Carbon coefficients: Coal

Climate Mitigation Services
Rick Heede
Carbon Majors Project
21-May-12

Calculation of Coal Coefficients by Coal Rank (EPA values)

(prior to adjusting for oxidation and non-fuel uses)

	Million Btu/sh ton	kgC/million Btu	kgC/ton	kgC/tonne	Percent C	3.664191 CO2/C Tonne CO2/tonne	Non-energy uses (100% oxidation) adjustment factor	Adjusted Coal Coefficient tonne CO2/tonne coal	Not including methane, included elsewhere
Lignite	14.21	26.28	373.4	411.6	41.2%	1.5082	0.9998	1.5080	Lignite
Sub-bituminous	17.25	26.46	456.4	503.1	50.3%	1.8434	0.9998	1.8431	Sub-bituminous
Bituminous	24.93	25.47	635.0	699.9	70.0%	2.5647	0.9998	2.5643	Bituminous
Anthracite	25.09	28.24	708.4	780.9	78.1%	2.8614	0.9998	2.8609	Anthracite
Metallurgical coal	26.28	25.54	671.2	739.8	74.0%	2.7108	0.9998	2.7104	Metallurgical coal
Thermal coal	19.73	25.74	507.8	559.8	56.0%	2.0510	0.9998	2.0507	Thermal coal
	prod weighted av	25.99							

year	U.S. ave. utility coal million Btu/ton
1950	23.94
1955	24.06
1960	23.93
1965	23.78
1970	22.57
1975	21.78
1980	21.30
1985	20.96
1990	20.78
1995	20.54
2000	20.51
2005	19.99
2010	19.61
arithmetic average	20.32
average of bit. & su	21.09
ave bit & sub-bit., l	20.66

Carbon Majors applies IPCC-derived coefficients in “Coal Emissions” worksheet

Calculation of Coal Coefficients by Coal Rank (IPCC default values)

(prior to adjusting for oxidation and non-fuel uses)

	IPCC default value GJ/tonne	IPCC values kgC/GJ	calculation kgC/tonne	Percent C	3.664191 CO2/C Tonne CO2/tonne	Non-energy uses (100% oxidation) adjustment factor	Adjusted Coal Coefficient tonne CO2/tonne coal	Not including methane, included elsewhere
Lignite	11.90	27.60	328.44	32.8%	1.2035	0.9998	1.203	Lignite
Sub-bituminous	18.90	26.20	495.18	49.5%	1.8144	0.9998	1.814	Sub-bituminous
Bituminous	25.80	25.80	665.64	66.6%	2.4390	0.9998	2.439	Bituminous
Anthracite	26.70	26.80	715.56	71.6%	2.6219	0.9998	2.622	Anthracite
Metallurgical coal	28.20	25.80	727.56	72.8%	2.6659	0.9998	2.665	Metallurgical coal
Thermal coal	22.35	26.00	581.10	58.1%	2.1293	0.9998	2.129	Thermal coal

thermal coal is assumed to be the average of bituminous and sub-bituminous

IPCC does not specify average boiler fuel default value, and figure may be revised

linked to “Coal Emissions” worksheet, column “FT” (2010)

Thermal: Sub-bit	14.8%
Thermal: Bituminou	14.5%

Average of the EPA and IPCC coefficients

Calculation of Coal Coefficients by Coal Rank (IPCC default values)

calculation kgC/tonne	Percent C	3.664191 CO2/C Tonne CO2/tonne	Non-energy uses (100% oxidation) adjustment factor	Coal Coefficient Average EPA & IPCC tonne CO2/tonne coal	Not including methane, included elsewhere	IPCC / EPA values percent	
370.02	37.0%	1.3558	0.9998	1.3556	Lignite	79.80%	
499.13	49.9%	1.8289	0.9998	1.8286	Sub-bituminous	98.43%	0.852
682.79	68.3%	2.5019	0.9998	2.5015	Bituminous	95.10%	0.873
748.23	74.8%	2.7417	0.9998	2.7412	Anthracite	91.63%	
733.69	73.4%	2.6884	0.9998	2.6879	Metallurgical coal	98.34%	
570.43	57.0%	2.0902	0.9998	2.0898	Thermal coal	103.81%	

International Energy Agency

www.iea.org/stats/defs/sources/coal.asp

	kcal /kg low value	kcal /kg high value	kJ/kg low value	kJ/kg high value	btu per lb			EPA values Million Btu/sh ton EPA 2011 App 4 Table A-249	Tg C / Q Btu tC / billion Btu Table A-251
Coking Coal					12,500	Lignite		25.00	26.65
Lignite		4,165		17,435	6,435	Sub-bituminous		12.87	26.50
Patent Fuel and Brown Coal / Peat Briquettes					-	Bituminous		-	25.44
Peat					-	Anthracite		-	28.28
Other Bituminous Coal and Anthracite	5,700		23,865		12,815	Metallurgical coal	col	25.63	31.00
Sub-Bituminous Coal	4,165	5,700	17,435	23,865	12,985	“Unspecified”	ex|	25.97	25.34

EPA Climate Leaders: Emission Factors for Greenhouse Gas Inventories

EPA Climate Leaders data, calculations by E Source / Richard Heede
www.epa.gov/climateleaders/guidance/ghg-emissions.html
Last Modified: 21 May 2012

Stationary Combustion Emission Factors

Fuel Type	Heating Value	CO_2 Factor	CO_2 Factor	CO_2 Factor	CO_2 Factor	CH_4 Factor	N_2O Factor	CO_2 Factor	CH_4 Factor	N_2O Factor
	mmBtu/short ton	kg CO_2/mmBtu	kg C/million Btu	kg C/ton	kg C/tonne	g CH_4 /mmBtu	g N_2O /mmBtu	kg CO_2 /short ton	g CH_4 /short ton	g N_2O /short ton
Coal and Coke										
Anthracite Coal	25.09	103.54	28.24	708.43	780.90	11	1.6	2,598	276	40
Bituminous Coal	24.93	93.40	25.47	634.98	699.94	11	1.6	2,328	274	40
Sub-bituminous Coal	17.25	97.02	26.46	456.39	503.08	11	1.6	1,674	190	28
Lignite Coal	14.21	96.36	26.28	373.40	411.60	11	1.6	1,369	156	23
Mixed (Commercial Sector)	21.39	95.26	25.98	555.66	612.51	11	1.6	2,038	235	34
Mixed (Electric Power Sector)	19.73	94.38	25.74	507.80	559.75	11	1.6	1,862	217	32
Mixed (Industrial Coking)	26.28	93.65	25.54	671.15	739.81	11	1.6	2,461	289	42
Mixed (Industrial Sector)	22.35	93.91	25.61	572.37	630.93	11	1.6	2,099	246	36
Coke	24.80	102.04	27.83	690.10	760.70	11	1.6	2,531	273	40

EIA AER 2010, Table 7.2: Coal Production; data for 2010

percent by rank	million tons	rank
6.7%	73.2	lignite
46.2%	501.2	sub-bituminous
46.9%	509.0	bituminous
0.2%	1.9	anthracite
100%	1,085.3	total

EPA (2011) US Inventory, Annex 4, Table A-251: 2009 Potential Emissions 2009

	Apparent consumptior	Percent	Carbon Coefficients	Potential emissions	Percent
rank	Q Btu	% of consumption	Tg C / Q Btu	Tg CO2-e	% of pot. emissions
Lignite	0.9	4.1%	26.65	85.31	4.2%
Sub-bituminous	8.6	40.5%	26.50	839.40	41.4%
Bituminous	11.8	55.2%	25.44	1,100.24	54.2%
Anthracite	0.0	0.2%	28.28	4.56	0.2%
Coke		0.0%	31.00	-	0.0%
Unspecified		0.0%	25.34	-	0.0%
total	21.3	100.0%		2,029.5	100.0%

TABLE 2.2
DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN THE ENERGY INDUSTRIES
(kg of greenhouse gas per TJ on a net calorific basis)

Fuel	CO_2 Default emission factor	CO_2 Lower	CO_2 Upper	CH_4 Default emission factor	CH_4 Lower	CH_4 Upper	N_2O Default emission factor	N_2O Lower	N_2O Upper
Anthracite	98 300	94 600	101000	1	0.3	3	r 1.5	0.5	5
Coking Coal	94 600	87 300	101000	1	0.3	3	r 1.5	0.5	5
Other Bituminous Coal	94 600	89 500	99 700	1	0.3	3	r 1.5	0.5	5
Sub-Bituminous Coal	96 100	92 800	100000	1	0.3	3	r 1.5	0.5	5
Lignite	101 000	90 900	115000	1	0.3	3	r 1.5	0.5	5

IPCC (2006) Guidelines, Vol. 2: Energy, Table 2.2: Default Emissions Factors for Stationary Combustion in the Energy Industries, page 2.15; kg CO2/TJ

TABLE 1.2
DEFAULT NET CALORIFIC VALUES (NCVs) AND LOWER AND UPPER LIMITS OF THE 95% CONFIDENCE INTERVALS [1]

Fuel type English description		Net calorific value (TJ/Gg)	Lower	Upper
Crude Oil		42.3	40.1	44.8
Orimulsion		27.5	27.5	28.3
Natural Gas Liquids		44.2	40.9	46.9
Gasoline	Motor Gasoline	44.3	42.5	44.8
Gasoline	Aviation Gasoline	44.3	42.5	44.8
Gasoline	Jet Gasoline	44.3	42.5	44.8
Jet Kerosene		44.1	42.0	45.0
Other Kerosene		43.8	42.4	45.2
Shale Oil		38.1	32.1	45.2
Gas/Diesel Oil		43.0	41.4	43.3
Residual Fuel Oil		40.4	39.8	41.7
Liquefied Petroleum Gases		47.3	44.8	52.2
Ethane		46.4	44.9	48.8
Naphtha		44.5	41.8	46.5
Bitumen		40.2	33.5	41.2
Lubricants		40.2	33.5	42.3
Petroleum Coke		32.5	29.7	41.9
Refinery Feedstocks		43.0	36.3	46.4
Other Oil	Refinery Gas [2]	49.5	47.5	50.6
Other Oil	Paraffin Waxes	40.2	33.7	48.2
Other Oil	White Spirit and SBP	40.2	33.7	48.2
Other Oil	Other Petroleum Products	40.2	33.7	48.2
Anthracite		26.7	21.6	32.2
Coking Coal		28.2	24.0	31.0
Other Bituminous Coal		25.8	19.9	30.5
Sub-Bituminous Coal		18.9	11.5	26.0
Lignite		11.9	5.50	21.6
Oil Shale and Tar Sands		8.9	7.1	11.1
Brown Coal Briquettes		20.7	15.1	32.0

IPCC (2006) Guidelines, Chapter 1: Introduction, Table 1.2

TABLE 1.3
DEFAULT VALUES OF CARBON CONTENT

Fuel type English description	Default carbon content [1] (kg/GJ)	Lower	Upper
Crude Oil	20.0	19.4	20.6
Orimulsion	21.0	18.9	23.3
Natural Gas Liquids	17.5	15.9	19.2
Motor Gasoline	18.9	18.4	19.9
Aviation Gasoline	19.1	18.4	19.9
Jet Gasoline	19.1	18.4	19.9
Jet Kerosene	19.5	19	20.3
Other Kerosene	19.6	19.3	20.1
Shale Oil	20.0	18.5	21.6
Gas/Diesel Oil	20.2	19.8	20.4
Residual Fuel Oil	21.1	20.6	21.5
Liquefied Petroleum Gases	17.2	16.8	17.9
Ethane	16.8	15.4	18.7
Naphtha	20.0	18.9	20.8
Bitumen	22.0	19.9	24.5
Lubricants	20.0	19.6	20.5
Petroleum Coke	26.6	22.6	31.3
Refinery Feedstocks	20.0	18.8	20.9
Refinery Gas [2]	15.7	13.3	19.0
Paraffin Waxes	20.0	19.7	20.3
White Spirit & SBP	20.0	19.7	20.3
Other Petroleum Products	20.0	19.7	20.3
Anthracite	26.8	25.8	27.5
Coking Coal	25.8	23.8	27.6
Other Bituminous Coal	25.8	24.4	27.2
Sub-Bituminous Coal	26.2	25.3	27.3
Lignite	27.6	24.8	31.3
Oil Shale and Tar Sands	29.1	24.6	34

IPCC (2006) Guidelines, Chapter 1: Introduction, Table 1.3

TABLE 1.4
DEFAULT CO_2 EMISSION FACTORS FOR COMBUSTION [1]

	Fuel type English description	Default carbon content (kg/GJ)	Default carbon oxidation factor	Effective CO_2 emission factor (kg/TJ) [2]		
				Default value [3]	95% confidence interval	
		A	B	C=A*B*44/12*1000	Lower	Upper
	Crude Oil	20.0	1	73 300	71 100	75 500
	Orimulsion	21.0	1	77 000	69 300	85 400
	Natural Gas Liquids	17.5	1	64 200	58 300	70 400
Gasoline	Motor Gasoline	18.9	1	69 300	67 500	73 000
Gasoline	Aviation Gasoline	19.1	1	70 000	67 500	73 000
Gasoline	Jet Gasoline	19.1	1	70 000	67 500	73 000
	Jet Kerosene	19.5	1	71 500	69 700	74 400
	Other Kerosene	19.6	1	71 900	70 800	73 700
	Shale Oil	20.0	1	73 300	67 800	79 200
	Gas/Diesel Oil	20.2	1	74 100	72 600	74 800
	Residual Fuel Oil	21.1	1	77 400	75 500	78 800
	Liquefied Petroleum Gases	17.2	1	63 100	61 600	65 600
	Ethane	16.8	1	61 600	56 500	68 600
	Naphtha	20.0	1	73 300	69 300	76 300
	Bitumen	22.0	1	80 700	73 000	89 900
	Lubricants	20.0	1	73 300	71 900	75 200
	Petroleum Coke	26.6	1	97 500	82 900	115 000
	Refinery Feedstocks	20.0	1	73 300	68 900	76 600
Other Oil	Refinery Gas	15.7	1	57 600	48 200	69 000
Other Oil	Paraffin Waxes	20.0	1	73 300	72 200	74 400
Other Oil	White Spirit & SBP	20.0	1	73 300	72 200	74 400
	Other Petroleum Products	20.0	1	73 300	72 200	74 400
	Anthracite	26.8	1	98 300	94 600	101 000
	Coking Coal	25.8	1	94 600	87 300	101 000
	Other Bituminous Coal	25.8	1	94 600	89 500	99 700
	Sub-Bituminous Coal	26.2	1	96 100	92 800	100 000
	Lignite	27.6	1	101 000	90 900	115 000
	Oil Shale and Tar Sands	29.1	1	107 000	90 200	125 000

IPCC (2006) Guidelines, Chapter 1: Introduction, Table 1.4

Table A-269: Conversion Factors to Energy Units

Fuel Type (Units)	Factor
Solid Fuels (Million Btu/Short ton)	
Anthracite coal	22.573
Bituminous coal	23.89
Sub-bituminous coal	17.14
Lignite	12.866
Coke	24.8
Natural Gas (Btu/Cubic foot)	**1,027**
Liquid Fuels (Million Btu/Barrel)	
Motor gasoline	5.150
Aviation gasoline	5.048
Kerosene	5.670
Jet fuel, kerosene-type	5.670
Distillate fuel	5.825
Residual oil	6.287
Naphtha for petrochemicals	5.248
Petroleum coke	6.024
Other oil for petrochemicals	5.825
Special naphthas	5.248
Lubricants	6.065
Waxes	5.537
Asphalt	6.636
Still gas	6.000
Misc. products	5.796

EPA (2011) U.S. Inventory, Annex 6: Emission Factors, table A-269.

In pounds of carbon dioxide per million Btu, U.S. average factors are 227.4 for anthracite, 216.3 for lignite, 211.9 for subbituminous coal, and 205.3 for bituminous coal. Coking coal US Average (1992): 206.2 lb CO2 per million Btu. Coal used to produce coke is virtually all bituminous in rank; less than 1 percent is anthracite.

www.engineeringtoolbox.com/classification-coal-d_164.html

Typical Moisture Content in Coal

- Anthracite Coal : 2.8 - 16.3 weight %
- Bituminous Coal : 2.2 - 15.9 weight %
- Lignite Coal : 39 weight %

Typical Fixed Carbon Content in Coal

- Anthracite Coal : 80.5 - 85.7 weight %
- Bituminous Coal : 44.9-78.2 weight %
- Lignite Coal : 31.4 weight %

Typical Bulk Density of Coal

- Anthracite Coal : 50 - 58 (lb/ft3), 800 - 929 (kg/m3)
- Bituminous Coal : 42 - 57 (lb/ft3), 673 - 913 (kg/m3)
- Lignite Coal : 40 - 54 (lb/ft3), 641 - 865 (kg/m3)

Typical Ash Content in Coal

- Anthracite Coal : 9.7 - 20.2 weight %
- Bituminous Coal : 3.3-11.7 weight %
- Lignite Coal : 4.2 weight %

Table FE5. Average Carbon Dioxide Emission Factors for Coal-Consuming Sector and State, 1980 and 1992

State	Sector									
	Electric Utilities		Industrial				Residential/Commercial		State Average[b]	
			Coking Coal[a]		Other Coal					
	1980	1992	1980	1992	1980	1992	1980	1992	1980	1992
Alabama	205.0	205.3	205.5	206.1	205.5	205.7	205.4	205.5	205.1	205.4
Alaska	214.0	214.0	–	–	–	–	–	214.0	214.0	214.0
Arizona	208.0	207.7	–	–	209.2	206.7	–	208.6	208.1	207.6
Arkansas	212.7	212.7	–	–	201.4	205.2	205.3	222.3	210.7	212.5
California	–	–	208.7	–	205.6	204.2	204.5	204.1	207.5	204.1
Colorado	211.5	209.8	212.6	–	212.6	212.5	212.6	211.0	211.7	209.9
Connecticut	–	204.9	–	–	–	204.7	226.1	220.2	226.1	205.2
Delaware	206.0	206.9	–	–	205.9	207.4	221.8	221.1	206.0	207.0
District of Columbia	–	–	–	–	205.0	–	205.5	206.3	205.4	206.3
Florida	204.0	204.4	–	–	204.2	205.1	205.0	205.7	204.0	204.5
Georgia	204.3	204.8	–	–	204.9	204.9	204.7	204.9	204.3	204.8
Hawaii	–	–	–	–	–	204.4	–	–	–	204.4
Idaho	–	–	–	–	212.6	212.2	205.4	205.0	210.7	211.3
Illinois	207.1	206.2	205.2	206.5	204.2	203.7	203.9	203.9	206.7	205.9
Indiana	204.0	205.6	205.0	206.0	203.7	204.5	203.7	203.8	204.3	205.5
Iowa	207.2	211.1	–	–	205.7	208.3	205.1	204.2	207.0	210.7
Kansas	209.2	210.9	–	–	201.9	205.3	202.2	202.9	209.0	210.8
Kentucky	204.0	204.1	204.6	206.3	205.4	205.4	204.6	204.6	204.1	204.2
Louisiana	212.7	212.9	–	–	203.9	210.9	201.3	–	212.1	212.8
Maine	–	–	–	–	206.0	204.9	216.2	213.0	207.9	205.3
Maryland	206.6	207.0	205.9	–	206.1	208.4	210.6	211.7	206.3	207.1
Massachusetts	206.4	206.8	–	–	206.3	207.0	218.2	214.1	207.6	206.9
Michigan	206.0	208.9	205.5	–	204.8	205.3	205.0	205.0	205.7	208.5
Minnesota	212.9	213.0	–	–	211.6	211.8	208.6	212.3	212.7	212.9
Mississippi	204.7	204.5	–	–	204.0	204.6	202.6	227.4	204.7	204.5
Missouri	204.5	206.2	205.2	–	203.6	204.5	202.1	203.4	204.5	206.1
Montana	213.9	213.5	–	–	211.2	211.4	205.6	213.3	213.7	213.5
Nebraska	211.7	212.7	–	–	212.3	213.1	212.6	219.2	211.7	212.7
Nevada	208.2	208.4	–	–	204.5	204.1	208.4	204.1	208.1	208.3
New Hampshire	206.9	206.3	–	–	207.0	207.1	227.2	225.4	207.0	206.5
New Jersey	206.6	206.6	–	–	218.3	207.3	227.2	227.1	207.1	206.8
New Mexico	205.7	205.7	–	–	212.0	212.7	209.8	206.3	205.7	205.7
New York	205.7	206.1	205.5	206.1	206.9	207.0	218.9	218.0	206.3	206.5
North Carolina	205.6	205.8	–	–	204.8	205.7	204.9	206.2	205.6	205.8
North Dakota	218.8	218.8	–	–	218.8	218.3	218.5	216.8	218.8	218.6
Ohio	204.4	204.4	205.4	206.4	204.0	204.5	203.8	205.5	204.5	204.6
Oklahoma	210.5	212.6	–	–	202.2	207.5	205.7	207.0	210.0	212.3
Oregon	212.7	212.9	–	–	212.7	211.5	205.6	204.1	212.5	212.8
Pennsylvania	206.1	206.2	205.7	206.1	207.9	208.5	221.2	219.7	206.4	206.7
Rhode Island	–	–	–	–	210.0	–	223.9	227.4	217.2	227.4
South Carolina	204.9	205.0	–	–	205.0	205.3	204.8	205.3	204.9	205.0
South Dakota	218.1	218.8	–	–	210.5	212.7	212.0	212.8	217.6	217.9
Tennessee	204.0	204.0	210.2	–	204.8	205.5	204.5	204.6	204.1	204.2
Texas	213.0	212.9	209.8	–	212.3	212.3	213.7	211.0	212.8	212.9
Utah	204.1	204.3	210.8	205.6	205.2	204.1	204.1	204.1	205.7	204.4
Vermont	205.7	–	–	–	207.8	212.2	227.4	227.4	216.0	216.8
Virginia	205.9	206.0	206.2	206.2	205.1	206.2	205.0	206.3	205.7	206.1
Washington	208.7	209.3	–	–	206.3	205.8	204.3	206.9	208.3	209.1
West Virginia	206.9	207.0	205.3	206.7	205.4	206.6	205.0	210.2	206.6	207.0
Wisconsin	207.0	209.9	205.4	–	205.5	206.1	205.8	204.9	206.8	209.5
Wyoming	212.7	212.0	–	–	212.0	212.5	212.3	212.7	212.6	212.1
U.S. Average[b]	**206.7**	**207.7**	**205.8**	**206.2**	**205.9**	**207.1**	**210.6**	**211.2**	**206.5**	**207.6**

[a]No allowances have been made for carbon retained in non-energy coal chemical byproducts from the coal carbonization process.
[b]Weighted average. The weights used are consumption values by sector.

B.D. Hong and E. R. Slatick (1994) Carbon Dioxide Emission Factors for Coal, originally published in Energy Information Administration, Quarterly Coal Report, January-April 1994, DOE/EIA-0121(94/Q1) (Washington, DC, August 1994), pp. 1-8.)

Schweinfurth, S.P., 2009, An introduction to coal quality, in Pierce, B.S., and Dennen, K.O., eds., The National Coal Resource Assessment Overview: U.S. Geological Survey Professional Paper 1625–F, Chapter C, 16 p.

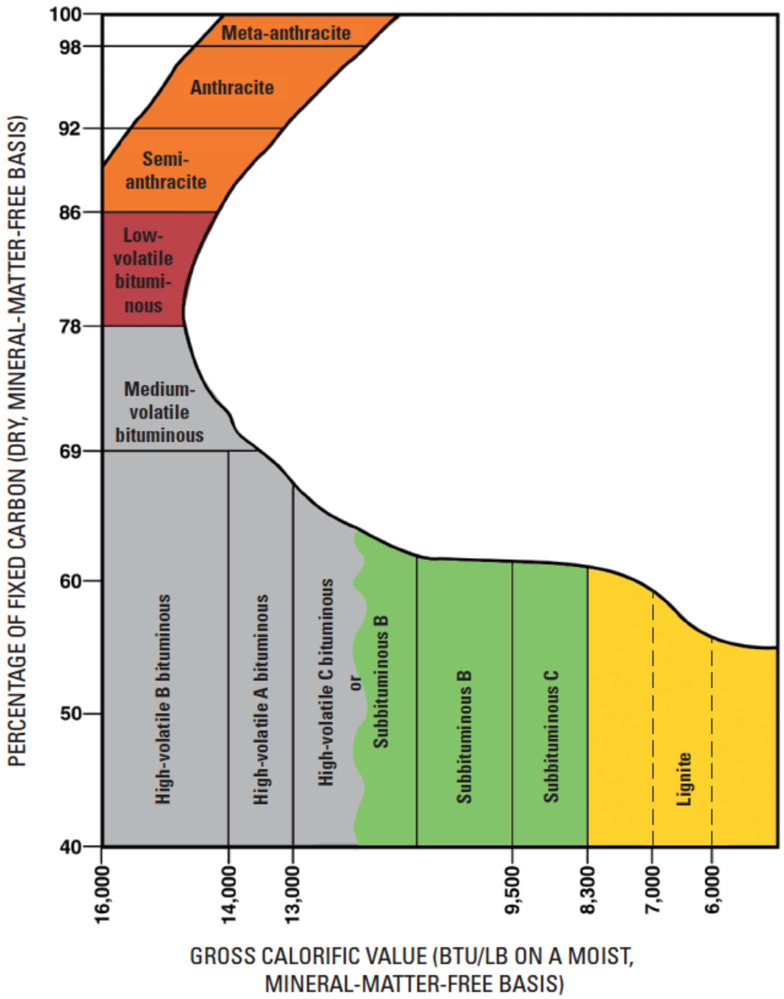


Table A- 249: Conversion Factors to Energy Units (Heat Equivalents)

Fuel Category (Units)	Fuel Type	Production	Imports	Exports	Stock Change	Adjustment	Bunkers	U.S. Territories
Solid Fuels (Million Btu/Short Ton)	Anthracite Coal	22.57						
	Bituminous Coal	23.89						
	Sub-bituminous Coal	17.14				28.16		
	Lignite	12.87				12.87		
	Coke		25.00	25.63	25.00			
	Unspecified		25.00	25.97	20.86	25.85		25.14
Natural Gas (BTU/Cubic Foot)		1,026	1,025	1,009	1,026	1,025		1,026
Liquid Fuels (Million Btu/Barrel)	Crude Oil	5.80	5.99	5.80	5.80		5.80	5.80
	Nat Gas Liquids and LRGs	3.69	3.69	3.69	3.69		3.69	3.69
	Other Liquids	5.83	5.83	5.83	5.83		5.83	5.83
	Motor Gasoline	5.22	5.22	5.22	5.22	5.22	5.22	5.22
	Aviation Gasoline		5.05	5.05	5.05		5.05	5.05
	Kerosene		5.67	5.67	5.67		5.67	5.67
	Jet Fuel		5.67	5.67	5.67		5.55	5.67
	Distillate Fuel		5.83	5.83	5.83	5.83	5.83	5.83
	Residual Oil		6.29	6.29	6.29	6.29	6.29	6.29
	Naphtha for petrochemical feedstocks		5.25	5.25	5.25		5.25	5.25
	Petroleum Coke		6.02	6.02	6.02	6.02	6.02	6.02
	Other Oil for petrochemical feedstocks		5.83	5.83	5.83	5.83	5.83	5.83
	Special Naphthas		5.25	5.25	5.25		5.25	5.25
	Lubricants		6.07	6.07	6.07		6.07	6.07
	Waxes		5.54	5.54	5.54		5.54	5.54
	Asphalt/Road Oil		6.64	6.64	6.64		6.64	6.64
	Still Gas		6.00	6.00	6.00		6.00	6.00
	Misc. Products		5.80	5.80	5.80		5.80	5.80

Data Sources: Coal and lignite production: EIA (2010); Unspecified Solid Fuels: EIA (2011); Coke, Natural Gas and Petroleum Products: EIA (2011).

US EPA (2011) Inventory of U.S. Emissions, Annex 4 IPCC Reference Approach for Estimating CO2 Emissions from Fossil Fuel Combustion

Nov11: Jonker (2001) notes on energy used in mining, and ancillary emissions of methane and CO2.

	short tons	Q Btu
Hard Coal	7,984,900	151.539

Anthracite	670,571
bituminous	6,240,371
Lignite	1,073,958
Total	7,984,900

Energy Information Administration, International Energy Statistics, Coal Production, www.eia.gov/countries/data.cfm

Figure 5. Diagram showing classification of coals by rank in the United States. Rank is a measure of the progressive alteration in the series from lignite to anthracite.
Higher rank coals are generally harder, contain less moisture and volatile matter, and have higher calorific values. Modified from Trumbull (1960).
For a more detailed explanation of coal-rank determination, see American Society for Testing and Materials (1999). Figure 5. Diagram showing classification of coals by rank in the United States.
Rank is a measure of the progressive alteration in the series from lignite to anthracite.
Higher rank coals are generally harder, contain less moisture and volatile matter, and have higher calorific values. Modified from Trumbull (1960).
For a more detailed explanation of coal-rank determination, see American Society for Testing and Materials (1999).

Figure 65. World coal consumption by region, 1980-2035 (quadrillion Btu)

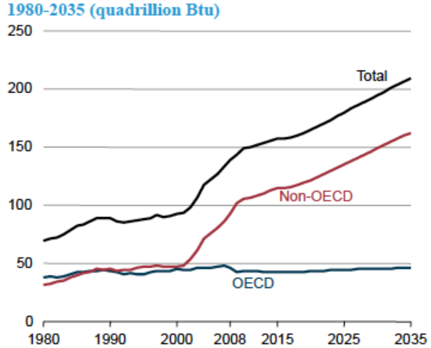
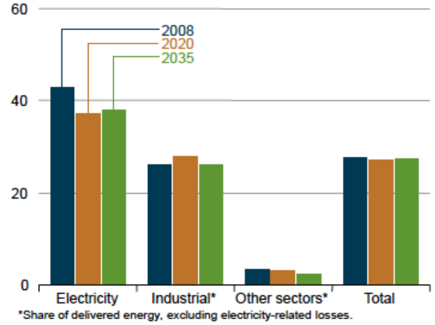


Figure 66. Coal share of world energy consumption by sector, 2008, 2020 and 2035 (percent)



*Share of delivered energy, excluding electricity-related losses.

U.S. Energy Information Administration | International Energy Outlook 2011 69

Table 10. World recoverable coal reserves as of January 1, 2009 (billion short tons)

Region/Country	Recoverable reserves by coal rank: Bituminous and anthracite	Subbituminous	Lignite	Total	2008 production	Reserves-to-production ratio (years)
World total	**445.7**	**287.0**	**215.3**	**948.0**	**7.5**	**126.3**
United States[a]	119.2	108.2	33.2	260.6	1.2	222.3
Russia	54.1	107.4	11.5	173.1	0.3	514.9
China	68.6	37.1	20.5	126.2	3.1	40.9
Other non-OECD Europe and Eurasia	42.2	19.1	40.1	101.4	0.3	291.9
Australia and New Zealand	40.9	2.5	41.4	84.8	0.4	191.1
India	61.8	0.0	5.0	66.8	0.6	117.5
OECD Europe	6.2	0.8	54.3	61.3	0.7	94.2
Africa	34.7	0.2	0.0	34.9	0.3	123.3
Other non-OECD Asia	3.9	3.9	6.8	14.7	0.4	34.4
Other Central and South America	7.6	1.0	0.0	8.6	0.1	95.8
Canada	3.8	1.0	2.5	7.3	0.1	97.2
Brazil	0.0	5.0	0.0	5.0	0.0	689.5
Other[b]	2.6	0.6	0.1	3.4	0.0	184.5

[a]Data for the U.S. represent recoverable coal estimates as of January 1, 2010.
[b]Includes Mexico, Middle East, Japan and South Korea.
Sources: World Energy Council and EIA.

EIA (2011) IEO, page 80.

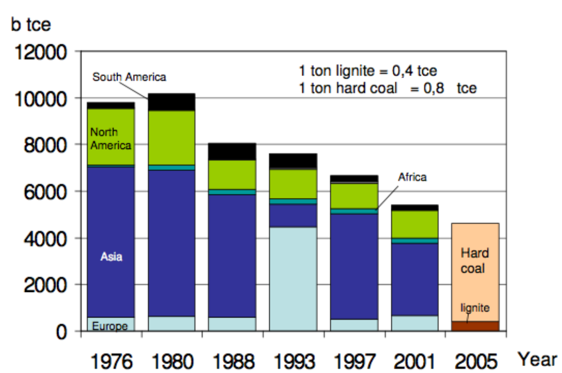
Energy Information Administration (2011) International Energy Outlook 2011, US Department of Energy, 301 pp.

Sector percentages (approximate)

Electricity	43%	Figure 66 does not make sense (RH)
Industrial	25%	
Other	4%	
Gen losses?	28%	too little to be gen losses
Total	100%	

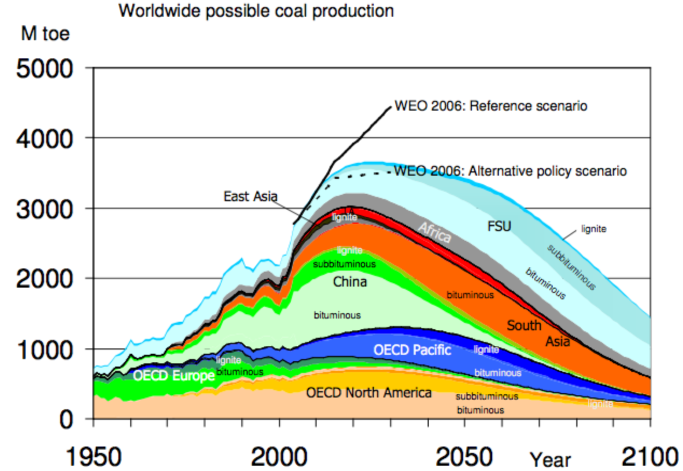
“Of the coal produced worldwide in 2008, 60 percent was shipped to electricity producers and 36 percent to industrial consumers, with most of the remainder going to consumers in the residential and commercial sectors.”
EIA (2011) IEO, page 69.

History of Assessment of world coal resources



Reported resource assessments by the BGR since 1976. The physical tons of coal are converted into btce (billion tons of coal equivalent) for reasons of comparison. For comparison, 1 btce = 833 Mtoe.

Worldwide possible coal production



Energy Watch Group (2007) Coal: Resources and Future Production, Jul07, 47 pp, by Werner Zittel & Jorg Schindler (Ludwig Bolkow Systemtechnik), Ottobrunn, Germany, 47 pp. www.energywatchgroup.org

Cell: H9
Comment: Rick Heede:
U.S. EPA Climate Leaders (2011) Emissions Factors for Greenhouse Gas Inventories, www.epa.gov/climateleaders/guidance/ghg-emissions.html This data source allows calculation of kg Carbon per tonne of coal produced by rank and by extension tCO_2 per tonne of coal.
We compare these values to the coefficients in U.S EPA (2011) Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2009, Annnex 2: Methodology and Data for Estimating CO_2 Emissions from Fossil Fuel Combustion, Annex 2, Table A-37: Carbon Coefficients for Coal by Consuming Sector and Coal Rank (Tg/QBtu, 1990-2009) in cell E10.

Cell: I10
Comment: Rick Heede:
Accounting for oxygen isotopes, personal communication, Kevin Baumert, World Resources Institute.

Cell: L10
Comment: Rick Heede:
CMS adds methane emissions from coal operations in the entity summary worksheet; see also the "Coal Emissions Factor Calc" worksheet for details.

Cell: D11
Comment: Rick Heede:
US EPA (2011) Inventory of U.S. Emissions, Annex 4 IPCC Reference Approach for Estimating CO_2 Emissions from Fossil Fuel Combustion, Table A-249: Conversion Factors to Energy Units (Heat Equivalents), lists coal types by rank in million Btu per short ton. "Average utility coal is derived from coal consumed by electric utilities;" see note below.

Cell: E11
Comment: Rick Heede:
U.S. EPA Climate Leaders (2011) Emissions Factors for Greenhouse Gas Inventories, www.epa.gov/climateleaders/guidance/ghg-emissions.html
We compare this data to the coefficients in U.S EPA (2011) Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2009, Annnex 2: Methodology and Data for Estimating CO_2 Emissions from Fossil Fuel Combustion, Annex 2, Table A-37: Carbon Coefficients for Coal by Consuming Sector and Coal Rank (Tg/QBtu, 1990-2009). Also compared to IPCC default emission factors in IPCC (2006) Guidelines; talbes reproduced at right.

	EPA Climate Leaders 2011	conversion	EPA 2011 U.S. Inv.	IPCC default values	
	kgC/MMBtu	kgC/GJ	kgC/GJ	kgC/GJ	
Lignite	26.28	24.91	26.65	27.60	
Sub-bit.	26.46	25.10	26.50	26.20	
Bitumin.	25.47	24.16	25.44	25.80	
Antracite	28.24	26.79	28.28	26.80	
Ind. coking	25.54	24.23	25.61	25.80	
Electric Power	25.74	24.42	26.05	26.00	(average of bit & sub-bit)

Cell: F11
Comment: Rick Heede:
Calculated by multiplying million Btu/ton by kgC/million Btu = kgC/ton.

Cell: G11
Comment: Rick Heede:
Calculated by multiplying kgC/ton by 1.1023 tons per tonne.

Cell: J11
Comment: Rick Heede:
CMS applies a factorfor non-fuel uses of coal (averaged over 1980-2010 from US data, EIA, see "Non-fuel uses" worksheet). U. S. Energy Information Administration (2011) Annual Energy Review 2010 Table 1.15 Fossil Fuel Consumption for Nonfuel Use Estimates, 1980-2010, www.eia.gov/totalenergy/data/annual
CMS analysis includes a ten percent sequstration factor for the coal used for non-energy purposes.
The CMS result is 0.016 percent of total emissions from coal being sequestered, thus 1-0.00016 (0.99984) of the carbon in the coal is combusted to Carbon Dioxide) is slightly higher than the factor applied by CDIAC (0.982); CDIAC includes a 99 percent oxidation factor, which IPCC protocol eliminated in the 20006 Guidance.

Cell: O12
Comment: Rick Heede:
U.S. EIA (2011) Annual Energy Review, Table 7.2: Coal Production by rank of coal, data for 1950 to 2010. The gradual decrease reflects the increased proportion of western coals, which are chiefly sub-bituminous.

Cell: H23

Comment: Rick Heede:
Data sources:
IPCC (2006) IPCC Guidelines for National GHG Inventories, Volume 2: Energy, Introduction, Table 1-3: Default Values of Carbon Content (in kgC/GJ), page 21.

Also see cell notes below.

Cell: F25
Comment: Rick Heede:
2. IPCC values: 2006 IPCC Guidelines for National GHG Inventories, Volume 2: Energy, Introduction, Table 1.3: Default Values of Carbon Content (in kgC/GJ), page 21.
Note: IPCC does not list “average utility coal”, which the Carbon Majors project uses as a default value for coal producers that show coal production as either “thermal coal” or does not specify coal rank. CMS estimates this value by averaging bituminous and sub-bituminous coal.

Cell: O27
Comment: Rick Heede:
This calculation is based on US EIA data for 1950-2010: heat content of coal consumed by electric utilities, AER (2011), Table A-5. It is done to check on the reasonableness of assuming an average coal heat content of 21.2 million Btu per short ton of utility coal and/or unknown coal rank mined by coal operators from 1900 to 2010. While utility coal varies by time and geography, most coal post-World War II has been combusted in utility boilers.

Cell: O29
Comment: Rick Heede:
Adjusted by weighting for relative production quantities, 2010. U.S. EIA (2011) Annual Energy Review, Table 7.2: Coal Production, data for 2010.

Cell: E32
Comment: Rick Heede:
IPCC does not show average thermal coal used for electricity generation. We average the heating values of bituminous and sub-bituminous. This may be revised.

Cell: E33
Comment: Rick Heede:
CMS has not found IPCC (nor US EIA) data on world coal consumption by rank. (EIA data shows production for hard coal, bituminous, lignite, and metallurgical coal, and anthracite -- though not for sub-bituminous coal.)
Search for UN and IEA statistics on coal consumption (or production, if consumption data not available) for thermal uses and/or electricity boilers.
BP Annual Statistical Review does not show production or consumption by rank. BP rpt does show “Proved reserves at end 2011” of anthracite and bituminous (404,762 million tonnes, 47.01 percent of total) and sub-bituminous and lignite (456,176 million tonnes, 52.99 percent of total). Clearly this proportion does not equal the proportion of coal produced and/or consumed for thermal uses.

Cell: BT37
Comment: Rick Heede:
Jonker, Chris (2001) “Greenhouse Gas, Australian Coal Supply and Rising Import Demand A Contradiction or an Opportunity?” 24-25Sep01, Director, Barlow Jonker Pty Ltd At: EU-Australia Conference, Aachen, Germany, 13 pp. page 12: “One (1) tonne of export quality thermal coal contains 27 GJ of energy, while 1 cubic metre of methane contains 37 MJ of energy. On average one tonne of coal in-situ contains 10 cubic metre of methane, which represents 370 MJ of energy, equivalent to 0.014 tonnes of export quality thermal coal. Since methane is estimated to be 20 times as greenhouse intensive as CO2, per tonne of coal produced, the venting to air of methane has a greenhouse contribution of the same order as that of burning 0.28 tonne of coal in a power station. On the other hand the production of electricity from methane produces considerably less CO2 than the production of electricity from coal.” Also: Energy Intensity In Coal Mining The utilization of energy in coal mining, i.e. the energy intensity, averaged 0.21GJ/tonne equivalent to 0.009GJ/GJ and ranged as follows: (seee table), and: Greenhouse Gas Emission Intensity In Coal Mining Expressed as CO2 equivalent the industry averaged 0.079 tonnes CO2 per tonne saleable coal. The ranges were as follows (see table).

Cell: H38
Comment: Rick Heede:
This table averages the values in Table 1 and 2 above; see cell notes above.

Cell: L39
Comment: Rick Heede:
CMS adds methane emissions from coal operations in the entity summary worksheet; see also the “Coal Emissions Factor Calc” worksheet for details.