From the carbon content of natural gas to estimated emissions per billion cubic feet (Bcf)

Climate Mitigation Services
Rick Heede
Carbon Majors Project
4-Jun-13

Table 1 Natural Gas

		Kg carbon per Million Btu	Million Btu per 1,000 cf	Kg carbon per 1,000 cf	Kg CO2 per 1,000 cf
		kgC/million Btu (HHV)	(HHV) million Btu/kcf	kgC/kcf	kgCO2/kcf
Step 1:	Carbon in produced natural gas (net production)	14.46	1.028	14.86	54.44
Step 2:	Energy inputs to gas extraction, transport, processing, & delivery	(applied in SummaryRanking.xls)		14.86	54.44
Step 3:	Vented carbon dioxide, gas operations	(applied in SummaryRanking.xls)		14.86	54.44
Step 4:	Direct venting of methane (intentional & fugitive), gas ops	(applied in SummaryRanking.xls)		14.86	54.44
Step 5:	Flaring of natural gas, gas operations	(applied in SummaryRanking.xls)		14.86	54.44
Step 6:	Adjust for carbon sequestered through non-energy uses of gas	estimated in “non-energy uses”	0.98144	14.58	53.43
Step 7:	Adjust for oxidation rate	100 percent	1.00000	14.58	53.43
Step 8:	Convert step 7 factor to emissions per billion cubic feet (Bcf)	Million tonnes Carbon and CO2 per billion cf (Bcf)		0.01458	0.05343
Step 9:	Link to Gas Emissions worksheet	Million tonnes Carbon and CO2 per billion cf (Bcf)		0.01458	0.05343

		Kg carbon per million Btu	Million Btu per 1,000 cf	final kg C/kcf		
Table 2a	Values (based on EPA and EIA factors)	14.46	1.104	15.97	94.5%	93.0%
		Kg carbon per billion Joules	Billion joules per 1,000 cf	final kg C/kcf		
Table 2b	Values (based on IPCC and UN factors)	15.30	1.105	16.91	105.9%	87.9%

Table 2c	Standard heating value (per UN), “net calorific value.”	39,021	kJ/m^3
		39.02	MJ/m^3
		35.31467	cf/m^3
		1.1050	MJ/cf (calculated)
		1.1050	GJ/kcf
		1,055	J/Btu

Cumulative CM gas prod’n	2,247,891	Bcf
Cumulative CM gas prod’n	63,653	Bcm
Carbon content	33,400	MtC
Of which carbon sequestered	620	MtC
	35.3147	
	1.8870	mtCO2/Bcm

Table 2d	IPCC default values	48.00	net calorific value, TJ/Gg
		15.30	default carbon content, kgC/GJ
		14.50	kg C/million Btu

EIA / EPA background data on default values for natural gas

Table A-40: Composition of Natural Gas (Percent)

Compound	Average	Median
Methane	93.07	95.00
Ethane	3.21	2.79
Propane	0.59	0.48
Higher Hydrocarbons	0.32	0.30
Non-hydrocarbons	2.81	1.43
Higher Heating Value (Btu per cubic foot)	1,027	1,031

Source: Gas Technology Institute (1992).

Table A-43: Carbon Content of Flare Gas (Tg C/QBtu)

Relevant Sub-Sample	Average Carbon Content
>1,100 Btu/cf	15.31

Source: EPA (2010)

EPA (2012) Table A-43, Annex 2, page A-65.

EPA Energy Hub	
0.001028	mmBtu/scf
53.02	kgCO2/mmBtu
0.054505	kgCO2/scf
54.50	kgCO2/kcf
14.87	kgC/kcf
100.11%	% of final (F15)

Table A-42: Carbon Content Coefficients for Natural Gas (Tg Carbon/QBtu)

Fuel Type	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Natural Gas	14.45	14.46	14.46	14.46	14.44	14.46	14.47	14.46	14.46	14.44	14.46	14.46	14.46	14.46	14.46	14.46	14.46

Source: EPA (2010)

EPA (2012) Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990 – 2010, Annex 2: Methodology and Data for Estimating CO2 Emissions from Fossil Fuel Combustion,
Table A-42: Carbon Content Coefficients for Natural Gas (Tg Carbon/QBtu), page A-64

Pure methane, 75% C by weigh	14.20	TgC/QBtu
EPA 2011	1,005	Btu/sf

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

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

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

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

Table A4. Approximate Heat Content of Natural Gas, Selected Years, 1949-2011
(Btu per Cubic Foot)

	Production		Consumption [1]		
Year	Marketed	Dry	End-Use Sectors [2]	Electric Power Sector [3]	Total
1949	1,120	1,035	1,035	1,035	1,035
1950	1,119	1,035	1,035	1,035	1,035
1955	1,120	1,035	1,035	1,035	1,035
1960	1,107	1,035	1,035	1,035	1,035
1965	1,101	1,032	1,032	1,032	1,032
1970	1,102	1,031	1,031	1,031	1,031
1975	1,095	1,021	1,020	1,026	1,021
1976	1,093	1,020	1,019	1,023	1,020
1977	1,093	1,021	1,019	1,029	1,021
1978	1,088	1,019	1,016	1,034	1,019
1979	1,092	1,021	1,018	1,035	1,021
1980	1,098	1,026	1,024	1,035	1,026
1981	1,103	1,027	1,025	1,035	1,027
1982	1,107	1,028	1,026	1,036	1,028
1983	1,115	1,031	1,031	1,030	1,031
1984	1,109	1,031	1,030	1,035	1,031
1985	1,112	1,032	1,031	1,038	1,032
1986	1,110	1,030	1,029	1,034	1,030
1987	1,112	1,031	1,031	1,032	1,031
1988	1,109	1,029	1,029	1,028	1,029
1989	1,107	1,031	1,031	[3]1,028	1,031
1990	1,105	1,029	1,030	1,027	1,029
1991	1,108	1,030	1,031	1,025	1,030
1992	1,110	1,030	1,031	1,025	1,030
1993	1,106	1,027	1,028	1,025	1,027
1994	1,105	1,028	1,029	1,025	1,028
1995	1,106	1,026	1,027	1,021	1,026
1996	1,109	1,026	1,027	1,020	1,026
1997	1,107	1,026	1,027	1,020	1,026
1998	1,109	1,031	1,033	1,024	1,031
1999	1,107	1,027	1,028	1,022	1,027
2000	1,107	1,025	1,026	1,021	1,025
2001	1,105	1,028	1,029	1,026	1,028
2002	[R]1,103	[R]1,024	[R]1,025	1,020	[R]1,024
2003	[R]1,103	1,028	1,029	1,025	1,028
2004	1,104	1,026	1,026	1,027	1,026
2005	1,104	1,028	1,028	1,028	1,028
2006	1,103	1,028	1,028	1,028	1,028
2007	[R]1,102	[R]1,027	[R]1,027	1,027	[R]1,027
2008	1,100	1,027	1,027	1,027	1,027
2009	1,101	1,025	1,025	1,025	1,025
2010	[R]1,097	[R]1,023	[R]1,023	1,022	[R]1,023
2011	[E]1,097	[E]1,022	[E]1,023	[P]1,021	[E]1,022

EIA (2012) Annual Energy Review 2011, Table A4.
Note: "The values in this table are for gross heat contents."

Year	Marketed prod'n, HHV	Dry natural gas, HHV	Average of Mark & Dry
1949	1,120	1,035	1,078
1950	1,119	1,035	1,077
1955	1,120	1,035	1,078
1960	1,107	1,035	1,071
1965	1,101	1,032	1,067
1970	1,102	1,031	1,067
1971	1,103	1,031	1,067
1972	1,100	1,027	1,064
1973	1,093	1,021	1,057
1974	1,097	1,024	1,061
1975	1,095	1,021	1,058
1976	1,093	1,020	1,057
1977	1,093	1,021	1,057
1978	1,088	1,019	1,054
1979	1,092	1,021	1,057
1980	1,098	1,026	1,062
1981	1,103	1,027	1,065
1982	1,107	1,028	1,068
1983	1,115	1,031	1,073
1984	1,109	1,031	1,070
1985	1,112	1,032	1,072
1986	1,110	1,030	1,070
1987	1,112	1,031	1,072
1988	1,109	1,029	1,069
1989	1,107	1,031	1,069
1990	1,105	1,029	1,067
1991	1,108	1,030	1,069
1992	1,110	1,030	1,070
1993	1,106	1,027	1,067
1994	1,105	1,028	1,067
1995	1,106	1,026	1,066
1996	1,109	1,026	1,068
1997	1,107	1,026	1,067
1998	1,109	1,031	1,070
1999	1,107	1,027	1,067
2000	1,107	1,025	1,066
2001	1,105	1,028	1,067
2002	1,103	1,024	1,064
2003	1,103	1,028	1,066
2004	1,104	1,026	1,065
2005	1,104	1,028	1,066
2006	1,103	1,028	1,066
2007	1,102	1,027	1,065
2008	1,100	1,027	1,064
2009	1,101	1,025	1,063
2010	1,097	1,023	1,060
2011	1,097	1,022	1,060
average	1,104.3	1,027.6	1,065.9
1,042			linked table 1

IPCC background data on default values for natural gas

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

Fuel		CO_2			CH_4			N_2O		
		Default emission factor	Lower	Upper	Default emission factor	Lower	Upper	Default emission factor	Lower	Upper
Coal Tar		n 80 700	68 200	95 300	n 1	0.3	3	r 1.5	0.5	5
Derived Gases	Gas Works Gas	n 44 400	37 300	54 100	n 1	0.3	3	0.1	0.03	0.3
Derived Gases	Coke Oven Gas	n 44 400	37 300	54 100	r 1	0.3	3	0.1	0.03	0.3
Derived Gases	Blast Furnace Gas	n 260 000	219000	308 000	r 1	0.3	3	0.1	0.03	0.3
Derived Gases	Oxygen Steel Furnace Gas	n 182 000	145 000	202 000	r 1	0.3	3	0.1	0.03	0.3
Natural Gas		56 100	54 300	58 300	r 1	0.3	3	0.1	0.03	0.3
Municipal Wastes (non-biomass fraction)		n 91 700	73 300	121 000	30	10	100	4	1.5	15
Industrial Wastes		n 143 000	110 000	183 000	30	10	100	4	1.5	15
Waste Oils		n 73 300	72 200	74 400	30	10	100	4	1.5	15
Peat		106 000	100 000	108 000	n 1	0.3	3	n 1.5	0.5	5
Solid Biofuels	Wood / Wood Waste	n 112 000	95 000	132 000	30	10	100	4	1.5	15
Solid Biofuels	Sulphite lyes (Black Liquor) [a]	n 95 300	80 700	110 000	n 3	1	18	n 2	1	21
Solid Biofuels	Other Primary Solid Biomass	n 100 000	84 700	117 000	30	10	100	4	1.5	15
Solid Biofuels	Charcoal	n 112 000	95 000	132 000	30	10	100	4	1.5	15
Liquid Biofuels	Biogasoline	n 70 800	59 800	84 300	r 3	1	10	0.6	0.2	2
Liquid Biofuels	Biodiesels	n 70 800	59 800	84 300	r 3	1	10	0.6	0.2	2
Liquid Biofuels	Other Liquid Biofuels	n 79 600	67 100	93 300	r 3	1	10	0.6	0.2	2
Gas Biomass	Landfill Gas	n 54 600	46 200	66 000	r 1	0.3	3	0.1	0.03	0.3
Gas Biomass	Sludge Gas	n 54 600	46 200	66 000	r 1	0.3	3	0.1	0.03	0.3
Gas Biomass	Other Biogas	n 54 600	46 200	66 000	r 1	0.3	3	0.1	0.03	0.3
Other non-fossil fuels	Municipal Wastes (biomass fraction)	n 100 000	84 700	117 000	30	10	100	4	1.5	15

[a] Includes the biomass-derived CO_2 emitted from the black liquor combustion unit and the biomass-derived CO_2 emitted from the kraft mill lime kiln.

n indicates a new emission factor which was not present in the *IPCC 1996 Guidelines*.

r indicates an emission factor that has been revised since the *IPCC 1996 Guidelines*.

IPCC (2006) Guidelines 2006, Volume 2: Energy, Chapter 2: Stationary Combustion, Table 2.2

TABLE 1.4 (CONTINUED)
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	95% confidence interval	
				Lower	Upper
	A	B	C=A*B*44/12*1000		
Natural Gas	15.3	1	56 100	54 300	58 300

IPCC 2006 Table 1.4

Natural Gas	48.00	TJ/Gg

(46.5 to 50.4 TJ/Gg)

2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 1: Introduction, table 1.2 Default Calorific Values

AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI

United Nations background data on heat value of natural gas

Table V

HEAT VALUES OF GASES

POUVOIRS CALORIFIQUES DES GAZ

NATURAL GAS - GAZ NATUREL
(Kilojoules/Cubic Metres) - (Kilojoules/Mètres Cubes)

Standard Heat Value	**39021**	**Pouvoir calorifique standard**
Albania	35000 (N)	Albanie
Algeria	39565 (N)	Algérie
Argentina	40337* (G)	Argentine
Australia	35658 (G)	Australie
Austria	39600 (G)	Autriche
Bangladesh	35064	Bangladesh
Belarus	34760 (N)	Bélarus
Belgium	39687* (G)	Belgique
Bolivia	37263	Bolivie
Brazil	43740	Brésil
Brunei	43000	Brunéi
Bulgaria	35152* (G)	Bulgarie
Canada	38550* (G)	Canada
China	38979 (N)	Chine
Chile	37263	Chili
Colombia	34598	Colombie
Croatia	38000 (G)	Croatie
Denmark	40901 (N)	Danemark
Ecuador	48441* (G)	Équateur
Estonia	33537	Éstonie
Finland	39170 (G)	Finlande
France	39205* (G)	France
Germany	33339 (G)	Allemagne
Greece	57211 (G)	Grèce
Hungary	32456 (N)	Hongrie
India	38586 (N)	Inde
Iran (Islamic Rep. of)	39356*	Iran (Rép. islamique)
Ireland	37604* (G)	Irlande
Israel	38728*	Israël
Italy	37306 (G)	Italie
Japan	41023 (G)	Japon
Kazakhstan	33949 (N)	Kazakhstan
Latvia	33597	Lettonie
Lithuania	33949	Lituanie
Luxembourg	40773 (G)	Luxembourg
Mexico	44257* (G)	Mexique
Netherlands	33320 (G)	Pays-Bas

Table V (continued - suite)

HEAT VALUES OF GASES

POUVOIRS CALORIFIQUES DES GAZ

NATURAL GAS - GAZ NATUREL
(Kilojoules/Cubic Metres) - (Kilojoules/Mètres Cubes)

New Zealand	42537 (G)	Nouvelle-Zélande
Norway	42091 (G)	Norvège
Pakistan	34805	Pakistan
Peru	34598	Pérou
Poland	28811 (G)	Pologne
Romania	33514 (N)	Roumanie
Russian Federation	33704 (N)	Fédération de Russie
Slovakia	32663 (N)	Slovaquie
Slovenia	35729 (G)	Slovénie
Spain	42530 (G)	Espagne
Sweden	38880 (G)	Suède
Switzerland	40319 (G)	Suisse
Thailand	37258 (N)	Thaïlande
Trinidad and Tobago	38937	Trinité-et-Tobago
Tunisia	46055	Tunisie
Turkey	34500 (N)	Turquie
Turkmenistan	33949 (N)	Turkménistan
Ukraine	33949 (N)	Ukraine
United Kingdom	39211 (G)	Royaume-Uni
United States	38304 (N)	États-Unis
Uzbekistan	33949 (N)	Ouzbékistan
Venezuela	44380 (G)	Venezuela
Yugoslavia	35588 (N)	Yougoslavie

3. Gaseous fuels

Table 12. Gaseous fuel equivalents a/

INTO → / FROM Thousand cubic metres b/	Giga-joules	Million Btus	Megawatt hours	Giga-calories	Barrels oil	Tons coal equivalent	Tons oil equivalent
	M U L T I P L Y	B Y					
Natural gas	39.02	36.98	10.84	9.32	6.50	1.331	0.932
Coke oven gas	17.59	16.67	4.88	4.20	2.94	0.600	0.420
Blast furnace gas	4.00	3.79	1.11	0.96	0.66	0.137	0.096
Refinery gas c/	46.1	43.7	12.8	11.0	7.69	1.571	1.100
Gasworks gas	17.59	16.67	4.88	4.20	2.94	0.600	0.420
Biogas	20.0	19.0	5.6	4.8	3.36	0.686	0.480
Methane	33.5	31.7	9.30	8.0	5.59	1.143	0.800
Ethane	59.5	56.3	16.5	14.2	9.92	2.029	1.420
Propane	85.8	81.3	23.8	20.5	14.33	2.929	2.050
Isobutane	108.0	102.0	30.0	25.8	18.0	3.686	2.580
Butane	111.8	106.0	31.0	26.7	18.6	3.814	2.670
Pentane	134.0	127.0	37.2	32.0	22.36	4.571	3.200

Table V, United Nations (2012) Energy Statistics Yearbook 2009, UN Statistics Division, Jun12;
unstats.un.org/unsd/energy/yearbook/default.htm

Note: the “Standard Heat Value” of 39,021 kJ/m^3 is based on Table 12, page 28, United Nations (1987) *Energy Statistics: Definitions, Units of Measure and Conversion Factors*, UN Statistical Office, New York, Series F-44, 65 pp.,
unstats.un.org/unsd/publication/SeriesF/SeriesF_44E.pdf

United Nations (1987) *Energy Statistics: Definitions, Units of Measure and Conversion Factors*, UN Statistical Office, New York, Series F-44, 65 pp.,

Footnotes to Table 12:

a/ All heat values correspond to net calorific value.

b/ Under standard reference conditions. To convert from SRC to STP, multiply by 1.0757.

Cell: G13
Comment: Rick Heede:
We use the isotopic value of CO2 in converting from carbon to CO2. CO2 conversion is, precisely: CO2/C: (C: 12.0107) + (O = 15.9994 x 2) = 44.0095/12.0107 = 3.664191. Kevin Baumert, WRI, May 2005, personal communication.

Cell: C15
Comment: Rick Heede:
CMS first considered applying an emission factor based on the IPCC default value and the UN “Standard Heating Value” for natural gas (see Table 2c below), but rejected this EF as being unreasonably high.
CMS and our technical reviewers agreed that applying a factor based on US EPA and EIA factors provides a conserative emission factor based on published, substantiated, and peer-reviewed data. THe EF combines the EPA’s value of 14.46 Tg/QBtu with the average HHV heating values of Marketed and Dry Natural Gas Production for 1949-2011.
These factors are documented and described at right.

Cell: D15
Comment: Rick Heede:
EIA and EPA data on carbon content of natural gas (14.46 kgC per million Btu -- usually expressed as 14.46 TgC/QBtu: 14.46 million tonnes of carbon per quadrillion (10^15 Btu)).
EPA (2012) Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990 – 2010, Annex 2: Methodology and Data for Estimating CO2 Emissions from Fossil Fuel Combustion, Table A-42: Carbon Content Coefficients for Natural Gas (Tg Carbon/QBtu), page A-64.

Cell: E15
Comment: Rick Heede:
Natural gas producers typically report “natural gas available for sale”, we use the EIA HHV heating values data for 1949-2011 for “Dry Natural Gas Production” from EIA (2012) Annual Energy Review 2011, Table A-4: Approximate Heat Content of Natural Gas 1949-2011 (reproduced on page 2 and linked to cell Y50).
The Marketed Production averages 1,104.3 Btu/scf over 1949-2011, whereas Dry Natural Gas Production averages 1,027.6 Btu/scf. It might be more accurate to average of the “Dry”and “marketed” data sets 1949-2011 to 1,065.9 Btu/scf, but we apply the “dry” heating value as a conservatism.
Note: these are “gross heating value”, or HHV. Dry natural gas, on the other hand, has a default gross heating value of 1,028 Btu per cf (or 34.37 MJ/m^3).
Natural Gas Marketed Production is defined as “Natural gas gross withdrawals from production reservoirs, less gas used for reservoir repressuring; nonhydrocarbon gases removed in treating or processing operations; and quantities of vented natural gas and flared natural gas. Includes all quantities of natural gas used in field and processing operations.” EIA AER glossary.
Since both the carbon content and heating value factors are HHV we do not need to adjust for the HHV = 1.1 of LHV in this calculation. EPA and EIA both use HHV (unless otherwise noted).

Cell: C17
Comment: Rick Heede:
CMS accounts for company use of produced natural gas in the summary entity worksheet -- along with attributing fugitive methane emissions, vented CO2, flared gas, etc. See the SumRanking.xls worksheet for details.
The objective is to attribute CO2 and CH4 emissions to the producing entities that are in addition to marketed marketed natural gas, or in company terminology, “gas available for sale.” These reported quantities do not account for field-use of gas in engines, compressors, processing plants, fugitive emissions, or vented CO2 (separating sour gas CO2 to the atmosphere).

Cell: C19
Comment: Rick Heede:
CMS attributes entrained CO2 removed from raw gas in the summary entity worksheet. See the SumRanking.xls worksheet for details.
The “non-hydrocarbon gas removed from natural gas” rate equalled 3.12 percent (836.7 Bcf of 26,836 Bcf total production) in the U.S. in 2010 (EIA (2011) Natural Gas Annual 2010, Table 1). In addition, 3,431 Bcf was used for repressuring (12.79 percent), 166 Bcf was vented and flared (0.62 percent), 22,402 Bcf was marketed (83.48 percent), and 1,070 Bcf in processing loss (3.99 percent).

Cell: C21
Comment: Rick Heede:
CMS estimates and attributes methane releases from natural gas production, processing, and transportation, as well as flaring, in the Carbon Majors entity summary worksheet. See the SumRanking.xls worksheet for details.

Cell: C23
Comment: Rick Heede:
CMS attributes CO2 emissions from flaring operations at production and processing facilities in the Carbon Majors entity summaary worksheet. See the SumRanking.xls worksheet for details and calculations.

Cell: C25
Comment: Rick Heede:
See the separate worksheet in this workbook (“Non-energy uses”), in which CMS calculates the percentage of the natural gas supplied (on average, over the past 31 years, based on US data by EIA and CMS adjustments for re-emission to the atmosphere) that is sequestered into fertilizers and methanol.

Cell: C27
Comment: Rick Heede:
IPCC 2006 Guidance uses a 100 percent oxidation factor (revised from 99.5 percent in the 1996 Guidance).

Cell: D36
Comment: Rick Heede:
EIA and EPA data on carbon content of natural gas (14.46 kgC per million Btu -- usually expressed as 14.46 TgC/QBtu: 14.46 million tonnes of carbon per quadrillion (10^15 Btu)).
EPA (2012) Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990 – 2010, Annex 2: Methodology and Data for Estimating CO2 Emissions from Fossil Fuel Combustion, Table A-42: Carbon Content Coefficients for Natural Gas (Tg Carbon/QBtu), page A-64.

Cell: E36
Comment: Rick Heede:
We use the heat content of marketed natural gas (US average 1949-2010) at 1,105.9 Btu per cf, equiv to 36.98 MJ/m^3, as representative of produced natural gas (this has varied from 1,088 to 1,120 since 1949). EIA (2011) Annual Energy Review 2010, Table A4 (reproduced on page 2 and averaged in and linked to cell W50).
Note: this is "gross heating value", or HHV. Dry natural gas, on the other hand, has a default gross heating value of 1,028 Btu per cf (or 34.37 MJ/m^3).
Natural Gas Marketed Production is defined as "Natural gas gross withdrawals from production reservoirs, less gas used for reservoir repressuring; nonhydrocarbon gases removed in treating or processing operations; and quantities of vented natural gas and flared natural gas. Includes all quantities of natural gas used in field and processing operations." EIA AER glossary.
Since both the carbon content and heating value factors are HHV we do not need to adjust for the HHV = 1.1 of LHV in this calculation. EPA and EIA both use HHV (unless otherwise noted).

Cell: H36
Comment: Rick Heede:
The new IPCC / UN EF value is 16.3 percent higher than the EPA / EIA value; inverse is 86 percent.

Cell: C38
Comment: Rick Heede:
We derive an emission factor for natural gas production (prior to accounting for non-energy uses, vented CO2, etc) from IPCC default factor (kgC/GJ) and GJ/thousand cubic feet (based on UN Statistics Dept "standard heating value" of natural gas (net calorific value)).
Numerically, this is: 15.30 kgC/GJ * 1.1050 GJ/kcf = 16.91 kgC/kcf, or 61.95 kgCO2/kcf.

Cell: D38
Comment: Rick Heede:
The IPCC default value for natural gas is 15.3 kgC/GJ (range from 14.8 to 15.9 kgC/GJ) and is "on a net calorific basis." IPCC Guidelines 2006 Volume 2: Energy, chapter 1: Introduction, Table 1.3. Also listed as 56,100 kgCO2/TJ in Table 2.2 on page 3. IPCC 2006 Guidelines vol 2, ch. 2: Stationary Combustion, Table 2.2.

Cell: E38
Comment: Rick Heede:
Calculated in Table 2c below and is based on UN Statistics' heating value for natural gas.

Cell: D40
Comment: Rick Heede:
Standard heating value of natural gas, "net calorific value." See Table V, United Nations (2012) Energy Statistics Yearbook 2009, UN Statistics Division, Jun12; unstats.un.org/unsd/energy/yearbook/default.htm. chapter on natural gas heating values puts "Standard Heat Value" at 39,021 kJ/m^3. Reference to Table 12, page 28, United Nations (1987) Energy Statistics: Definitions, Units of Measure and Conversion Factors, UN Statistical Office, New York, Series F-44, 65 pp., unstats.un.org/unsd/publication/SeriesF/SeriesF_44E.pdf

Cell: D47
Comment: Rick Heede:
Net calorific value of natural gas shown as 48.0 TJ/Gg (range from 46.5 to 50.4 TJ/Gg), IPCC 2006 Guidelines vol 2, ch. 1: Introduction, Table 1.2.
Also lists crude oil at 42.3 TJ/Gg, and coal from 11.9 to 28.2 TJ/Gg.
Nowhere does the IPCC show conversions or default values for TJ or Gg per cubic meter of natural gas, or, for that matter, for crude oil or coal.
Thus we resort to UN heating value above.

Cell: D48
Comment: Rick Heede:
The IPCC default value for natural gas is 15.3 kgC/GJ (range from 14.8 to 15.9 kgC/GJ). IPCC Guidelines 2006 Volume 2: Energy, chapter 1: Introduction, Table 1.3. Also listed as 56,100 kgCO2/TJ in Table 2.2 at right. IPCC 2006 Guidelines vol 2, ch. 2: Stationary Combustion, Table 2.2.

Cell: R51
Comment: Rick Heede:
"The U.S. Energy Information Administration typically uses gross heat content values." EIA AER Glossary.