



NETL Life Cycle Inventory Data

Process Documentation File

Process Name: Combustion of Natural Gas
Reference Flow: 1 kg of natural gas
Brief Description: This unit process includes the emissions associated with the combustion of natural gas

Section I: Meta Data

Geographical Coverage: United States **Region:** N/A
Year Data Best Represents: 2012
Process Type: Energy Conversion (EC)
Process Scope: Gate-to-Gate Process (GG)
Allocation Applied: No
Completeness: All Relevant Flows Captured

Flows Aggregated in Data Set:

- Process
 Energy Use
 Energy P&D
 Material P&D

Relevant Output Flows Included in Data Set:

- Releases to Air:
 Greenhouse Gases
 Criteria Air
 Other
 Releases to Water:
 Inorganic
 Organic Emissions
 Other
 Water Usage:
 Water Consumption
 Water Demand (throughput)
 Releases to Soil:
 Inorganic Releases
 Organic Releases
 Other

Adjustable Process Parameters:

Ace_ene	<i>[kg/kg natural gas] Acenaphthene emissions per kg of combusted natural gas</i>
Ace_ylene	<i>[kg/kg natural gas] Acenaphthylene emissions per kg of combusted natural gas</i>
Ace_yde	<i>[kg/kg natural gas] Acetaldehyde emissions per kg of combusted natural gas</i>

Acrolein	<i>[kg/kg natural gas] Acrolein emissions per kg of combusted natural gas</i>
NH3	<i>[kg/kg natural gas] Ammonia emissions per kg of combusted natural gas</i>
Anthracene	<i>[kg/kg natural gas] Anthracene emissions per kg of combusted natural gas</i>
Arsenic	<i>[kg/kg natural gas] Arsenic emissions per kg of combusted natural gas</i>
Barium	<i>[kg/kg natural gas] Barium emissions per kg of combusted natural gas</i>
Benzene	<i>[kg/kg natural gas] Benzene emissions per kg of combusted natural gas</i>
Benz_cene	<i>[kg/kg natural gas] Benzo (a) anthracene emissions per kg of combusted natural gas</i>
Benz_a_pyr	<i>[kg/kg natural gas] Benzo (a) pyrene emissions per kg of combusted natural gas</i>
Benz_b_fluor	<i>[kg/kg natural gas] Benzo (b) fluoranthene emissions per kg of combusted natural gas</i>
Benz_e_pyrene	<i>[kg/kg natural gas] Benzo (e) pyrene emissions per kg of combusted natural gas</i>
Benz_per	<i>[kg/kg natural gas] Benzo (g,h,i) perylene emissions per kg of combusted natural gas</i>
Benz_k_fluor	<i>[kg/kg natural gas] Benzo (k) fluoranthene emissions per kg of combusted natural gas</i>
Beryllium	<i>[kg/kg natural gas] Beryllium emissions per kg of combusted natural gas</i>
Biphenyl	<i>[kg/kg natural gas] Biphenyl emissions per kg of combusted natural gas</i>
But_1_3	<i>[kg/kg natural gas] 1,3-Butadiene emissions per kg of combusted natural gas</i>
n_butane	<i>[kg/kg natural gas] n-Butane emissions per kg of combusted</i>

	<i>natural gas</i>
Cadmium	<i>[kg/kg natural gas] Cadmium emissions per kg of combusted natural gas</i>
CO	<i>[kg/kg natural gas] Carbon dioxide emissions per kg of combusted natural gas</i>
CO2	<i>[kg/kg natural gas] Carbon monoxide emissions per kg of combusted natural gas</i>
C_tetrachlor	<i>[kg/kg natural gas] Carbon tetrachloride emissions per kg of combusted natural gas</i>
Chlorobenzene	<i>[kg/kg natural gas] Chlorobenzene emissions per kg of combusted natural gas</i>
Chloroform	<i>[kg/kg natural gas] Chloroform emissions per kg of combusted natural gas</i>
Chromium	<i>[kg/kg natural gas] Chromium emissions per kg of combusted natural gas</i>
Chrysene	<i>[kg/kg natural gas] Chrysene emissions per kg of combusted natural gas</i>
Cobalt	<i>[kg/kg natural gas] Cobalt emissions per kg of combusted natural gas</i>
Copper	<i>[kg/kg natural gas] Copper emissions per kg of combusted natural gas</i>
Cyanide	<i>[kg/kg natural gas] Cyanide emissions per kg of combusted natural gas</i>
Cyclohexane	<i>[kg/kg natural gas] Cyclohexane emissions per kg of combusted natural gas</i>
Cyclopentane	<i>[kg/kg natural gas] Cyclopentane emissions per kg of combusted natural gas</i>
Dib_anth	<i>[kg/kg natural gas] Dibenzo(a,h)anthracene emissions per kg of combusted natural gas</i>
Dichlorobenzene	<i>[kg/kg natural gas] Dichlorobenzene, mixed isomers emissions per kg of combusted natural gas</i>
1_1_Dichlor_eth	<i>[kg/kg natural gas] 1,1-</i>

Dichloromethane	<i>Dichloroethane emissions per kg of combusted natural gas</i>
1_3_Dichlor_pro	<i>[kg/kg natural gas] Dichloromethane emissions per kg of combusted natural gas</i>
Dimethyl_a_anth	<i>[kg/kg natural gas] 1,3-Dichloropropene emissions per kg of combusted natural gas</i>
Ethane	<i>[kg/kg natural gas] Dimethylbenz(a)anthracene emissions per kg of combusted natural gas</i>
Ethyl_chlor	<i>[kg/kg natural gas] Ethane emissions per kg of combusted natural gas</i>
Ethyl_b	<i>[kg/kg natural gas] Ethyl chloride emissions per kg of combusted natural gas</i>
Ethyl_dibrom	<i>[kg/kg natural gas] Ethylbenzene emissions per kg of combusted natural gas</i>
Ethyl_dichlor	<i>[kg/kg natural gas] Ethylene dibromide emissions per kg of combusted natural gas</i>
Fluoran	<i>[kg/kg natural gas] Ethylene dichloride emissions per kg of combusted natural gas</i>
Fluor	<i>[kg/kg natural gas] Fluoranthene emissions per kg of combusted natural gas</i>
Form	<i>[kg/kg natural gas] Flourene emissions per kg of combusted natural gas</i>
Ind_pyr	<i>[kg/kg natural gas] Formaldehyde emissions per kg of combusted natural gas</i>
Isobutane	<i>[kg/kg natural gas] Indeno(1,2,3-cd)pyrene emissions per kg of combusted natural gas</i>
Isobut_hyde	<i>[kg/kg natural gas] Isobutane emissions per kg of combusted natural gas</i>
Iso_xylene	<i>[kg/kg natural gas] Isobutyraldehyde emissions per kg of combusted natural gas</i>
	<i>[kg/kg natural gas] Isomers of xylene emissions per kg of combusted</i>

	<i>natural gas</i>
Lead	<i>[kg/kg natural gas] Lead emissions per kg of combusted natural gas</i>
Manganese	<i>[kg/kg natural gas] Manganese emissions per kg of combusted natural gas</i>
Mercury	<i>[kg/kg natural gas] Mercury emissions per kg of combusted natural gas</i>
CH4	<i>[kg/kg natural gas] Methane emissions per kg of combusted natural gas</i>
Methyl_alch	<i>[kg/kg natural gas] Methyl alcohol emissions per kg of combusted natural gas</i>
2_Methyl_Naph	<i>[kg/kg natural gas] 2-Methyl Naphthalene emissions per kg of combusted natural gas</i>
3_Methyl_ene	<i>[kg/kg natural gas] 3-Methylcholanthrene emissions per kg of combusted natural gas</i>
Methyl_hex	<i>[kg/kg natural gas] Methylcyclohexane emissions per kg of combusted natural gas</i>
Molybdenum	<i>[kg/kg natural gas] Molybdenum emissions per kg of combusted natural gas</i>
N_Hex	<i>[kg/kg natural gas] N-Hexane emissions per kg of combusted natural gas</i>
N_Non	<i>[kg/kg natural gas] N-Nonane emissions per kg of combusted natural gas</i>
N_Oct	<i>[kg/kg natural gas] N-Octane emissions per kg of combusted natural gas</i>
N_Pent	<i>[kg/kg natural gas] N-Pentane emissions per kg of combusted natural gas</i>
Napth	<i>[kg/kg natural gas] Naphthalene emissions per kg of combusted natural gas</i>
Nickel	<i>[kg/kg natural gas] Nickel emissions per kg of combusted natural gas</i>
NOx	<i>[kg/kg natural gas] Nitrogen oxides (NOx) emissions per kg of</i>

	<i>combusted natural gas</i>
N2O	<i>[kg/kg natural gas] Nitrous oxide emissions per kg of combusted natural gas</i>
Perchlor_ene	<i>[kg/kg natural gas] Perchloroethylene emissions per kg of combusted natural gas</i>
Perylene	<i>[kg/kg natural gas] Perylene emissions per kg of combusted natural gas</i>
Phen	<i>[kg/kg natural gas] Phenanthrene emissions per kg of combusted natural gas</i>
Phenol	<i>[kg/kg natural gas] Phenol emissions per kg of combusted natural gas</i>
Phos	<i>[kg/kg natural gas] Phosphorus emissions per kg of combusted natural gas</i>
PM10_Great	<i>[kg/kg natural gas] Particulate matter greater than 10 microns emissions per kg of combusted natural gas</i>
PM25_PM10 PM25	<i>[kg/kg natural gas] Particulate matter between 2.5 and 10 microns emissions per kg of combusted natural gas</i>
PAH	<i>[kg/kg natural gas] Particulate matter less than 2.5 microns emissions per kg of combusted natural gas</i>
Prop_oxide	<i>[kg/kg natural gas] Polycyclic aromatic hydrocarbons (PAH) emissions per kg of combusted natural gas</i>
Propane	<i>[kg/kg natural gas] Propylene oxide emissions per kg of combusted natural gas</i>
Propylene	<i>[kg/kg natural gas] Propane emissions per kg of combusted natural gas</i>
Pyrene	<i>[kg/kg natural gas] Propylene dichloride emissions per kg of combusted natural gas</i>
Selenium	<i>[kg/kg natural gas] Pyrene emissions per kg of combusted natural gas</i>
	<i>[kg/kg natural gas] Selenium emissions per kg of combusted natural gas</i>

Styrene	<i>[kg/kg natural gas] Styrene emissions per kg of combusted natural gas</i>
SO2	<i>[kg/kg natural gas] Sulfur dioxide emissions per kg of combusted natural gas</i>
SOX	<i>[kg/kg natural gas] Sulfur oxides (SOx) emissions per kg of combusted natural gas</i>
Tetrachlor_eth	<i>[kg/kg natural gas] 1,1,2,2-Tetrachloroethane emissions per kg of combusted natural gas</i>
Toluene	<i>[kg/kg natural gas] Toluene emissions per kg of combusted natural gas</i>
TOC	<i>[kg/kg natural gas] Total organic compounds (TOC) emissions per kg of combusted natural gas</i>
Trichlor_eth	<i>[kg/kg natural gas] 1,1,2-Trichloroethane emissions per kg of combusted natural gas</i>
1_3_Trimeth_ben	<i>[kg/kg natural gas] 1,2,3-Trimethylbenzene emissions per kg of combusted natural gas</i>
1_4_Trimeth_ben	<i>[kg/kg natural gas] 1,2,4-Trimethylbenzene emissions per kg of combusted natural gas</i>
1_5_Trimeth_ben	<i>[kg/kg natural gas] 1,3,5-Trimethylbenzene emissions per kg of combusted natural gas</i>
2_4_Trimeth_ben	<i>[kg/kg natural gas] 2,2,4-Trimethylpentane emissions per kg of combusted natural gas</i>
Vanadium	<i>[kg/kg natural gas] Vanadium emissions per kg of combusted natural gas</i>
Vinyl_Chlor	<i>[kg/kg natural gas] Vinyl chloride emissions per kg of combusted natural gas</i>
VOC	<i>[kg/kg natural gas] Volatile organic compounds (VOC) emissions per kg of combusted natural gas</i>
Zinc	<i>[kg/kg natural gas] Zinc emissions per kg of combusted natural gas</i>

Tracked Input Flows:

Natural_Gas

[Technosphere] Natural gas for combustion

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *Stage3_Natural_Gas_Combustion.01.xlsx*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant input and output flows associated with the combustion of natural gas utilized for several downstream processes. The reference flow of this unit process is: 1 kg of natural gas

Boundary and Description

This unit process provides a summary of relevant input and output flows associated with the combustion of natural gas. There are several grouping scenarios that represent the type of equipment, sector, technology, and control resulting in 99 unique scenarios. The types of equipment covered are external combustion boilers and internal combustion engines. The sectors covered are electricity generation, industrial and commercial/industrial. The technologies covered are tangentially or non-tangentially fired boilers and 2-cycle, 4-cycle, or turbine engines. Control technologies covered uncontrolled, wet scrubber, select catalytic reduction (SCR), select non-catalytic reduction, flue gas recirculating, low NO_x, afterburner, water injection or pre-combustion chamber. Furthermore the equipment use can be specified as combustion in boiler for electricity only or combined heat and power (CHP) otherwise known as cogeneration (EPA, 2014). **Table 1** lists all specific scenarios covered in this unit process. The commercial sector includes the combustion of natural gas in a reciprocating or turbine engine or an external combustion boiler for nonmanufacturing business, such as private and public organizations, government activities, social groups, or institutional living quarters (EPA, 2014). Non-greenhouse gas (GHG) emissions for electric generation, industrial, and commercial scenarios were taken from the U.S.EPA's

(United States Environmental Protection Agency) WebFIRE database (EPA, 2012), while GHG emissions for these scenarios were derived from EPA’s 2011 GHG Emission Factors Hub (EPA 2011). **Figure 1** shows the scope and boundary of this unit process. **Table 2** lists all inputs and outputs for Scenario 1: External Combustion Boilers, Electric Generation, Natural Gas, Boilers > 100 Million Btu/hr except Tangential, Uncontrolled, Pre-NSPS Boiler.

Figure 1: Unit Process Scope and Boundary

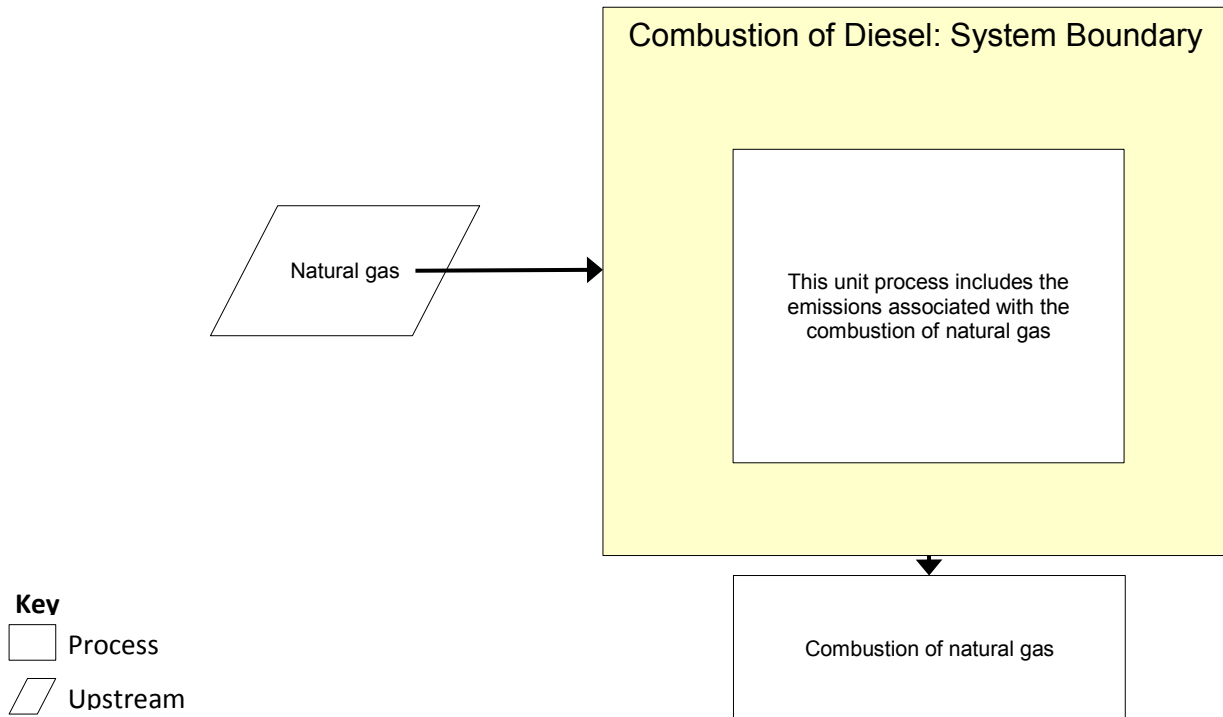


Table 1: Combustion Scenarios

Scenario ID	Scenario Name
1	External Combustion Boilers, Electric Generation, Natural Gas, Boilers > 100 Million Btu/hr except Tangential, Uncontrolled, Pre-NSPS Boiler
2	External Combustion Boilers, Electric Generation, Natural Gas, Boilers > 100 Million Btu/hr except Tangential, Uncontrolled, Post NSPS Boiler
3	External Combustion Boilers, Electric Generation, Natural Gas, Boilers > 100 Million Btu/hr except Tangential, Wet Scrubber - Medium Efficiency
4	External Combustion Boilers, Electric Generation, Natural Gas, Boilers > 100 Million Btu/hr except Tangential, SCR
5	External Combustion Boilers, Electric Generation, Natural Gas, Boilers > 100 Million Btu/hr except Tangential, SNCR
6	External Combustion Boilers, Electric Generation, Natural Gas, Boilers > 100 Million Btu/hr except Tangential, Flue Gas Recirculation
7	External Combustion Boilers, Electric Generation, Natural Gas, Boilers > 100 Million Btu/hr except Tangential, Low NOx Burners
8	External Combustion Boilers, Electric Generation, Natural Gas, Boilers < 100 Million Btu/hr except Tangential, Uncontrolled
9	External Combustion Boilers, Electric Generation, Natural Gas, Boilers < 100 Million Btu/hr except Tangential, SCR
10	External Combustion Boilers, Electric Generation, Natural Gas, Boilers < 100 Million Btu/hr except Tangential, SNCR
11	External Combustion Boilers, Electric Generation, Natural Gas, Boilers < 100 Million Btu/hr except Tangential, Flue Gas Recirculation
12	External Combustion Boilers, Electric Generation, Natural Gas, Boilers < 100 Million Btu/hr except Tangential, Low NOx Burners
13	External Combustion Boilers, Electric Generation, Natural Gas, Tangentially Fired Units, Uncontrolled
14	External Combustion Boilers, Electric Generation, Natural Gas, Tangentially Fired Units, Wet Scrubber - Medium Efficiency
15	External Combustion Boilers, Electric Generation, Natural Gas, Tangentially Fired Units, SCR
16	External Combustion Boilers, Electric Generation, Natural Gas, Tangentially Fired Units, SNCR
17	External Combustion Boilers, Electric Generation, Natural Gas, Tangentially Fired Units, Flue Gas Recirculation
18	External Combustion Boilers, Electric Generation, Natural Gas, Tangentially Fired Units, Low NOx Burners
19	External Combustion Boilers, Industrial, Natural Gas, > 100 Million Btu/hr, Uncontrolled, Pre-NSPS Boiler
20	External Combustion Boilers, Industrial, Natural Gas, > 100 Million Btu/hr, Uncontrolled, Post NSPS Boiler
21	External Combustion Boilers, Industrial, Natural Gas, > 100 Million Btu/hr, SCR
22	External Combustion Boilers, Industrial, Natural Gas, > 100 Million Btu/hr, SNCR
23	External Combustion Boilers, Industrial, Natural Gas, > 100 Million Btu/hr, Flue Gas Recirculation



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24	External Combustion Boilers, Industrial, Natural Gas, > 100 Million Btu/hr, Low NOx Burners
25	External Combustion Boilers, Industrial, Natural Gas, 10-100 Million Btu/hr, Uncontrolled
26	External Combustion Boilers, Industrial, Natural Gas, 10-100 Million Btu/hr, SCR
27	External Combustion Boilers, Industrial, Natural Gas, 10-100 Million Btu/hr, SNCR
28	External Combustion Boilers, Industrial, Natural Gas, 10-100 Million Btu/hr, Flue Gas Recirculation
29	External Combustion Boilers, Industrial, Natural Gas, 10-100 Million Btu/hr, Low NOx Burners
30	External Combustion Boilers, Industrial, Natural Gas, < 10 Million Btu/hr, Uncontrolled
31	External Combustion Boilers, Industrial, Natural Gas, < 10 Million Btu/hr, SCR
32	External Combustion Boilers, Industrial, Natural Gas, < 10 Million Btu/hr, SNCR
33	External Combustion Boilers, Industrial, Natural Gas, Cogeneration, Uncontrolled
34	External Combustion Boilers, Industrial, Natural Gas, Cogeneration, SCR
35	External Combustion Boilers, Industrial, Natural Gas, Cogeneration, SNCR
36	External Combustion Boilers, Commercial/Institutional, Natural Gas, > 100 Million Btu/hr, Uncontrolled, Pre-NSPS Boiler
37	External Combustion Boilers, Commercial/Institutional, Natural Gas, > 100 Million Btu/hr, Uncontrolled, Post-NSPS Boiler
38	External Combustion Boilers, Commercial/Institutional, Natural Gas, > 100 Million Btu/hr, SCR
39	External Combustion Boilers, Commercial/Institutional, Natural Gas, > 100 Million Btu/hr, SNCR
40	External Combustion Boilers, Commercial/Institutional, Natural Gas, > 100 Million Btu/hr, Flue Gas Recirculation
41	External Combustion Boilers, Commercial/Institutional, Natural Gas, > 100 Million Btu/hr, Low NOx Burners
42	External Combustion Boilers, Commercial/Institutional, Natural Gas, 10-100 Million Btu/hr, Uncontrolled
43	External Combustion Boilers, Commercial/Institutional, Natural Gas, 10-100 Million Btu/hr, SCR
44	External Combustion Boilers, Commercial/Institutional, Natural Gas, 10-100 Million Btu/hr, SNCR
45	External Combustion Boilers, Commercial/Institutional, Natural Gas, 10-100 Million Btu/hr, Flue Gas Recirculation
46	External Combustion Boilers, Commercial/Institutional, Natural Gas, 10-100 Million Btu/hr, Low NOx Burners
47	External Combustion Boilers, Commercial/Institutional, Natural Gas, < 10 Million Btu/hr, Uncontrolled
48	External Combustion Boilers, Commercial/Institutional, Natural Gas, < 10 Million Btu/hr, SCR
49	External Combustion Boilers, Commercial/Institutional, Natural Gas, < 10 Million



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	Btu/hr, SNCR
50	External Combustion Boilers, Commercial/Institutional, Natural Gas, < 10 Million Btu/hr, Flue Gas Recirculation
51	External Combustion Boilers, Commercial/Institutional, Natural Gas, < 10 Million Btu/hr, Low NOx Burners
52	Internal Combustion Engines, Electric Generation, Natural Gas, Turbine, Uncontrolled
53	Internal Combustion Engines, Electric Generation, Natural Gas, Turbine, Steam or Water Injection
54	Internal Combustion Engines, Electric Generation, Natural Gas, Turbine, Pre-Combustion Chamber
55	Internal Combustion Engines, Electric Generation, Natural Gas, Turbine, SCR
56	Internal Combustion Engines, Electric Generation, Natural Gas, Turbine, SNCR
57	Internal Combustion Engines, Electric Generation, Natural Gas, Turbine, Afterburner
58	Internal Combustion Engines, Electric Generation, Natural Gas, Reciprocating, Uncontrolled
59	Internal Combustion Engines, Electric Generation, Natural Gas, Reciprocating, SCR
60	Internal Combustion Engines, Electric Generation, Natural Gas, Reciprocating, SNCR
61	Internal Combustion Engines, Industrial, Natural Gas, Turbine, Uncontrolled
62	Internal Combustion Engines, Industrial, Natural Gas, Turbine, Steam or Water Injection
63	Internal Combustion Engines, Industrial, Natural Gas, Turbine, Pre-Combustion Chamber
64	Internal Combustion Engines, Industrial, Natural Gas, Turbine, Ammonia Injection
65	Internal Combustion Engines, Industrial, Natural Gas, Turbine, SCR
66	Internal Combustion Engines, Industrial, Natural Gas, Turbine, SNCR
67	Internal Combustion Engines, Industrial, Natural Gas, Reciprocating, Uncontrolled
68	Internal Combustion Engines, Industrial, Natural Gas, Reciprocating, SCR
69	Internal Combustion Engines, Industrial, Natural Gas, Reciprocating, SNCR
70	Internal Combustion Engines, Industrial, Natural Gas, Turbine:Cogeneration, Uncontrolled
71	Internal Combustion Engines, Industrial, Natural Gas, Turbine:Cogeneration, Steam or Water Injection
72	Internal Combustion Engines, Industrial, Natural Gas, Turbine:Cogeneration, Pre-Combustion Chamber
73	Internal Combustion Engines, Industrial, Natural Gas, Turbine:Cogeneration, SCR
74	Internal Combustion Engines, Industrial, Natural Gas, Turbine:Cogeneration, SNCR
75	Internal Combustion Engines, Industrial, Natural Gas, Reciprocating:Cogeneration, Uncontrolled



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76	Internal Combustion Engines, Industrial, Natural Gas, Reciprocating:Cogeneration, SCR
77	Internal Combustion Engines, Industrial, Natural Gas, Reciprocating:Cogeneration, SNCR
78	Internal Combustion Engines, Industrial, Natural Gas, 2-cycle Lean Burn, Uncontrolled
79	Internal Combustion Engines, Industrial, Natural Gas, 2-cycle Lean Burn, SCR
80	Internal Combustion Engines, Industrial, Natural Gas, 2-cycle Lean Burn, SNCR
81	Internal Combustion Engines, Industrial, Natural Gas, 4-cycle Rich Burn, Uncontrolled
82	Internal Combustion Engines, Industrial, Natural Gas, 4-cycle Rich Burn, SCR
83	Internal Combustion Engines, Industrial, Natural Gas, 4-cycle Rich Burn, SNCR
84	Internal Combustion Engines, Industrial, Natural Gas, 4-cycle Lean Burn, Uncontrolled
85	Internal Combustion Engines, Industrial, Natural Gas, 4-cycle Lean Burn, SCR
86	Internal Combustion Engines, Industrial, Natural Gas, 4-cycle Lean Burn, SNCR
87	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Reciprocating, Uncontrolled
88	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Reciprocating, SCR
89	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Reciprocating, SNCR
90	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Turbine, Uncontrolled
91	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Turbine, Steam or Water Injection
92	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Turbine, Pre-Combustion Chamber
93	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Turbine, SCR
94	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Turbine, SNCR
95	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Turbine:Cogeneration, Uncontrolled
96	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Turbine:Cogeneration, Steam or Water Injection
97	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Turbine:Cogeneration,Pre-Combustion Chamber
98	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Turbine:Cogeneration, SCR
99	Internal Combustion Engines, Commercial/Institutional, Natural Gas, Turbine:Cogeneration, SNCR

Table 2: Unit Process Input and Output Flows – Passenger Car

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Natural gas [Natural gas products]	1.00	kg
Outputs		
US: Natural gas, combusted in industrial equipment [Flows]	1.00E+00	
Acentaphthene [Group PAH to air]	4.24E-11	kg
Acenaphthylene [Organic emissions to air (group VOC)]	4.24E-11	kg
Acetaldehyde (Ethanal) [Group NMVOC to air]	0.00E+00	kg
Acrolein [Group NMVOC to air]	0.00E+00	kg
Ammonia [Inorganic emissions to air]	7.54E-05	kg
Anthracene [Group PAH to air]	5.65E-11	kg
Arsenic (+V) [Heavy metals to air]	4.71E-09	kg
Barium [Inorganic emissions to air]	1.04E-07	kg
Benzene [Group NMVOC to air]	4.95E-08	kg
Benzo{a}anthracene [Group PAH to air]	4.24E-11	kg
Benzo{a}pyrene [Group PAH to air]	2.83E-11	kg
Benzo{b}fluoranthene [Group PAH to air]	4.24E-11	kg
Benzo{e}anthracene [Group NMVOC to air]	0.00E+00	kg
Benzo{ghi}perylene [Group PAH to air]	2.83E-11	kg
Benzo{k}fluoranthene [Group PAH to air]	4.24E-11	kg
Beryllium [Inorganic emissions to air]	2.83E-10	kg
Biphenyl [Group NMVOC to air]	0.00E+00	kg
1,3-Butadiene [Group NMVOC to air]	0.00E+00	kg
Butane (n-butane) [Group NMVOC to air]	4.95E-05	kg
Cadmium [Heavy metals to air]	2.59E-08	kg
Carbon dioxide [Inorganic emissions to air]	2.83E+00	kg
Carbon monoxide [Inorganic emissions to air]	1.98E-03	kg
Carbon tetrachloride (tetrachloromethane) [Halogenated organic emissions to air]	0.00E+00	kg
Chlorobenzene [Halogenated organic emissions to air]	0.00E+00	kg
Trichloromethane (chloroform) [Halogenated organic emissions to air]	0.00E+00	kg
Chromium (unspecified) [Heavy metals to air]	3.30E-08	kg
Chrysene [Group PAH to air]	4.24E-11	kg
Cobalt [Heavy metals to air]	1.98E-09	kg
Copper [Inorganic emissions to air]	2.00E-08	kg
Cyanide (unspecified) [Inorganic emissions to air]	0.00E+00	kg
Cyclohexane (hexahydro benzene) [Group NMVOC to air]	0.00E+00	kg
Cyclopentane [Group NMVOC to air]	0.00E+00	kg

Dibenz(a,h)anthracene [Group PAH to air]	2.83E-11	kg
Dichlorobenzene (m-DCB; 1,3-Dichlorobenzene) [Halogenated organic emissions to air]	2.83E-08	kg
Dichloroethane (ethylene dichloride) [Halogenated organic emissions to air]	0.00E+00	kg
Dichloromethane (methylene chloride) [Halogenated organic emissions to air]	0.00E+00	kg
1,3-dichloropropene [Organic emissions to air (group VOC)]	0.00E+00	kg
Dimethylbenz(a)anthracene [Group NMVOC to air]	3.77E-10	kg
Ethane [Group NMVOC to air]	7.30E-05	kg
Ethyl chloride [Halogenated organic emissions to air]	0.00E+00	kg
Ethyl benzene [Group NMVOC to air]	0.00E+00	kg
1,2-Dibromoethane [Halogenated organic emissions to air]	0.00E+00	kg
Ethylendichloride [Organic intermediate products]	0.00E+00	kg
Fluoranthene [Group NMVOC to air]	7.07E-11	kg
Fluorene [Group NMVOC to air]	6.59E-11	kg
Formaldehyde (methanal) [Group NMVOC to air]	1.77E-06	kg
Indeno[1,2,3-cd]pyrene [Group PAH to air]	4.24E-11	kg
iso-Butane [Group NMVOC to air]	0.00E+00	kg
iso-Butyraldehyde [Group NMVOC to air]	0.00E+00	kg
Xylene (dimethyl benzene) [Group NMVOC to air]	0.00E+00	kg
Lead [Heavy metals to air]	1.18E-08	kg
Manganese [Heavy metals to air]	8.95E-09	kg
Mercury [Heavy metals to air]	6.12E-09	kg
Methane [Organic emissions to air]	5.42E-05	kg
Methanol [Group NMVOC to air]	0.00E+00	kg
2-Methyl Naphthalene [Group NMVOC to air]	5.65E-10	kg
3-Methylcholanthrene [Group PAH to air]	4.24E-11	kg
Methylcyclohexane [Group NMVOC to air]	0.00E+00	kg
Molybdenum [Heavy metals to air]	2.59E-08	kg
Hexane (isomers) [Group NMVOC to air]	4.24E-05	kg
Nonane [Group NMVOC to air]	0.00E+00	kg
Octane [Group NMVOC to air]	0.00E+00	kg
Pentane (n-pentane) [Group NMVOC to air]	6.12E-05	kg
Naphthalene [Group PAH to air]	1.44E-08	kg
Nickel (+II) [Heavy metals to air]	4.95E-08	kg
Nitrogen oxides [Inorganic emissions to air]	6.59E-03	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	5.18E-05	kg
Tetrachloroethene (perchloroethylene) [Halogenated organic emissions to air]	0.00E+00	kg
Perylene [Group NMVOC to air]	0.00E+00	kg

Phenanthrene [Group PAH to air]	4.00E-10	kg
Phenol (hydroxy benzene) [Group NMVOC to air]	0.00E+00	kg
Phosphorus [Inorganic emissions to air]	0.00E+00	kg
Dust (> PM10) [Particles to air]	0.00E+00	kg
Dust (PM2,5 - PM10) [Particles to air]	0.00E+00	kg
Dust (PM2.5) [Particles to air]	4.47E-05	kg
Polycyclic aromatic hydrocarbons (carcinogenic) [Group PAH to air]	0.00E+00	kg
Propylene oxide [Group NMVOC to air]	0.00E+00	kg
Propane [Group NMVOC to air]	3.77E-05	kg
Dichloropropane [Halogenated organic emissions to air]	0.00E+00	kg
Pyrene [Group PAH to air]	1.18E-10	kg
Selenium [Heavy metals to air]	5.65E-10	kg
Styrene [Group NMVOC to air]	0.00E+00	kg
Sulphur dioxide [Inorganic emissions to air]	1.41E-05	kg
Sulphur oxide [Inorganic emissions to air]	0.00E+00	kg
1,1,2,2-Tetrachloroethane [Halogenated organic emissions to air]	0.00E+00	kg
Toluene (methyl benzene) [Group NMVOC to air]	8.01E-08	kg
Total organic carbon [Other emissions to air]	2.59E-04	kg
1,1,2-Trichloroethane [Halogenated organic emissions to air]	0.00E+00	kg
1,2,3-Trimethylbenzene [Group NMVOC to air]	0.00E+00	kg
1,2,4-Trimethylbenzene [Group NMVOC to air]	0.00E+00	kg
1,3,5-Trimethylbenzene [Group NMVOC to air]	0.00E+00	kg
2,2,4-Trimethylpentane [Group NMVOC to air]	0.00E+00	kg
Vanadium (+III) [Heavy metals to air]	5.42E-08	kg
Vinyl chloride (VCM; chloroethene) [Halogenated organic emissions to air]	0.00E+00	kg
NMVOC (unspecified) [Group NMVOC to air]	1.30E-04	kg
Zinc [Inorganic emissions to air]	6.83E-07	kg

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows.

Embedded Unit Processes

None.

References

EPA (2014)

U.S. Energy Information Administration (2014).
 Definitions of EIA Distillate Categories and
 Fuels Contained in the Distillate Grouping. EIA.
 Washington, DC.
http://www.eia.gov/dnav/pet/tbldefs/pet_cons



EPA (2012) [_821dsta_tbldef2.asp](#). Last Accessed: March 25, 2014
U.S. Environmental Protection Agency (2012). WebFIRE. EPA. Washington, DC.
<http://cfpub.epa.gov/webfire/> Last Accessed: March 23, 2014

EPA (2011) U.S. Environmental Protection Agency (2011). Emission factors for greenhouse gas inventories. EPA. Washington, DC.
<http://www.epa.gov/climateleadership/inventory/ghg-emissions.html>. Last Accessed: March 24, 2014



Section III: Document Control Information

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Revision History:

Original Version

How to Cite This Document: This document should be cited as:

NETL (2014). NETL Life Cycle Inventory Data – Unit Process: Combustion of Natural Gas. U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: January 2015 (version 01). www.netl.doe.gov/LCA (<http://www.netl.doe.gov/LCA>)

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