

A1

Units

LARGE NUMBERS

The data about global consumption of water and energy need large numbers. There are two primary naming systems for large numbers. The USA and France (among others) use one system, while Germany, UK, and other European countries use the other. In the USA 1 billion is 10^9 while the British name is milliard. One trillion (10^{12}) in the USA is called one billion in many European countries (one trillion in many European countries is 10^{18}). Here we consistently define billion as 10^9 .

POWER AND ENERGY

The SI (International System of Units) or metric unit of **energy** is Joule.

1 J is defined as 1 Ws (wattsecond). 1 J is the designated name for the work 1 newton metre, in other words, the force 1 newton along the length 1 metre. The basic power unit watt (W) is defined as 1 J/s.

$$1 \text{ J} = 1 \text{ Ws (wattsecond)} \quad 1 \text{ megajoule (MJ)} = 10^6 \text{ J} \quad 1 \text{ gigajoule (GJ)} = 10^9 \text{ J} \\ 1 \text{ terajoule (TJ)} = 10^{12} \text{ J} \quad 1 \text{ petajoule (PJ)} = 10^{15} \text{ J} \quad 1 \text{ exajoule (EJ)} = 10^{18} \text{ J}$$

Kilowatt-hour (kWh) is a standard unit of electrical energy.

Since 1 kW (kilowatt) = 1000 W and 1 hour = 3600 seconds we get:

$$1 \text{ kWh} = (10^3 \text{ W}) (3600 \text{ s}) = 3.6 \times 10^6 \text{ Ws} = 3.6 \times 10^6 \text{ J} = 3.6 \text{ MJ (exact).}$$

The annual electrical energy use for a nation is typically expressed in TWh.

$$1 \text{ TWh} = 1000 \text{ GWh} = 10^6 \text{ MWh} = 10^9 \text{ kWh} = 10^{12} \text{ Wh}$$

The unit toe (ton of oil equivalent) is often used to indicate large energy productions. One toe is a unit of energy defined as the amount of energy released

by burning one ton of crude oil. IEA and OECD define this to be 41.87 GJ or 11.63 MWh. Note that toe should be used carefully when converting electrical units. Some reports take thermal generating unit efficiency into consideration when converting kWh to toe. With a 38% plant efficiency one toe corresponds to 16 GJ.

Power is energy per time unit, the rate of energy production or consumption.

$$1 \text{ MW (megawatt)} = 10^3 \text{ kW} = 10^6 \text{ W} \qquad 1 \text{ GW (gigawatt)} = 10^3 \text{ MW}$$

A plant with the average power capacity of 1 MW will produce $1 \times 8760 = 8760$ MWh or 8.76 GWh in a year.

In a thermal power plant, we distinguish between the electrical power (MWe) and the thermal power (MWth).

MASS AND VOLUME

$$1 \text{ pound (lb)} = 0.4536 \text{ kg}$$

$$1 \text{ metric ton} = 0.984 \text{ long ton or English ton}$$

$$1 \text{ Mt} = 10^6 \text{ ton} \quad 1 \text{ Gt} = 10^9 \text{ ton}$$

Gas emission is often measured in Tg, where $1 \text{ Tg} = 10^{12} \text{ g} = 10^6$ metric tons

Natural gas is converted to barrels of oil equivalent. 1 ton of oil equivalent $\cong 1125 \text{ m}^3$ of natural gas This is based on the average equivalent energy content of natural gas reserves.