ENERGY NUMERACY: UNITS

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

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

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

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

Energy (Output)
DIM ML^2/T^3 x T = ML^2/T^2 again↑
SI 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

Power (Rate) PER each time UNIT
For a time PERIOD

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

<table>
<thead>
<tr>
<th>Contents (varying by qualities)</th>
<th>Crude oil, m.t.</th>
<th>Crude oil, bbl</th>
<th>Natural gas MMBtu</th>
<th>Anthracite coal, s.t.</th>
<th>kWh per unit</th>
<th>Specific energy, MJ/kg</th>
<th>Carbon content, kg C/GJ</th>
<th>Carbon emission, kg CO2-eq/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude oil, various qualities</td>
<td>X</td>
<td>TOE 0.14 m.t.</td>
<td>TOE 0.02 m.t.</td>
<td>TOE 0.7 m.t.</td>
<td>42</td>
<td>20</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>Crude oil, various qualities</td>
<td>BOE 7.3 bbls</td>
<td>X</td>
<td>BOE 0.18 bbls</td>
<td>BOE 5 bbls</td>
<td>42</td>
<td>20</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>Natural gas, standard</td>
<td>40 MMBtu</td>
<td>6 MMBtu</td>
<td>X</td>
<td>20-25 MMBtu</td>
<td>52</td>
<td>14</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Anthracite (hard) coal</td>
<td>1.5 s.t.</td>
<td>0.20 s.t.</td>
<td>0.05 s.t.</td>
<td>X</td>
<td>29</td>
<td>26</td>
<td>0.34</td>
<td></td>
</tr>
</tbody>
</table>

Sources:
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! ✿
**RENEWABLE ENERGY MEASURES**

<table>
<thead>
<tr>
<th>Energy density, W/m²</th>
<th>Levelized cost of energy, unsubsidized, $/MWh (reference combined cycle gas turbine power (CCGT), $52-78)</th>
<th>Average capacity factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onshore wind</td>
<td>200-1000</td>
<td>$32-77</td>
</tr>
<tr>
<td>Photovoltaic solar (PV)</td>
<td>90-300</td>
<td>$50-300</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0.05-0.25</td>
<td>$82-117</td>
</tr>
</tbody>
</table>

**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 CO₂-eq or 9.8 GtC  
(mass of CO₂ = 3.67 x C, 44/12)  
by region (China 20.8 Gt CO₂ (28% total, 58% growth), US 6.9 Gt CO₂ (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

**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 m³ = 60,000 m.t. LNG = 3 Bcf gas.  
- LNG train? 5 MMT/y, for 5 GW of CCGT power plant.