emissions Project - Operation

Device/Activity	Max. Fuel consumption, MMBtu/hr	Annual Op. hours	CO ₂ , MT/year	CH ₄ , MT/year	N ₂ O, MT/year	Total CO ₂ e, MT/year
SCC-800 Combined Cycle Unit 10 ¹	460.8	7596	185722.6	3.500237	0.35002368	185,914
SCC-800 Combined Cycle Unit 11 ¹	460.8	7596	185722.6	3.500237	0.35002368	185,914
TRENT60 Simple Cycle Unit 12	577	1700	52046.55	0.9809	0.09809	52,100
TRENT60 Simple Cycle Unit 13	577	1700	52046.55	0.9809	0.09809	52,100
Emergency Engine ²	4.4574	52	12.2985	0.000232	2.3178E-05	12
SF6 releases (Fairmont Switchyard)			0	0	0	96
Facility Occupants (Operational)			213.38	0.52	5.37E-03	270
Total Project GHG Emissions:						476,406

NOTES:

¹SCC-800 combined cycle Unit 10 and 11 operating load are assumed to be 90% operating load.

²Emergency engine operating load is assume to be 50% operating load.

Emission Factors for Greenhouse Gas Inventories

Last Modified: 19 November 2015

Red text indicates an update from the 2014 version of this document.

Typically, greenhouse gas emissions are reported in units of carbon dioxide equivalent (CO₂e). Gases are converted to CO₂e by multiplying by their global warming potential (GWP). The emission factors listed in this document have not been converted to CO₂e. To do so, multiply the emissions by the corresponding GWP listed in the table below.

Gas	100-Year GWP
CH ₄	25
N ₂ O	298

Source: Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4), 2007. See the source note to Table 9 for further explanation.

Table 1 Stationary Combustion Emission Factors

Fuel Type	Heating Value mmBtu per short ton	CO ₂ Factor kg CO ₂ per mmBtu	CH ₄ Factor g CH ₄ per mmBtu	N ₂ O Factor g N ₂ O per mmBtu	CO ₂ Factor kg CO ₂ per short ton	CH ₄ Factor g CH ₄ per short ton	N ₂ O Factor g N ₂ O per short ton	Unit
Coal and Coke								
Anthracite Coal	25.09	103.69	11	1.6	2,602	276	40	short tons
Bituminous Coal	24.93	93.28	11	1.6	2,325	274	40	short tons
Sub-bituminous Coal	17.25	97.17	11	1.6	1,676	190	28	short tons
Lignite Coal	14.21	97.72	11	1.6	1,389	156	23	short tons
Mixed (Commercial Sector)	21.39	94.27	11	1.6	2,016	235	34	short tons
Mixed (Electric Power Sector)	19.73	95.52	11	1.6	1,885	217	32	short tons
Mixed (Industrial Coking)	26.28	93.90	11	1.6	2,468	289	42	short tons
Mixed (Industrial Sector)	22.35	94.67	11	1.6	2,116	246	36	short tons
Coal Coke	24.80	113.67	11	1.6	2,819	273	40	short tons
Fossil Fuel-derived Fuels (Solid)								
Municipal Solid Waste	9.95	90.70	32	4.2	902	318	42	short tons
Petroleum Coke (Solid)	30.00	102.41	32	4.2	3,072	960	126	short tons
Plastics	38.00	75.00	32	4.2	2,850	1,216	160	short tons
Tires	28.00	85.97	32	4.2	2,407	896	118	short tons
Biomass Fuels (Solid)								
Agricultural Byproducts	8.25	118.17	32	4.2	975	264	35	short tons
Peat	8.00	111.84	32	4.2	895	256	34	short tons
Solid Byproducts	10.39	105.51	32	4.2	1,096	332	44	short tons
Wood and Wood Residuals	17.48	93.80	7.2	3.6	1,640	126	63	short tons
	mmBtu per scf	kg CO ₂ per mmBtu	g CH ₄ per mmBtu	g N ₂ O per mmBtu	kg CO ₂ per scf	g CH ₄ per scf	g N ₂ O per scf	
Natural Gas								
Natural Gas	0.001026	53.06	1.0	0.10	0.05444	0.00103	0.00010	scf
Fossil-derived Fuels (Gaseous)								
Blast Furnace Gas	0.000092	274.32	0.022	0.10	0.02524	0.000002	0.000009	scf
Coke Oven Gas	0.000599	46.85	0.48	0.10	0.02806	0.000288	0.000060	scf
Fuel Gas	0.001388	59.00	3.0	0.60	0.08189	0.004164	0.000833	scf
Propane Gas	0.002516	61.46	0.022	0.10	0.15463	0.000055	0.000252	scf
Biomass Fuels (Gaseous)								
Landfill Gas	0.000485	52.07	3.2	0.63	0.025254	0.001552	0.000306	scf
Other Biomass Gases	0.000655	52.07	3.2	0.63	0.034106	0.002096	0.000413	scf
	mmBtu per gallon	kg CO ₂ per mmBtu	g CH ₄ per mmBtu	g N ₂ O per mmBtu	kg CO ₂ per gallon	g CH ₄ per gallon	g N ₂ O per gallon	
Petroleum Products								
Asphalt and Road Oil	0.158	75.36	3.0	0.60	11.91	0.47	0.09	gallon
Aviation Gasoline	0.120	69.25	3.0	0.60	8.31	0.36	0.07	gallon
Butane	0.103	64.77	3.0	0.60	6.67	0.31	0.06	gallon
Butylene	0.105	68.72	3.0	0.60	7.22	0.32	0.06	gallon
Crude Oil	0.138	74.54	3.0	0.60	10.29	0.41	0.08	gallon
Distillate Fuel Oil No. 1	0.139	73.25	3.0	0.60	10.18	0.42	0.08	gallon
Distillate Fuel Oil No. 2	0.138	73.96	3.0	0.60	10.21	0.41	0.08	gallon
Distillate Fuel Oil No. 4	0.146	75.04	3.0	0.60	10.96	0.44	0.09	gallon
Ethane	0.068	59.60	3.0	0.60	4.05	0.20	0.04	gallon
Ethylene	0.058	65.96	3.0	0.60	3.83	0.17	0.03	gallon
Heavy Gas Oils	0.148	74.92	3.0	0.60	11.09	0.44	0.09	gallon
Isobutane	0.099	64.94	3.0	0.60	6.43	0.30	0.06	gallon
Isobutylene	0.103	68.86	3.0	0.60	7.09	0.31	0.06	gallon
Kerosene	0.135	75.20	3.0	0.60	10.15	0.41	0.08	gallon
Kerosene-Type Jet Fuel	0.135	72.22	3.0	0.60	9.75	0.41	0.08	gallon
Liquefied Petroleum Gases (LPG)	0.092	61.71	3.0	0.60	5.68	0.28	0.06	gallon
Lubricants	0.144	74.27	3.0	0.60	10.69	0.43	0.09	gallon
Motor Gasoline	0.125	70.22	3.0	0.60	8.78	0.38	0.08	gallon
Naphtha (<401 deg F)	0.125	68.02	3.0	0.60	8.50	0.38	0.08	gallon
Natural Gasoline	0.110	66.88	3.0	0.60	7.36	0.33	0.07	gallon
Other Oil (>401 deg F)	0.139	76.22	3.0	0.60	10.59	0.42	0.08	gallon
Pentanes Plus	0.110	70.02	3.0	0.60	7.70	0.33	0.07	gallon
Petrochemical Feedstocks	0.125	71.02	3.0	0.60	8.88	0.38	0.08	gallon
Petroleum Coke	0.143	102.41	3.0	0.60	14.64	0.43	0.09	gallon
Propane	0.091	62.87	3.0	0.60	5.72	0.27	0.05	gallon
Propylene	0.091	65.95	3.0	0.60	6.00	0.27	0.05	gallon
Residual Fuel Oil No. 5	0.140	72.93	3.0	0.60	10.21	0.42	0.08	gallon
Residual Fuel Oil No. 6	0.150	75.10	3.0	0.60	11.27	0.45	0.09	gallon
Special Naphtha	0.125	72.34	3.0	0.60	9.04	0.38	0.08	gallon
Still Gas	0.143	66.72	3.0	0.60	9.54	0.43	0.09	gallon
Unfinished Oils	0.139	74.54	3.0	0.60	10.36	0.42	0.08	gallon
Used Oil	0.138	74.00	3.0	0.60	10.21	0.41	0.08	gallon
Biomass Fuels (Liquid)								
Biodiesel (100%)	0.128	73.84	1.1	0.11	9.45	0.14	0.01	gallon
Ethanol (100%)	0.084	68.44	1.1	0.11	5.75	0.09	0.01	gallon
Rendered Animal Fat	0.125	71.06	1.1	0.11	8.88	0.14	0.01	gallon
Vegetable Oil	0.120	81.55	1.1	0.11	9.79	0.13	0.01	gallon
Biomass Fuels (Kraft Pulping Liquor, by Wood Furnish)								
North American Softwood		94.4	1.9	0.42				
North American Hardwood		93.7	1.9	0.42				
Bagasse		95.5	1.9	0.42				
Bamboo		93.7	1.9	0.42				
Straw		95.1	1.9	0.42				

Source:

Solid, gaseous, liquid, and biomass fuels: Federal Register (2009) EPA; 40 CFR Parts 86, 87, 89 et al. Mandatory Reporting of Greenhouse Gases; Final Rule, 30Oct09, 261 pp. Tables C-1 and C-2 at FR pp. 56409-56410. Revised emission factors for selected fuels: Federal Register (2010) EPA; 40 CFR Part 98. Mandatory Reporting of Greenhouse Gases; Final Rule, 17Dec10, 81 pp. With Amendments from Memo, Table of Final 2013 Revisions to the Greenhouse Gas Reporting Rule (PDF) to 40 CFR part 98, subparts C and AA: Table C-1 to Subpart C—Default CO₂ Emission Factors and High Heat Values for Various Types of Fuel, Table C-2 to Subpart C—Default CH₄ and N₂O Emission Factors for Various Types of Fuel, and Table AA-1 to Subpart AA of Part 98—Kraft Pulping Liquor Emissions Factors for Biomass-Based CO₂, CH₄, and N₂O.
<http://www.epa.gov/ghareporting/documents/pdf/2013/documents/memo-2013-technical-revisions.pdf>
<http://www.epa.gov/ghareporting/reporters/subpartc.html>

Table 2 Mobile Combustion CO₂ Emission Factors

Fuel Type	kg CO ₂ per unit	Unit
Aviation Gasoline	8.31	gallon
Biodiesel (100%)	9.45	gallon
Compressed Natural Gas (CNG)	0.05444	scf
Diesel Fuel	10.21	gallon
Ethanol (100%)	5.75	gallon
Kerosene-Type Jet Fuel	9.75	gallon
Liquefied Natural Gas (LNG)	4.46	gallon
Liquefied Petroleum Gases (LPG)	5.68	gallon
Motor Gasoline	8.78	gallon
Residual Fuel Oil	11.27	gallon

Source:

Federal Register (2009) EPA; 40 CFR Parts 86, 87, 89 et al; Mandatory Reporting of Greenhouse Gases; Final Rule, 30Oct09, 261 pp. Tables C-1 and C-2. Table of Final 2013 Revisions to the Greenhouse Gas Reporting Rule, September 24, 2013.
LNG sourced from: GREET™ Software, GREET1_2013 Model, Argonne National Laboratory. The GREET model provides carbon content and fuel density, which are used to develop the CO₂ emission factor.

Table 3 Mobile Combustion CH₄ and N₂O Emission Factors for On-Road Gasoline Vehicles

Vehicle Type	Year	CH ₄ Factor (g / mile)	N ₂ O Factor (g / mile)
Gasoline Passenger Cars	1973-74	0.1696	0.0197
	1975	0.1423	0.0443
	1976-77	0.1406	0.0458
	1978-79	0.1389	0.0473
	1980	0.1326	0.0499
	1981	0.0802	0.0626
	1982	0.0795	0.0627
	1983	0.0782	0.0630
	1984-93	0.0704	0.0647
	1994	0.0531	0.0560
	1995	0.0358	0.0473
	1996	0.0272	0.0426
	1997	0.0268	0.0422
	1998	0.0249	0.0393
	1999	0.0216	0.0337
	2000	0.0178	0.0273
	2001	0.0110	0.0158
	2002	0.0107	0.0153
	2003	0.0114	0.0135
	2004	0.0145	0.0083
	2005	0.0147	0.0079
	2006	0.0161	0.0057
	2007	0.0170	0.0041
2008	0.0172	0.0038	
2009-present	0.0173	0.0036	
Gasoline Light-Duty Trucks (Vans, Pickup Trucks, SUVs)	1973-74	0.1908	0.0218
	1975	0.1634	0.0513
	1976	0.1594	0.0555
	1977-78	0.1614	0.0534
	1979-80	0.1594	0.0555
	1981	0.1479	0.0660
	1982	0.1442	0.0681
	1983	0.1368	0.0722
	1984	0.1294	0.0764
	1985	0.1220	0.0806
	1986	0.1146	0.0848
	1987-93	0.0813	0.1035
	1994	0.0646	0.0982
	1995	0.0517	0.0908
	1996	0.0452	0.0871
	1997	0.0452	0.0871
	1998	0.0391	0.0728
	1999	0.0321	0.0564
	2000	0.0346	0.0621
	2001	0.0151	0.0164
	2002	0.0178	0.0228
	2003	0.0155	0.0114
	2004	0.0152	0.0132
2005	0.0157	0.0101	
2006	0.0159	0.0089	
2007	0.0161	0.0079	
2008-present	0.0163	0.0066	
Gasoline Heavy-Duty Vehicles	<1981	0.4604	0.0497
	1982-84	0.4492	0.0538
	1985-86	0.4090	0.0515
	1987	0.3675	0.0849
	1988-1989	0.3492	0.0933
	1990-1995	0.3246	0.1142
	1996	0.1278	0.1680
	1997	0.0924	0.1726
	1998	0.0641	0.1693
	1999	0.0578	0.1435
	2000	0.0493	0.1092
	2001	0.0528	0.1235
	2002	0.0546	0.1307
	2003	0.0533	0.1240
	2004	0.0341	0.0285
	2005	0.0326	0.0177
	2006	0.0327	0.0171
	2007	0.0330	0.0153
	2008-present	0.0333	0.0134
	Gasoline Motorcycles	1960-1995	0.0899
1996-present		0.0672	0.0069

Source: EPA (2015) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013. All values are calculated from Tables A-102 through A-106.

Table 4 Mobile Combustion CH₄ and N₂O Emission Factors for On-Road Diesel and Alternative Fuel Vehicles

Vehicle Type	Vehicle Year	CH ₄ Factor (g / mile)	N ₂ O Factor (g / mile)
Diesel Passenger Cars	1960-1982	0.0006	0.0012
	1983-1995	0.0005	0.0010
	1996-present	0.0005	0.0010
Diesel Light-Duty Trucks	1960-1982	0.0011	0.0017
	1983-1995	0.0009	0.0014
	1996-present	0.0010	0.0015
Diesel Medium- and Heavy-Duty Vehicles	1960-present	0.0051	0.0048
CNG Light-Duty Vehicles		0.737	0.050
CNG Medium- and Heavy-Duty Vehicles		1.966	0.175
CNG Buses		1.966	0.175
LPG Light-Duty Vehicles		0.037	0.067
LPG Medium- and Heavy-Duty Vehicles		0.066	0.175
LNG Medium- and Heavy-Duty Vehicles		1.966	0.175
Ethanol Light-Duty Vehicles		0.055	0.067
Ethanol Medium- and Heavy-Duty Vehicles		0.197	0.175
Ethanol Buses		0.197	0.175
Biodiesel Light-Duty Vehicles		0.0005	0.001
Biodiesel Medium- and Heavy-Duty Vehicles		0.005	0.005
Biodiesel Buses		0.005	0.005

Source: EPA (2015) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013. All values are calculated from Tables A-105 through A-107.

Table 5 Mobile Combustion CH₄ and N₂O Emission Factors for Non-Road Vehicles

Vehicle Type	CH ₄ Factor (g / gallon)	N ₂ O Factor (g / gallon)
Residual Fuel Oil Ships and Boats	0.11	0.57
Gasoline Ships and Boats	0.64	0.22
Diesel Ships and Boats	0.06	0.45
Diesel Locomotives	0.80	0.26
Gasoline Agricultural Equip.	1.26	0.22
Diesel Agricultural Equip.	1.44	0.26
Gasoline Construction Equip.	0.50	0.22
Diesel Construction Equip.	0.57	0.26
Jet Fuel Aircraft	0.00	0.30
Aviation Gasoline Aircraft	7.06	0.11
Other Gasoline Non-Road Vehicles	0.50	0.22
Other Diesel Non-Road Vehicles	0.57	0.26
LPG Non-Road Vehicles	0.50	0.22
Biodiesel Non-Road Vehicles	0.57	0.26

Source: EPA (2015) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013. All values are calculated from Table A-108.

Note: LPG non-road vehicles assumed equal to other gasoline sources. Biodiesel vehicles assumed equal to other diesel sources.

Table 6 Electricity Emission Factors

eGRID Subregion	Total Output Emission Factors			Non-BaseLoad Emission Factors		
	CO ₂ Factor (lb CO ₂ /MWh)	CH ₄ Factor (lb CH ₄ /MWh)	N ₂ O Factor (lb N ₂ O/MWh)	CO ₂ Factor (lb CO ₂ /MWh)	CH ₄ Factor (lb CH ₄ /MWh)	N ₂ O Factor (lb N ₂ O/MWh)
AKGD (ASCC Alaska Grid)	1,268.73	0.02634	0.00759	1,377.77	0.02866	0.00338
AKMS (ASCC Miscellaneous)	481.17	0.01865	0.00355	1,404.49	0.05564	0.01070
AZNM (WECC Southwest)	1,152.89	0.01865	0.01511	1,280.59	0.02153	0.01071
CAMX (WECC California)	650.31	0.03112	0.00567	1,333.93	0.03881	0.01379
ERCT (ERCOT All)	1,143.04	0.01670	0.01233	1,331.47	0.09682	0.01715
FRCC (FRCC All)	1,125.35	0.04005	0.01185	1,402.27	0.11801	0.01943
HIMS (HICC Miscellaneous)	1,200.10	0.06808	0.01268	1,739.00	0.03017	0.02626
HIOA (HICC Oahu)	1,576.38	0.09041	0.02155	1,965.21	0.05260	0.03272
MROE (MRO East)	1,522.57	0.02430	0.02555	1,303.42	0.03140	0.00356
MROW (MRO West)	1,425.15	0.02760	0.02426	1,081.11	0.02250	0.00232
NEWE (NPCC New England)	637.90	0.07284	0.01071	1,079.73	0.06770	0.01290
NWPP (WECC Northwest)	665.75	0.01260	0.01038	1,228.56	0.03900	0.01304
NYCW (NPCC NYC/Westchester)	696.70	0.02551	0.00293	1,492.01	0.03274	0.01869
NYLI (NPCC Long Island)	1,201.20	0.07820	0.00987	1,856.21	0.03391	0.02872
NYUP (NPCC Upstate NY)	408.80	0.01559	0.00383	1,791.71	0.02176	0.02785
RFCE (RFC East)	858.56	0.02644	0.01149	1,917.96	0.02329	0.02884
RFCM (RFC Michigan)	1,569.23	0.03036	0.02412	1,301.65	0.02743	0.00975
RFCW (RFC West)	1,379.48	0.01711	0.02167	1,696.79	0.02817	0.02483
RMPA (WECC Rockies)	1,822.65	0.02166	0.02813	1,743.96	0.02284	0.02611
SPNO (SPP North)	1,721.65	0.02022	0.02714	1,790.57	0.05310	0.02994
SPSO (SPP South)	1,538.63	0.02375	0.01998	2,112.08	0.02611	0.03063
SRMV (SERC Mississippi Valley)	1,052.92	0.02095	0.01061	1,590.13	0.02760	0.01619
SRMW (SERC Midwest)	1,710.75	0.01958	0.02750	1,018.87	0.03761	0.00604
SRSO (SERC South)	1,149.05	0.02266	0.01549	1,579.07	0.03830	0.02284
SRTV (SERC Tennessee Valley)	1,337.15	0.01739	0.02078	1,669.58	0.02289	0.02066
SRVC (SERC Virginia/Carolina)	932.87	0.02395	0.01460	1,236.02	0.02156	0.01052
US Average	1,136.53	0.02378	0.01588	1,549.36	0.03099	0.01986

Source: EPA eGRID2012, October 2015

Note: Total output emission factors can be used as default factors for estimating GHG emissions from electricity use when developing a carbon footprint or emissions inventory. Annual non-base-load output emission factors should not be used for those purposes, but can be used to estimate GHG emissions reductions from reductions in electricity use.

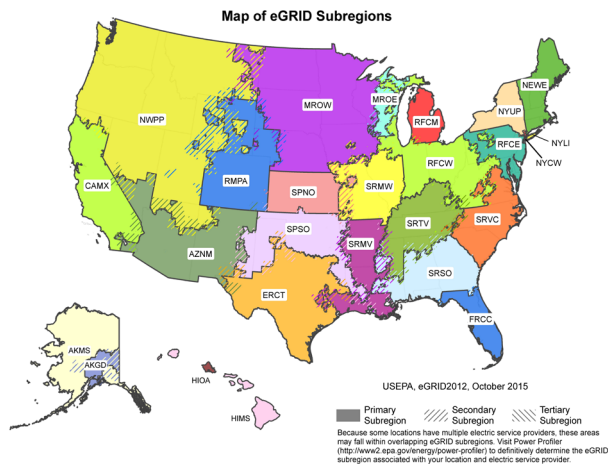


Table 7 Steam and Heat Emission Factors

	CO ₂ Factor (kg / mmBtu)	CH ₄ Factor (g / mmBtu)	N ₂ O Factor (g / mmBtu)
Steam and Heat	66.33	1.250	0.125

Assumptions:

Natural gas fuel used to generate steam or heat, at 80 percent thermal efficiency. Emission factors are per mmBtu of steam or heat purchased.

Table 8 Business Travel Emission Factors

Vehicle Type	CO ₂ Factor (kg / unit)	CH ₄ Factor (g / unit)	N ₂ O Factor (g / unit)	Units
Passenger Car ^A	0.355	0.021	0.015	vehicle-mile
Light-Duty Truck ^B	0.485	0.020	0.022	vehicle-mile
Motorcycle	0.191	0.070	0.007	vehicle-mile
Intercity Rail (i.e. Amtrak) ^C	0.136	0.0083	0.0030	passenger-mile
Commuter Rail ^D	0.169	0.0085	0.0034	passenger-mile
Transit Rail (i.e. Subway, Tram) ^E	0.120	0.0025	0.0017	passenger-mile
Bus	0.055	0.0006	0.0005	passenger-mile
Air Travel - Short Haul (< 300 miles) ^F	0.251	0.0039	0.0083	passenger-mile
Air Travel - Medium Haul (>= 300 miles, < 2300 miles) ^F	0.143	0.0000	0.0047	passenger-mile
Air Travel - Long Haul (>= 2300 miles) ^F	0.167	0.0006	0.0056	passenger-mile

Source:

CO₂, CH₄, and N₂O emissions data for on-road vehicles are from Table 2-13 of the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013. Vehicle-miles and passenger-miles data for on-road vehicles are from Table VM-1 of the Federal Highway Administration Highway Statistics 2013.

Fuel consumption data and passenger-miles data for rail are from Tables A.14 to A.16 and 9.10 to 9.12 of the Transportation Energy Data Book: Edition 33. Fuel consumption was converted to emissions by using fuel and electricity emission factors presented in the tables above.

Air Travel factors from 2015 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. Version 1.0 July 2015.

Notes:

^A Passenger car: includes passenger cars, minivans, SUVs, and small pickup trucks (vehicles with wheelbase less than 121 inches).

^B Light-duty truck: includes full-size pickup trucks, full-size vans, and extended-length SUVs (vehicles with wheelbase greater than 121 inches).

^C Intercity rail: long-distance rail between major cities, such as Amtrak

^D Commuter rail: rail service between a central city and adjacent suburbs (also called regional rail or suburban rail)

^E Transit rail: rail typically within an urban center, such as subways, elevated railways, metropolitan railways (metro), streetcars, trolley cars, and tramways.

^F These factors represent a methodology change from previous factors, based on improved data.

Table 9 Product Transport Emission Factors

Vehicle Type	CO ₂ Factor (kg / unit)	CH ₄ Factor (g / unit)	N ₂ O Factor (g / unit)	Units
Medium- and Heavy-Duty Truck	1.430	0.015	0.013	vehicle-mile
Passenger Car ^A	0.355	0.021	0.015	vehicle-mile
Light-Duty Truck ^B	0.485	0.020	0.022	vehicle-mile
Medium- and Heavy-Duty Truck ^C	0.148	0.0015	0.0014	ton-mile
Rail	0.024	0.0019	0.0006	ton-mile
Waterborne Craft	0.059	0.0005	0.0040	ton-mile
Aircraft	1.307	0.0000	0.0402	ton-mile

Source:

CO₂, CH₄, and N₂O emissions data for on-road vehicles are from Table 2-13 of the U.S. Greenhouse Gas Emissions and Sinks: 1990–2013. Vehicle-miles and passenger-miles data for on-road vehicles are from Table VM-1 of the Federal Highway Administration Highway Statistics 2013.

CO₂e emissions data for non-road vehicles are based on Table A-117 of the U.S. Greenhouse Gas Emissions and Sinks: 1990–2013, which are distributed into CO₂, CH₄, and N₂O emissions based on fuel/vehicle emission factors. Freight ton-mile data for non-road vehicles are from Table 1-50 of the Bureau of Transportation Statistics, National Transportation Statistics for 2014 (Data based on 2011).

Notes:

Vehicle-mile factors are appropriate to use when the entire vehicle is dedicated to transporting the reporting company's product. Ton-mile factors are appropriate when the vehicle is shared with products from other companies.

^A Passenger car: includes passenger cars, minivans, SUVs, and small pickup trucks (vehicles with wheelbase less than 121 inches).

^B Light-duty truck: includes full-size pickup trucks, full-size vans, and extended-length SUVs (vehicles with wheelbase greater than 121 inches).

^C These factors represent a methodology change from previous factors, based on improved data.

Table 10a Global Warming Potentials (GWPs)

Gas	100-Year GWP
CO ₂	1
CH ₄	25
N ₂ O	298
HFC-23	14,800
HFC-32	675
HFC-41	92
HFC-125	3,500
HFC-134	1,100
HFC-134a	1,430
HFC-143	353
HFC-143a	4,470
HFC-152	53
HFC-152a	124
HFC-161	12
HFC-227ea	3,220
HFC-236cb	1,340
HFC-236ea	1,370
HFC-236fa	9,810
HFC-245ca	693
HFC-245fa	1,030
HFC-365mfc	794
HFC-43-10mee	1,640
SF ₆	22,800
NF ₃	17,200
CF ₄	7,390
C ₂ F ₆	12,200
C ₃ F ₈	8,830
c-C ₃ F ₈	10,300
C ₂ F ₁₀	8,860
C ₃ F ₁₂	9,160
C ₄ F ₁₄	9,300
C ₁₀ F ₁₈	>7,500

Source:

100-year GWPs from IPCC Fourth Assessment Report (AR4), 2007. IPCC AR4 was published in 2007 and is among the most current and comprehensive peer-reviewed assessments of climate change. AR4 provides revised GWPs of several GHGs relative to the values provided in previous assessment reports, following advances in scientific knowledge on the radiative efficiencies and atmospheric lifetimes of these GHGs and of CO₂. Because the GWPs provided in AR4 reflect an improved scientific understanding of the radiative effects of these gases in the atmosphere, the values provided are more appropriate for supporting the overall goal of organizational GHG reporting than the Second Assessment Report (SAR) GWP values previously used in the Emission Factors Hub.

While EPA recognizes that Fifth Assessment Report (AR5) GWPs have been published, in an effort to ensure consistency and comparability of GHG data between EPA's voluntary and non-voluntary GHG reporting programs (e.g. GHG Reporting Program and National Inventory), EPA recommends the use of AR4 GWPs. The United States and other developed countries to the UNFCCC have agreed to submit annual inventories in 2015 and future years to the UNFCCC using GWP values from AR4, which will replace the current use of SAR GWP values. Utilizing AR4 GWPs improves EPA's ability to analyze corporate, national, and sub-national GHG data consistently, enhances communication of GHG information between programs, and gives outside stakeholders a consistent, predictable set of GWPs to avoid confusion and additional burden.

Table 10b GWPs for Blended Refrigerants

ASHRAE #	100-year GWP	Blend Composition
R-401A	16	53% HCFC-22, 34% HCFC-124, 13% HFC-152a
R-401B	14	61% HCFC-22, 28% HCFC-124, 11% HFC-152a
R-401C	19	33% HCFC-22, 52% HCFC-124, 15% HFC-152a
R-402A	2,100	38% HCFC-22, 6% HFC-125, 2% propane
R-402B	1,330	6% HCFC-22, 38% HFC-125, 2% propane
R-403B	3,444	56% HCFC-22, 39% PFC-218, 5% propane
R-404A	3,922	44% HFC-125, 4% HFC-134a, 52% HFC-143a
R-406A	0	56% HCFC-22, 41% HCFC-142b, 4% isobutane
R-407A	2,107	20% HFC-32, 40% HFC-125, 40% HFC-134a
R-407B	2,804	10% HFC-32, 70% HFC-125, 20% HFC-134a
R-407C	1,774	23% HFC-32, 25% HFC-125, 52% HFC-134a
R-407D	1,627	15% HFC-32, 15% HFC-125, 70% HFC-134a
R-407E	1,552	25% HFC-32, 15% HFC-125, 60% HFC-134a
R-408A	2,301	47% HCFC-22, 7% HFC-125, 46% HFC-143a
R-409A	0	60% HCFC-22, 25% HCFC-124, 15% HCFC-142b
R-410A	2,088	50% HFC-32, 50% HFC-125
R-410B	2,229	45% HFC-32, 55% HFC-125
R-411A	14	87.5% HCFC-22, 11% HFC-152a, 1.5% propylene
R-411B	4	94% HCFC-22, 3% HFC-152a, 3% propylene
R-413A	2,053	88% HFC-134a, 9% PFC-218, 3% isobutane
R-414A	0	51% HCFC-22, 28.5% HCFC-124, 16.5% HCFC-142b
R-414B	0	5% HCFC-22, 39% HCFC-124, 9.5% HCFC-142b
R-417A	2,346	46.6% HFC-125, 5% HFC-134a, 3.4% butane
R-422A	3,143	85.1% HFC-125, 11.5% HFC-134a, 3.4% isobutane
R-422D	2,729	65.1% HFC-125, 31.5% HFC-134a, 3.4% isobutane
R-423A	2,280	47.5% HFC-227ea, 52.5% HFC-134a
R-424A	2,440	50.5% HFC-125, 47% HFC-134a, 2.5% butane/pentane
R-426A	1,508	5.1% HFC-125, 93% HFC-134a, 1.9% butane/pentane
R-428A	3,607	77.5% HFC-125, 2% HFC-143a, 1.9% isobutane
R-434A	3,245	63.2% HFC-125, 16% HFC-134a, 18% HFC-143a, 2.8% isobutane
R-500	32	73.8% CFC-12, 26.2% HFC-152a, 48.8% HCFC-22
R-502	0	48.8% HCFC-22, 51.2% CFC-115
R-504	325	48.2% HFC-32, 51.8% CFC-115
R-507	3,985	5% HFC-125, 5% HFC-143a
R-508A	13,214	39% HFC-23, 61% PFC-116
R-508B	13,396	46% HFC-23, 54% PFC-116

Source:

100-year GWPs from IPCC Fourth Assessment Report (AR4), 2007. See the source note to Table 9 for further explanation. GWPs of blended refrigerants are based on their HFC and PFC constituents, which are based on data from <http://www.epa.gov/ozone/snapi/refrigerants/reblend.html>.