From the carbon content of petroleum and non-energy uses to estimated emissions per barrel

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

Table 1 Petroleum & Natural Gas Liquids

		KgC/GJ	GJ/bbl	Kg carbon per bbl	Kg CO2 per bbl
Step 1:	Carbon in extracted oil	20.00	5.78	115.67	423.85
Step 2:	Adjust for natural gas liquids (NGLs) in reported production	100 percent	4.729%	110.20	403.80
Step 3:	Inputs of own fuels to production, transportation, & processing	(applied in SummaryRanking.xls)		110.20	403.80
Step 4:	Vented carbon dioxide, oil operations	(applied in SummaryRanking.xls)		110.20	403.80
Step 5:	Fugitive, leaked, or vented methane	(applied in SummaryRanking.xls)		110.20	403.80
Step 6:	Flaring at oil operations	(applied in SummaryRanking.xls)		110.20	403.80
Step 7:	Adjust for net carbon sequestered through non-fuel uses of oil	estimated in "non-energy uses" worksheet	8.018%	101.37	371.43
Step 8:	Oxidation factor	100 percent		101.37	371.43
Step 9:	Convert step 8 factor to CO2e emissions per million barrels	Million tonnes Carbon and CO2 per milllion barrels		0.1014	0.3714

Table 2

IPCC net calorific value	42.30	TJ/Gg (TJ/kt; GJ/t)		
	0.86	specific gravity		
	158.99	L /bbl	computed percent C	
	136.7291	kg/bbl	84.60%	
	7.3137	bbl /tonne	(F15/D37)	
	20.00	kgC/GJ, default C content IPCC		
	5.78	GJ/bbl		
	0.8600	UN, crude oil: specific gravity	Cumulative CM oil prod'n	984,657 Mbbl
		(unspecified origin)	Cumulative CM oil prod'n	134,631 Mt
	0.9610	Suriname (high)	Carbon content	113,898 MtC
	0.7240	Indonesia (low)	Carbon sequestered	9,132 MtC
	UN (2012) Energy Statistics Yearbook 2009, Jun, 696 pp.			
	1,055.06	J/Btu		0.0508 tCO2/t

EIA / EPA background data on default values for crude oil and petroleum products

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

Table A-57: Carbon Content Coefficients for Petroleum Products, 1990-2007 [Tg C/QBtu]

Fuel Type	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Petroleum														
Asphalt and Road Oil	20.62	20.62	20.62	20.62	20.62	20.62	20.62	20.62	20.62	20.62	20.62	20.62	20.62	20.62
Aviation Gasoline	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87
Distillate Fuel Oil	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95
Jet Fuel[a]	19.40	19.34	19.33	19.33	19.33	19.33	19.33	19.33	19.33	19.33	19.33	19.33	19.33	19.33
Kerosene	19.72	19.72	19.72	19.72	19.72	19.72	19.72	19.72	19.72	19.72	19.72	19.72	19.72	19.72
LPG (energy use)[a]	17.21	17.20	17.20	17.18	17.23	17.25	17.20	17.21	17.20	17.21	17.20	17.19	17.19	17.18
LPG (non-energy use)[a]	16.83	16.87	16.86	16.88	16.88	16.84	16.81	16.83	16.82	16.84	16.81	16.81	16.78	16.76
Lubricants	20.24	20.24	20.24	20.24	20.24	20.24	20.24	20.24	20.24	20.24	20.24	20.24	20.24	20.24
Motor Gasoline[a]	19.41	19.38	19.36	19.35	19.33	19.33	19.34	19.34	19.35	19.33	19.33	19.33	19.33	19.33
Residual Fuel	21.49	21.49	21.49	21.49	21.49	21.49	21.49	21.49	21.49	21.49	21.49	21.49	21.49	21.49
Other Petroleum														
Av Gas Blend Comp.	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87	18.87
Mo Gas Blend Comp[a]	19.41	19.38	19.36	19.35	19.33	19.33	19.34	19.34	19.35	19.33	19.33	19.33	19.33	19.33
Crude Oil[a]	20.16	20.23	20.25	20.24	20.24	20.19	20.23	20.29	20.30	20.28	20.33	20.33	20.33	20.33
Misc. Products[a]	20.16	20.23	20.25	20.24	20.24	20.19	20.23	20.29	20.30	20.28	20.33	20.33	20.33	20.33
Misc. Products (Terr.)	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Naphtha (<401 deg. F)	18.14	18.14	18.14	18.14	18.14	18.14	18.14	18.14	18.14	18.14	18.14	18.14	18.14	18.14
Other oil (>401 deg. F)	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95	19.95
Pentanes Plus	18.24	18.24	18.24	18.24	18.24	18.24	18.24	18.24	18.24	18.24	18.24	18.24	18.24	18.24
Petrochemical Feed.	19.37	19.37	19.37	19.37	19.37	19.37	19.37	19.37	19.37	19.37	19.37	19.37	19.37	19.37
Petroleum Coke	27.85	27.85	27.85	27.85	27.85	27.85	27.85	27.85	27.85	27.85	27.85	27.85	27.85	27.85
Still Gas	17.51	17.51	17.51	17.51	17.51	17.51	17.51	17.51	17.51	17.51	17.51	17.51	17.51	17.51
Special Naphtha	19.86	19.86	19.86	19.86	19.86	19.86	19.86	19.86	19.86	19.86	19.86	19.86	19.86	19.86
Unfinished Oils[a]	20.16	20.23	20.25	20.24	20.24	20.19	20.23	20.29	20.30	20.28	20.33	20.33	20.33	20.33
Waxes	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81
Other Wax and Misc.	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81	19.81

[a] C contents vary annually based on changes in fuel composition.

[b] C content for utility coal used in the electric power calculations. All coefficients based on higher heating value. Higher heating value (gross heating value) is the total amount of heat released when a fuel is burned. Coal, crude oil, and natural gas all include chemical compounds of carbon and hydrogen. When those fuels are burned, the carbon and hydrogen combine with oxygen in the air to produce CO_2 and water. Some of the energy released in burning goes into transforming the water into steam and is usually lost. The amount of heat spent in transforming the water into steam is counted as part of gross heat content. Lower heating value (net heating value), in contrast, does not include the heat spent in transforming the water into steam. Using a simplified methodology based on International Energy Agency defaults, higher heating value can be converted to lower heating value for coal and petroleum products by multiplying by 0.95 and for natural gas by multiplying by 0.90. Carbon content coefficients are presented in higher heating value because U.S. energy statistics are reported by higher heating value.

Table A-56: Physical Characteristics of Liquefied Petroleum Gases

Compound	Chemical Formula	1990-2007 Density (bbl / MT)	Updated Density (bbl / MT)	1990-2007 Energy Content (MMBtu/bbl)	Updated Energy Content (MMBtu/bbl)	1990-2007 C Content Coefficient (Tg C/QBtu)	Updated C Content Coefficient (Tg C/QBtu)
Ethane	C_2H_6	16.88	11.55	2.916	3.082	16.25	17.16
Propane	C_3H_8	12.44	12.76	3.824	3.836	17.20	16.76
Isobutane	C_4H_{10}	11.20	11.42	4.162	3.974	17.75	17.77
n-butane	C_4H_{10}	10.79	10.98	4.328	4.326	17.72	17.75

Sources: Updated: Densities – CRC Handbook of Chemistry and Physics, 89th Ed. (2008/09); Energy Contents – EPA (2009b). All values are for the compound in liquid form. The density and energy content of ethane are for refrigerated ethane (-89 degrees C). Values for n-butane are for pressurized butane (-25 degrees C). Values in previous editions of this inventory: Gurthrie (1960).

U.S. Environmental Protection Agency (2012) Inventory of U.S.: 1990 – 2010, Annex 2:
table A-56: Physical Characterisitcs of Liquefied Petroleum Gases, page A-87.

U.S. Environmental Protection Agency (2012) Inventory of U.S.: 1990 – 2010, Annex 2: Methodology and Data for Estimating CO2 Emissions from Fossil Fuel Combustion,
Table A-57: Carbon Content Coefficients for Petroleum Products, 1990-2007 [Tg C/QBtu), page A-88

Note: All coefficients based on higher heating value.

IPCC background data on default values for crude oil and petroleum products

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			CH_4			N_2O		
		Default emission factor	Lower	Upper	Default emission factor	Lower	Upper	Default emission factor	Lower	Upper
Crude Oil		73 300	71 000	75 500	r 3	1	10	0.6	0.2	2
Orimulsion		r 77 000	69 300	85 400	r 3	1	10	0.6	0.2	2
Natural Gas Liquids		r 64 200	58 300	70 400	r 3	1	10	0.6	0.2	2
Gasoline	Motor Gasoline	r 69 300	67 500	73 000	r 3	1	10	0.6	0.2	2
	Aviation Gasoline	r 70 000	67 500	73 000	r 3	1	10	0.6	0.2	2
	Jet Gasoline	r 70 000	67 500	73 000	r 3	1	10	0.6	0.2	2
Jet Kerosene		r 71 500	69 700	74 400	r 3	1	10	0.6	0.2	2
Other Kerosene		71 900	70 800	73 700	r 3	1	10	0.6	0.2	2
Shale Oil		73 300	67 800	79 200	r 3	1	10	0.6	0.2	2
Gas/Diesel Oil		74 100	72 600	74 800	r 3	1	10	0.6	0.2	2
Residual Fuel Oil		77 400	75 500	78 800	r 3	1	10	0.6	0.2	2
Liquefied Petroleum Gases		63 100	61 600	65 600	r 1	0.3	3	0.1	0.03	0.3
Ethane		61 600	56 500	68 600	r 1	0.3	3	0.1	0.03	0.3
Naphtha		73 300	69 300	76 300	r 3	1	10	0.6	0.2	2
Bitumen		80 700	73 000	89 900	r 3	1	10	0.6	0.2	2
Lubricants		73 300	71 900	75 200	r 3	1	10	0.6	0.2	2
Petroleum Coke		r 97 500	82 900	115000	r 3	1	10	0.6	0.2	2
Refinery Feedstocks		73 300	68 900	76 600	r 3	1	10	0.6	0.2	2
Other Oil	Refinery Gas	n 57 600	48 200	69 000	r 1	0.3	3	0.1	0.03	0.3
	Paraffin Waxes	73 300	72 200	74 400	r 3	1	10	0.6	0.2	2
	White Spirit and SBP	73 300	72 200	74 400	r 3	1	10	0.6	0.2	3
	Other Petroleum Products	73 300	72 200	74 400	r 3	1	10	0.6	0.2	2
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
Oil Shale and Tar Sands		107 000	90 200	125000	1	0.3	3	r 1.5	0.5	5
Brown Coal Briquettes		97 500	87 300	109000	n 1	0.3	3	r 1.5	0.5	5
Patent Fuel		97 500	87 300	109000	1	0.3	3	n 1.5	0.5	5
Coke	Coke Oven Coke and Lignite Coke	r 107 000	95 700	119 000	1	0.3	3	r 1.5	0.5	5
	Gas Coke	r 107 000	95 700	119 000	r 1	0.3	3	0.1	0.03	0.3

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

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

2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Chapter 1: Introduction

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	
					Lower	Upper
		A	B	C=A*B*44/12*1000		
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
	Aviation Gasoline	19.1	1	70 000	67 500	73 000
	Jet Gasoline	19.1	1	70 000	67 500	73 000
Jet Kerosene		19.5	1	71 500	69 700	74 400

2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Chapter 1: Introduction

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
	Aviation Gasoline	44.3	42.5	44.8
	Jet Gasoline	44.3	42.5	44.8
Jet Kerosene		44.1	42.0	45.0

2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Chapter 1: Introduction

IPCC default value: Table 1.2: Crude oil = 42.3 TJ/Gg, at 7.33 bbl per tonne, 1 bbl = 136.4 kg, 42.3 MJ/kg * 136.4 kg = 5.771 GJ per bbl.

Table 1.3: Crude = 20.0 kgC/GJ, thus 1 bbl = 20.0 kgC/GJ * 5.7708 GJ/bbl = 115.416 kgC per bbl.

Cell: C15
Comment: Rick Heede:
Sep2012: IPCC factors and values are used in this calculation; see following cell notes for details.
Previous note:
Carbon content of crude varies by API gravity and supply mixes but averages 20.23 kgC/million Btu (EIA 1605 reporting, EPA US Emissions reports, etc).
The typical barrel of oil is set by EIA (e.g., Annual Energy Review 2003, Table A2) at 5.80 million btu (US production) and varies for US imports between 5.802 and 5.971 over 1949-2003. We use 5.80 million btu per barrel in this report.

Cell: D15
Comment: Rick Heede:
The IPCC default value for crude oil is 20.0 kgC/GJ (range from 19.4 to 20.6 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: E15
Comment: Rick Heede:
Calculated in Table 2.

Cell: F15
Comment: Rick Heede:
This result -- 117.33 kgC/bbl (Jan12) -- is slightly higher than the IPCC default value calculated from its 2006 Guidelines (Energy, Introduction, Tables 1.2 and 1.3): 115.42 kgC/bbl.
IPCC default value: Table 1.2: Crude oil = 42.3 TJ/Gg, at 7.33 bbl per tonne, 1 bbl = 136.4 kg, 42.3 MJ/kg * 136.4 kg = 5.7708 GJ per bbl.
Table 1.3: Crude = 20.0 kgC/GJ, thus 1 bbl = 20.0 kgC/GJ * 5.7708 GJ/bbl = 115.416 kgC per bbl.

Cell: C17
Comment: Rick Heede:
Natural gas liquids are lighter than crude oil and have lower emission factors per unit volume (we focus here on EF on the basis of volume, rather than energy content, because oil and gas producers report production in bbl). The emission factor for butane (276.36 kgCO2/bbl), ethane (181.44 kgCO2/bbl), propane (234.78 kgCO2/bbl), and natural gasoline (308.70 kgCO2/bbl) averages to 250.32 kg CO2/gallon. Crude oil's emission factor is 431.76 kg CO2/gallon; the unweighted average NGL emission factor is thus 42 percent lower than crude oil. (data: U.S. Environmental Protection Agency (2011b) Emission Factors for Greenhouse Gas Inventories, epa.gov/climateleaders/ guidance/ghg-emissions.html);
EIA world production data for 1980-2012 show that Natural Gas Plant Liquids (NGPLs) comprise an average of 8.16 percent of total crude oil, lease condensate, and NGPLs for 1980-2012.
The formula for the adjustment to crude oil emission factor (115.67 kgC/bbl) is as follows: 0.0816 * (1-0.42044), which lowers the emission factor for combined crude oil and NGL to 110.20 kgC/bbl, or 403.80 kgCO2/bbl.

Cell: C19
Comment: Rick Heede:
Dec2012: CMS does add company fuel and emissions to attributed entity emissions, since producers vary in their inputs of own fuels in production, transportation, shipping, processing, refining, and other direct Scope 1 emission sources. As estimated in the "Entity CDP Scopes 1-3" worksheet in the AncillaryCH4&CO2.xls, the emissions from own fuel inputs for the ten petroleum producers analyzed from the inventories submitted to the Carbon Disclosure Project for 2010 ranges from 4.8 percent (Hess) to 15.7 perent (ENI SpA) and averages 10.4 percent compared to emissions from oil and natural gas production. The preliminary conclusions in the previous notes below are reasonable approximations, though based on different data and methodology. ExxonMobil's estimated own fuel use in our analysis of the company's CDP submission for 2010 are equivalent to 12.9 percent of product emissions (79.4 MtCO2 compared to product emissions of 614 MtCO2).

Cell: C21
Comment: Rick Heede:
Sep2012: CMS does not attribute vented CO2 in this worksheet. CMS does add a factor for vented CO2 from both oil and gas operations for each carbon major entity in the final entity summary worksheet.
This value (as of Dec2012) is 0.408 kgCO2/tCO2, or 0.041 percent.

Cell: C23
Comment: Rick Heede:
Sep2012: CMS does not attribute fugitive methane in this worksheet. CMS does add a factor for methane from both oil and gas operations for each carbon major entity in the final entity summary worksheet.
This value (as of Dec2012) is 1.807 kgCH4/tCO2 and 37.94 kgCO2e/tCO2, or 3.79 percent.
Previous note:
There is a paucity of measured data and even estimates of the amount of methane directly vented to the atmosphere from oil and natural gas operations. Certainly, most methane is not vented but flared for safety reasons, but there are numerous instances where fugitive leaks are routine. Moreover, methane was routinely vented rather than flared early in the 20th century. Accidental and uncapped releases of natural gas -- such as the 16-month-long event at one of Apache Corporation's fields in Texas from Oct1981 to Feb1983 * -- are not uncommon. In addition, routine methane releases from tank purges, valve leakage, seal leakage, and so forth. Most such "routine" fugitive methane releases are attributed to natural gas operations.
* See the "Gas Emissions factor Calc" and production worksheet for Apache Corp for details of the event and CMS carbon emissions estimate thereof.
Delucchi (2003) cites estimates off US offshore (including underwater) direct venting of natural gas of 48 cf to as high as 150 cf per barrel of oil produced. This 48 cf/bbl converts to 0.922 kg CH4 (19.2 g/cf of CH4, ignoring the non-methane components) per barrel, and at 21x the GWP of CO2 is equivalent to 19.36 kgCO2e, or 5.28 kgCe/bbl. As a factor relative to the potential carbon dioxide in a bbl of oil (117.33 kgC/bbl, this represents 4.5 percent. This is twice

as high as the global methane rate used in the above calculation and in this worksheet, but then the US offshore natural gas venting rate is for offshore in the 1970s, and even that high rate has declined since.

Cell: C25
Comment: Rick Heede:
Sep2012: CMS does not attribute flared CO2 in this worksheet. CMS does add a factor for flared CO2 from both oil and gas operations for each carbon major entity in the final entity summary worksheet.
This value (as of Dec2012) is 28.03 kgCO2/tCO2, or 2.80 percent.

Cell: C27
Comment: Rick Heede:
See the separate worksheet in this workbook ("Non-fuel uses"), in which CMS calculates (as of Dec2012) that 9.34 percent of total oil supplied to the U.S. economy (on average, 1980-2010, based on US data by EIA and EPA) is sequestered into petrochemicals and plastics, lubricants, waxes, polishes, petroleum coke, asphalt and road oils, etc.
Note that CMS has calculated, based on EIA (and secondarily, on IPCC) estimates, assumptions, and/or default values the fractions of non-fuel uses presumed to re-enter the atmosphere within a 20-year time horizon. Such as near-term oxidation or combustion of lubricants (either in the engines lubricated or post-collection and used as powerplant fuel), or as longer-term combustion of, say, petrochemicals and plastics in waste-to-energy plants, or the combustion of waxes, or the oxidation of the volatile components of polishes and paints).
The Oak Ridge National Lab's Carbon Dioxide Information Analysis Center (CDIAC)'s emissions database -- against which ultimate emissions estimated by CMS is compared year by year as well as cumulatively 1751-2010 -- makes the following footnote: "When calculating global total CO2 emissions from liquids, we have estimated that a quantity of liquids equivalent to 6.7% of liquids produced are not oxidized each year and another 1.5% passes through burners unoxidized or is otherwise spilled. Hence, 91.8% of annual liquid production is oxidized each year." http://cdiac.esd.ornl.gov/trends/emis/factors.htm
CMS averages the CDIAC and US carbon storage rates for crude oil & NGL production -- (6.7 percent + 9.29 percent)/2 = 8.0 percent. This rate is applied here to account for the carbon produced in crude oil & NGL production that is not oxidised to CO2 and is deducted from the carbon coefficient for the average barrel of liquid fuel produced.

Cell: C29
Comment: Rick Heede:
IPCC 2006 Guidelines state a default oxidation factor of 100 percent; Chapter 1, Introduction, Table 1.4.
IPCC (1997) Guidelines for National Greenhouse Gas Inventories, vol 3, p. 1-28. Also EIA (2001) Emissions of Greenhouse Gases in the United States in 2000, Table A.3. While the EIA and EPA retain the use of this non-combustion factor, the IPCC's 2006 Guidelines appears to back away from its application. For example, IPCC's reference approach (Energy: chapter 6, p. 6-11): "Carbon Unoxidised During Fuel Combustion: A small part of the fuel carbon entering combustion escapes oxidation but the majority of this carbon is later oxidised in the atmosphere. It is assumed that the carbon that remains unoxidised (e.g. as soot or ash) is stored indefinitely. For the purposes of the Reference Approach, unless country-specific information is available, a default value of 1 (full oxidation) should be used."
CDIAC uses a factor of 1.5 percent for a combination of non-oxidised fuel and fuel spills. Per IPCC, fuel spills and most of non-oxidised fuel is, in fact, oxidised over a relatively short period. All in all, the deductions used by CMS -- carbon sequestered through non-fuel uses of liquid fuels at 8.0 percent, vs CDIAC's sum for the same two components at 8.2 percent.

Cell: D36
Comment: Rick Heede:
Net calorific value of crude oil at 42.3 TJ/Gg (range from 40.1 to 44.8 TJ/Gg), IPCC 2006 Guidelines vol 2, ch. 1: Introduction, Table 1.2.
Also lists natural gas as 48.0 TJ/Gg, and coal from 11.9 to 28.2 TJ/Gg.

Cell: D37
Comment: Rick Heede:
United Nations (2012) Energy Statistics Yearbook 2009, Jun, 696 pp. Table II: specific Gravities of Crude Petroleum. unstats.un.org/unsd/energy/yearbook/default.htm

Cell: D41
Comment: Rick Heede:
The IPCC default value for crude oil is 20.0 kgC/GJ (range from 19.4 to 20.6 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: D42
Comment: Rick Heede:
Calculated result. Based on IPCC default value for net calorific value (42.3 GJ/Tonne) divided by 7.3137 bbl /tonne. The result is dependent on the specific gravity, which the UN (Energy Statistics Yearbook, 2009, Appendix, "unspecified" oil, values for which varies from a high of 0.961 in Suriname to a low of 0.724 in Indonesia). Crude oil from Texas (45 GJ/t) would yield 6.25 GJ/bbl. Other unofficial sources put the average value at ~6.1 GJ/bbl (wikipedia).

Cell: I50
Comment: Rick Heede:

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