Appendix 2

Conversion of units

A2.1 POWER AND ENERGY

It is important to distinguish between power and energy. Power is energy *per time unit*, the *rate* of energy production or consumption. The SI (International System of Units) or metric unit of energy is joule (*J*) and 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 *J* = 1 *Ws* (wattsecond)
1 megajoule (*MJ*) = 10^6 *J*
1 gigajoule (*GJ*) = 10^9 *J*

Kilowatt-hour (*kWh*) is a standard unit of electric energy. Since 1 *kW* (kilowatt) = 1,000 *W* and 1 hour = 3,600 seconds we get:

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

1 *MW* (megawatt) = 10^3 *kW* = 10^6 *W* (typically, a large industrial plant or wastewater treatment system has a power rating of the order *MW*).

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In a thermal power plant, we must distinguish between the *electric power* (MW_e) and the *thermal* power (MW_{th}).

1 *GW* (gigawatt) = 10^3 *MW*
(a typical power capacity of a large nuclear power plant).
1 *TWh* = 1,000 *GWh* = 10^6 *MWh* = 10^9 *kWh* = 10^{12} *Wh*

The annual electric energy use for a nation is typically expressed in *TWh*. For example, all used water treatment in Sweden requires annually about 0.6 *TWh* = 600 *GWh*. Consequently, there is an average power level of 600/8,760 = 0,068 *GW* = 68 *MW* every hour of the day and night. With nine million inhabitants, every citizen uses on average 7.5 *W* for used water treatment. About the same power and energy is used for supplying drinking water.

We still see the old unit *horsepower* in American publications:

1 horsepower = 1 *hp* = 746 *W*

A2.2 PRESSURE

The metric unit for pressure is *pascal* (*Pa*), where 1 *Pa* = 1 Newton/m^2, which is a very low pressure.

1 bar = 10^5 *Pa* = 0.1 *MPa*; 1 *MPa* = 10 *bar*

Old units are:

1 psi (pound/$inch^2$) = 6,895 *Pa*; 1 bar = 14.5 psi

A2.3 HEAT CONTENT

Before it was realised that heat was a form of energy, it was measured in terms of its ability to raise the temperature of water. The calorie and the British thermal units were defined in this way.

Calorie (cal): In a traditional definition one calorie is the amount of heat required to raise the temperature of 1 gram of water by 1°C, from 14.5°C to 15.5°C.

British thermal unit (*Btu*) is the English system analogue of the calorie.

1 *Btu* is the amount of heat required to increase the temperature of one pound of water (which weighs exactly 16 ounces) by 1°F.

1 *Btu* = 251.9958 *cal*.

In 1948 it was decided that, since heat is a form of energy, the SI unit for heat should be the same as for all other forms of energy, the joule. One *cal* is defined to be 4.1860 *J* (exactly) with no reference to heating of water. (The "calorie" used in nutrition is really a kilocalorie.)

The relationship between the *kWh* and the *Btu* depends upon which "Btu" is used.

1 megajoule (*MJ*) = 10^6 *J* = 0.278 *kWh* = 947.8 *Btu*; 1 *kWh* = 3412 *Btu*
1,000 *Btu* = 0.293 *kWh*; 100,000 *Btu* = 1 therm

The unit "quad" is often used in the U.S.:

1 quad = 1 quadrillion (10^{15}) *Btu* = 1.05506 * 10^{12} megajoule (*MJ*) = 1.055 *EJ* (note that quadrillion in Europe = 10^{24})

A2.4 VOLUME, AREA AND LENGTH

Some common metric length units:

1 micron = 1 micrometre = 10^{-6} *m*
1 angstrom (*Å*) = 10^{-10} *m* (named after the Swedish physicist A. J. Ångström, 1814–1874)
10 *Å* = 1 *nm* = 10^{-9} *m*

Metric area units:

1 *hectare* = 100^2 m^2
1 km^2 = 1000^2 m^2

Non-metric units:

1 US gallon = 3.78 litres; 1 UK gallon = 4.546 litres = 1.2 US liquid gallons
1 American barrel = a liquid measure of oil, usually crude oil = 42 US gallons = 159 litres
Barrel of oil equivalent refers to the energy equal to a barrel of crude oil,

= 5.8*10^6 *Btu* or 6119 *MJ*

Acre-foot (the volume of one acre (4,047 m^2 or 43,560 ft^2) with the depth of 1 foot (0.305 *m*)) is often used, particularly in the

U.S., to denote the annual water consumption for a family or for irrigation.

1 acre-foot=4,047 $m^2 \cdot 0.305\,m$=1,233.5 m^3 (=43560 ft^3=326,700 gallons).
1 cubic foot = 0.305^3 m^3 = 0.0284 m^3 = 28.4 litres; 1 m^3 = 35.25 cubic feet

A2.5 MASS

1 pound (*lb*) = 0.4536 *kg*
1 metric ton = 0.984 long ton or English ton

A2.6 CONCENTRATION

Concentrations are often measured in *mg/l* (=*ppm*, parts per million) = kg/m^3

A2.7 WATER USE IN ENERGY PRODUCTION/ GENERATION

In some US sources we find *gallons/MBtu* (millions of *Btu*):

1 *MBtu* = 293 *kWh* = 1054 *MJ*
1,000 gallon/*MBtu* = 12.9 litres/*kWh* = 3.59 *litres/MJ*
1 *litre/MJ* = 279 gallons/*MBtu*

A2.8 ENERGY USE IN WATER OPERATIONS

kWh/million gallons:

1,000 *kWh*/million gallons = 1 *MWh*/million gallons = 0.264 kWh/m^3
1 kWh/m^3 = 3,780 *kWh*/million gallons = 3.78 *MWh*/million gallons

kWh/acre-foot:

1,000 *kWh*/acre-foot = 1 *MWh*/acre-foot = 0.81 kWh/m^3
1 kWh/m^3 = 1230 *kWh*/acre-foot = 1.23 *MWh*/acre-foot