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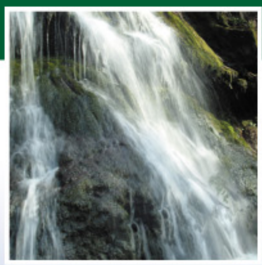

Chapter 2
Introduction to Renewable Energy Terminology

TIPPERARY INSTITUTE

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2 Introduction to Renewable Energy Terminology

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2.1 Objectives

Having completed this section of the training course and manual, learners should:

- Understand the concepts of energy and power.
- Be familiar with the kWh and kW.
- Be able to calculate the energy output of a boiler or generator.

2.2 Number conventions

Please note that commas and points in numbers are used differently in different countries. This training manual follows the conventional use in Ireland, which is:

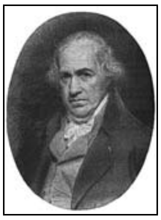
- 1,231 is one thousand two hundred and thirty one units
- 1.231 is one unit and two tenths, three hundredths and one thousandth
- "One billion", "one trillion" etc. have their European meanings (rather than the American).

2.3 Energy and power

Energy and power are two of the key concepts in the renewable energy sector. The word "energy" derives from the Greek words *en* (in) and *ergon* (work) (Boyle, 2004). Energy is the ability to do work, that is to move a 'body' against a resisting force. A 'body' can be in the form of a solid, liquid or gas. Work is done when a solid object is moved, or when water or air is pumped. These processes require energy. The standard (Système International d'Unités) unit of energy is the Joule (named after James Joule, 1818-1889, Figure 2.1). The symbol for the joule is J.

(Wikimedia, 2007)

Figure 2.1 James Joule



(Wikimedia, 2007)

Figure 2.2 James Watt

Power is the rate at which energy is converted from one form to another – the rate at which work is done. For example, a wind turbine converts the kinetic energy of the wind into electrical energy (electricity). A more powerful wind turbine will produce electrical energy at a greater rate than a less powerful one. The unit of power is the watt (symbol W) (named after James Watt, 1736-1819, Figure 2.2). The power is one watt if work is being done (energy is being converted) at the rate of one joule per second. So by definition, one watt equals one joule per second. An electric light bulb rated at 11 watts converts electrical energy into light and heat at a rate of 11 joules per second (Figure 2.3). Similarly, a motorbike engine with a maximum power output of 45,000 watts (45 "kW") is capable of using chemical energy (in the form of petrol) to produce up to 45,000 joules per second of kinetic energy in the rear wheel (Figure 2.4).

(Wikimedia, 2007)

Figure 2.3 11 W light bulb

(Wikimedia, 2007)

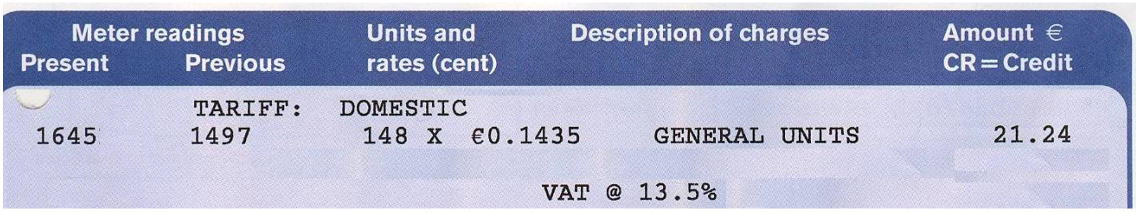
Figure 2.4 Motorbike

The term "capacity" in often used to refer to the power of renewable energy equipment. For example, a wind turbine may be described as having a maximum capacity of 850 kW_e. The subscript "e" in kW_e is used to indicate electricity generation capacity (rather than thermal production capacity, which is indicated with a "th" subscript). Other terms for power are "power rating", "rated capacity", "nameplate rating" (Boyle, 2004, p417).

2.4 Units of energy - joule and kWh

One joule is a very small quantity of energy - one chocolate bar contains about 1,000,000 joules of energy. The kiloWatt hour (kWh) is perhaps a more convenient unit of energy for the renewable energy sector, for two reasons.

Firstly, the kWh is a larger unit of energy than the joule - one kWh equals 3,600,000 joules. Secondly, the definition of the kWh is linked to the operation of energy consuming or energy producing appliances (see section 2.7 on calculating energy consumption or production). The familiar 'units' on an electricity utility bill are in kWh (Figure 2.5).



Meter readings Present	Meter readings Previous	Units and rates (cent)	Description of charges	Amount € CR = Credit
	TARIFF:	DOMESTIC		
1645	1497	148 X €0.1435	GENERAL UNITS	21.24
			VAT @ 13.5%	

Figure 2.5 An electricity utility bill showing "units" used (kWh)
(adapted from ESB, 2007)

2.5 *Energy contents of fuels*

The energy contents (or "calorific values") of fuels are often expressed using the kWh as the unit of energy. In formal technical literature the joule is used as the unit of energy for fuels <u>before</u> they are converted into heat or electricity, and the kWh is used as the unit of energy for the heat or electricity produced. However this convention is not followed in practical applications, nor is it used in this training course and manual. Table 2.1 shows the energy contents of a selection of fuels, in kWh per tonne, per litre or per kilogram (depending on the units in which the fuel is supplied). The impact of moisture content on the calorific value of wood fuel is discussed in chapter 10.

Fuel	**Units of Supply**	**Energy Content** kWh per Unit of Supply
Coal - industrial fines	tonnes	7,759
Wood – chips (28% moisture content)	tonnes	3,700
Wood – pellets (10% moisture content)	tonnes	4,800
Gas Oil	litres	10.55
Liquefied Petroleum Gas	kilograms	7.09

Table 2.1 Energy contents of selected fuels
(based on SEI, 2006a)

2.6 Prefixes for units

The Système International d'Unités includes a series of prefix names and symbols to allow multiples and submultiples of units (e.g. the joule) to be formed. A selection of SI prefixes commonly used in the renewable energy sector is presented in Table 2.2.

Meaning..	Factor	Prefix Name	Prefix Symbol
One thousand	10^3	kilo	k
One million	10^6	mega	M
One billion	10^9	giga	G
One trillion	10^{12}	tera	T
One quadrillion	10^{15}	peta	P
One quintillion	10^{18}	exa	E

Table 2.2 Selected SI prefixes
(BIPM, 2006; Boyle, 2004)

As discussed previously, one joule is a very small quantity of energy. The SI prefixes are therefore frequently used, as shown in Table 2.3.

In Words	In Numbers	In Factor	In Prefixes
One thousand	1,000 J	10^3 J	One kilojoule (kJ)
One million	1,000,000 J	10^6 J	One megajoule (MJ)
One billion	1,000,000,000 J	10^9 J	One gigajoule (GJ)
One trillion	1,000,000,000,000 J	10^{12} J	One terajoule (TJ)
One quadrillion	1,000,000,000,000,000 J	10^{15} J	One petajoule (PJ)
One quintillion	1,000,000,000,000,000,000 J	10^{18} J	One exajoule (EJ)

Table 2.3 Application of selected SI prefixes

As an example of the use of these prefixes, the Total Primary Energy Requirement (TPER) of the Republic of Ireland in 2005 was 655 PJ (SEI, 2006b). These prefixes can also be applied to the unit of power, the watt. In the renewable energy sector, power is generally expressed in kW, MW or GW. For example, Ireland's electricity generating capacity is 6,524 MW_e (EirGrid, 2006). Table 2.4 shows the use of the prefixes in converting from units based on the kWh to units based on the joule.

Units based on kWh			Units based on the joule	
1	kWh	equals	3.6	MJ
1	MWh	equals	3.6	GJ
1	GWh	equals	3.6	TJ
1	TWh	equals	3.6	PJ

Table 2.4 Conversion from units based on kWh

2.7 Calculating energy consumption or production

As stated previously, the definition of the kWh unit of energy is linked to the operation of energy consuming or energy producing appliances (see section 2.4 on units of energy – joule and kWh). One kWh is defined as the amount of energy consumed (or produced) by a one kilowatt (1,000 W) appliance in one hour. Energy consumption or production is therefore linked to the power of the relevant appliance, generator or boiler – the relationship is given in Formula 2.1.

Energy Consumption or Production = Power x Time

Formula 2.1 Energy consumption or production

In Formula 2.1, if the power is stated in kW and time is stated in hours, the energy consumption or production will be in units of kWh. If the power is in MW and time is in hours, the energy consumption or production will be in MWh. While the kWh is the unit of energy most familiar to householders, the MWh is commonly used as the trading unit in large scale renewable electricity generation. Example 2.1 shows how Formula 2.1 can be applied in a domestic situation to calculate energy consumption. Example 2.2 and Example 2.3 show the application in larger scale electricity and heat production. The "power" in Formula 2.1 may therefore be an input rating or an output rating, depending on the context.

Question:

If an electric shower has a maximum power rating of 8.5 kW, how many units of electricity will it use in ten minutes at the maximum setting?

Answer:

Energy Consumption (kWh) = Power (kW) x Time (Hours)

Firstly, the time (10 minutes) is converted to hours

= 10 ÷ 60 = 0.167 hours

The energy consumption can then be calculated using Formula 2.1:

= 8.5 kW x 0.167 hours

= 1.4 kWh

Example 2.1 Electrical energy (electricity) consumption

Question:

If a wind turbine operates at its maximum rated capacity of 1 MW_e for 2 hours, how much electricity will it produce?

Answer:

Energy Production (MWh) = Power (MW) x Time (Hours)

= 1 MW_e x 2 hours

= 2 MWh of electricity

= 2,000 kWh of electricity (1 MWh = 1,000 kWh)

Example 2.2 Electrical energy (electricity) production

Question:

If an oil-fired boiler operates at its maximum rated capacity of 700 kW_{th} for 5 hours, how much heat will it produce?

Answer:

Energy Production (kWh) = Power (kW) x Time (Hours)

= 700 kW_{th} x 5 hours

= 3,500 kWh_{th} = 3.5 MWh_{th}

Example 2.3 Thermal energy (heat) production

It is important to note that in Example 2.2 and Example 2.3 the turbine and the boiler operate at their maximum rated capacity for the time duration specified. However, a wind turbine has a continuously variable power output, from zero up to its maximum rating, an oil-fired boiler likewise. Over the course of a year, the turbine will operate over its entire power range, depending on the wind speed. Similarly, the output of the oil-fired boiler will follow the heat demand of the building, from no demand in summer to peak demand in winter. To estimate the total energy production over a year, information on the power duration / load duration / capacity factor is required (see chapter on wind energy for application of capacity factor approach).

2.8 Case study on Building Energy Rating

This case study on Building Energy Rating (BER) is used to illustrate the concepts of kWh, energy contents of fuels, and conversion efficiencies of energy-producing appliances. There are two approaches to calculating BER: the top-down approach which uses simulation software and data on a building's dimensions and specifications; and the bottom-up approach which uses data on a building's actual energy usage. This case study uses the bottom-up approach, and real data to calculate a BER. The two person household is located in Co. Tipperary, Ireland, and has 84 m^2 of living area. The fuels used are electricity, oil, wood and peat. The calculation of BER is presented in Table 2.5.

Fuel Type	Quantity per year	Units of Use	Conversion Factor to kWh	Primary Energy Used kWh per year	Conversion Efficiency %	Net Energy Delivered kWh per year
Electricity						
General Domestic	2,132	kWh	1	2,132	100%	2,132
Heating						
Electric Storage Heaters	2,208	kWh	1	2,208	100%	2,208
Oil	1,235	litres	10.55	13,029	63%	8,143
Wood	0.189	tonnes	4200	794	65%	516
Peat - briquettes	0.093	tonnes	4917	458	65%	298
Heating subtotal				*16,489*		*11,165*
Total of Electricity and Heating				18,621		13,297
Area of house (m2) excluding unheated porch				84		84
Building Energy Rating (kWh per m2 per year)				**222**		**159**
Electricity Energy Rating (kWh per m2 per year)				**25**		**25**
Heat Energy Rating (kWh per m2 per year)				**197**		**133**

Table 2.5 Calculation of BER using bottom-up approach

Notes on table

- Electricity and oil are annual averages from 4.6 years of data
- Solid fuel figures are extrapolated from one month of monitoring in October 2004
- Conversion factors and efficiencies for electricity and oil from SEI, 2006c
- Conversion factor for wood from Healion, 2002
- Conversion factor for briquettes from Bord na Móna, 2001
- Conversion efficiency for wood and peat from SEI, 2006d

Based on the BER label for Ireland (Figure 2.6) (as required under the EU Energy Performance of Buildings Directive 2002/91/EC) the performance of the case study household was benchmarked (Figure 2.7). The rating of a house built to current Irish building regulations is also shown (SEI, 2006e).

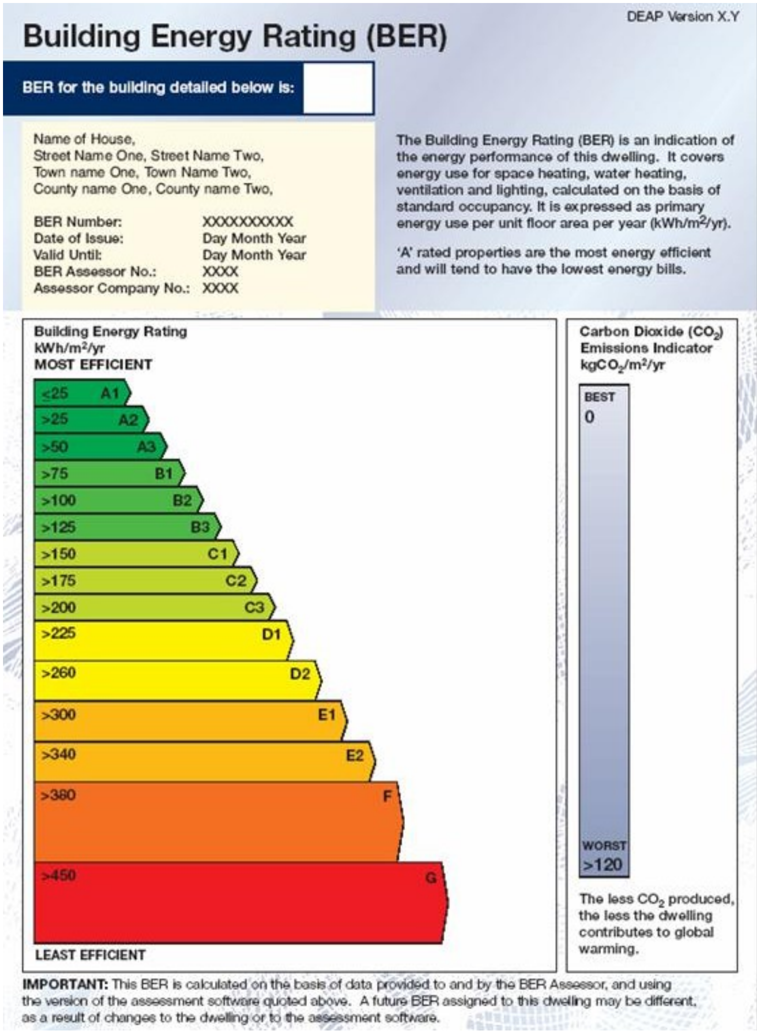


Figure 2.6 BER label
(SEI, 2007)

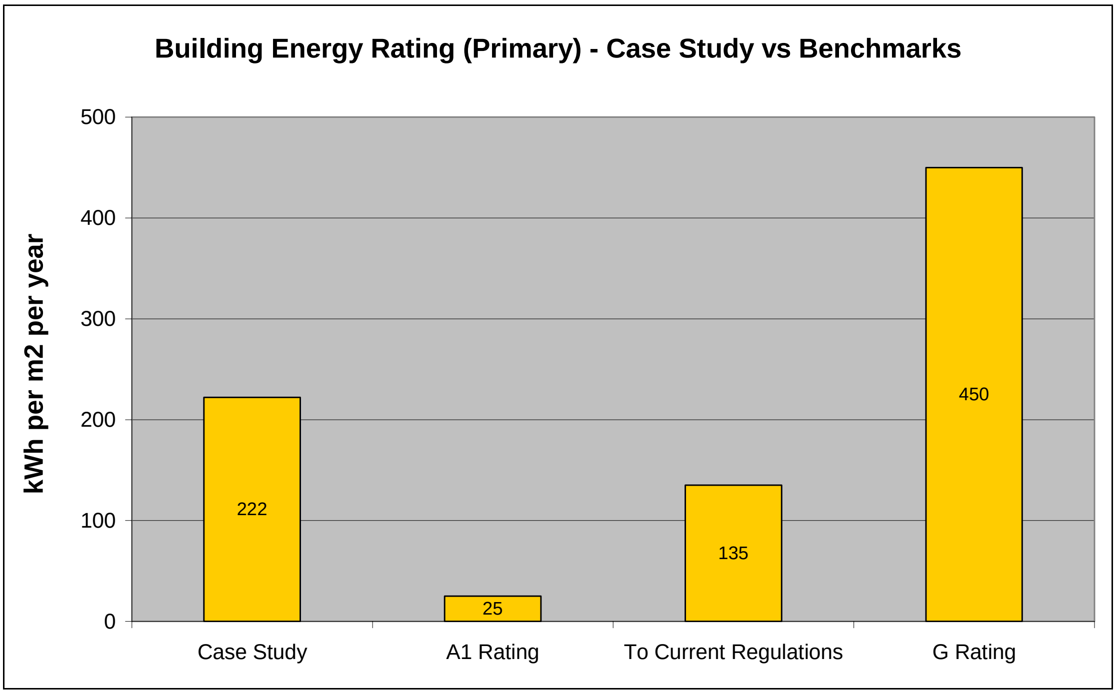


Figure 2.7 Benchmarking of case study household

2.9 Other units of energy and power

The unit of energy “Tonne of Oil Equivalent” (TOE), and multiples thereof, is often used in energy statistics. Table 2.6 shows how quantities expressed in this unit can be converted to the units presented previously.

TOE-based	Joule-based	kWh-based
1 TOE	42 GJ	11.7 MWh
1 kTOE	42 TJ	11.7 GWh
1 MTOE	42 PJ	11.7 TWh

Table 2.6 Conversion from Tonne of Oil Equivalent units

The British Thermal Unit (BTU) is a unit of energy still used as a basis in specifying heating systems. One BTU equals 1,055 joules or 1.055 kJ. The ‘therm’ is a related unit of energy, equal to 100,000 BTU.

The unit of power based on the BTU is the “BTU per hour” which equals 0.29 W, or 1,000 BTU per hour which equals 0.29 kW.

The power of an engine is often quoted in 'horsepower' (HP). One HP is equivalent to 746 watts (0.746 kW).

2.10 Summary

The kWh is perhaps the most frequently used unit of energy in the renewable energy sector. The energy output (in kWh) of a heat or electricity-producing appliance can be calculated if information is available on the time (hours) for which the appliance operates at a particular power (in kW). The kWh is often used to express the energy contents of fuels, and the energy rating of buildings. Quantities expressed in other units of energy can be converted to quantities in kWh once the appropriate conversion factor is known.

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