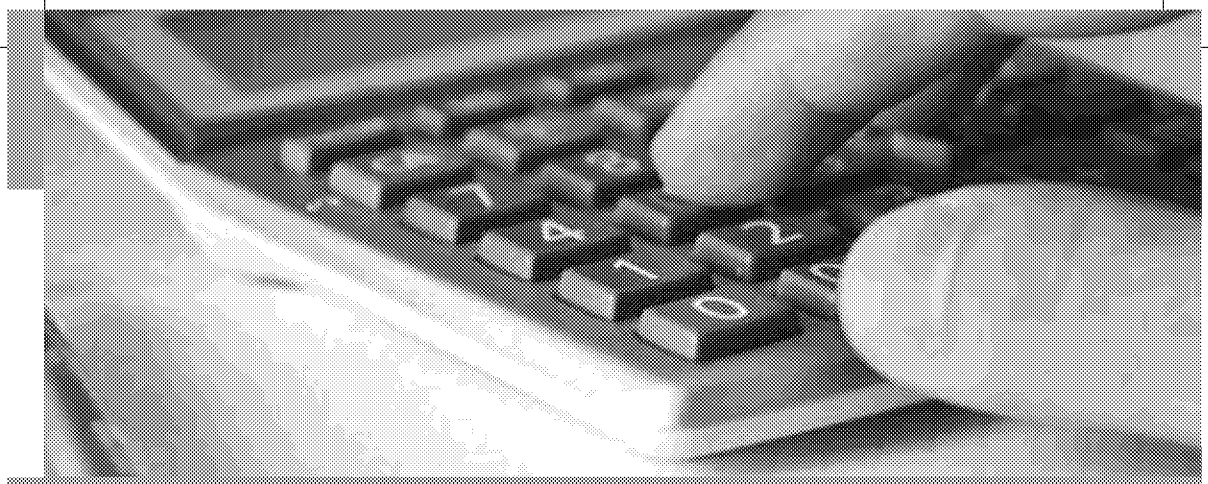

International Gas Union (IGU)
News, views and knowledge on gas – worldwide

Natural Gas Conversion Guide

IGU
INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

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Message from the President of IGU

Dear colleagues,

Thanks to technology, the energy industry today is moving towards an almost seamless environment. The consumer is now no longer locked to a single type of fuel. The ability to switch between using oil, natural gas and coal, has enabled one to take full advantage of the most efficient and lowest priced source of energy. However, to do so, one has to calculate and compare which fuel, at the given point in time, would provide the "best value for money".

As a spokesperson for the IGU, I find a conversion guide almost a necessity. You can never know what type of questions would be asked. Even within the gas industry, we use different measurement systems for different regions of the world. Hence, the best way is to equip oneself with a tool which would enable one to carry out a quick comparison of natural gas using a common denominator or making inter-fuel comparisons.

This Natural Gas Conversion Guide is IGU's contribution to assist analysts from different types of background to quickly convert and find the equivalent value between the three fossil fuels, under a given set of parameters. This guide comprises four sections, namely: standard conversion tables; characteristics and conversion tables for natural gas, liquefied natural gas (LNG), and liquefied petroleum gas (LPG); inter-fuel conversion; and a set of glossary of terms and abbreviations. The guide also comes in two sizes, a normal A5-sized handbook, and a pocket-sized booklet.

For those who do not have a copy of the guide, you can log onto the IGU website (www.igu.org), and proceed to the section on natural gas conversion. For those who wish to undertake a more detailed conversion under a more complex environment, we have also included in the guide a list of "links" to a few websites.

The publication of this conversion guide has been made possible from the contributions of a few organisations which had provided their experts to participate in this initiative. I therefore wish to express our heartfelt gratitude to PETRONAS, Shell, and Tokyo Gas, for their invaluable contributions. I also wish to thank those organisations whose previous publications have been used as reference by the team during the course of developing the conversion guide, in particular Shell, The Petroleum Economist, and Alphatania.

To conclude, I wish to emphasise that this guide is meant only as a tool and a quick guide to assist you to find the equivalent values for natural gas, LNG, LPG, oil and coal. I trust that you would find the guide to be handy and useful.

Thank you.

Datuk (Dr) Abdul Rahim Hashim
President, IGU
2009 - 2012 Malaysian IGU Presidency Triennium

Natural Gas Conversion Guide

SECTION 1

INTERNATIONAL GAS UNION
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Standard Conversion Tables

Conversion factors are rounded up to at most four **decimal places for approximation purpose.**

(1) Length

multiply by

	centimetre (cm)	metre (m)	kilometre (km)	inch (in)	foot (ft)	yard (yd)	mile
cm		0.01	1.0×10^{-5}	0.3937	0.0328	0.0109	6.214×10^{-6}
m	100		0.001	39.37	3.281	1.094	6.214×10^{-4}
km	100,000	1,000		39,370	3,281	1,094	0.6214
in	2.54	0.0254	2.540×10^{-5}		0.0833	0.0278	1.578×10^{-5}
ft	30.48	0.3048	3.048×10^{-4}	12		0.3333	1.894×10^{-4}
yd	91.44	0.9144	9.144×10^{-4}	36	3		5.682×10^{-4}
mile	160,934	1,609	1.609	63,360	5,280	1,760	

Example: To convert 100 centimetres (cm) to inches (inch): 100 centimetres = 100 x 0.3937 = 39.37 inches

(2) Area

multiply by

	square metre (m^2)	square inch (in^2)	square foot (ft^2)	square yard (yd^2)	acre	hectare
m^2		1,550	10.76	1.196	2.471×10^{-4}	1.0×10^{-4}
in^2	6.452×10^{-4}		0.0069	7.716×10^{-4}	1.594×10^{-7}	6.452×10^{-8}
ft^2	0.0929	144		0.1111	2.296×10^{-5}	9.290×10^{-6}
yd^2	0.8361	1,296	9		2.066×10^{-4}	8.361×10^{-5}
acre	4,047	6,272,640	43,560	4,840		0.4047
hectare	10,000	15,500,031	107,639	11,960	2.471	

(3) Volume

multiply by →

	cubic metre (m^3)	cubic inch (in^3)	cubic foot (ft^3)	cubic yard (yd^3)	litre (ℓ)	Imperial gallon liquid (Imp. gal.)	US gallon liquid (US gal.)	Oil barrel (US bbl)
m^3		61,024	35.31	1.308	1,000	220.0	264.2	6.290
in^3	1.639×10^{-5}		5.787×10^{-4}	2.143×10^{-5}	0.0164	0.0036	0.0043	1.031×10^{-4}
ft^3	0.0283	1,728		0.0370	28.32	6.229	7.481	0.1781
yd^3	0.7646	46,656	27		764.6	168.2	202.0	4.809
ℓ	0.001	61.02	0.0353	0.0013		0.22	0.2642	0.0063
Imp. gal.	0.0045	277.4	0.1605	0.0059	4.546		1.201	0.0286
US gal.	0.0038	231	0.1337	0.005	3.785	0.8327		0.0238
US bbl	0.159	9,702	5.615	0.2079	159	34.97	42	

(4) Velocity

multiply by →

	metre/second (m/s)	metre/minute (m/min)	kilometre/ hour (km/h)	foot/second (ft/s)	foot/minute (ft/min)	mile/hour (mi/h)	yard/hour (yd/h)
m/s		60	3.6	3.281	196.9	2.237	3,937
m/min	0.0167		0.06	0.0547	3.281	0.0373	65.62
km/h	0.2778	16.67		0.9113	54.68	0.6214	1,094
ft/s	0.3048	18.29	1.097		60	0.6818	1,200
ft/min	0.0051	0.3048	0.0183	0.0167		0.0114	20
mi/h	0.4470	26.82	1.609	1.467	88		1,760
yd/h	2.540×10^{-4}	0.0152	9.144×10^{-4}	8.333×10^{-4}	0.05	5.682×10^{-4}	

(5) Mass

		← multiply by →						
						ton		
		kilogram (kg)	grain (gr)	ounce (oz)	pound (lb)	metric (tonne)	long	short
	kg		15,432	35.27	2.205	0.001	9.842×10^{-4}	0.0011
	gr	6.480×10^{-5}		0.0023	1.429×10^{-4}	6.480×10^{-8}	6.378×10^{-8}	7.143×10^{-8}
	oz	0.0283	437.5		0.0625	2.835×10^{-5}	2.790×10^{-5}	3.125×10^{-5}
	lb	0.4536	7,000	16		4.536×10^{-4}	4.464×10^{-4}	5.0×10^{-4}
ton	metric	1,000	15,432,358	35,274	2,205		0.9842	1.102
ton	long	1,016	15,680,000	35,840	2,240	1.016		1.12
ton	short	907.2	14,000,000	32,000	2,000	0.9072	0.8929	

Note: tonne is an alternative designation for the metric ton.

(6) Force Or Weight

		← multiply by →						
						ton-force		
		newton (N)	kilogram-force (kgf)	pound-force (lbf)	poundal (pdl)	metric (tonne)	long	short
	N		0.1020	0.2248	7.233	1.020×10^{-4}	1.004×10^{-4}	1.124×10^{-4}
	kgf	9.807		2.205	70.93	0.001	9.842×10^{-4}	0.0011
	lbf	4.448	0.4536		32.17	4.536×10^{-4}	4.464×10^{-4}	5.0×10^{-4}
	pdl	0.1383	0.0141	0.0311		1.410×10^{-5}	1.388×10^{-5}	1.554×10^{-5}
ton	metric	9,807	1,000	2,205	70,932		0.9842	1.102
ton	long	9,964	1,016	2,240	72,070	1.016		1.12
ton	short	8,896	907.2	2,000	64,348	0.9072	0.8929	

(7) Pressure

multiply by

	bar = 100 kN/m²	kilogram-force square centimetre (kgf/cm²)	pound-force/ square inch (lbf/in²) (psi)	Standard atmosphere (atm)	millimetre mercury at 0 °C (mmHg)	inch mercury at 32 °F (inHg)	inch water at 4 °C (inAq)
bar		1.020	14.50	0.9869	750.1	29.53	401.5
kgf/cm²	0.9807		14.22	0.9678	735.6	28.96	393.7
psi	0.0689	0.0703		0.0680	51.71	2.036	27.68
atm	1.013	1.033	14.70		760	29.92	406.8
mmHg	0.0013	0.0014	0.0193	0.0013		0.0394	0.5352
inHg	0.0339	0.0345	0.4912	0.0334	25.40		13.60
inAq	0.0025	0.0025	0.0361	0.0025	1.868	0.0736	

(8) Mass Per Unit Volume

multiply by

	kilogram/ cubic metre (kg/m³)	grains/cubic feet (gr/ft³)	pound/cubic inch (lb/in³)	pound/ cubic feet (lb/ft³)	pound/gallon Imperial (lb/gal)	pound/gallon US (lb/gal)	tonnes/ cubic metre (tonnes/m³)
kg/m³		437	3.613×10^{-5}	0.0624	0.01	0.0083	0.001
gr/ft³	0.0023		8.267×10^{-8}	1.429×10^{-4}	2.293×10^{-5}	1.910×10^{-5}	2.288×10^{-6}
lb/in³	27,680	12,096,000		1,728	277.4	231	27.68
lb/ft³	16.02	7,000	5.787×10^{-4}		0.1605	0.1337	0.0160
lb/gal (Imp.)	99.78	43,602	0.0036	6.229		0.8327	0.0998
lb/gal (US)	119.8	52,364	0.0043	7.481	1.201		0.1198
tonnes/m³	1,000	436,996	0.0361	62.43	10.02	8.345	

(9) Energy Or Work

	← multiply by →				
	Joule (J) = Nm	kilowatt-hour (kWh)	kilocalorie (kcal)	horsepower hours (metric)	British thermal unit (Btu)
J		2.778×10^{-7}	2.388×10^{-4}	3.777×10^{-7}	9.478×10^{-4}
kWh	3,600,000		859.8	1.360	3,412
kcal	4,187	0.0012		0.0016	3.968
hp-h (metric)	2,647,796	0.7355	632.4		2,510
Btu	1,055	2.931×10^{-4}	0.2520	3.985×10^{-4}	

(10) Power

	← multiply by →				
	kilowatt (kW) = kJ/s	kilocalories/sec (kcal/s)	toncal/day	horsepower (metric) (hp)	British thermal unit/hour (Btu/h)
kW		0.2388	20.64	1.360	3,412
kcal/s	4.187		86.40	5.692	14,286
toncal/day	0.0485	0.0116		0.0659	165.3
hp (metric)	0.7355	0.1757	15.18		2,510
Btu/h	2.931×10^{-4}	7.0×10^{-5}	0.006	3.985×10^{-4}	

(11) Rates Of Flow

	← multiply by →					
	cubic metre/minute (cm/min)	cubic metre/hour (cm/h) x 10^3	cubic metre/day (cm/d) x 10^3	cubic foot/min (cf/min)	cubic foot/hour (cf/h) x 10^3	cubic foot/day (cf/d) x 10^6
cm/min		0.06	1.44	35.31	2.119	50.85
cm/h x 10^3	16.67		24	588.6	35.31	847.6
cm/d x 10^3	0.6944	0.0417		24.52	1.471	35.31
cf/min	0.0283	0.0017	0.0408		0.06	1.44
cf/h x 10^3	0.4719	0.0283	0.6796	16.67		24
cf/d x 10^3	0.0197	0.0012	0.0283	0.6944	0.0417	

(12) Temperature

°C	-50	-40	-30	-20	-10	0.0	+10	20	30	40	50	60	70	80	90	100
°F	-58	-40	-22	-4	14	32	50	68	86	104	122	140	158	176	194	212

From	To	Formula
Degrees Celsius	Degrees Fahrenheit	[(9/5) x °C] + 32
Degrees Fahrenheit	Degrees Celsius	(°F – 32) x 5/9
Degrees Celsius	Kelvins	°C + 273.15
Kelvins	Degrees Celsius	°C – 273.15

Natural Gas Conversion Guide

SECTION 2

INTERNATIONAL GAS UNION
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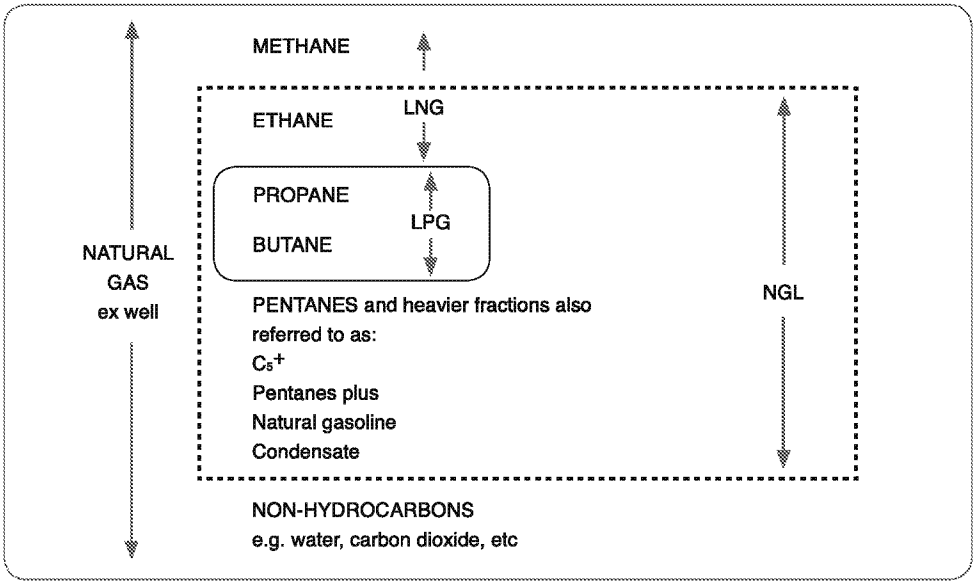
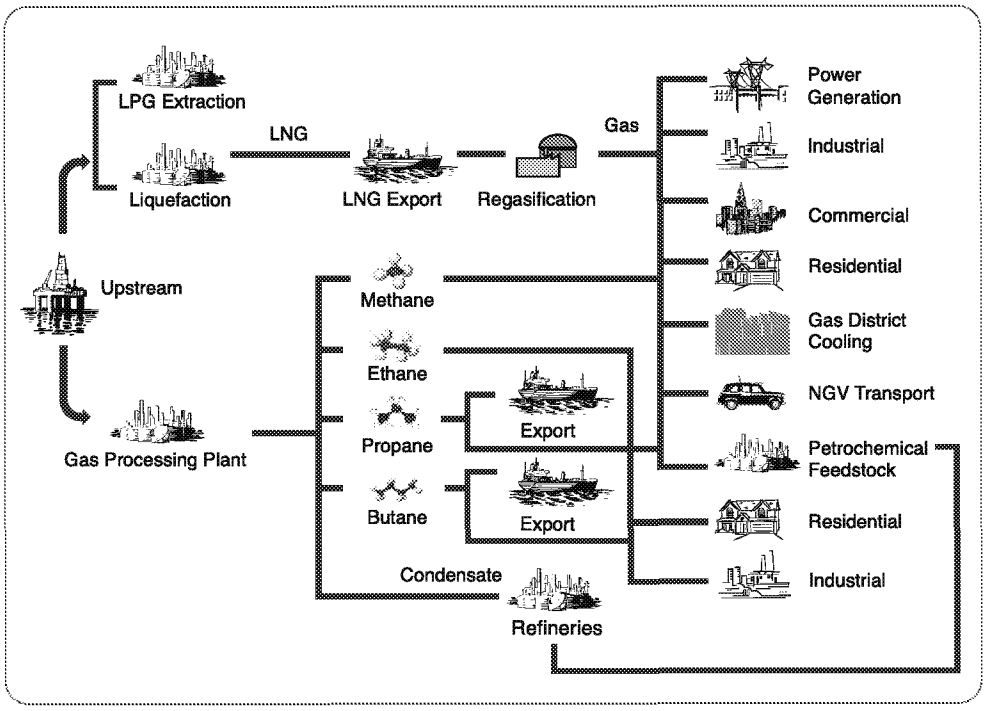
Terminology And Constituents Of Natural Gas



LNG = liquefied natural gas
LPG = liquefied petroleum gas
NGL = natural gas liquids

Natural Gas Value Chain



INTERNATIONAL GAS UNION
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Remarks & Key Assumptions

This section is intended to provide additional information as a reference ONLY on the properties/characteristics of natural gas, liquefied natural gas (LNG) and liquefied petroleum gas (LPG) for background understanding.

The approximations in the tables in Section 2 and Section 3 are based upon the following assumptions:-

(i) For natural gas:

- "Gas State" in conversion tables is assumed at Normal, N (0 °C, 1 atm)
  1,100 Btu/scf (60 °F, 1 atm) = 1,163 Btu/cf (0 °C, 1 atm)
  *Scf = Standard cubic feet. Standard means "(60 °F, 1 atm)"

(ii) For LNG

- 1 tonne LNG = 1,300 Nm^3 gas [*N: Normal. Normal means "(0 °C, 1 atm)"];
- Density = 450 kg/m^3 LNG

(iii) For LPG,

- An assumed 50/50 propane/butane mixture with *(r)* and *(p)* indicating that the LPG is either refrigerated or pressurised.
- The simulation software known as "Virtual Materials Group (VMG) Process Simulator" is used in the process. Other assumptions are as below:-
- Pressurised *(p)*: temperature = 20 °C, Vapour Fraction (VapFrac) = 0
- Refrigerated *(r)*: temperature = each boiling point, Pressure = 0 kPa (g), g = gauge pressure

Corresponding boiling points ->

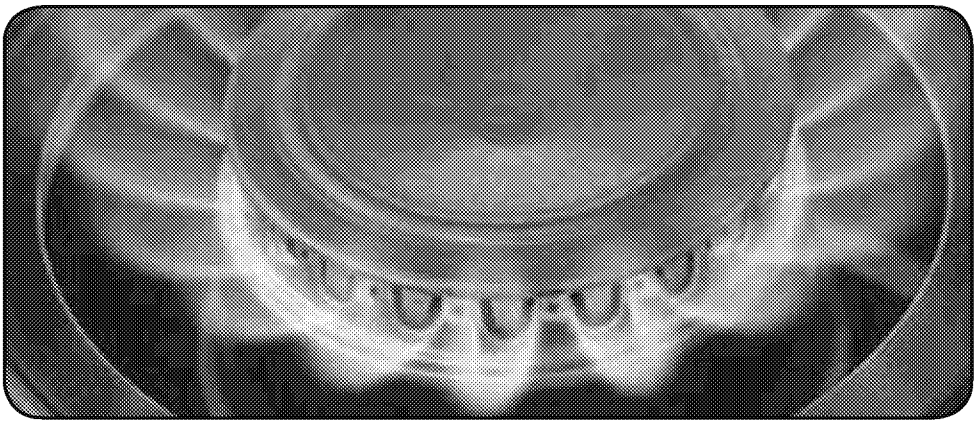
Ethane	:	-88.7 °C
Propane	:	-42.2 °C
n-Butane	:	-0.6 °C
C3.C4 mix	:	-29.2 °C

(iv) Calorific values, mmBtu (gross):

	mmBtu/tonne (gross)	mmBtu/bbl	mmBtu/m^3
LNG	53.4	3.82	24.0
LPG *(r)*	47.3	4.52	28.5
LPG *(p)*	47.3	4.13	25.9
Oil	39.68	5.80	
Coal	27.3		

(v) 1 tonne of oil equivalent (toe) = 41.868 GJ = 39.68 mmBtu

(vi) 1 barrel of oil equivalent (boe) = 5,800,000 Btu = 5.8 mmBtu



Natural Gas (NG)

Introduction	❋ Naturally occurring natural gas was discovered and identified in America as early as 1626, when French explorers discovered natives igniting gases that were seeping into and around Lake Erie. ❋ Conventional natural gas is commonly found in underground sandstone and limestone formation whereas Unconventional Gas refers to coal bed methane, shale gas, gas hydrates and tight sand gas.
Definition	❋ A gaseous hydrocarbon fuel obtained from underground sources. ❋ Natural gas remains in the gaseous state under the temperature and pressure conditions in service.
Composition	❋ A mixture of primarily methane (CH_4) and may also include ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}) and other higher hydrocarbons. It generally also includes some inert gases, such as nitrogen (N) and carbon dioxide (CO_2), plus minor amounts of trace constituents.
Characteristics	❋ Colourless, odourless, tasteless, shapeless and lighter than air. At atmospheric pressure, it is gaseous at any temperature over -161 °C. ❋ High ignition temperature and narrow flammability range, making it an inherently safe fossil fuel compared to other fuel sources. ❋ Condenses to LNG when cooled to a temperature of approximately -161 °C at atmospheric pressure. ❋ Commercialised natural gas is practically sulphur free and produces virtually no sulphur dioxide (SO_2), emits lower levels of nitrogen oxides (NOx) and CO_2 than other fossil fuels.
Boiling Point	❋ Methane, the main component of natural gas, has a boiling point of −161 °C (-257.8 °F) at a pressure of one atmosphere.
Uses	❋ Gas district cooling ❋ Fuel for industrial and residential ❋ Transportation ❋ Power sector ❋ LNG ❋ Feedstock in petrochemical industry ❋ Cooking ❋ Heating
Calorific Value	❋ 1 ft^3 gas = 900 Btu – 1,200 Btu ❋ 1 ft^3 gas = 1,055 kJ
Energy Density	❋ Specific energy = 53.6 MJ/kg that is equivalent to 38.7 MJ/m^3 (0.0387 MJ/ℓ)
Pricing Formulas	❋ Regionalised pricing : North America, Europe and Asia ❋ Oil-indexed in Asia and continental Europe ❋ Gas-to-gas competition in North America and North Western Europe

(1) Heat & Volume

multiply by

	cm = Nm^3	cf = ft^3	mmBtu	GJ	Mcal	kWh	boe
cm		35.31	0.0411	0.0433	10.35	12.03	0.0071
cf	0.0283		0.0012	0.0012	0.2930	0.3407	2.005×10^{-4}
mmBtu	24.36	860.1		1.055	252.0	293.1	0.1724
GJ	23.08	815.2	0.9478		238.8	277.8	0.1634
Mcal	0.0967	3.413	0.0040	0.0042		1.163	6.842×10^{-4}
kWh	0.0831	2.935	0.0034	0.0036	0.8598		5.883×10^{-4}
boe	141.3	4,989	5.8	6.119	1,462	1,700	

Note: 1 PetaJoule (PJ) = 1 million GigaJoule (GJ)

(2) Energy Consumption

multiply by

	N bcm/yr	mmcf/d (0 °C, 1 atm)	boe/d x 10^3	toe/yr x 10^3
N bcm/yr		96.75	19.39	1,035
mmcf/d	0.0103		0.2005	10.69
boe/d x 10^3	0.0516	4.989		53.35
toe/yr x 10^3	0.0010	0.0935	0.0187	

boe volumes are normally expressed in gross and toe in net

(3) Gross Calorific Value < > Net Calorific Value (Natural Gas)

	Gross	Net
Gross	1	0.9
Net	1.1	1

(4) Gas Consumption for Industrial Purposes

PROCESS	INPUT	OUTPUT
Power Generation (Open Cycle)	1.0 bcm gas into plant	3,700 GWh electricity
Power Generation (Combined Cycle)	1.0 bcm gas into plant	5,800 GWh electricity
LNG Project (Plant and Shipping)	1.0 bcm gas into plant	0.85 bcm regasified
Ammonia / Urea Production	1.0 bcm gas into plant	1.8 million tonnes fertiliser
Methanol Production	1.0 bcm gas into plant	1.1 million tonnes methanol
Gas-to-Liquids	1.0 bcm gas into plant	4.0 million barrels oil

These figures can vary greatly, depending on such factors as the process used, the design and age of the plant, efficiency of operation, ambient conditions, etc. They should be used with caution and only for general exercises. All numbers are rounded.

(5) Pipeline Capacities

External diameter (inches)	Capacity (bcm/y)
20	2.0
24	3.2
28	4.7
32	6.6
36	9.0
40	11.7
44	14.9

These numbers are indicative only and can vary widely

Liquefied Natural Gas (LNG)

Introduction	❋ Natural gas liquefaction dates back to the 19th century when British chemist and physicist Michael Faraday experimented with liquefying different types of gases, including natural gas. ❋ The first LNG plant was built in West Virginia in 1912 and began operation in 1917. In January 1959, the world's first LNG tanker, *The Methane Pioneer*, carried an LNG cargo from Lake Charles, Louisiana to Canvey Island, United Kingdom.
Definition	❋ Natural gas, which after processing has been liquefied for storage and transportation purpose. At atmospheric pressure, the LNG will be at temperature between -161 °C and -158 °C.
Composition	❋ Primarily methane (CH_4) but also contains other components like ethane (C_2H_6), butane (C_4H_{10}) up to hexane (C_6H_{14}) and nitrogen (N). ❋ Impurities may include carbon dioxide (CO_2), sulphur (S), carbonyl sulphide (COS), mercaptans and mercury (Hg).
Characteristics	❋ Colourless, odourless and lighter than air. ❋ Volume is typically 585 times smaller in a liquid state based on composition, pressure and temperature. ❋ With its clean burning properties, it produces less air pollutants and can be more efficient compared to traditional fuels e.g. oil, diesel, wood, coal and other organic matters. ❋ LNG is an option when piping gas is not possible or economically viable due to distance, environment (deep sea, natural reserve, mountains) or political reasons.
Boiling Point	❋ Typical -161.5 °C
Uses	❋ Power generation ❋ Transportation ❋ Heating ❋ Cooling
Calorific Value	❋ At normal (N) state, the range is in between 930 Btu/cf and 1,185 Btu/cf
Energy Density	❋ Roughly in the range 410 kg/m³ (0.41 kg/ℓ) to 500 kg/m³ (0.5 kg/ℓ) depending on temperature, pressure and composition. ❋ Specific energy = 56.3 MJ/kg that is equivalent to 25,300 MJ/m³ (25.3 MJ/ℓ).
Pricing Formulas	❋ Market price will vary according to where it is being sold, the local 'marker' prices (e.g. HH, NBP), and the other contractual terms (e.g. crude oil-linked price, spot cargo, long term, etc.)

LNG Conversion Tables

(1) Mass, Volume and Heat

multiply by

	Tonnes LNG	m^3 LNG	Nm^3 gas	ft^3 gas	mmBtu	boe
Tonnes LNG		2.222	1,300	45,909	53.38	9.203
m^3 LNG	0.450		585	20,659	24.02	4.141
m^3 gas	7.692×10^{-4}	0.0017		35.31	0.0411	0.0071
ft^3 gas	2.178×10^{-5}	4.8×10^{-5}	0.0283		0.0012	2.005×10^{-4}
mmBtu	0.0187	0.0416	24.36	860.1		0.1724
boe	0.1087	0.2415	141.3	4,989	5.8	

(2) LNG Characteristics

The average composition is chosen as being representative among compositions provided by different receiving terminals

Origin	Nitrogen N2 %	Methane C1 %	Ethane C2 %	Propane C3 %	C4+ %	LNG density kg/m^3	Gas density kg/m^3 (n)	Expansion ratio m^3(n)/m^3 liq	Gas GCV MJ/m^3 (n)
Abu Dhabi	0.3	84.8	13.2	1.6	0.1	467	0.826	566	44.9
Algeria-Arzew	0.6	88.0	9.0	2.0	0.5	464	0.813	570	44.1
Algeria-Bethioua 1	0.9	88.1	8.4	2.0	0.7	455	0.806	573	35.7
Algeria-Bethioua 2	0.6	90.7	7.8	0.8	0.0	450	0.780	577	36.0
Algeria-Skikda	0.5	91.8	6.9	0.6	0.1	446	0.769	580	35.5
Australia-NWS	0.1	87.4	8.3	3.4	0.8	467	0.831	562	45.3
Brunei	0.1	90.6	5.0	2.9	1.5	461	0.816	564	44.6
Egypt-Damietta	0.1	97.7	1.8	0.22	0.2	427	0.730	585	40.8
Egypt-Idku	0.0	95.9	2.8	0.9	0.5	436	0.752	579	38.9
Equatorial Guinea	0.0	93.4	6.5	0.0	0.0	439	0.755	585	42.0
Indonesia-Arun	0.2	90.7	6.2	2.0	1.0	457	0.803	569	43.9
Indonesia-Badak	0.0	91.2	5.5	2.4	0.9	456	0.801	568	43.9
Indonesia-Tangguh			2.9	0.5	0.2	432	0.744	580	41.0
Libya	0.7	81.6	13.4	3.7	0.7	485	0.867	559	46.6
Malaysia	0.3	90.3	5.3	3.1	1.1	461	0.813	567	44.3
Nigeria	0.1	92.1	5.3	2.1	0.5	458	0.809	566	44.2
Norway	0.8	91.8	5.7	1.3	0.4	451	0.782	577	40.1
Oman	0.4	87.9	7.3	2.9	1.6	470	0.834	563	45.3
Peru	0.6	89.1	10.3	0.1	0.0	456		579	
Qatar-Qatargas I	0.4	90.1	6.2	2.3	1.0	460	0.808	569	44.0
Russia-Sakhalin	0.1	92.6	4.5	1.9	0.2	449		570	
Trinidad	0.0	97.1	2.5	0.2	0.1	429	0.727	590	39.8
U.S.A-Alaska	0.2	99.7	0.1	0.0	0.0	423	0.719	589	39.9
Yemen	0.0	93.3	5.7	0.9	0.1	434	0.765	567	38.5

Liquefied Petroleum Gas (LPG)

Introduction	◈ Discovered by Dr. Walter Snelling in 1910. ◈ First commercial production was in 1912 and sold commercially by 1920. ◈ First LPG cooking stove was made in 1912. ◈ First LPG-fueled car was developed in 1913.
Definition	◈ A mixture of propane and butane which has been liquefied by reducing the temperature, increasing the pressure or a combination of both. LPG is commonly called "bottled gas."
Composition	◈ It is made up primarily by propane (C_3H_8) and butane (C_4H_{10}), or a mix of the two. ◈ Other hydrocarbons that include propylene, butylenes, isobutene and isobutylene may also be present.
Characteristics	◈ A higher percentage of propane is used in winter since propane is lighter than butane and the same for butane in summer since it has a higher vapor pressure and lower boiling point. ◈ Non-toxic, flammable gas, odorless, colorless and heavier than air. ◈ Volume typically is 250 times smaller in a liquid state based on composition, pressure and temperature. ◈ Can be easily condensed, packaged, stored and utilised, which makes it an ideal energy source for a wide range of applications.
Boiling Point	◈ Varies considerably from about -42 °C to 0 °C (-44 °F to 32 °F) at atmospheric pressure.
Uses	◈ Transportation ◈ Domestic use ◈ Industrial ◈ Petrochemical
Calorific Value (in Gas State)	◈ 1 ft^3 propane = 2,716 Btu ◈ 1 ft^3 n-butane = 3,572 Btu
Energy Density (in Liquid State)	◈ Specific energy propane *(p)* = 50.4 MJ/kg that is equivalent to 25,400 MJ/m^3 (25.4 MJ/*ℓ*) ◈ Specific energy n-butane *(p)* = 49.5 MJ/kg that is equivalent to 28,800 MJ/m^3 (28.8 MJ/*ℓ*) *(Note: p means pressurised for propane and n-butane)*
Pricing Formulas	◈ Wholesale market price of LPG (quoted in USD). ◈ Annual consumption ◈ Cost plus

(1) LPG & Ethane: Weight, Volume and Heat

C_3. C_4 mix is treated separately in which the results are generated from the VMG Simulator.

Cubic Metres Per Tonne

m^3/tonne	Ethane	Propane	n-Butane	C_3. C_4 mix
Pressurised *(p)*	3.00	1.98	1.72	1.82
Refrigerated *(r)*	1.84	1.71	1.66	1.66

mmBtu Per Tonne

mmBtu/tonne	Ethane	Propane	n-Butane	C_3. C_4 mix
Pressurised *(p)*	49.2	47.7	46.6	47.3
Refrigerated *(r)*				

Barrels Per Tonne

bbl/tonne	Ethane	Propane	n-Butane	C_3. C_4 mix
Pressurised *(p)*	18.9	12.5	10.8	11.5
Refrigerated *(r)*	11.5	10.8	10.4	10.5

mmBtu Per Cubic Metre

mmBtu/m^3	Ethane	Propane	n-Butane	C_3. C_4 mix
Pressurised *(p)*	16.4	24.1	27.3	25.9
Refrigerated *(r)*	26.8	27.8	28.2	28.5

mmBtu Per Barrel

mmBtu/bbl	Ethane	Propane	n-Butane	C_3. C_4 mix
Pressurised *(p)*	2.60	3.83	4.34	4.13
Refrigerated *(r)*	4.26	4.42	4.49	4.52

1 Barrel Per Day = Tonnes Per Annum

1 bbl/d = tonne/y	Ethane	Propane	n-Butane	C_3. C_4 mix
Pressurised *(p)*	19.3	29.3	33.8	31.8
Refrigerated *(r)*	31.6	33.8	34.9	34.9

Natural Gas Conversion Guide

SECTION 3

INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

Inter-fuel Conversion Tables

The tables contain quick reference equivalents and other factors of general relevance to the natural gas industry. All figures are to be taken as APPROXIMATE VALUES only for use when a high degree of precision is not required. The approximations in these tables are based upon the assumptions that are listed in page 18.

(1) Natural Gas: Cubic Metre Equivalents

	Per Year			Per Day		
1 bcm natural gas per year =	35.31×10^9 41.06×10^{12}	cf Btu	gas	96.75×10^6 112.5×10^9	cf Btu	gas
	0.77×10^6 10.75×10^6	tonnes barrels	LNG	2,107 29,457	tonnes barrels	LNG
	0.87×10^6 9.08×10^6 9.95×10^6	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*	2,378 24,869 27,268	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*
	1.03×10^6 7.08×10^6	tonnes barrels	oil	2,835 19,395	tonnes barrels	oil
	1.50×10^6	tonnes	coal	4,120	tonnes	coal

	Per Year			Per Day		
1 mmcm natural gas per day =	12.9×10^9 15.0×10^{12}	cf Btu	gas	35.31×10^6 41.06×10^9	cf Btu	gas
	0.28×10^6 3.92×10^6	tonnes barrels	LNG	769.2 10,752	tonnes barrels	LNG
	0.32×10^6 3.31×10^6 3.63×10^6	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*	868 9,077 9,953	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*
	0.38×10^6 2.58×10^6	tonnes barrels	oil	1,035 7,079	tonnes barrels	oil
	0.55×10^6	tonnes	coal	1,504	tonnes	coal

(2) Natural Gas: Cubic Foot Equivalents

	Per Year			Per Day		
1 tcf natural gas per year =	1.0×10^{12}	cf	gas	2.74×10^{9}	cf	gas
	28.32×10^{9}	cm		77.58×10^{6}	cm	
	29.30×10^{6}	tonnes	oil	80,269	tonnes	oil
	200.5×10^{6}	barrels		0.55×10^{6}	barrels	
	42.59×10^{6}	tonnes	coal	0.12×10^{6}	tonnes	coal

• *cm = m^3 = kilolitre*

	Per Year			Per Day		
100 mmcf natural gas per day =	36.50×10^{9}	cf	gas	1.0×10^{6}	cf	gas
	1.034×10^{9}	cm		2.83×10^{6}	cm	
	42.44×10^{12}	Btu		0.12×10^{12}	Btu	
	0.795×10^{6}	tonnes	LNG	2,178	tonnes	LNG
	11.11×10^{6}	barrels		30,446	barrels	
	0.897×10^{6}	tonnes	LPG	2,458	tonnes	LPG
	9.38×10^{6}	barrels	LPG *(r)*	25,703	barrels	LPG *(r)*
	10.29×10^{6}	barrels	LPG *(p)*	28,183	barrels	LPG *(p)*
	1.07×10^{6}	tonnes	oil	2,930	tonnes	oil
	7.32×10^{6}	barrels		20,046	barrels	
	1.55×10^{6}	tonnes	coal	4,259	tonnes	coal

INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

(3) LNG: Volumetric Equivalents

	Per Year			Per Day		
1 MTPA LNG =	45.91×10^9 1.30×10^9 53.38×10^{12}	cf cm Btu	gas	0.126×10^9 3.56×10^6 146.2×10^9	cf cm Btu	gas
	78.48×10^6 2.22×10^6 13.98×10^6	cf cm barrels	LNG	0.22×10^6 6,088 38,294	cf cm barrels	LNG
	1.13×10^6 11.80×10^6 12.94×10^6	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*	3,092 32,329 35,448	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*
	1.35×10^6 9.20×10^6	tonnes barrels	oil	3,685 25,213	tonnes barrels	oil
	1.96×10^6	tonnes	coal	5,357	tonnes	coal

	Per Year			Per Day		
1 mmcm LNG per year =	20.66×10^9 0.585×10^9 24.02×10^{12}	cf cm Btu	gas	56.60×10^6 1.603×10^6 65.81×10^9	cf cm Btu	gas
	0.45×10^6 6.29×10^6	tonnes barrels	LNG	1,233 17,232	tonnes barrels	LNG
	0.508×10^6 5.31×10^6 5.82×10^6	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*	1,391 14,548 15,952	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*
	0.605×10^6 4.14×10^6	tonnes barrels	oil	1,658 11,346	tonnes barrels	oil
	0.88×10^6	tonnes	coal	2,410	tonnes	coal

(4) LPG (Refrigerated)
Equivalent based on 50% C_3, 50% C_4

	Per Year			Per Day		
1 MT LPG per year =	40.68×10^9 1.15×10^9	cf cm	gas	111.5×10^6 3.16×10^6	cf cm	gas
	0.886×10^6 12.39×10^6	tonnes barrels	LNG	2,428 33,935	tonnes barrels	LNG
	1.66×10^6 10.46×10^6	cm barrels	LPG *(r)*	4,555 28,649	cm barrels	LPG *(r)*
	1.19×10^6 8.16×10^6	tonnes barrels	oil	3,266 22,343	tonnes barrels	oil
	1.73×10^6	tonnes	coal	4,747	tonnes	coal

	Per Year			Per Day		
10,000 bbl LPG per day =	14.2×10^9 0.402×10^9	cf cm	gas	38.91×10^6 1.102×10^6	cf cm	gas
	0.349×10^6 0.58×10^6	tonnes cm	LPG *(r)*	956.3 1,590	tonnes cm	LPG *(r)*
	0.416×10^6 2.85×10^6	tonnes barrels	oil	1,140 7,799	tonnes barrels	oil
	0.605×10^6	tonnes	coal	1,657	tonnes	coal

	Per Year			Per Day		
1 mmcm LPG per year =	24.47×10^9 0.693×10^9	cf cm	gas	67.04×10^6 1.90×10^6	cf cm	gas
	0.601×10^6 6.29×10^6	tonnes barrels	LPG *(r)*	1,648 17,232	tonnes barrels	LPG *(r)*
	0.717×10^6 4.91×10^6	tonnes barrels	oil	1,964 13,439	tonnes barrels	oil
	1.04×10^6	tonnes	coal	2,855	tonnes	coal

(5) LPG (Pressurised)
Equivalent based on 50% C_3, 50% C_4

	Per Year			Per Day		
1 MT LPG per year =	40.68×10^9 1.15×10^9	cf cm	gas	111.5×10^6 3.16×10^6	cf cm	gas
	0.886×10^6 12.39×10^6	tonnes barrels	LNG	2,428 33,935	tonnes barrels	LNG
	1.82×10^6 11.47×10^6	cm barrels	LPG *(p)*	4,994 31,413	cm barrels	LPG *(p)*
	1.19×10^6 8.16×10^6	tonnes barrels	oil	3,266 22,343	tonnes barrels	oil
	1.73×10^6	tonnes	coal	4,747	tonnes	coal

	Per Year			Per Day		
10,000 bbl LPG per day =	12.95×10^9 0.367×10^9	cf cm	gas	35.48×10^6 1.0048×10^6	cf cm	gas
	0.318×10^6 0.58×10^6	tonnes cm	LPG *(p)*	872.2 1,590	tonnes cm	LPG *(p)*
	0.379×10^6 2.60×10^6	tonnes barrels	oil	1,040 7,113	tonnes barrels	oil
	0.552×10^6	tonnes	coal	1,511	tonnes	coal

	Per Year			Per Day		
1 mmcm LPG per year =	22.32×10^9 0.632×10^9	cf cm	gas	61.14×10^6 1.73×10^6	cf cm	gas
	0.549×10^6 6.29×10^6	tonnes barrels	LPG *(p)*	1,503 17,232	tonnes barrels	LPG *(p)*
	0.654×10^6 4.47×10^6	tonnes barrels	oil	1,791 12,257	tonnes barrels	oil
	0.95×10^6	tonnes	coal	2,604	tonnes	coal

(6) Oil and Coal Equivalents

	Per Year			Per Day		
1 MT oil per year =	34.13×10^9 0.967×10^9 39.68×10^{12}	cf cm Btu	gas	93.51×10^6 2.65×10^6 108.7×10^9	cf cm Btu	gas
	0.743×10^6 10.39×10^6	tonnes barrels	LNG	2,037 28,470	tonnes barrels	LNG
	0.839×10^6 8.77×10^6 9.62×10^6	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*	2,299 24,036 26,354	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*
	6.84×10^6	barrels	oil	18,745	barrels	oil
	1.45×10^6	tonnes	coal	3,982	tonnes	coal

	Per Year			Per Day		
1 MT coal per year =	23.48×10^9 0.665×10^9 27.30×10^{12}	cf cm Btu	gas	64.33×10^6 1.82×10^6 74.79×10^9	cf cm Btu	gas
	0.511×10^6 7.15×10^6	tonnes barrels	LNG	1,401 19,586	tonnes barrels	LNG
	0.577×10^6 6.035×10^6 6.618×10^6	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*	1,581 16,535 18,130	tonnes barrels barrels	LPG LPG *(r)* LPG *(p)*
	0.688×10^6	tonnes	oil	1,885	tonnes	oil

	Per Year			Per Day		
10,000 bbl oil per day =	18.21×10^9 0.52×10^9 21.17×10^{12}	cf cm Btu	gas	49.89×10^6 1.41×10^6 58.0×10^9	cf cm Btu	gas
	0.533×10^6	tonnes	oil	1,462	tonnes	oil
	0.775×10^6	tonnes	coal	2,125	tonnes	coal

Natural Gas Conversion Guide

SECTION 4

IGU
INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

Selected References

The following references were used by the team in the preparation of this guide.

The IGU wishes to thank and record its appreciation to the respective publishers and organisations:-

[1] NATURAL GAS Physical and Engineering Data, Shell Companies in Malaysia, March 1983
[2] Natural Gas Equivalents, Shell International Gas Limited, 1992
[3] Natural Gas Fundamentals by Malcolm W.H. Peebles, Shell International Gas Limited, 1992
[4] The Alphatania Natural Gas Glossary of Terms & Measurements and Natural Gas Conversion Tables, Alphatania Ltd.
[5] The Fundamentals of the Natural Gas Industry, The Petroleum Economist and Gas World International, October 1995
[6] Fundamental of Natural Gas: An International Perspective, Vivek Chandra, September 2006
[7] Virtual Materials Group (VMG) Process Simulator, commercially available software
[8] LNG Industry in 2010, The International Group of Liquefied Natural Gas Importers (GIIGNL)
[9] Gas and LNG Industry Glossary, Alphatania Training, http://www.gasstrategies.com/industry-glossary
[10] Santos, Conversion Calculator, http://www.santos.com/conversion-calculator.aspx
[11] Conversion Factors, BP, http://www.bp.com/conversionfactors.jsp
[12] Online Conversion, http://www.onlineconversion.com/
[13] OECD, Glossary of Statistical Terms, http://stats.oecd.org/glossary/detail.asp?ID=4109
[14] General Facts on LPG, LPGSOLUTIONS, http://www.lpg-solutions.co.uk/facts.html
[15] Standards, The American Society for Testing and Materials (ASTM) International, http://www.astm.org/Standard/index.shtml

Natural Gas Conversion Guide

SECTION 5

GLOSSARY OF TERMS

A

Acid Gas

Natural gas that contains a certain quantity of gases such as carbon dioxide (CO_2) or hydrogen sulphide (H_2S). These gases will form acidic compound when combined with moisture.

Associated Gas

Gas which coexists with oil in a primarily oil field. It may be cap gas or solution gas, where the differences are the behaviour and treatment.

Atmospheric Pressure

The pressure of the weight of air and water vapour on the surface of the earth.

B

Boil-off gas

Volume of gas naturally converted to gaseous phase when LNG in a storage tank or ship warms to its boiling temperature. It may be collected and used for ship fuel or reliquefied to LNG.

Boiling point

Temperature at which a substance changes its state from liquid to gas.

Bottled Gas

Usually butane or propane or both, stored in the liquid form at moderate pressure in steel containers. Used in small residential and commercial applications.

British thermal Unit (Btu)

A Btu is defined as the amount of heat required to raise the temperature of one 1 pound (0.454 kg) of liquid water by 1 °F (0.556 °C) at a constant pressure of an atmosphere.

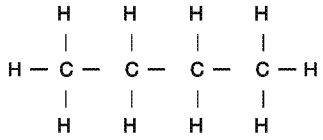
Bunker fuel

Any fuel oil or diesel fuel taken into the bunkers of ships.

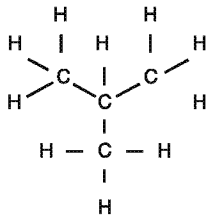
Butane

A member of the alkane group of hydrocarbons that consists of four carbon atoms in its molecule (C_4H_{10}, often abbreviated to C_4 in non-technical usage). Colourless, flammable gas at normal temperature and pressure but is easily liquefied by pressure for storage and transportation are few of its characteristics. There are two isomeric forms, Normal and Iso-Butane. At atmospheric pressure, Normal Butane liquefies at -100 °C and Iso-Butane (Methylpropane) at 120 °C.

Normal Butane



Iso-Butane (Methylpropane)



C

C_{6+}

All hydrocarbons with a carbon number of 6 and above also referred to as hexane and heavier fractions.

Calorie (cal)

A unit of heat that equals to 4.1868 joules. Formerly defined as the quantity of heat required to raise the temperature of 1 gram of water by 1°C under standard conditions. It has now largely been replaced by the joule for scientific purposes.

Calorific Value (CV)

The amount of heat produced in a complete combustion of a fuel. This can be measured either dry or saturated with water vapour; and net or gross.

Cap Gas

Gas found in a gas cap in relation with oil but not commingled with it.

Capacity Charge

Fee made for reserving capacity in a pipeline, a gas store or other piece of infrastructure. Frequently used interchangeably with Demand Charge.

Churning	A term used in gas trading to point out the number of times on average that gas is traded between initial sale and ultimate consumption.
Coal Bed Methane (CBM)	Coal bed methane is methane that is or can be recovered from coal seams. Also well-known as Coal Seam Gas. Wells are drilled into suitable coal seams and the pressure in the rock is reduced, usually by pumping out water in order to recover CBM. The pumped out water may be saline and cause environmental issues until the methane can be desorbed from the coal. CBM is not trapped beneath a seal like conventional natural gas but is adsorbed into the coal.
Coal Gas	Coal Gas is gas manufactured by the destructive distillation of bituminous coal. The principal components are hydrogen (more than 50%), methane (10% to 30%) carbon monoxide and higher hydrocarbons.
Coal Mine Methane (CMM)	Methane recovered from coal mines, whichever while active or after abandonment, which can be used in local power generation or heat production.
Combined Cycle Gas Turbine (CCGT)	A CCGT is a type of electricity generation plant in which the heat generated from combustion of the gases is used twice. Gas Turbine is driven by burning the gas. Then, to raise steam for a secondary steam turbine unit, the hot exhaust gases need to be passed through a heat exchanger. Combined cycle plants have a thermal efficiency about 50% greater than a normal simple or open turbine.
Combined Heat and Power (CHP)	CHP is the use of a single unified system to deliver both the heat and power requirements of a project, minimising the waste of heat. The power is formed through gas turbines or another prime mover. The exhaust heat is harnessed for requirements other than electricity generation. Also known as cogeneration and total energy. It has a typical efficiency is of more than 70%.
Compressed Natural Gas (CNG)	Natural gas compressed into gas cylinders, mainly used as an alternative for liquid fuels in road vehicles. CNG remains a gas irrespective of the amount of pressure.
Condensate	Natural gas liquid with low vapour pressure, produced from a reservoir with high pressure and temperature. In a pipeline or separation plant, condensate will separate naturally through the normal process of condensation. Can refer to any mixture of relatively light hydrocarbons which stay put liquid at normal temperature and pressure. There will be some propane and butane dissolved in it. Not like crude oil, it contains little or none of the heavy hydrocarbons which make up heavy fuel oil. There are three main sources of condensate: a) The liquid hydrocarbons which are produced from a gas/condensate reservoir. These may be only somewhat distinguishable from a light stabilised crude oil. b) The liquid hydrocarbons which are recovered at the surface from non-associated gas. c) The liquid hydrocarbons which are separated out when raw gas is treated. This condensate normally consists of C_5 to C_8.
Critical Pressure	The minimum pressure which must be applied to a gas before it can be liquefied.
Critical Temperature	The temperature above which a gas will not liquefy, irrespective of the pressure applied.
Crude Oil	A mixture of hydrocarbons that exists as a liquid in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Crude is the raw material which is refined into LPG, gasoline/ petrol, naphtha, kerosene, diesel/gas oil, fuel oil, lubricating oil, paraffin wax and asphalt.
Cryogenics	The process of producing, maintaining and utilising very low temperatures (below -46 °C/ -50 °F). Relevant in the LNG business.
Custody transfer	The process of handing over the final product from its seller to the final buyer. At this point, both the final value of the cargo is determined and all liability is passed.

	D
Density (LNG or gas)	The mass of a liquid or gas sample divided by its volume at specified conditions of pressure and temperature. The density is commonly expressed in kg/m³.
Dew Point	When either hydrocarbons (hydrocarbon dew point) or water (water dew point) start to condense out of a given gas stream, the temperatures below this phenomenon is known as dew point. Condensation could reduce the accuracy of metering and creates the trouble of liquid slugs in pipelines, which will need to be cleared out from time to time by passing a Pig through the pipeline.
Downstream	Those activities in the gas chain closest to final customers.
Dry Gas	Another name for Lean Gas. It does not mean free of water, though in some cases it may be.
	E
Energy Density	The heating value per unit volume. It is measured as MJ per cubic metre. See Gross Heating Value.
Ethane	Ethane (C_2H_6, often abbreviated to C_2 in non-technical usage) is one of the main constituent elements of natural gas along with methane. Boils at -84.4 °C. It is a dry, colourless and odourless gas at normal temperatures. A feedstock for ethylene production.
Ethylene	Also known as Ethene. A colourless gas (C_2H_4) produced by cracking hydrocarbons such as ethane or naphtha and used as a feedstock for petrochemicals, such as fibres and many plastics. Boils at -103.7 °C.
	F
Feedstock	Hydrocarbons used as raw material in an industrial process, not as a fuel. The principal uses of natural gas as a feedstock are in the manufacture of ammonia, ammonia-based fertilisers and methanol.
Flash point	The lowest temperature corrected to barometric pressure of 101.3 kPa at which application of ignition source causes the vapor of a specimen of the sample to ignite under specified condition of test (ASTM D93).
Floating LNG	Floating LNG (FLNG) is the use of purpose built or converted ships to enable regasification of LNG (and liquefaction) to be carried out offshore. FLNG has the advantage that LNG production and importation can start more quickly than could happen onshore, where lead times are often lengthened by the local approval process. It also enables the processes to move location to satisfy short term demand.
Fractionation	A distillation process in which the distillate is collected as a number of separate fractions based on a different boiling range.
Fuel Gas	Gaseous fuels, in particular low pressure natural gas used to fuel production or treatment facilities.
Fuel oil	Fuel oil defines oils that make up distillation residue. It comprises all residue fuel oils, including those obtained by blending. Its kinematic viscosity is above 10 cSt at 80 °C. The flash point is always above 50 °C and the density is always higher than 0.90 kg/ℓ.
	G
Gas : Oil Ratio	The relationship between the volume of gas produced at atmospheric pressure and the volume of oil produced in a given field. This volume will normally vary considerably over the life of the field. May be expressed as a simple volumetric ratio e.g. 500:1 or as ft³/barrel.
Gas-to-Liquid (GTL)	Gas to Liquid (GTL) processes convert natural gas into Synthetic Gasoline or Middle Distillates, by using the Fischer-Tropsch synthesis method. Increasingly relevant where gas is found in fields remote from markets such that delivery by pipeline is likely to be uneconomic.
Gas Condensate Ratio	The ratio of gas to condensate in a gas or condensate reservoir, usually uttered in practice as the ratio of condensate to gas. Usual units are barrels of condensate per million cubic feet of gas.

Gas Liquefaction	The conversion of natural gas into LNG.
Gas Processing	The separation of oil, gas and the removal of impurities and natural gas liquids from natural gas to meet the delivery specification.
Gas Turbine	A turbine propelled by the expansion of compressed air, heated by the combustion of a fuel such as natural gas or gas oil. Commonly used for power generation.
Gravity	A common abbreviation usually means specific gravity in the UK and American Petroleum Institute (API) gravity in the US.
Greenfield	A planned development which must be built from scratch on a new site without existing infrastructure.
Gross Heating Value (GHV or HHV)	The amount of heat which would be released by the complete combustion in air of 1 kg, 1 Mol or 1 standard cubic metre (mass based, molar based or volume based) of gas at conditions of t2,p2; in such a way that the pressure (p1) at which the reaction takes place remains constant, and all the products of the combustion are returned to the same specified temperature (t1) as that of the reactants, all of these components being in the gaseous state except for water formed by combustion, which is condensed to the liquid state. The Gross Heating value mass based is expressed in MJ/kg, Molar based in KJ/Mol and volume based in MJ/m^3. This under standard conditions of 15 °C and 101,325 Pa. (ISO 6976:1995). See Energy Density.
	H
Heel LNG	LNG left in ship and shore storage tanks to maintain their cryogenic temperatures.
Henry Hub	Henry Hub is owned and operated by Sabine Pipe Line, LLC, which is a wholly owned subsidiary of ChevronTexaco and the largest centralised point for natural gas spot and futures trading in the United States. Henry Hub is based on the physical interconnection of nine interstate and four intrastate pipelines in Louisiana. The New York Mercantile Exchange (NYMEX) uses Henry Hub as the notional point of delivery for its natural gas futures contract. NYMEX deliveries at Henry Hub are treated in the same way as cash-market transactions. Many natural gas marketers also use Henry Hub as their physical contract delivery point or their price benchmark for spot trades of natural gas.
High Sulphur Fuel Oil (HSFO)	The term is the bottom of the oil barrel. The lowest priced oil product now, for environmental reasons, frequently banned or only allowed to be used where rigorous control of emissions is practiced. In some countries with developing gas-to-oil competition, it represents the marker for power station fuel.
Hub	Most frequently in the U.S. and now used in Europe. There are many hubs in the U.S., of which the most important is Henry Hub (HH). In Europe the largest hub is the National Balancing Point (NBP) in the U.K.
Hydrates	Ice-like solids in which methane molecules are held within the molecular spaces of the water molecule. Can form in pipelines and wells under certain conditions of near freezing temperatures and high pressures.
Hydrocarbon	An organic compound containing the elements hydrogen and carbon only. Hydrocarbons exist as solids, liquids and gases.
	I
Impurities	Unwanted components that could be present in the product that might cause damage to the manufacturing or processing facility. These can typically be solids, chemicals, carbon dioxide (CO_2), sulphur (S), mercaptans and mercury (Hg).
International Energy Agency (IEA)	The IEA compiles detailed energy statistics and country reports, including countries outside the organisation itself. An autonomous wing of the Organisation for Economic Co-operation and Development (OECD). A Paris-based organisation which co-ordinates the energy policies of its member countries.
International Gas Union (IGU)	A worldwide non-profit organisation that was founded in 1931 whose objective is to promote the political, technical and economic progress of the gas industry.

	J
Japan Crude Cocktail	Crude oil price based on average Japan importing price of a basket of crude oil commonly used as an index for Asian LNG pricing.
Joules	The derived SI unit of work or energy; the work done when the point of application of a force of 1 newton is displaced through a distance of 1 metre in the direction of the force.
	K
Kerosene	Kerosene (other than kerosene used for aircraft which is included with aviation fuels) comprises refined petroleum distillate intermediate in volatility between gasoline and gas/diesel oil. It is medium oil distilling between 150 °C and 300 °C.
	L
Lean Gas	Gas high in methane content typically 95% or more and with few higher fractions. Thus of relatively low calorific value. Also known as Dry Gas.
Line Pack	It is a procedure for allowing more gas to enter a pipeline than is being withdrawn, thus increasing the pressure, "filler" more gas into the system, and effectively creating storage. The "filled" gas can subsequently be withdrawn when needed. A useful method of meeting short term (hourly or diurnal) peak demand requirements.
Liquefaction	The conversion of natural gas into LNG.
Liquefied natural gas (LNG)	Natural Gas, which after processing has been liquefied for storage and transportation purpose. At ambient pressure the LNG will be at temperatures close between -161 °C to -158 °C.
Liquefied petroleum gas (LPG)	A mixture of propane and butane which has been liquefied by reducing the temperature, increasing the pressure or a combination of both. LPG is commonly called "bottled gas."
LNG Plant	LNG plants consist of one or more LNG trains, each of which is an independent gas liquefaction unit. It is more cost effective to add a train to an existing LNG plant, than to build a new LNG plant, because infrastructure built for early trains, such as ship terminals and other utilities, may be capable of being used or expanded for new LNG trains. The process of Liquefaction is carried out in a liquefaction plant.
Load Factor	Load factor is a measurement of utilisation for plant, or of the relationship between average and peak demand or supply, as determined by the formula: Average x 100 / Peak. For supply and demand calculations average and peak most often refer to daily demand within a year, but any other periods are possible. The resulting figure is usually expressed as a percentage.
Low sulphur fuel oil (LSFO)	Fuel oil with low sulphur content. Usually less dense than high sulphur fuel oil. In new markets with gas-to-oil competition, this frequently represents the marker fuel for large segments of the industrial market.
	M
Mercaptans	Chemical compounds of sulphur used as Odorants.
Methane	A colourless, odourless flammable gas, lighter than air under normal conditions (CH_4, often abbreviated to C_1 in non-technical usage). Methane is the first member in the alkane (paraffin) series and is the primary constituent of Natural Gas. At atmospheric pressure, it liquefies at -162 °C.
Methane number	Rating indicating the knocking characteristics of a fuel gas (ISO 14532)
Methanol	Methyl alcohol, produced from natural gas via Synthesis Gas. Used as a chemical in the resin and paint industry and in the manufacture of Methyl Tertiary Butyl Ether (MTBE) and acetic acid, but also of interest as a possible total or partial substitute for motor gasoline in cars. Very toxic.
Middle Distillate Synthesis (MDS)	A chemical process using the Fischer-Tropsch synthesis method for making synthetic middle distillates (principally naphtha, kerosene and gas oil) from natural gas.
Midstream	Those activities in the gas chain related to moving gas between the source and local distribution.

	N
Naphtha	A mixture of several highly volatile flammable liquid hydrocarbon distilled from petroleum, coal tar or natural gas and used as fuel, solvent, or as feedstock for various chemicals. A feedstock destined either for the petrochemical industry (e.g. ethylene manufacture or aromatics production) or for gasoline production by reforming or isomerisation within the refinery.
National Balancing Point (NBP)	The NBP is an imaginary (notional or virtual) point at which all gas that has paid the entry charge to enter the UK National Transmission System is deemed to be located. The point at which most UK gas trading takes place and the largest gas hub in Europe.
Natural Gas	A gaseous fuel obtained from underground sources and consisting of a complex mixture of hydrocarbons, primarily methane, but generally also including ethane, propane and higher hydrocarbons in much smaller amounts. It generally also includes some inert gases, such as nitrogen and carbon dioxide (CO_2), plus minor amounts of trace constituents. Natural gas remains in the gaseous state under the temperature and pressure conditions normally found in service.
Natural Gas Liquids (NGLs)	Heavier hydrocarbons found in natural gas production streams and extracted for disposal separately. Within defined limits ethane, propane and butane may be left in the gas to enrich the calorific value. The terms natural gas liquids and condensates are in practice used virtually interchangeably.
Natural Gasoline	Butanes and heavier fractions extracted from rich natural gas which, after stabilisation (removal of the lighter fractions) may be blended into motor gasoline.
Natural Gas Vehicle (NGV)	A motorised vehicle powered by natural gas.
Net Calorific Value (NCV)	The heat generated by the complete combustion of a unit volume of gas in oxygen, excluding the heat which would be recovered by condensing the water vapour formed. It is usually seen as a measure of the effective heat produced rather than the total heat in the gas.
Nitrogen Oxides	Oxides of Nitrogen (NOx) resulting from the combustion of fuels, causing atmospheric pollution in the form of smog.
Non-Associated Gas	Non-Associated is gas found in a reservoir which contains no crude oil, and can therefore be produced in patterns best suited to its own operational and market requirements.
	O
Odorants	Strong smelling chemicals injected into natural gas, which otherwise is odourless, in order to make its presence more easily detectable.
Odorisation	The process of giving odourless natural gas a smell for safety reasons by injecting small quantities of organic sulphur compounds, such as Mercaptans, typically at the rate of 30 ppm. Usually carried out at the city gate or at the exit from the high pressure transmission system.
Offtake Point	The point in a gas system where gas is taken by supply pipe to a consumer.
Oil Gasification	The conversion of oil or naphtha into gas to be used as a fuel.
Open Cycle Gas Turbine (OCGT)	A gas turbine, often derived from aero-engines, used for peak generation of electricity. Also used in conjunction with a steam turbine in a combined cycle power plant. When only the gas turbine is used it may be termed "single cycle".

	P
Peak Shaving	Peak shaving is a means of reducing the peak load on the gas transportation and supply system by supplying some gas from sources at or close to the point of ultimate consumption, thus improving the average load factor. Peak shaving may be daily or seasonal and will be handled in a variety of ways e.g. underground storage, peak shaving LNG plants, line pack, gas holders, propane-air plant and, occasionally, special peak shaving supply contracts.
Pentanes Plus	Often used interchangeably with Condensates or C_5+ but excluding Propanes and Butanes.
Petroleum	The general name for hydrocarbons, including crude oil, natural gas and NGLs. The name is derived from the Greek word petros (rock) and the Latin word oleum (oil).
Propane	A member of the alkane (paraffin) group of hydrocarbons with three carbon atoms in its molecule (C_3H_8, often abbreviated to C_3 in non-technical usage). Liquefies at -42 °C.
Proven Reserves	Those quantities of petroleum which, by analysis of geological and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under current economic conditions, operating methods, and government regulations. Proven (proved) reserves can be categorised as developed or undeveloped. Where probabilistic methods have been used to estimate reserves, proven reserves are those with a better than 90% chance of being economically recoverable. Sometimes abbreviated as P90. Reserves with a greater than 50% chance but less than 90% chance are defined as Probable, or P50. Reserves with a greater than 10% chance but less than 50% chance are Possible or P10. Reserves may be classified as proved, if facilities to process and transport them to market are operational at the time of the estimate or there is a reasonable expectation that such facilities will be installed.
	R
R : P Ratio	The reserves: production ratio is the number of years that current reserves would last at current production levels. Thus, reserves of 100 divided by consumption of 20 / year gives an R : P ratio of 5, and implies a life of 5 years for the reserves.
Raw Natural Gas	Natural gas still containing impurities and unwanted substances, such as water (H_2O), nitrogen (N), carbon dioxide (CO_2), hydrogen sulphide gas (H_2S) and helium (He).
Regasification	The reconversion of LNG into gas suitable for pipeline transportation.
Reticulation	A reticulation network is a small diameter, low pressure gas system serving residential and commercial customers. (From the Latin word reta, meaning net).
Rich Gas	Rich gas is gas with relatively large quantities of heavier fractions in its composition (typically up to about 15%) and thus of high calorific value. Also known as Wet Gas.
	S
Sales Gas	Raw gas, after processing to eliminate LPG, condensate and carbon dioxide. Usually, sales gas consists chiefly of methane and ethane and is odorised.
Sour Gas	Gas containing a high level of carbon dioxide (CO_2) or hydrogen sulphide (H_2S), which are acidic and corrosive in the presence of water. They may therefore need drying or removal to conserve the pipeline.
Specification	The technical description of the allowable limits of the chemical composition of gas which may be admitted into a pipeline or process.
Spot Trading	A loose term covering the buying and selling of gas other than under a long term contract. Generally, it means immediate delivery in trading parlance "spot delivery".
Storage	For natural gas, storage facilities fall into a number of categories. Seasonal storage comprises depleted gas fields; aquifers; salt cavity storage; mined caverns; and disused mines. Peak storage includes gas holders, line pack, lengths of pipeline buried specifically for storage use, and LNG storage used either for base-load or peak-shaving duties, depending on the market. Increasingly used in liberalised markets to enable gas to be traded at any time of the year for reasons not related to peak demand.

Sweet Gas	Gas containing little or no carbon dioxide (CO_2) or hydrogen sulphide (H_2S)
Synthesis gas (Syngas)	Synthetic gas mixture of hydrogen (H) and carbon monoxide (CO) produced from methane and other hydrocarbons and steam used to produce various chemicals notably methanol and GTL.
	T
Take or Pay (TOP)	A general provision in gas contracts under which, if the buyer's annual purchased volume is less than the Annual Contract Quantity minus any shortfall in the seller's deliveries, minus any Downward Quantity Tolerance, the buyer pays for such a shortfall as if the gas had been received. The buyer may have the right in subsequent years to take the gas paid for but not received, either free or for an amount to reflect changes in indexed prices.
Tariff	A schedule of rates or charges offered by a common carrier or utility. Tariffs are commonly available for all parts of the gas industry where third party access is enforced or offered, for example for gas transmission in pipelines, for the use of gas stores, for gas sales to residential customers.
Train	An LNG production unit.
Transmission	The transportation of huge quantities of gas at high pressures, often through national or regional transmission systems. The gas is then transferred into local distribution systems for supply to customers at lower pressures.
Transmission Pipeline	A network of pipelines moving natural gas from a gas processing plant via compressor stations, to storage centres or distribution points.
Treatment	Any gas purification process, but most generally applied to the treatment of gas immediately after production, to bring it to adequate standard for the market in question and/or to extract valuable components for separate sale. This may involve the removal of LPGs and will certainly involve stripping out condensates, carbon dioxide (CO_2) and hydrogen sulphide (H_2S) and other sulphur compounds mercury (Hg) and excessive water (H_2O) which may be in the raw gas.
	U
Unconventional gas	Collective term for natural gas, mainly methane, found such as coal bed methane, shale gas, gas hydrates and tight sand gas whereas conventional gas is found within sandstone and limestone reservoir.
Upstream	Upstream typically refers to exploration, development and production of oil and gas.
	V
Vapour pressure	The pressure exerted by the vapour escaping from a liquid. As the temperature of the liquid rises, its vapour pressure increases; eventually, it exceeds the pressure of the confining atmosphere and the liquid boils.
	W
Wet Gas	Natural gas containing condensable hydrocarbons. A synonym for rich gas.
Wobbe Index	Occasionally referred to as the Wobbe number. A measure of the rate at which gas will deliver heat on combustion and hence of the compatibility of a gas with gas burning equipment.
	Y
Yellow Tipping	Incomplete combustion whereby excess hydrocarbons can possibly result in unacceptable levels of carbon monoxide (CO) being produced (ISO 14532).

** A more detailed list of glossary terms can be obtained from the IGU website, www.igu.org under the section on natural gas conversion.*

GLOSSARY OF ABBREVIATIONS

A			
ACQ	Annual Contract Quantity	API	American Petroleum Institute
ADP	Annual Delivery Programme	ASTM	American Society for Testing and Materials
C			
C&F	Cost and Freight	CIF	Cost, Insurance and Freight
CBM	Coal Bed Methane	CMM	Coal Mine Methane
CCGT	Combined Cycle Gas Turbine	CNG	Compressed Natural Gas
CCS	Carbon Capture and Storage	COI	Confirmation of Intent
CHP	Combined Heat and Power	CV	Calorific value
D			
DDR	Daily Delivery Rate	DQT	Downward Quantity Tolerance
F			
FERC	The Federal Energy Regulatory Commission	FLNG	Floating LNG
G			
GCV	Gross Calorific Value	GHV	Gross Heating Value
GEMA	Gas and Electricity Markets Authority	GNL	Gaz Natural Liquifié (French language acronym for LNG)
H			
HCV	Higher Calorific Value	HOA	Heads of Agreement
HHV	Higher Heating Value	HSFO	High Sulphur Fuel Oil
I			
IEA	International Energy Agency	IPE	International Petroleum Exchange
IGU	International Gas Union	ISO	International Organisation for Standardisation
L			
LCV	Lower Calorific Value	LOI	Letter of Intent
LDC	Local Distribution Company	LPG	Liquefied Petroleum Gas
LHV	Lower Heating Value		
M			
MDQ	Maximum Daily Quantity	MDR	Maximum Daily Rate
MDS	Middle Distillate Synthesis		
N			
NBP	National Balancing Point	NHV	Net Heating Value
NCV	Net Calorific Value	NTPA	Negotiated Third Party Access
NGLs	Natural Gas Liquids	NYMEX	New York Mercantile Exchange
NGV	Natural Gas Vehicle		
O			
OCM	On the day Commodity Market		
S			
Syngas	Synthesis Gas		
T			
TPA	Third Party Access	TSO	Transmission System Operator
TOP	Take or Pay		
U			
UKCS	United Kingdom Continental Shelf		

GLOSSARY OF MEASUREMENTS

B

bar	A term to specify natural gas pressure in pipelines. 1 bar is equal to 0.987 standard atmospheric pressure.
bbl	A US barrel, 1 barrel = 0.159 cubic metres = 42 U.S. gallons (approx=35 imperial gallons).
bbl/day	Barrels per day. Used to quantify a refiner's output capacity or an oilfield's rate of flow.
bcf	Billion cubic feet (i.e. 10^9 cubic feet).
bcm	Billion cubic metres (i.e. milliard or 10^9 cubic metres).
billion	In the US, 10^9. The natural gas industry has generally adopted the US usage.
boe	Barrels of oil equivalent. To quantify on general energy requirements. 1 boe equals to 5.8 MMBtu gross.
Btu	British thermal unit (Btu). A unit of heat generally used in the gas industry. The most common multiple is one million Btu, normally abbreviated to mmBtu and USD/mmBtu is the unit for comparing gas prices on a common basis.

C

cal	Calorie is formerly the SI unit of energy. The most common multiple used is the Megacalorie (Mcal).
cf	Cubic foot; cubic feet. The amount of gas required to fill a volume of one cubic foot. The term applied to the volume of gas produced or consumed.
cm	Cubic metre. cm is also the official abbreviation for centimetre.

G

GJ	GigaJoule = (10^9) joule	GWh	Giga (10^9) Watts hour

K

kW	KiloWatt = One thousand Watts (measurement of capacity)
kWh	KiloWatt hour = One thousand Watts per hour (measurement of consumption)

M

Mcal	Megacalorie (one million calorie)	mmcm	Million (10^6) cubic metres
mcf	Thousand (10^3) cubic feet	mmscf	Million (10^6) standard cubic feet
mcm	Thousand (10^3) cubic metres	mmscm	Million (10^6) standard cubic metres
mrd	Milliard.Synonymous with US billion(10^9)	MT	Million (10^6) tonnes.
MJ	MegaJoule (10^6)	MTOE	Million (10^6) tonnes of oil equivalent
mmbbl	Million (10^6) barrels	MTPA	Million (10^6) tonnes per annum
mmBtu	Million (10^6) British thermal units	MW	MegaWatt. One million (10^6) Watts
mmcf	Million (10^6) cubic feet	MWh	MegaWatts hour

P

PJ	Petajoules. A standard unit in the Australian gas industry, equals to 1 million (10^6) GJ and nearly 1 million mmBtu.
ppm	Parts per million
psi	Pounds per square inch. The common US/English unit of pressure, 14.5 psi = 1 bar.

S

scf	standard cubic foot
scm	standard cubic metre
SI Multiples	These include10^3 kilo (k), 10^6 mega (M), 10^9 giga (G), 10^{12} tera (T), 10^{15} peta (P), 10^{18} exa (E).

T

tBtu	Trillion (10^{12}) Btu
tce	Tonne of coal equivalent
TJ	TeraJoules
tcf	Trillion (10^{12}) cubic feet
toe	Tonne of oil equivalent
tcm	Trillion (10^{12}) cubic metres
Ton (t)	To cover a variety of measures: the metric tonne (1,000 kg); the long tonne (2,240 lbs); the short tonne (2,000 lbs).

U

US $/bbl	US Dollars per barrel

W

Watt (W)	The basic unit of electrical power, defined as one joule per second

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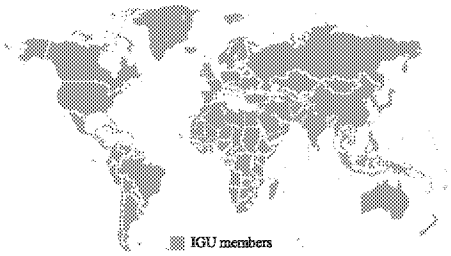
Notes

IGU
INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

Notes

IGU

The International Gas Union (IGU), founded in 1931, is a worldwide non-profit organisation promoting the political, technical and economic progress of the gas industry with the mission to advocate for gas as an integral part of a sustainable global energy system. IGU has more than 110 members worldwide and represents more than 95% of the world's gas market. The members are national associations and corporations of the gas industry. The working organisation of IGU covers the complete value chain of the gas industry from upstream to downstream. For more information please visit www.igu.org.



IGU
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