UNIT CONVERSIONS, EMISSIONS FACTORS, AND OTHER REFERENCE DATA

NOVEMBER 2004

CONTENTS

I. Carbon and CO_2 Conversions

To Convert	To	Multiply By
Carbon (short tons)	CO_2 (short tons)	3.667 or 44/12
CO_2 (short tons)	Carbon (short tons)	0.2727 or 12/44
CO_2 (metric tons)	CO_2 (short tons)	1.1023
CO_2 (short tons)	CO_2 (metric tons)	0.9072
CO_2 (pounds)	CO_2 (metric tons)	4.5359×10^{-4}
CO_2 (metric tons)	CO_2 (pounds)	2,204.6
CO_2 (pounds)	CO_2 (kilograms)	0.45359
CO_2 (kilograms)	CO_2 (pounds)	2.2046
Carbon (million metric tons carbon or carbon equivalent, MMTCE)	CO_2 (billion pounds)	8.0835
CO_2 (billion pounds)	Carbon (million metric tons carbon or equivalent, MMTCE)	0.1237

CO_2 Emission Factors by Fuel Type per Unit Volume, Mass, and Energy

Fossil Fuel	***Emission Factor***	***Emission Factor***	***Carbon Factor***	***Heat Content (HHV)***	***Carbon Content Coefficient***
Coal	(lb CO_2/ short ton)	(lb CO_2/ MMBtu)	(kg C/ short ton)	(MMBtu/ short ton)	(kg C/ MMBtu)
Anthracite Coal	5,675.29	226.16	709.04	25.09	28.26
Bituminous Coal	5,086.36	203.99	635.47	24.93	25.49
Sub-bituminous Coal	3,656.14	211.91	456.78	17.25	26.48
Lignite	2,991.33	210.47	373.72	14.21	26.30
Unspecified (industrial coking)	5,444.58	205.11	680.22	26.54	25.63
Unspecified (industrial other)	4,744.80	205.99	592.79	23.03	25.74
Unspecified (electric utility)	4,289.96	207.91	535.97	20.63	25.98
Unspecified (residential/commercial)	4,779.26	208.39	597.10	22.93	26.04
Natural Gas	(lb CO_2/ft^3)		(kg C/ft^3)	(Btu/ft^3)	
Natural Gas	0.120	116.39	0.0149	1,027	14.47
Petroleum	(lb CO_2/bbl)		(kg C/bbl)	(MMBtu/bbl)	
Distillate Fuel Oil (#1, 2, & 4)	930.15	159.66	116.21	5.825	19.95
Residual Fuel Oil (#5 & 6)	1,081.42	171.98	135.11	6.287	21.49
Petroleum Coke	1,342.84	222.88	167.77	6.024	27.85
LPG (average for fuel use)	535.79	138.75	66.60	3.861	17.25
Petroleum (Mobile Fuels)	(lb CO_2/gal)		(kg C/gal)	(MMBtu/gal)	
Motor Gasoline	19.37	154.91	2.42	0.125	19.36
Diesel Fuel	22.23	160.30	2.78	0.139	20.03
Avation Gasoline	18.15	151.01	2.27	0.120	18.87
Jet Fuel	20.89	154.69	2.61	0.135	19.33
LPG (HD-5)	12.70	138.58	1.58	0.092	17.23

Source: See end of document for table sources.

Other Conversions*:*

Energy Unit Conversions:

To Convert	To	Multiply By
mmBtu	Btu	10^6
Quads	Btu	10^{15}
kWh	Wh	10^3
MWh	kWh	10^3
GWh	MWh	10^3
TWh	MWh	10^6
kWh	Btu	3,412 (delivered**)
kWh	Quads	3.412×10^{-12} (delivered)
kWh	Btu	10,107 (primary)* (10,000 is often used for convenience)
Therms	Btu	10^5
Horsepower (hp) (mechanical)	kW	0.7456
Btu	Joule (J)	1,054.2
kWh	Joule (J)	3.6×10^6 (delivered)

Source: Primary kWh to Btu number from U.S. DOE/EIA, *2004 Annual Energy Outlook*, 2004, Appendix H.
* Based on this heat rate, electric generation is approximately 34% efficient.
** The term *Source* may also be used for Primary, and the term *Site* may also be used for Delivered energy. Electricity, delivered is the amount of electric energy delivered to the final customer after electric losses. Electricity, primary is the amount of energy (fuel) an electric generator must consume to generate and supply electric energy to consumers.

Energy (Heat) Content (kWh, Btu) of Fuels:

Fuel	Energy Content (Btu)
Coal (1 ton)	2.1×10^7
Oil (1 barrel)	5.8×10^6
Natural Gas (1 cubic foot)	0.97×10^3 (1,000 is often used for convenience)
Gasoline (1 gallon)	1.2×10^5

Mass Conversions Between the Following:

To Convert	To	Multiply By
Grams	Pounds	2.205×10^{-3}
Pounds	Grams	453.59
Pounds	Short Tons	5×10^{-4}
Short Tons	Pounds	2,000
Short Tons	Metric Tons	0.9072
Metric Tons	Short Tons	1.1023

Volume Conversions:

To Convert	To	Multiply By
Barrels (Oil)	Gallons	42
Gallons	Liters	3.785
Cubic Feet	Liters	28.317

Methane Conversions:

1 cubic foot (cf) of natural gas	= 1,030 Btu (1,000 is often used for convenience)
1 cubic foot of methane	= 1,014.6 Btu (HHV) (1,000 is often used for convenience)
1,000 cubic feet (mcf)	= 1 million Btu*
1 billion cubic feet (bcf)	= 1 trillion Btu*
1 cubic foot	19.26 grams
52 billion cubic feet (bcf)	= 1 teragram (10^{12} grams)
1 cubic foot landfill gas (50% methane)	= 500 Btu*

Source: U.S. DOE/EIA, *1997 Annual Energy Review*, 1998, Appendix B and U.S. DOE/EIA, *1996 Emissions of Greenhouse Gases in the United States*, 1997, Appendix E.
* Based on a 1,000 Btu to 1 cf conversion

II. Global Warming Potentials (GWP)

GWPs allow scientists and policymakers to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to other gases. GWP of a greenhouse gas is the ratio of radiative forcing (both direct and indirect), from one kilogram of greenhouse gas to one kilogram of CO_2 over a period of time, 100 years in this case as recommended by the Intergovernmental Panel on Climate Change (IPCC) and employed for US policymaking and reporting purposes. CO_2 was chosen as the reference gas to be consistent with the IPCC guidelines.

The IPCC has published its Third Assessment Report (TAR), providing the most current and comprehensive scientific assessment of climate change (IPCC 2001). Within this report, the GWPs of several gases were revised relative to the IPCC's Second Assessment Report (SAR) (IPCC 1996), and new GWPs have been calculated for an expanded set of gases. The table below compares both sets of GWP values. Government documents still frequently use the SAR values (e.g., national GHG inventory reports), but the TAR values are also now being used in non-government publications.

List of GWPs of the six Kyoto-covered gases:

Chemical	GWP, 100 Years (SAR)	GWP, 100 Years (TAR)
CO_2	1	1
Methane	21	23
N_2O	310	296
HFCs	140-12,100	120 – 12,000
SF_6	23,900	22,200
PFCs	6,500-9,200	5,700 – 11,900

Source: U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2002*, Annex 6.

To determine the carbon equivalent of a greenhouse gas (mass):

1. Convert million metric tons (MMT) of greenhouse gas to MMT CO_2-equivalent = MMT of GHG x GWP

2. Convert CO_2-equivalent to Carbon Equivalent = CO_2 x 0.2727

For example:

1. 2 MMT methane x 21 (SAR GWP of Methane) = 42 MMT CO_2-equivalent

2. 42 MMT CO_2 x 0.2727 = 11.45 MMTCE

III. Energy and Emission Reduction Equivalents

NOTE: Equivalents below have been rounded for convenience.

Annual Emissions and Fuel Consumption for an Average Passenger Vehicle:
Passenger vehicle fleet is 63.4% cars and 36.6% light truck (includes SUVs and minivans)
Calculations are based on a weighted average of cars and light trucks.

Average GHG emissions– CO_2E:	12,100 lbs/year (5.5 metric tons /year)
Average GHG emissions– CE:	3,300 lbs/year (1.5 metric tons/year)
Average CO_2 emissions:	11,470 lbs/year (5.2 metric tons/year)
Average Carbon emissions:	3,100 lbs/year (1.4 metric tons/year)
Average fuel consumption:	~600 gallons/year

Recommend: 1.5 MMTCE = annual GHG (CE) emissions equivalent to those of 1 million vehicles

Source: U.S. EPA, *Greenhouse Gas Emissions from a Typical Passenger Vehicle*, 2004.

Average Annual CO_2 Emissions for an Average Household:
Averages per U.S. household (includes single-family and multi-unit housing)
Averages include emissions from electricity and other sources (natural gas, petroleum, etc.)
Average loss rate for electricity is 8 - 9 percent.

Average CO_2 emissions:	22,880 lbs/year (10.4 metric tons/ year)
Average CO_2 emissions from electricity only:	16,290 lbs/ year (7.4 metric tons/ year)
Average Carbon emissions:	6,240 lbs/year (2.8 metric tons/year)
Average kWh:	10,660 kWh/ year (100 mmBtu/ year, delivered)

Source: EPA E-Grid 2002; RECS, 2001; Buildings Energy Databook, 2004

Average Annual CO_2 Emissions for an Average Single-Family Home:

Average CO_2 emissions:	24,900 lbs/year (11.3 metric tons/ year)
Average Carbon emissions:	6,800 lbs/year (3.1 metric tons/year)
Average kWh:	11,965 kWh/ year (124 mmBtu/ year, delivered)

Recommend: 3.1 MMTCE = annual Carbon emissions equivalent to those of 1 million homes

Source: RECS, 2001

The average single-family home adds more than twice as much greenhouse gas (CE) emissions to the atmosphere as the average passenger vehicle.

Emission Reductions as Compared to Tree Plantings:

1 acre of forest sequesters 2,200 lbs C /year (1.0 metric ton C/ year)

Source: R. Birdsey, 1996
Values are for average management of forest after being established on previous croplands or pasture.
Values are calculated over 120-year period.

Average Power Plant:

Average plant size (Coal):	600 MW
Average Capacity Factor (Coal):	75%
Average annual plant MWh (Coal):	4 million MWh/ year
Average NOx emissions rate (all sources):	3.0 lbs/ MWh
Average SO_2 emissions rate (all sources):	6.0 lbs/ MWh
Average CO_2 Emissions Factor (all sources):	1,392 lbs/MWh (1,515 lbs/MWh, delivered)

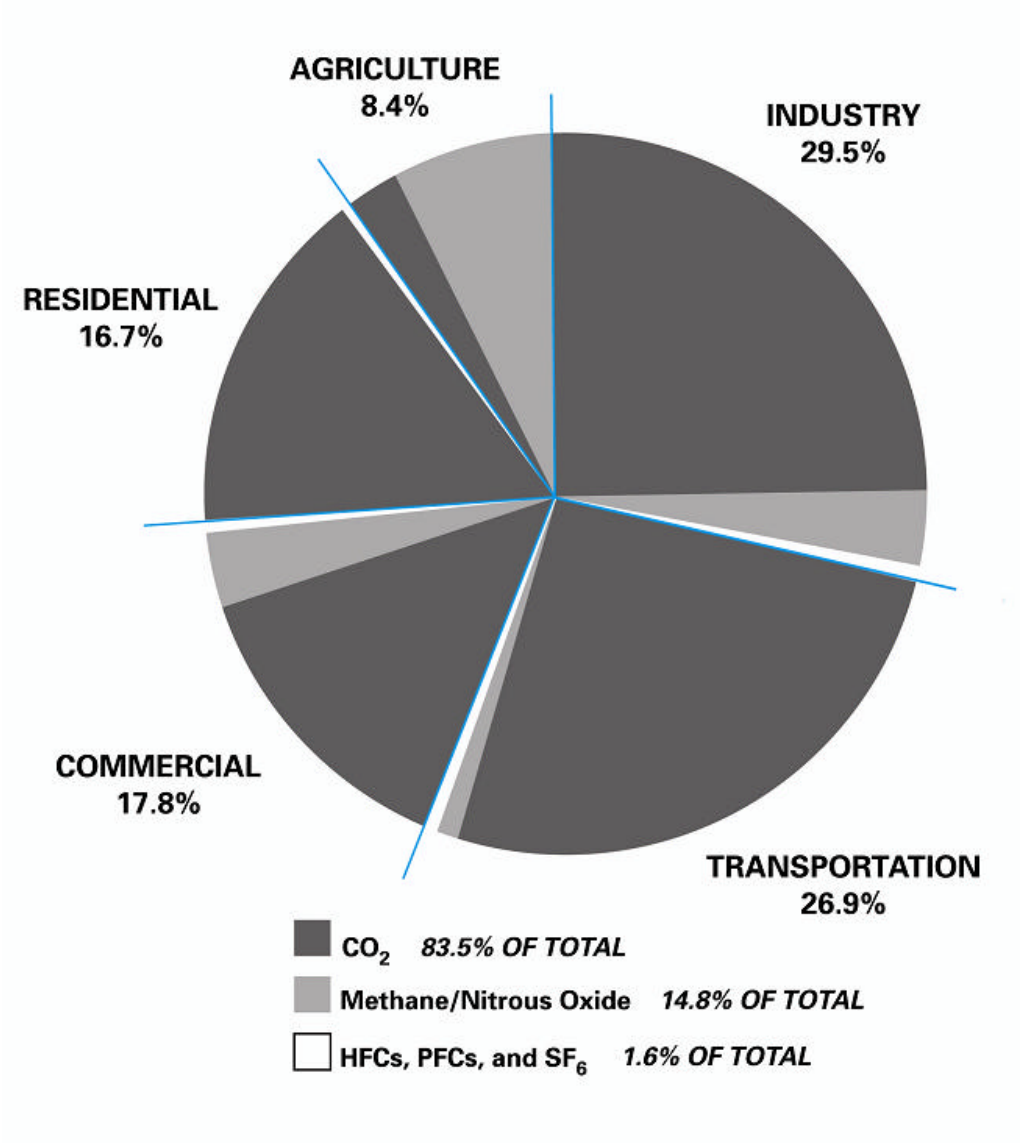
Source: U.S. EPA E-Grid, 2002, EIA *Electric Power Annual* 2001, 2003

IV. U.S. Greenhouse Gas Emissions

Read headings carefully for differences between GHG and CO_2 and the treatment of electricity-related emissions.

U.S. Greenhouse Gas Emissions by Sector and by Gas (Includes Electricity Used by Sector), 2002

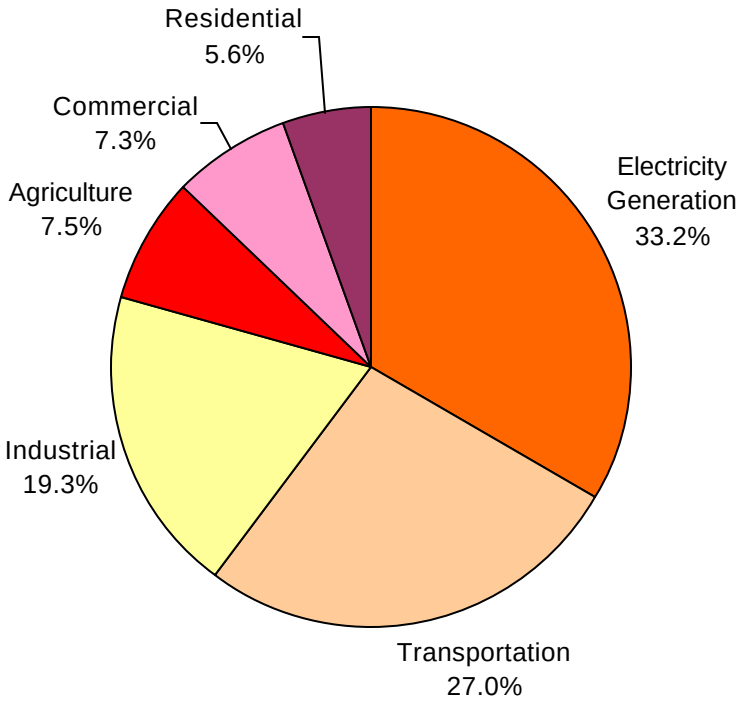
The following section presents the GHG emissions associated with energy use by each sector, which includes the emissions related to that sector's electricity consumption.



Source: U.S. EPA *U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2002*, 2004

Read headings carefully for differences between GHG and CO_2 and the treatment of electricity-related emissions. CO_2 is the predominant greenhouse gas, accounting for 83.5%, but not the only GHG.

U.S. Greenhouse Gas Emissions by Sector with Electricity Separated from Other Sectors, 2002



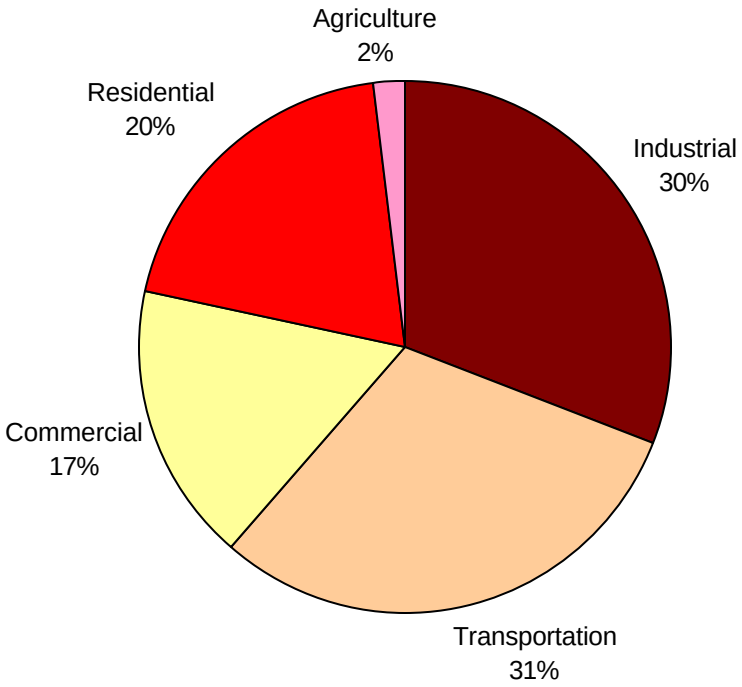
Source: U.S. EPA *U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2002*, 2004

SECTOR	MMTCO2E
Electricity Generation	2,286.8
Transportation	1,861.4
Industrial	1,331.9
Agriculture	519.8
Commercial	500.4
Residential	387.7
TOTAL	6,888.0

NOTE: Does not include U.S. territories.

Read headings carefully for differences between GHG and CO_2 and the treatment of electricity-related emissions. CO_2 is the predominant greenhouse gas, accounting for 83.5%, but not the only GHG.

U.S. CO2 Emissions by Sector (Includes Electricity Used by Sector), 2002



Source: U.S. EPA U.S. *Greenhouse Gas Emissions and Sinks: 1990 – 2002*, 2004

SECTOR	MMTCO2
Industrial	1,761.3
Transportation	1,767.5
Commercial	957.1
Residential	1,135.1
Agriculture	114.9
TOTAL	5,735.9

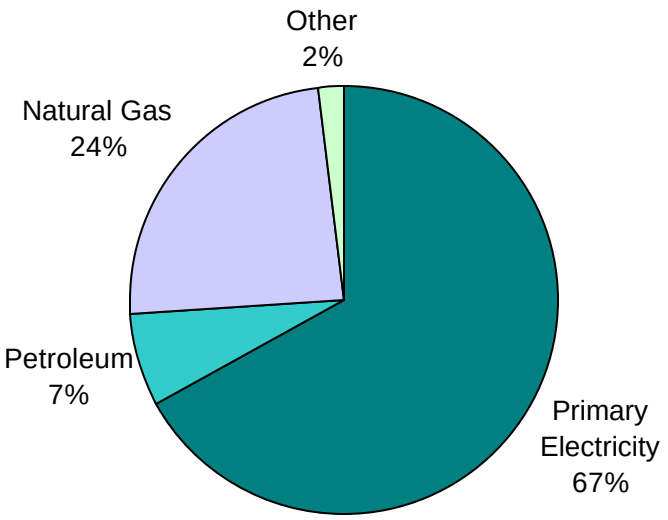
NOTE: Does not include U.S. territories.

V. Residential, Commercial, and Industrial Sector Energy

RESIDENTIAL SECTOR:

Total energy consumption, 2002:	20.88 Quads
Energy Intensity, 2002:	100 mmBtu per household, delivered

Residential Fuel Mix, 2002



Source: U.S. DOE/EIA, 2004 *Annual Energy Outlook*, U.S. DOE/EIA, 2004, Table A4.

Residential Energy Expenditures

Sector:	$160 billion
	$100 billion for electricity
Average household:	$1,500
	$940 for electricity

Electricity accounts for 63% of residential energy expenditures.

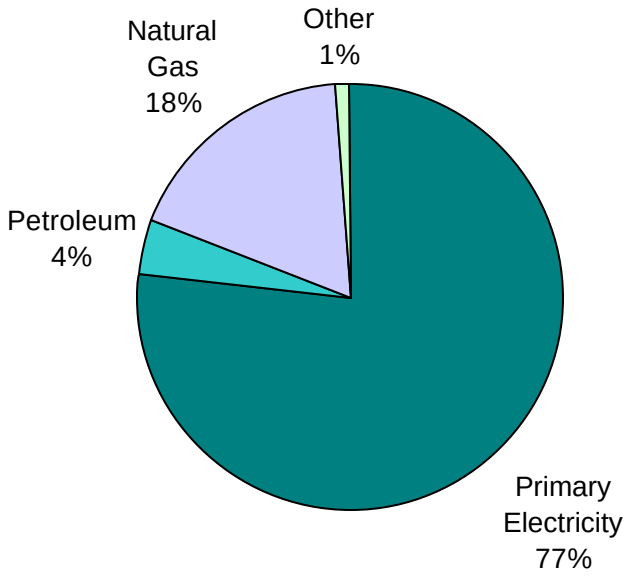
Sources: U.S. DOE/EIA, *2001 Residential Energy Consumption Survey (RECS)*, 2001

COMMERCIAL SECTOR:

Total energy consumption, 2002: 17.4 Quads (8.25 Quads, delivered)
Energy Intensity, 2002: 115 delivered kBtu per square foot

Source: U.S. DOE/EIA, 2004 *Annual Energy Outlook*, 2004, Table A5.

Commercial Fuel Mix, 2002



Source: U.S. DOE/EIA, 2004 *Annual Energy Outlook*, 2004, Table A2.

Commercial Energy Expenditures

Sector: $81.6 billion
$66.4 billion for electricity

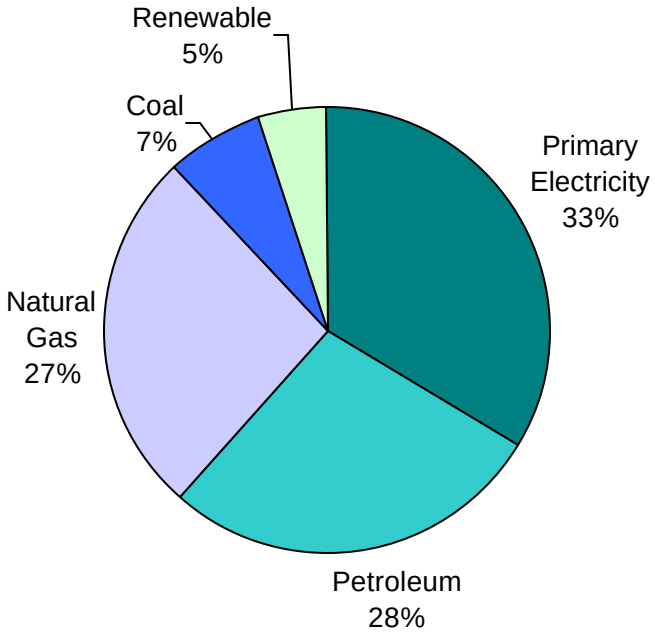
Sources: U.S. DOE/EIA, *1999 Commercial Building Energy Consumption Survey (CBECS)*, Table C2

INDUSTRIAL SECTOR:

Total energy consumption, 2002: 32.5 Quads (24.9 Quads delivered)

Source: U.S. DOE/EIA, 2004 *Annual Energy Outlook*, 2004, Table A2.

Industrial Fuel Mix, 2002



Source: U.S. DOE/EIA, 2004 *Annual Energy Outlook*, 2004, Table A2.

VI. List of Abbreviations

Btu	British Thermal Unit
KBtu	Thousand Btu
mmBtu	Million Btu
TBtu	Trillion Btu
Quad	Quadrillion Btu
kWh	Kilowatt-hour
MW	Megawatt
cf	Cubic Feet
HHV	High Heating Value
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
MMT	Million Metric Tons
MMTCE	Million Metric Tons Carbon Equivalent
C	Carbon
CE	Carbon Equivalent
CO_2	Carbon Dioxide
CH_4	Methane
N_2O	Nitrous Oxide
NO_x	Nitrogen Oxides
PFC	Perfluorocarbon
SF_6	Sulfur Hexafluoride
LPG	Liquefied Petroleum Gas

Sources for CO_2 Emissions Factors:

Coal - Carbon Content Coefficients from the *Documentation for Emissions of Greenhouse Gases in the United States 2002*, DOE/EIA-0638(2002), Energy Information Administration, Office of Integrated Analysis and Forecasting, U.S. Department of Energy, January 2004. Heat Contents calculated by EPA based on the same approach used to determine Carbon Content Coefficients. The approach utilizes coal physical characteristics from the *CoalQual Database Version 2.0*, U.S. Geological Survey, 1998, and coal production data from the *Coal Industrial Annual*, U.S. Department of Energy, Energy Information Administration, Washington, DC, 2002 (year 2000 data used).

Natural Gas and Petroleum (except LPG, Motor Gasoline, and Diesel Fuel) - Heat Contents from the *Annual Energy Review 2002, DOE/EIA 0384(2002)*, U.S. Department of Energy, Energy Information Administration, Washington, DC, October 2003. Carbon Content Coefficients from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002*, EPA430-R-04-003, U.S. EPA, Washington, DC, April 2004.

LPG - Heat Contents and Carbon Content Coefficients for LPG components from *Characteristics of Compounds*, V.B. Guthrie (ed.), Petroleum Products Handbook, New York, NY: Mcgraw Hill, 1960, p. 3-3. Carbon Content Coefficient value for LPG (average for fuel use) based on an assumed composition of 90% propane, 4.1% isobutane, and 5.4% n-butane by energy. Heat Content value for LPG (average for fuel use) based on an assumed composition of 91% propane, 3.8% isobutane, and 4.8% n-butane by volume. The assumed composition for LPG (average for fuel use) was based on consumption of LPG components for fuel use from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002*, EPA430-R-04-003, U.S. EPA, Washington, DC, April 2004. An average of years 2000-2003 was used. Heat Content and Carbon Content Coefficient for mobile source LPG (HD-5) based on a LPG (HD-5) composition of 95% Propane and 5% n-Butane by volume. This is an assumed composition for mobile source LPG taken from the *Code of Federal Regulations* (CFR) 40 CFR Part 86, Appendix XVI, 7-1-01 edition. Heat Content for LPG (HD-5) based on a weighted average volume percent (95% Propane and 5% n-Butane), Carbon Content Coefficient for LPG (HD-5) based on a weighted average energy percent (94.4% Propane and 5.6% n-Butane).

Motor Gasoline, and Diesel Fuel - The *Code of Federal Regulations* (CFR) 40 CFR 600.113-78 gives carbon content values of 2,421 g C/gallon for gasoline and 2,778 g C/gallon for diesel fuel. Heat Contents from the *Annual Energy Review 2002, DOE/EIA 0384(2002)*, U.S. Department of Energy, Energy Information Administration, Washington, DC, October 2003.

Note: CO_2 emission factors assume a carbon oxidation factor of 99% for all fuels except natural gas and LPG that assume a 99.5% carbon oxidation factor.

Values for some fuels may change over time. Factors shown here are appropriate for years 2000-2004.