ENERGY NUMERACY: UNITS

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ENERGY UNITS

dimensions, DIM: Mass, Length, Time; units: **SI Système Internationale,** *United States customary*

Mass DIM M
SI kilogram, kg = (10cm)^3 water ≈ *2.2 lbs.*
1 metric tonne, m.t. = 1000 kg

accelerate →

Force F = ma, DIM ML/T^2
SI newton, N = kg-m/sec^2
also **Weight**; Earth's **a** is g ≈ -9.8m/sec^2
1 pound ("libra"), lb. ≈ 4.45 N SI
1 short ton, s.t. = 2000 lbs.≈ 907 N SI

through a distance →

Work or Energy (Capacity)
DIM ML/T^2 x L = ML^2/T^2
SI joule, J = newton-meter, kg-m^2/sec^2
1 food Calorie ≈ 4184 J SI
1 British thermal unit, Btu ≈ 1055 J SI
Kinetic = mv^2/2; Potential = mgh

PER each time **UNIT** →

Power (Rate)
DIM ML^2/T^2 ÷ T = ML^2/T^3
SI watt, W = J/sec = kg-m^2/sec^3
1 horsepower ≈ 746 W SI

FOR a time **PERIOD** →

Energy (Output)
DIM ML^2/T^3 x T = ML^2/T^2 again↑
SI joule again, but it is a tiny unit
1 watt-hour, Wh = 3600 J ≈ 3.412 Btu
1 kilowatt-hour, kWh ≈ *3412 Btu*

1 gigajoule, GJ ≈*.947 MMBtu* ≈ *.278 MWh*
1 MMBtu ≈ 1.055 GJ ≈ *.293 MWh*
1 MWh = 3.6 GJ ≈ *3.4 MMBtu*

FOSSIL FUEL MEASURES

1 barrel of oil ("blue barrel"), bbl = 42 U.S. gallons (≈158.76 liters **SI**)
1000 standard cubic feet of gas, Mcf ≈ 1 million Btu or MMBtu (≈28.3 m^3 **SI**)
1 barrel/day, bpd ≈ 50 m.t./year **SI**
1000 bpd ≈ *2 trillion Btu per year*
1 m.t. LNG ≈ *1.2 TOE, 9 BOE, 53 MMBtu*

Equivalents
(often consolidated as barrels or metric tonnes of oil equivalent (BOE, TOE) or as Btus converted into joules (J) or watt-hours (Wh))

Contents *(varying by qualities)*

	Crude oil, m.t.	Crude oil, bbl	Natural gas MMBtu	Anthracite coal, s.t.	kWh per unit	Specific energy, MJ/kg	Carbon content, kg C/GJ	Carbon emission, kg CO_2-eq/kWh
Crude oil, various qualities	X	TOE 0.14 m.t.	TOE 0.02 m.t.	TOE 0.7 m.t.	TOE 11,630/m.t.	42	20	0.26
Crude oil, various qualities	BOE 7.3 bbls	X	BOE 0.18 bbls	BOE 5 bbls	BOE 1700/bbl	42	20	0.26
Natural gas, standard	40 MMBtu	6 MMBtu	X	20-25 MMBtu	300/MMBtu	52	14	0.2
Anthracite (hard) coal	1.5 s.t.	0.20 s.t.	0.05 s.t.	X	6000-8000/s.t.	29	26	0.34

Sources:

International Energy Agency, World Energy Outlook, 2016

World Energy Council, World Energy Resources, 2016

U.S. Energy Information Administration, Annual Energy Outlook 2016

U.S. Environmental Protection Agency, Greenhouse Gas Emissions, 2016

BP Statistical Review of World Energy, 2016

Lazard, Levelized Cost of Energy Analysis, 2015

☞***Conversions are approximate and based on a mix of qualities. This chart is exclusively for educational purposes, not legal, business or engineering purposes!***

ENERGY NUMERACY: TOTALS

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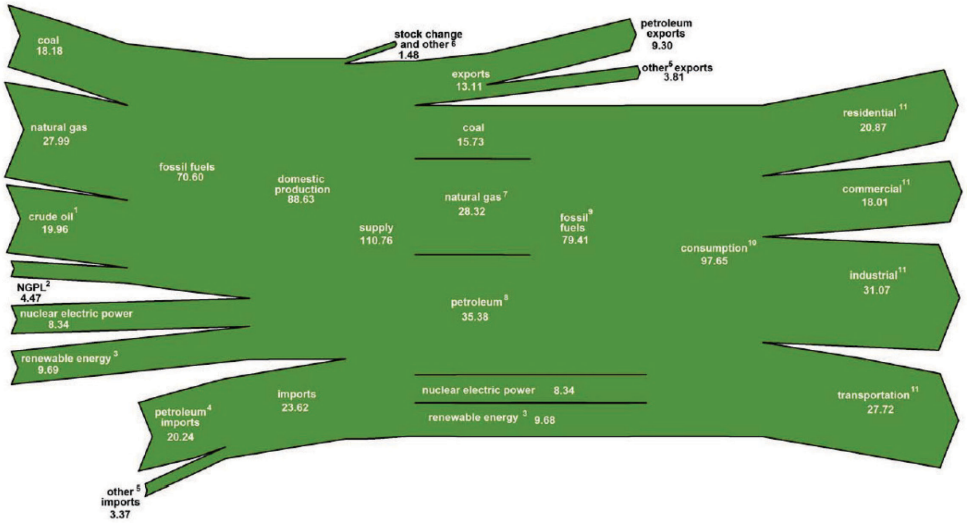
U.S. Energy Flow, 2015

quadrillion Btu



WORLD ENERGY FLOW

2015 production: 13 bn TOE, 515-555 quadrillion Btu ("Quads")
[1% growth from 2014]
33% oil [2%] (90 MMbpd, 78% non-US)
29% coal [-2%] (88% non-US)
24% gas [2%]
7% hydro [1%]
4% nuclear [1%]
2.8% renewable [15%]
(1/2 wind; solar, biofuels, geothermal, marine, waste)

WORLD CARBON EMISSIONS

2015 carbon emissions from fossil fuel sources:
36 Gt CO_2-eq or 9.8 GtC
(mass of CO_2 = 3.67 x C, 44/12)
by region (China 20.8 Gt CO_2 (28% total, 58% growth), US 6.9 Gt CO_2 (16% total, 20% growth))

by source 42% coal, 33% oil, 19% gas, 6% cement, 1% flaring

by sector 25% power, 24% ag/forest, 21% industry, 14% transport, 6% building, 10% other

Greenhouse gases from human activities, & CO_2-eq
76% CO_2
16% CH_4, 28-36x
6% N_2O, 265-298x
2% Fluorinated gases, 10,000x

RENEWABLE ENERGY MEASURES

	Energy density, W/m²	Levelized cost of energy, unsubsidized, $/MWh (reference combined cycle gas turbine power (CCGT), $52-78)	Average capacity factor
Onshore wind	200-1000	$32-77	30-55%
Photovoltaic solar (PV)	90-300	$50-300	10-30%
Geothermal	0.05-0.25	$82-117	85-90%

how big is a…
Power plant? usually 50 MW/CCGT unit.
Coal train? 120 cars @ 90-100 s.t./car.
Oil refinery? 200,000-500,000 bpd.
Oil tanker? 200,000-2MM barrels.
LNG tanker? 135,000 m^3 = 60,000 m.t. LNG = 3 Bcf gas.
LNG train? 5 MMT/y, for 5 GW of CCGT power plant.