

The Energy and Fuel Data Sheet

W1P1 – Revision 1

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Length, Area, Volume		Weight, Mass		Energy, Power ¹	
1 mile	= 1.609344 km	1 short ton	= 0.90718474 tonnes	1 kWh	= 3.6 MJ
1 foot	= 30.48 cm	1 long ton	= 1.016046909 tonnes	1 Btu	= 1055.056 J
1 inch	= 2.540 cm	1 pound	= 0.45359237 kg	1 therm	= 105.5056 MJ
1 imperial gallon	= 4.54609 L	1 kg	= 9.80665 Newtons	1 calorie	= 4.1868 J
1 US gallon	= 3.785411784 L	44.010 kg of CO ₂	= 12.011 kg of C	1 tonne of oil equivalent (toe)	= 41.868 GJ (LHV)
1 imperial pint	= 0.56826125 L	Speed		1 barrel of oil	≈ 5.70 GJ (IEA def.)
1 US pint	= 0.473176473 L	1 mph	= 0.44704 m/s	(LHV)	≈ 5.86 GJ (global avg.)
1 barrel of oil	= 158.987294928 L	1 km/h	= 0.27 m/s	1 mechanical hp	≈ 745.7 W
Pressure		Time		1 PS	≈ 735.5 W
1 atmosphere	= 1.01325 bar	1 day	= 86400 seconds		
1 atmosphere	= 101.325 kPa	1 year	= 8760 hours		
1 atmosphere	≈ 14.6959494 psi				
1 atmosphere	≈ 760 torr (mmHg)				
1 psi	= 6,894.757 Pa				

¹ Alternate definitions exist for many of these units, the ISO standards were chosen where possible.

General Properties for Some Common Fuels

This data is aggregated from 26 sources in order to give a representative view of each fuel's properties, with global scope and no specific application. The tables on the following pages give the data presented in each source, which can be used to represent more specific situations (e.g. automobile fuels in Europe).

		Density at STP	Ratio of HHV to LHV energy content	Net Calorific Value / LHV		Gross Calorific Value / HHV		Carbon Intensity
		(kg/m ³)		(MJ/L)	(MJ/kg)	(MJ/L)	(MJ/kg)	(g CO ₂ -eq / MJ LHV)
Crude Oil		856 ± 24	1.052 ± 0.001	36.84 ± 1.05	43.05 ± 1.40	38.76 ± 1.10	45.30 ± 1.47	73.5 ± 2.6
Petrol / Gasoline		741 ± 4	1.063 ± 0.015	32.70 ± 0.44	44.15 ± 0.74	34.77 ± 0.47	46.94 ± 0.70	70.8 ± 4.4
Diesel		837 ± 8	1.063 ± 0.011	35.94 ± 0.45	42.91 ± 0.46	38.19 ± 0.47	45.60 ± 0.49	74.3 ± 2.3
Fuel Oil		959 ± 17	1.058 ± 0.008	39.21 ± 1.09	40.87 ± 0.94	41.50 ± 1.15	43.26 ± 1.00	77.8 ± 2.1
LPG		533 ± 18	1.077 ± 0.008	24.67 ± 0.80	46.28 ± 0.74	26.57 ± 0.86	49.84 ± 0.80	63.9 ± 2.1
Kerosene		807 ± 6	1.053 ± 0.001	35.24 ± 0.41	43.69 ± 0.51	37.10 ± 0.43	45.99 ± 0.54	72.0 ± 1.8
Hydrogen	(35 MPa)	23.65 ± 0.09		2.837 ± 0.003		3.355 ± 0.004		
	(70 MPa)	39.69 ± 0.16	1.183 ± 0.001	4.761 ± 0.005	119.95 ± 0.13	5.631 ± 0.006	141.88 ± 0.16	0
	(liquid)	72.41 ± 0.72		8.685 ± 0.010		10.273 ± 0.011		
		(kg/m ³)	(HHV / LHV)		(MJ/kg)		(MJ/kg)	(g/MJ LHV)
Coal			1.050 ± 0.004	-	25.75 ± 2.64	-	27.05 ± 2.77	95.7 ± 7.0
		(kg/m ³)	(HHV / LHV)	(MJ/m ³)	(MJ/kg)	(MJ/m ³)	(MJ/kg)	(g/MJ LHV)
Natural Gas		0.768 ± 0.039	1.109 ± 0.003	35.22 ± 2.22	45.86 ± 3.95	39.05 ± 2.47	50.84 ± 4.38	56.9 ± 3.4
Hydrogen	(1 atm.)	0.0838 ± 0.0008	1.183 ± 0.001	10.05 ± 0.01	119.95 ± 0.13	11.88 ± 0.01	141.88 ± 0.16	0

Data Tables for Each Fuel

The following tables list the data sources consulted and the values they present. The author's calculations are shown when values were converted from their native units. The following indicators are used for the data:

- Values given in **purple** were derived from other data given solely by the source;
- Values given in **blue** were calculated using the aggregated data from other sources, as given in the table on page 2;
- Values given in **pink** were disregarded because their scope did not match the criteria of this study, they were non-primary sources that were still worth mentioning, or they were believed to be erroneous.

Selected studies are highlighted in bold as these were considered to be the most methodologically sound, and so their results were weighted more heavily in the aggregated table on page 2:

- Both the International Energy Agency (IEA) and the U.S. Energy Information Administration (EIA) provide country-specific data for several fuels, giving data such as national production levels, average densities and heat contents ([1-4] and [5]). Global average values were produced from these data sets where possible, by weighting each nation's value by its level of production. For other studies, the region represented by their data is given in brackets.
- The Intergovernmental Panel on Climate Change (IPCC) published authoritative reports on the emission factors for stationary and mobile fuel combustion, giving carbon intensities for several fuels which account for the emission of CH₄ and N₂O ([6, 7]).

Crude Oil		Density (kg/L)	Net Calorific Value / LHV		Gross Calorific Value / HHV		Carbon Intensity (g CO ₂ /MJ LHV)
			(MJ/L)	(MJ/kg)	(MJ/L)	(MJ/kg)	
IEA (definition) ²	[1]		35.67	41.868			
IEA Key World Energy Statistics (global)	[3]		36.83 ± 1.19	1.028 ± 0.026 toe/tonne = 43.03 ± 1.10	38.78 ± 1.25	45.31 ± 1.16	
IEA Oil Information (global)	[1] [8]	0.853	38.50	45.00	40.51	47.37	20g _c = 73.28
IEA Oil Information (weighted global average)	[1]	7.353 ± 0.168 barrels per tonne = 0.856 ± 0.020					
US EIA (weighted global average)	[5]	7.335 ± 0.219 barrels per tonne = 0.858 ± 0.026	36.89 ± 0.84	42.98 ± 1.62	5852 ± 133 kBtu per barrel = 38.84 ± 0.88	45.25 ± 1.71	
Internal Revenue Service (definition)	[9]				5800 kBtu per barrel = 38.49 MJ/L	44.98	
DUKES (UK)	[10]	1192 L/tonne = 0.839	36.4	43.4	38.3	45.7	
IPCC stationary (global)	[6]						73.55 ± 2.58

² The IEA defined an internationally recognised standard for a tonne of oil equivalent (toe) as being 10.0 kcal, or 41.868 GJ.

Petrol / Gasoline			Density (kg/L)	Net Calorific Value / LHV		Gross Calorific Value / HHV		Carbon Intensity (g CO ₂ /MJ LHV)
				(MJ/L)	(MJ/kg)	(MJ/L)	(MJ/kg)	
IEA	(Europe)	[2]		32.6	44.0	34.7	46.8	
	(America)			33.2	44.8	35.3	47.6	
	(Pacific)			33.0	44.6	35.1	47.4	
IEA (global)	[1] [8]	0.741	33.16	44.75	34.90	47.10	18.9 g _c = 69.25 g _{co₂}	
U.S. Energy Information Administration (USA)	[11]	8.53 barrels/tonne = 0.737						
DUKES (UK)	[10]	1362 L/tonne = 0.734	32.82	44.7	34.58	47.1	3.135 kg/kg (HHV) = 66.56 (HHV) = 70.13	
DEFRA (UK) ³	[12]	1354 L/tonne = 0.739	33.03	44.72	34.76	47.07	2317 g/L = 70.15	
IPCC stationary (global)	[6]						69.55 ± 3.12	
IPCC mobile (global)	[7]						71.15 ± 5.22	
ORNL Bioenergy (USA)	[13]	1356 L/tonne = 0.737	115,000 Btu/gal _{us} = 32.05	43.46	125,000 Btu/gal _{us} = 34.84	47.24	2.42 kg _c /gal _{us} = 2.34 kg _{co₂} /L = 73.1	
JEC (EU)	[14, 15]	0.745	32.2	43.2			3.17 kg/kg = 73.4	
GREET 1.8 (USA) (conventional gasoline)	[16]	2,819 g/gal _{us} = 0.745	116,090 Btu/gal _{us} = 32.36	43.45	124,340 Btu/gal _{us} = 34.66	46.54	86.3% carbon ratio = 72.8	
Transportation Energy Data Book (USA)	[17]	6.2 lb/gal _{us} = 0.743	115,400 Btu/gal _{us} = 32.16	43.29	125,000 Btu/gal _{us} = 34.84	46.90	19.34 MT/Quad = 67.17 (HHV) = 71.84	
College of the Desert (USA)	[18]			44.5		47.5		

³ Government statistics derived from data given in the Digest of UK Energy Statistics (DUKES) and the Standard Assessment Procedure (SAP 2005).

Diesel		Density (kg/L)	Net Calorific Value / LHV		Gross Calorific Value / HHV		Carbon Intensity (g CO ₂ /MJ LHV)
			(MJ/L)	(MJ/kg)	(MJ/L)	(MJ/kg)	
DUKES (UK)	[10]	1195 L/tonne = 0.837	35.90	42.9	38.16	45.6	3.164 kg/kg HHV = 69.39 (HHV) = 73.75
DEFRA (UK)	[12]	1203 L/tonne = 0.831	36.04	43.36	37.94	45.64	2629 g/L = 72.94
IPCC stationary (global)	[6]						74.35 ± 1.47
IPCC mobile (global)	[7]						75.39 ± 2.84
ORNL Bioenergy (USA)	[13]	0.849	130,500 Btu/gal _{US} = 36.37	42.84			2.77 kg _c /gal _{US} = 2.68 kg _{co₂} /L = 73.7
JEC (EU)	[14, 15]	0.832	35.9	43.1			3.16 kg/kg = 73.3
Determined for C _{15.35} H _{28.68}	[19]	0.832	35.70	42.92			
GREET 1.8 (USA)	[16]	3,206 g/gal _{US} = 0.847	129,488 Btu/gal _{US} = 36.19	42.61	138,490 Btu/gal _{US} = 38.60	45.58	87.1% carbon ratio = 74.9
Transportation Energy Data Book (USA)	[17]		128,700 Btu/gal _{US} = 35.87	42.83	138,700 Btu/gal _{US} = 38.66	46.16	
College of the Desert (USA)	[18]		35.59	42.5	37.52	44.8	

Note: when a source gave multiple options for diesel fuels, the data for low or ultra-low sulphur diesel were chosen.

Fuel Oil		Density (kg/L)	Net Calorific Value / LHV		Gross Calorific Value / HHV		Carbon Intensity (g CO ₂ /MJ LHV)
			(MJ/L)	(MJ/kg)	(MJ/L)	(MJ/kg)	
IEA	(Europe)	[2]	38.4	40.0	40.6	42.3	
	(America)		38.6	40.2	40.8	42.5	
	(Pacific)		40.9	42.6	43.3	45.1	
IEA (global)	[1] [8]	0.944	38.40	40.68	40.42	42.82	21.1 g _c = 77.31
U.S. Energy Information Administration (USA)	[11]	6.66 barrels/tonne = 0.944					
DUKES (UK)	[10]	1024 L/tonne = 0.977	39.84	40.8	42.48	43.5	3.216 kg/kg HHV = 73.93 (HHV) = 78.82
DEFRA (UK)	[12]	1033 L/tonne = 0.968	39.86	41.18	41.96	43.34	77.99
IPCC stationary (global)	[6]						77.65 ± 2.02

LPG		Density	Net Calorific Value / LHV		Gross Calorific Value / HHV		Carbon Intensity
		(kg/L)	(MJ/L)	(MJ/kg)	(MJ/L)	(MJ/kg)	(g CO₂/MJ LHV)
IEA	(Europe)	[2]	24.5	46.0	26.4	49.4	
	(America)		25.2	47.3	27.1	50.8	
	(Pacific)		25.4	47.7	27.3	51.3	
IEA (global) ⁴	[1] [8]	0.539	24.87	46.15	26.99	50.08	17.2 g _c = 63.02
U.S. Energy Information Administration (USA)	[11]	11.60 barrels/tonne = 0.542					
DUKES (UK) ⁴	[10]	1849 L/tonne = 0.541	24.88	46.0	26.61	49.2	214 g/kWh (HHV) = 63.58
DEFRA (UK)	[12]	1968 L/tonne = 0.508	23.87	46.98	25.13	49.45	62.63
IPCC stationary (global)	[6]						63.15 ± 2.07
IPCC mobile (global)	[7]						64.46 ± 2.00
JEC (EU)	[14, 15]	0.550	25.3	46.0			3.02 kg/kg = 65.7
GREET 1.8 (USA)	[16]	1,923 g/gal _{US} = 0.508	84,950 Btu/gal _{US} = 23.68	46.61	91,410 Btu/gal _{US} = 25.48	50.15	
NEF (Japan)	[20, 21]						58.7 (HHV) = 63.1
Transportation Energy Data Book (USA)	[17]						16.99 MT/Quad = 59.00 (HHV) = 63.4

Kerosene		Density	Net Calorific Value / LHV		Gross Calorific Value / HHV		Carbon Intensity
		(kg/L)	(MJ/L)	(MJ/kg)	(MJ/L)	(MJ/kg)	(g CO₂/MJ LHV)
IEA	(Europe)	[2]	34.7	43.0	36.5	45.3	
	(America)		35.3	43.8	37.2	46.1	
	(Pacific)		34.6	42.9	36.4	45.2	
IEA (global)	[1] [8]	0.810	35.44	43.75	37.30	46.05	19.6 g _c = 71.82
U.S. Energy Information Administration (USA)	[11]	7.73 barrels/tonne = 0.814					
DUKES (UK)	[10]	1245 L/tonne = 0.803	35.26	43.9	37.11	46.2	3.150 kg/kg (HHV) = 68.18 (HHV) = 71.75
DEFRA (UK)	[12]	1250 L/tonne = 0.800	35.11	43.89	36.96	46.20	71.73
IPCC stationary (global)	[6]						72.15 ± 1.82
NEF (Japan)	[20, 21]						67.9 (HHV) = 71.5
Transportation Energy Data Book (USA)	[17]		128,100 Btu/gal _{US} = 35.70	44.26	135,000 Btu/gal _{US} = 37.63	46.64	19.72 MT/Quad = 68.49 (HHV) = 72.2

⁴ Assuming 60% propane and 40% butane by mass.

Natural Gas	Density (kg/m ³)	Net Calorific Value / LHV		Gross Calorific Value / HHV		Carbon Intensity (g CO ₂ /MJ LHV)	
		(MJ/m ³)	(MJ/kg)	(MJ/m ³)	(MJ/kg)		
IEA (global)	[3]		35.14 ± 2.19	45.75 ± 3.68	38.95 ± 2.43	50.71 ± 4.08	
IEA	[8]						15.3 g _c = 56.06
US EIA (weighted global average)	[5]		34.64	45.11	38.40	50.00	
DUKES (UK production)	[10]		36.0	46.9	40.0	52.1	184 g/kWh (HHV) =
(UK consumption)			35.6	46.4	39.6	51.6	51.11 (HHV) = 56.82
DEFRA (UK)	[12]	1340651 L/tonne = 0.7459	35.64	47.78	39.60	53.09	57.17
IPCC stationary (global)	[6]						56.15 ± 2.07
IPCC mobile (global)	[7]						58.96 ± 4.13
(Europe)		0.791	35.7	45.1	39.5	50.0	56.4
JEC (Russia)	[15]	0.727	35.8	49.2	39.7	54.5	55.1
(Netherlands)		0.827	31.4	38.0	34.8	42.1	
GREET 1.8 (USA)	[16]	22.0 g/ft ³ = 0.777	983 Btu/ft ³ = 36.6	47.14	1,089 Btu/ft ³ = 40.6	52.23	72.4% carbon ratio = 56.3
ORNL Bioenergy (USA)	[13]		930 Btu/ft ³ = 34.7	45.1	1027 Btu/ft ³ = 38.3	49.8	14.4 g _c /MJ = 52.8
NEF (Japan)(13A gas)	[20, 21]						51.25 g/MJ HHV = 56.8
Combustion (global)	[22]		35.16	45.76	38.90	50.64	
Transportation Energy Data Book (dry gas)	[17]				1027 Btu/ft ³ = 38.3	49.8	14.47 MT/Quad = 50.25 (HHV) = 55.69

Hydrogen			Density (kg/m ³)	Net Calorific Value / LHV (MJ/m ³) (MJ/kg)		Gross Calorific Value / HHV (MJ/m ³) (MJ/kg)	
NIST	20°C, 101.325 kPa		0.0837547				
	20°C, 35 MPa	[23, 24]	23.6507				
	20°C, 70 MPa		39.6931				
	20 K, 101.325 kPa		72.4073				
JEC (EU)	[14, 15]	0.0893	10.73 10.06	120.1			
REET 1.8	[16]	2.55 g/ft ³ = 0.09005	290 Btu/ft ³ = 10.81 10.05	119.99	343 Btu/ft ³ = 12.78 11.89	141.92	
Transportation Energy Data Book (USA)	[17]	0.08988	10.02	113,400 Btu = 119.64	11.86	134,200 Btu = 141.59	
US Department of Energy (USA)	[18]	0.08519	10.04	119.93	11.88	141.86	
Glenn Research Centre (USA)	[25]	0.08513	10.04 10.05	119.93 51,596 Btu/lb = 120.01	11.88 11.89	141.86 61,031 Btu/lb = 141.96	
M. Mikkola	0°C, 1 atm 20K, 1 atm	[26]	0.08987 70.99	10.78 / 10.05 8515 / 8685	119.96	12.74 / 11.88 10065 / 10267	141.79

Data for the density and volumetric energy density of hydrogen was based on various definitions of the gas state (temperature, pressure) within the different sources. This was corrected for by adopting a single reference for the gas state, and using the gas density of 0.0837547 kg/m³ to recalculate the volumetric energy densities in all references.

Density data is taken solely from the NIST equation of state calculator for STP conditions as defined by NIST (20°C and 101.325 kPa). Typical conditions for hydrogen fuel cell vehicles are also given for reference (as used in the summary table on page 2). Note that NIST gives the density of hydrogen as being 0.0898851 kg/m³ at 0°C and 1 atmosphere, which is the a commonly quoted value in other sources [23].⁵

⁵ <http://webbook.nist.gov/cgi/fluid.cgi?ID=C1333740&Action=Page%20> is a more direct URL to the thermophysical properties of hydrogen.

Coal		Grade and End Use	Net Calorific Value / LHV (MJ/kg)	Gross Calorific Value / HHV (MJ/kg)	Carbon Intensity (g CO ₂ /MJ LHV)
IEA (definition) ⁶	[2]			29.31	
IEA Key World Energy Statistics (weighted global average)⁷	[3]	<i>All</i>	0.563 ± 0.064 toe/tonne = 23.56 ± 2.67	24.75 ± 2.81	
IEA (global)	[8]	<i>All</i>			26.13 gc = 95.76
IEA Coal Information (weighted global average)⁸	[2]	<i>Anthracite, coking and other bituminous coals</i>	27.49 ± 1.19	28.87 ± 1.25	
IEA Energy Prices & Taxes (weighted global average)⁹	[4]	<i>Steam coal for electrical power generation</i>	25.86 ± 2.68	27.16 ± 2.82	
US EIA (weighted global average)¹⁰	[5]	<i>All</i>	18.65 ± 3.64	19.59 ± 3.82	
DUKES (UK)	[10]	<i>All UK consumers UK power stations</i>	24.5 23.8	25.8 25.0	2.301 kg/kg (HHV) = 90.61 (HHV) = 95.30
DEFRA (UK)	[12]	<i>Hard coals</i>	28.98	30.50	86.49
IPCC stationary (global)	[6]	<i>Coking, bituminous and sub- bituminous coals used in centralised power stations</i>			95.59 ± 5.33
JEC (EU)	[15]		29.4	30.88	96.3
GREET 1.8 (USA)	[16]	<i>Bituminous</i>	22,460,600 Btu/ton = 26.12	23,445,900 Btu/ton = 27.27	75.5% carbon ratio = 105.9
ORNL Bioenergy (USA)	[13]	<i>Bituminous</i>	27–30		746 gc/kg = 91.1–101.2
Transportation Energy Data Book (USA)	[17]	<i>All US production</i> <i>All US consumption</i>	21,352,000 Btu/ton = 24.83 21,015,000 Btu/ton = 24.44		26.04 MT/Quad = 90.43 (HHV) = 94.98 25.98 MT/Quad = 90.23 (HHV) = 94.77

These values aim to represent power-station grade hard coal, typically defined as anthracite, coking coal and other bituminous coals.

⁶ The IEA defined an internationally recognised standard for a tonne of coal equivalent (tce) as being 7.0 kcal, or 29.3076 GJ.

⁷ Covers output from the top ten producing countries, accounting for 87% of global production.

⁸ Covers consumption from 30 countries (with the notable exception of China), accounting for 35% of global consumption.

⁹ Covers consumption from 24 countries (with the notable exception of China), accounting for 32% of global consumption.

¹⁰ Covers output from 71 countries, accounting for virtually all global production. This was discounted as it included significant amounts of lower grade lignite and peat production.

Data Sources for Other Fuels

Many of the cited sources gave data on alternative fuels which are not listed above, including:

- Biodiesel [14, 16, 17, 19];
- Syndiesel [14-16];
- ETBE/MTBE [14-16];
- Ethanol blends [8, 14-17, 19];
- Methanol [8, 14-18];
- Naphtha [14-17];
- Peat [8].

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