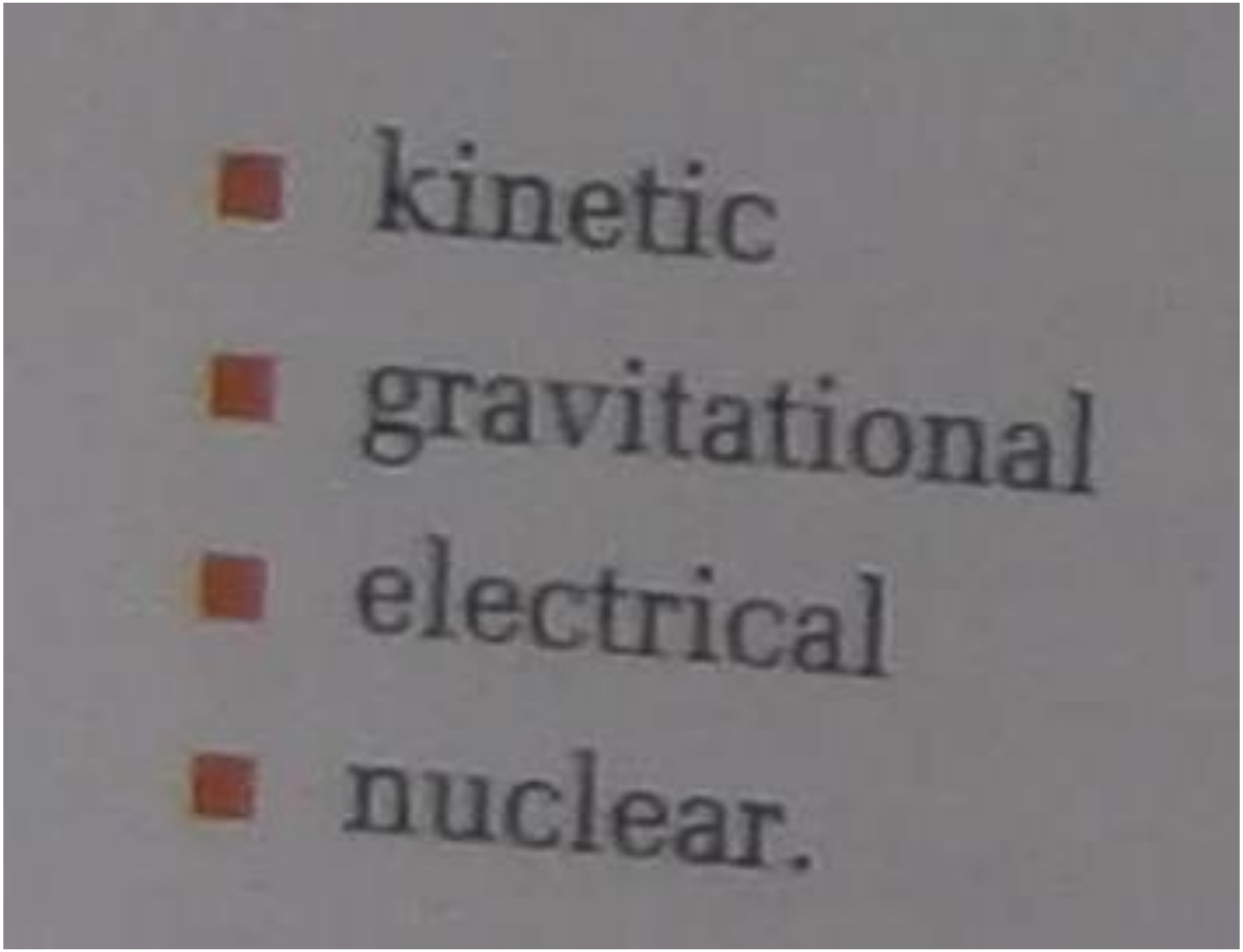
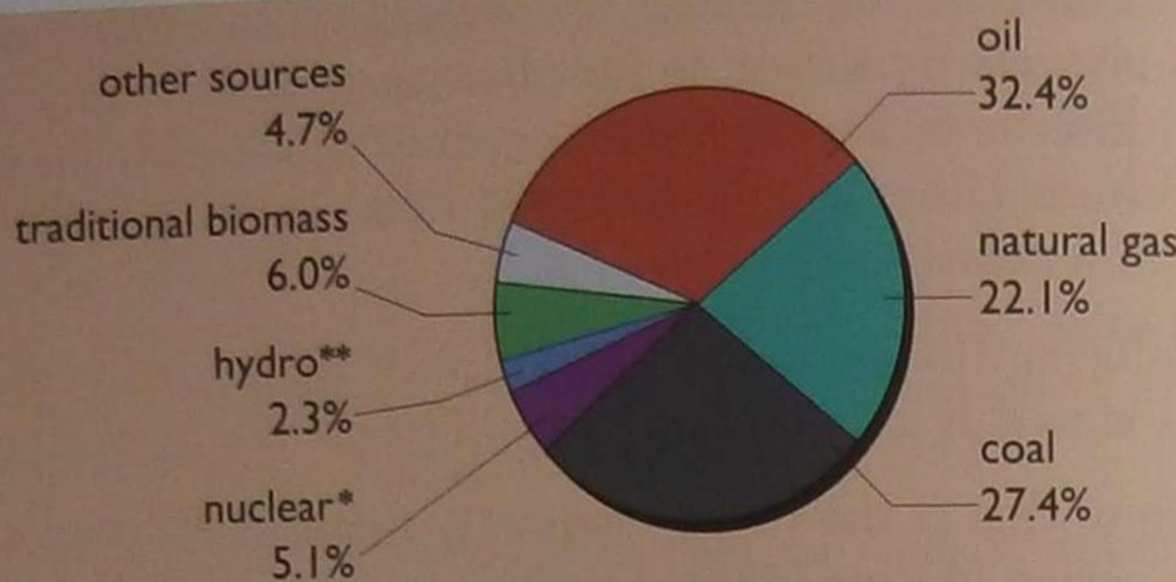
FORM OF ENERGY



- kinetic
- gravitational
- electrical
- nuclear.



* The nuclear contribution is the notional primary energy that would be needed to produce the actual output at an efficiency of 38%.

** The hydro contribution is the actual electrical output.

Total: about 502 EJ, equivalent to 12 billion tonnes of oil, or an average continuous rate of energy consumption of 15.9 TW.

Figure 1.2 Percentage contributions to world primary energy consumption in 2009. 'Other sources' are 'new' biomass, solar and geothermal energy, and energy from wind, wave, tide and wastes (sources: authors' estimates based on BP, 2010; IEA, 2009; WWEA, 2010)

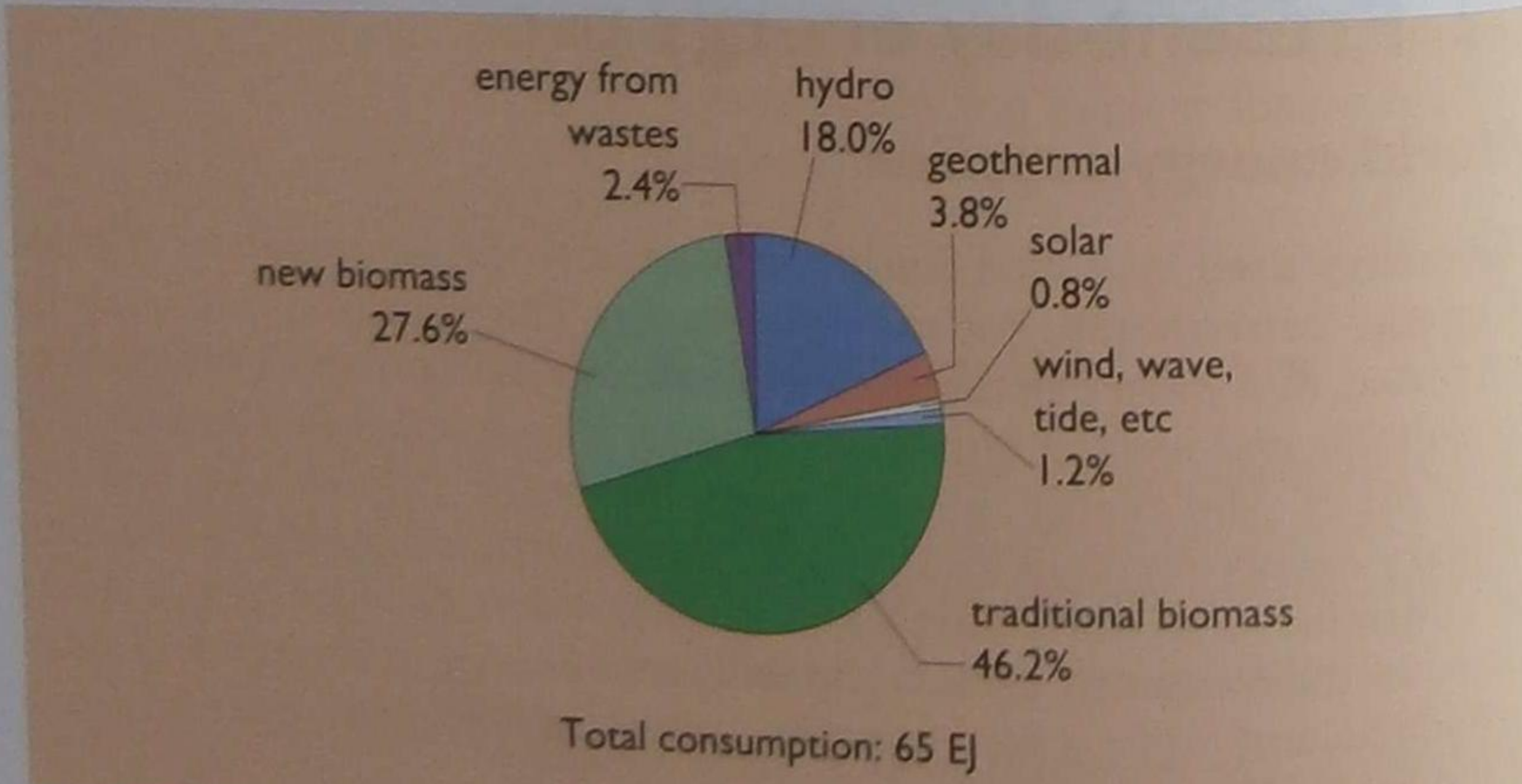


Figure 1.3 Chart showing percentage breakdown of individual renewable energy sources' contributions to world primary energy supplies in 2008 (sources: authors' estimates based on IEA, 2009; BP, 2010)

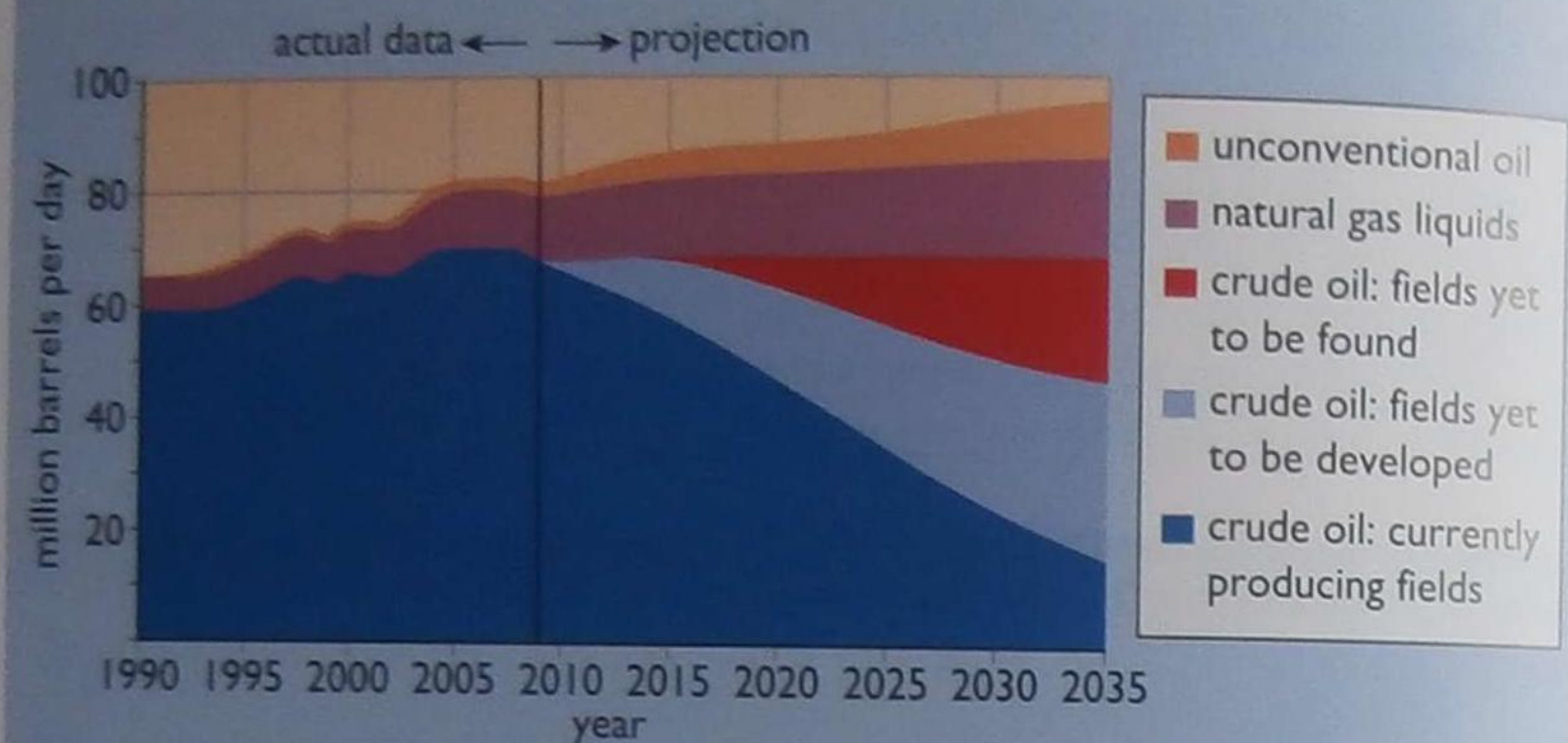


Figure 1.4 An International Energy Agency chart indicating the challenges involved in maintaining current levels of conventional oil production (source: IEA, 2010a)

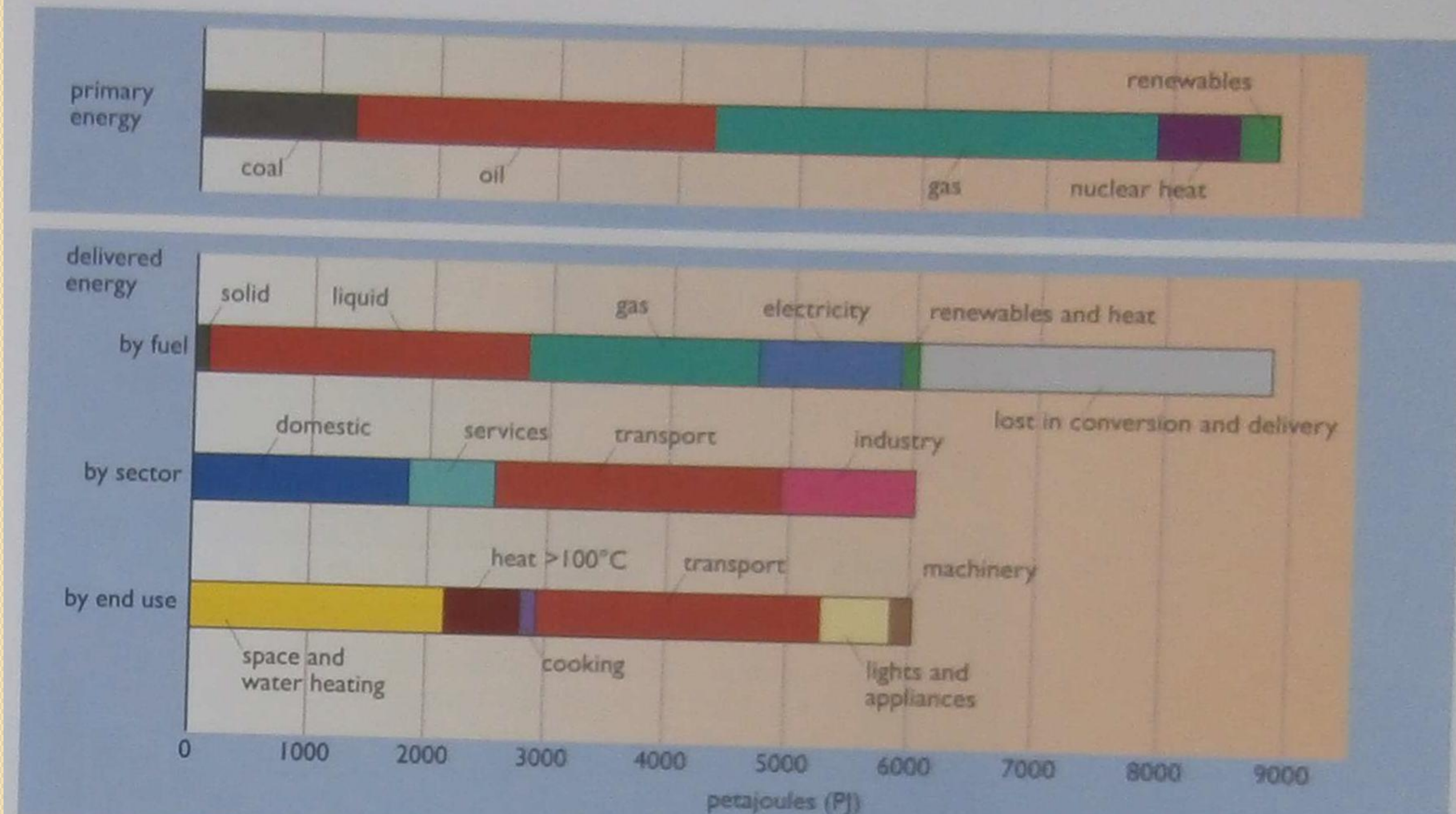


Figure 1.5 UK primary and delivered energy use, 2009 (sources: DECC, 2010a, DECC, 2010b). Note: in the second bar, 'electricity' includes renewable electricity; 'renewables and heat' includes biofuels for transport and heat from CHP plants

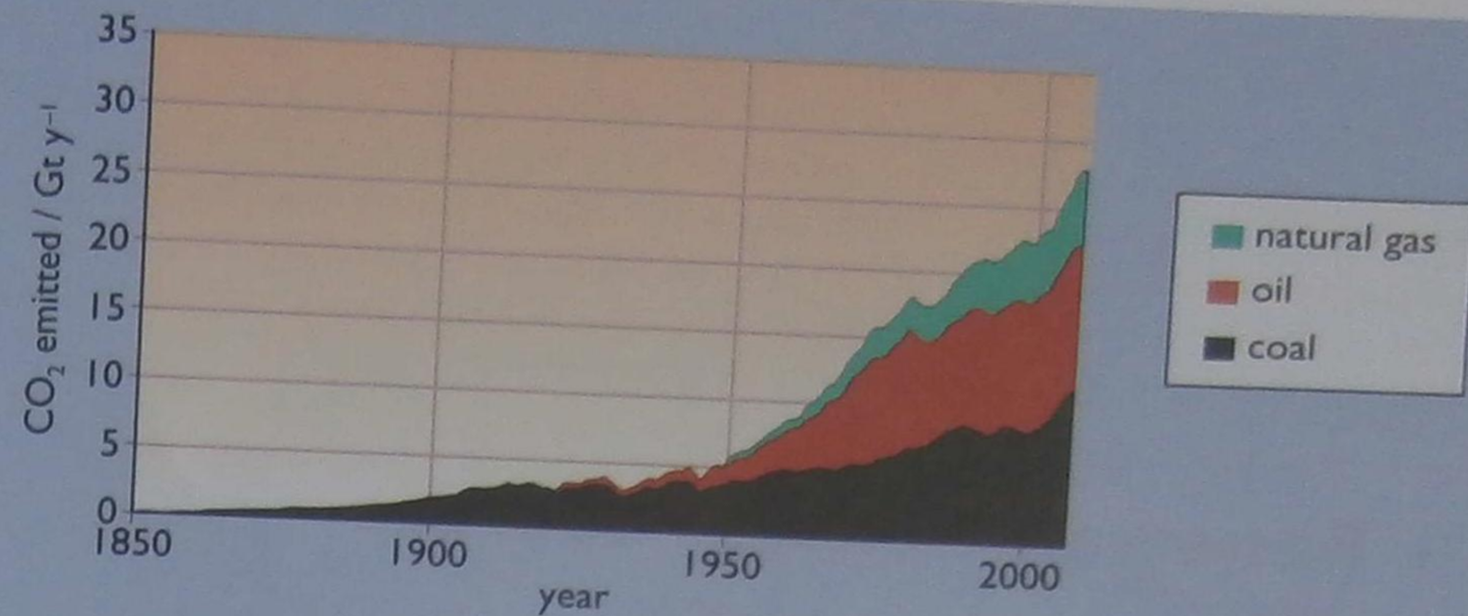


Figure 1.7 CO_2 emissions from the burning of fossil fuels 1850–2009 (sources: Boden et al., 2010; IEA, 2010b; BP, 2010)

that the Earth's surface temperature could rise by between 1.4 and 5.8 °C (depending on the assumptions made) by the end of the twenty-first century. Such rises would probably be associated with an increased frequency of climatic extremes, such as floods or droughts, and serious disruptions to agriculture and natural ecosystems. The thermal expansion of the world's oceans could mean that sea levels would rise by around 0.5 m by the end of the century, which could inundate some low-lying areas. Beyond 2100, or perhaps before, much greater sea level rises could occur if major Antarctic ice sheets were to melt.

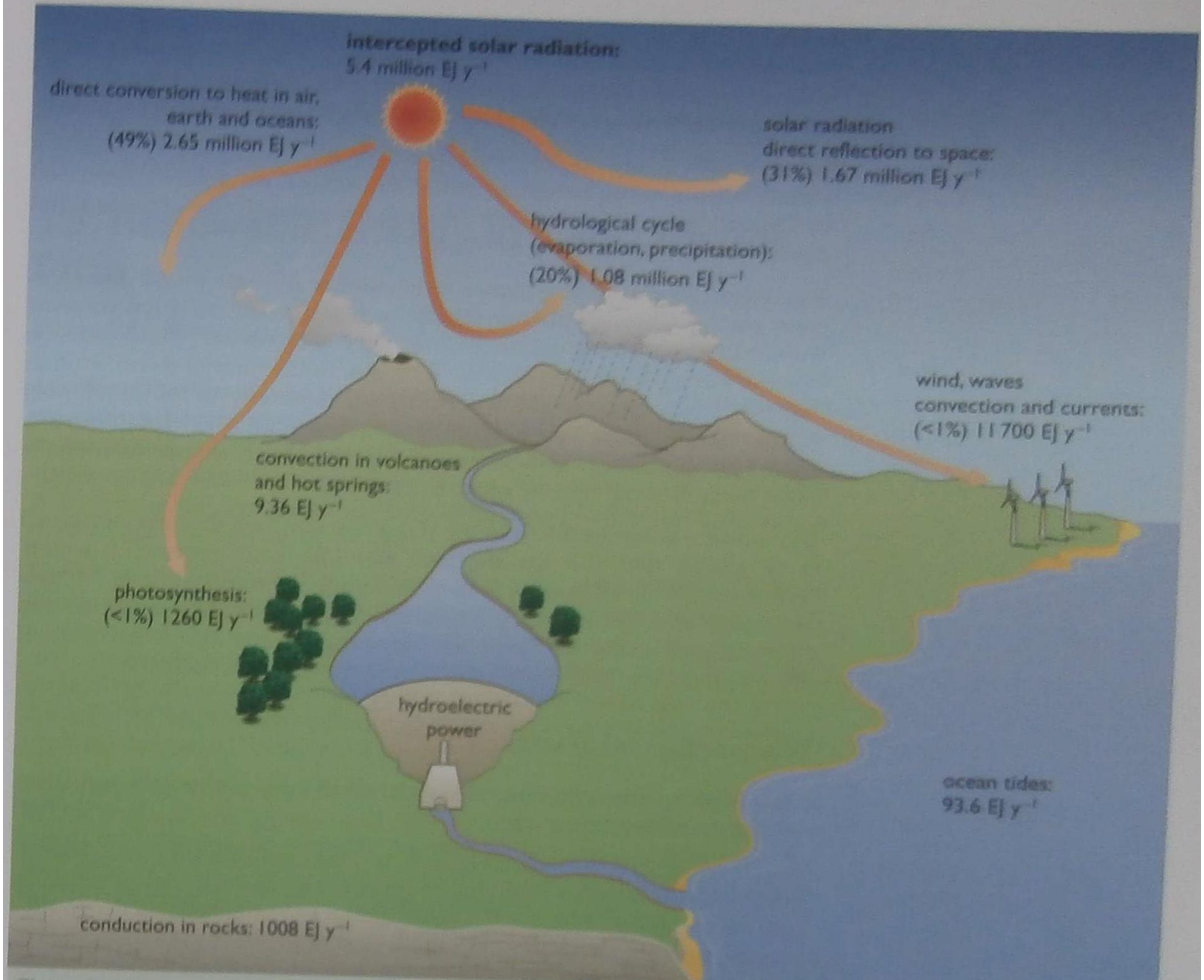


Figure 1.9 The various forms of renewable energy depend primarily on incoming solar radiation, which totals some 5.4 million EJ per year

Bioenergy, discussed in Chapter 4, is another indirect manifestation of solar energy. Through photosynthesis in plants, solar radiation converts water and atmospheric carbon dioxide into carbohydrates, which form the basis of more complex molecules. Biomass, in the form of wood or other 'biofuels', is a major world energy source, especially in the developing world. Gaseous and liquid fuels derived from biological sources make significant contributions to the energy supplies of some countries. Biofuels can also be derived from wastes, many of which are biological in origin.

Biofuels are a renewable resource if the rate at which they are consumed is no greater than the rate at which new plants are re-grown – which, unfortunately, is often not the case. Although the combustion of biofuels generates atmospheric CO_2 emissions, these should be offset by the CO_2 absorbed when the plants were growing, but significant emissions of other greenhouse gases can result if the combustion is inefficient.

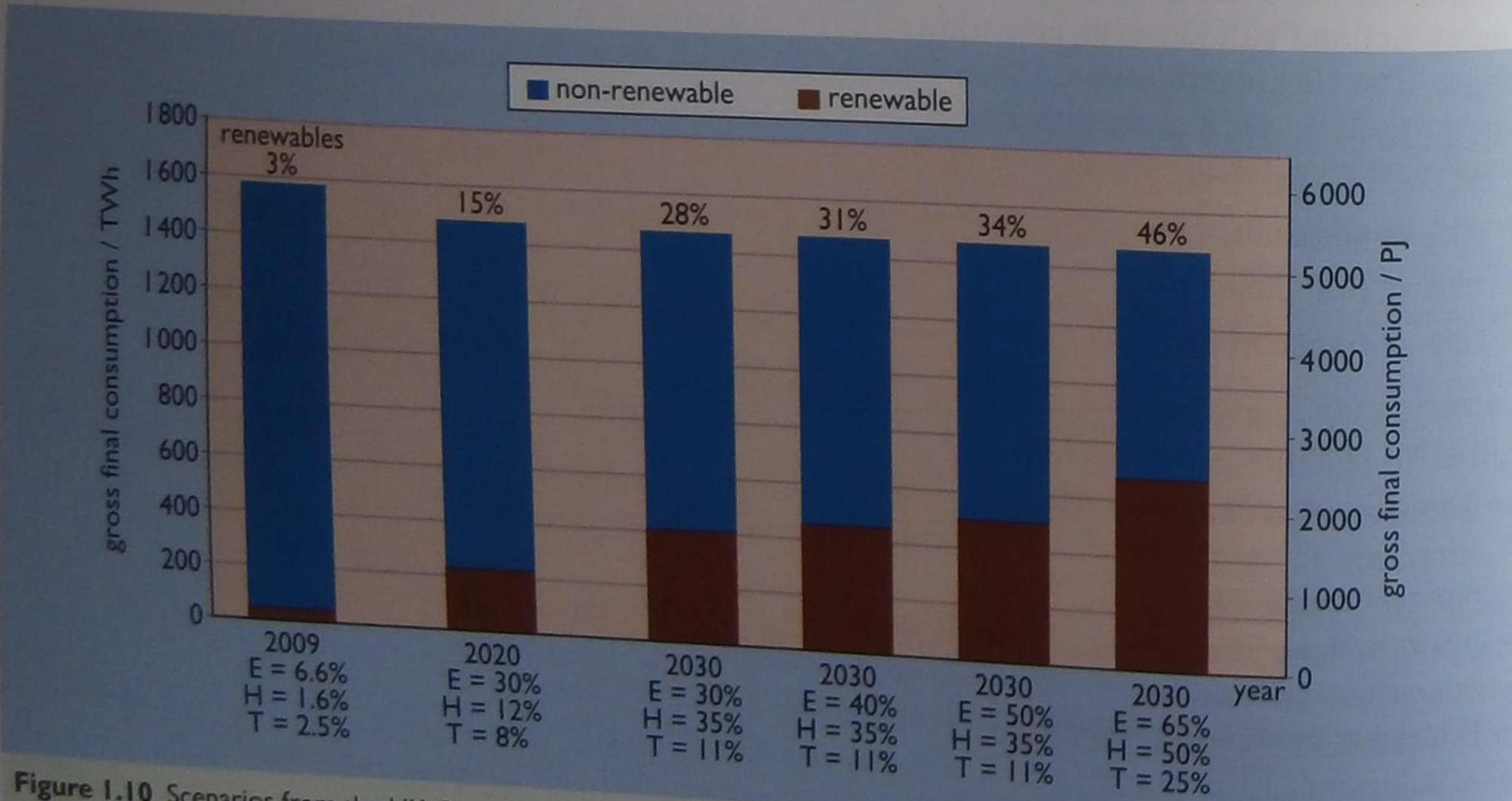
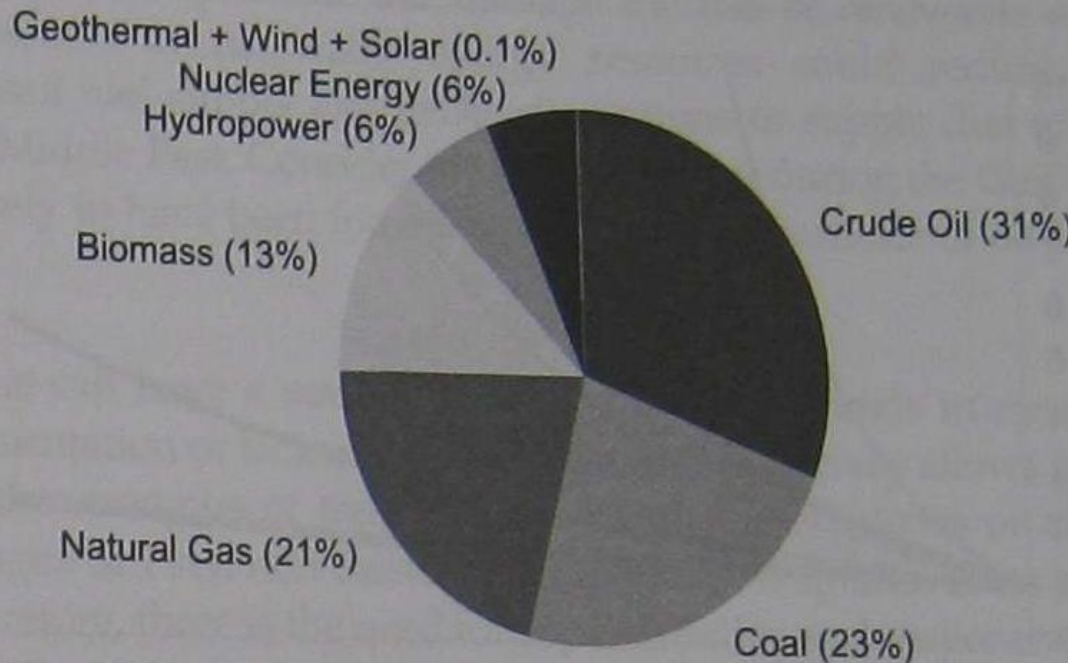


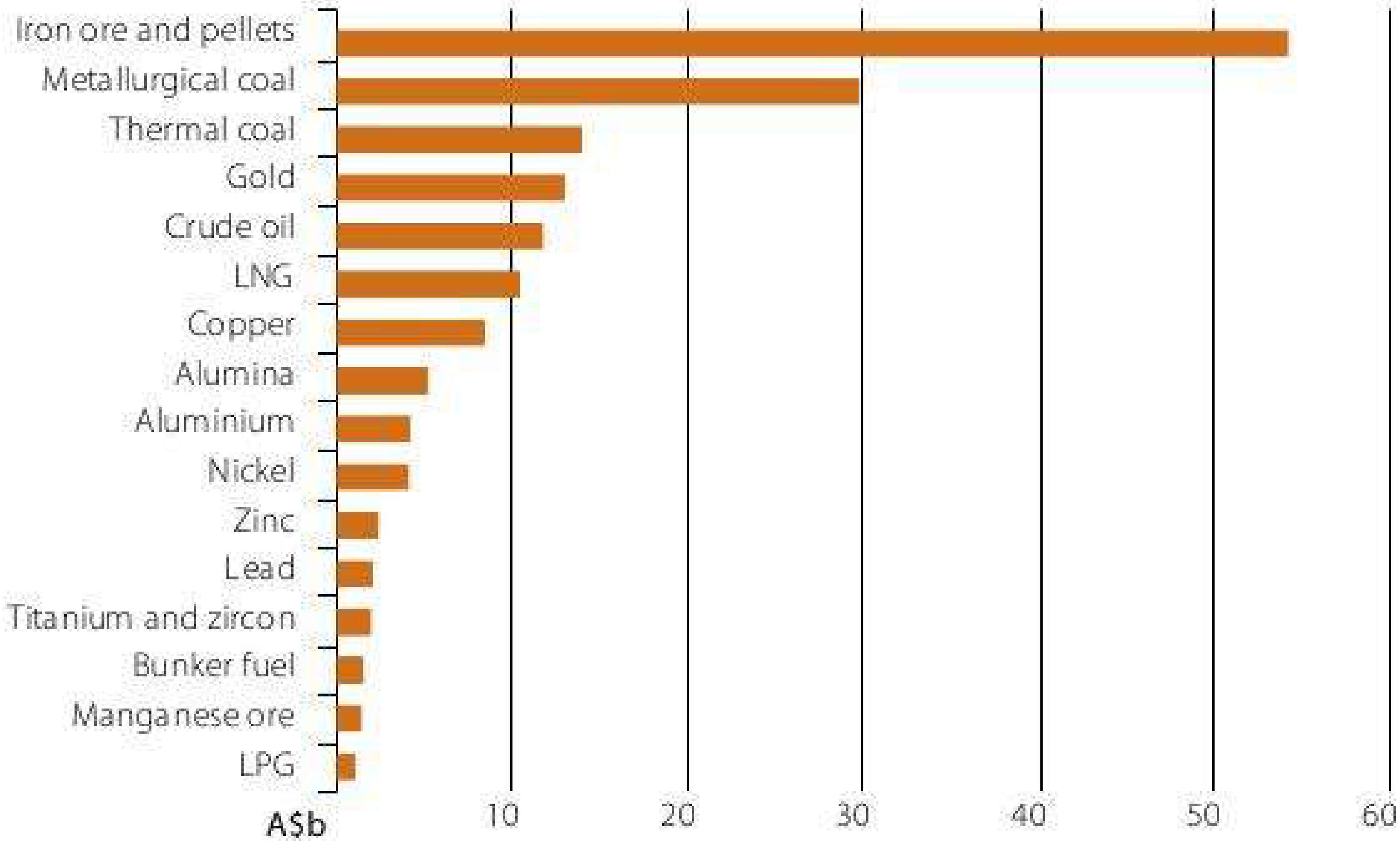
Figure 1.10 Scenarios from the UK Committee on Climate Change illustrating the potential contribution of renewables to UK heat (H), electricity (E) and transport energy (T), and to overall gross final energy consumption, by 2020 and 2030, compared with the contributions in 2009 (adapted from CCC, 2011). Note: 'gross final consumption' shown above is approximately equivalent to 'delivered energy', excluding losses in conversion and delivery, as shown in the last three bars of Figure 1.5 above



World Energy Consumption 1994/5

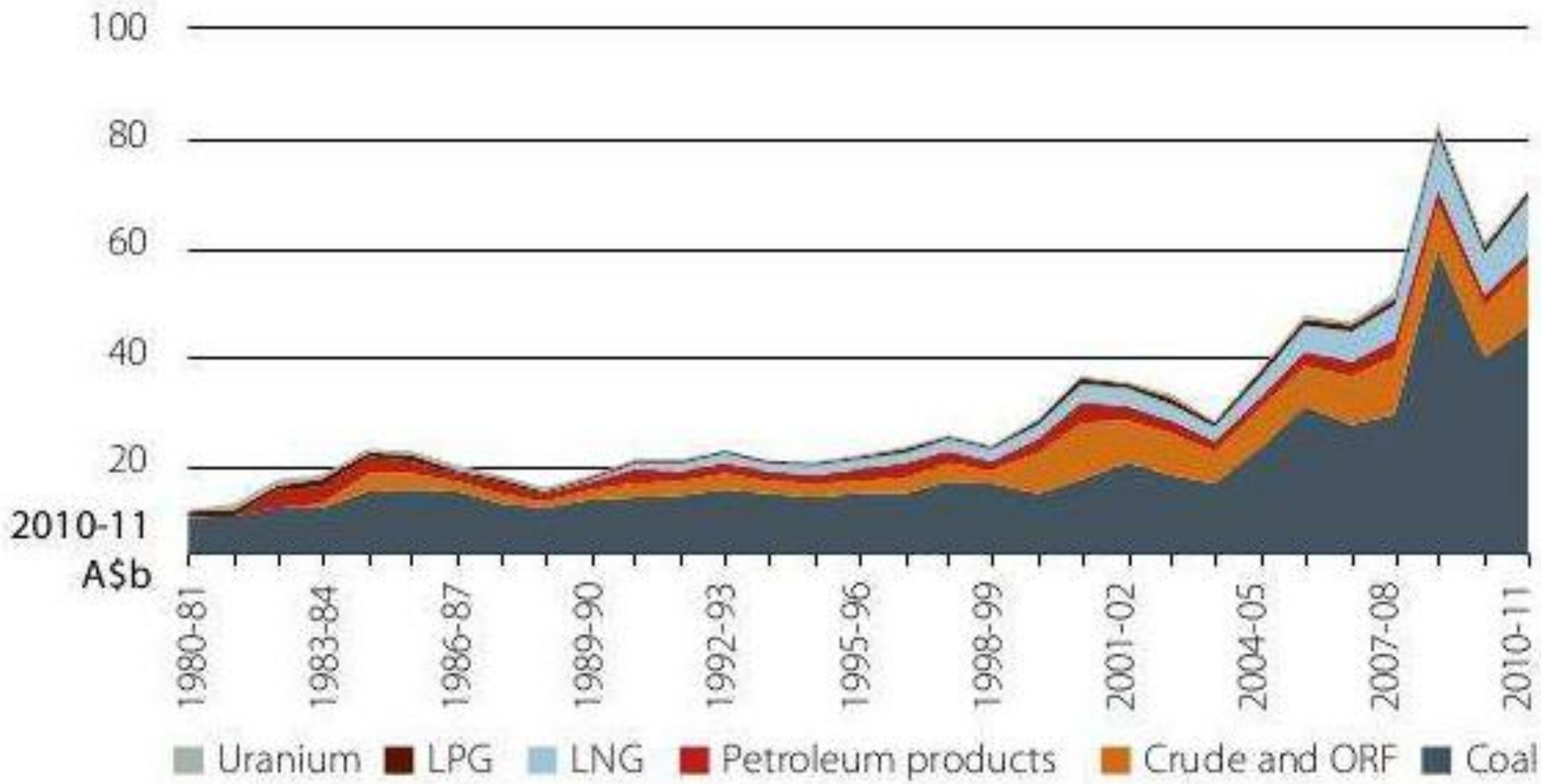
Figure 3 - World Energy Consumption by Energy Source.
(Source: Adapted from BP)

Figure 2: Australia's major resources and energy exports, 2010–11



Source: BREE 2011, Resources and Energy Statistics.

Figure 3: Australia's energy exports



Source: BREE 2011, Resources and Energy Quarterly.

Map 1: Australia's energy resources

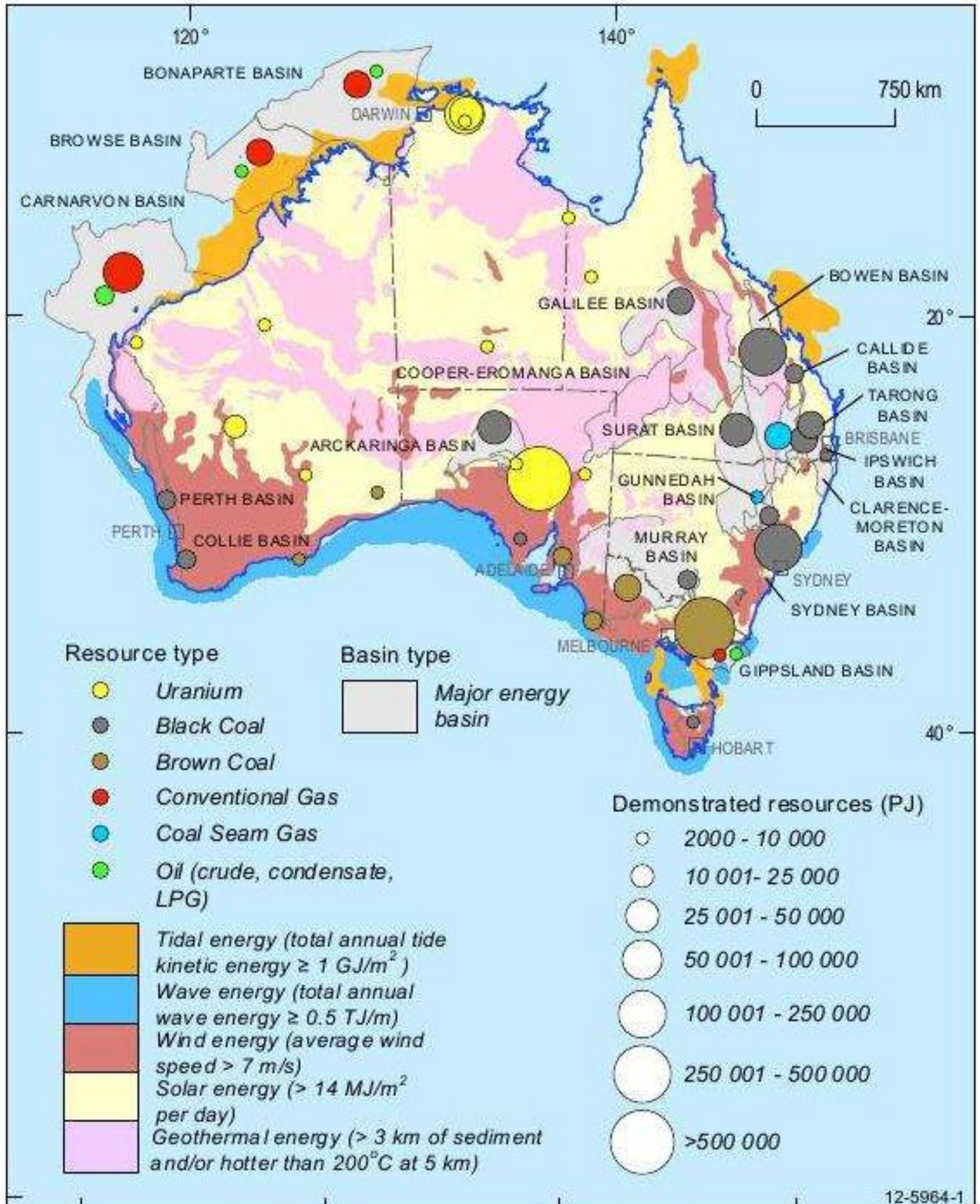


Table 2: Australia's economic demonstrated resources, 31 December 2010

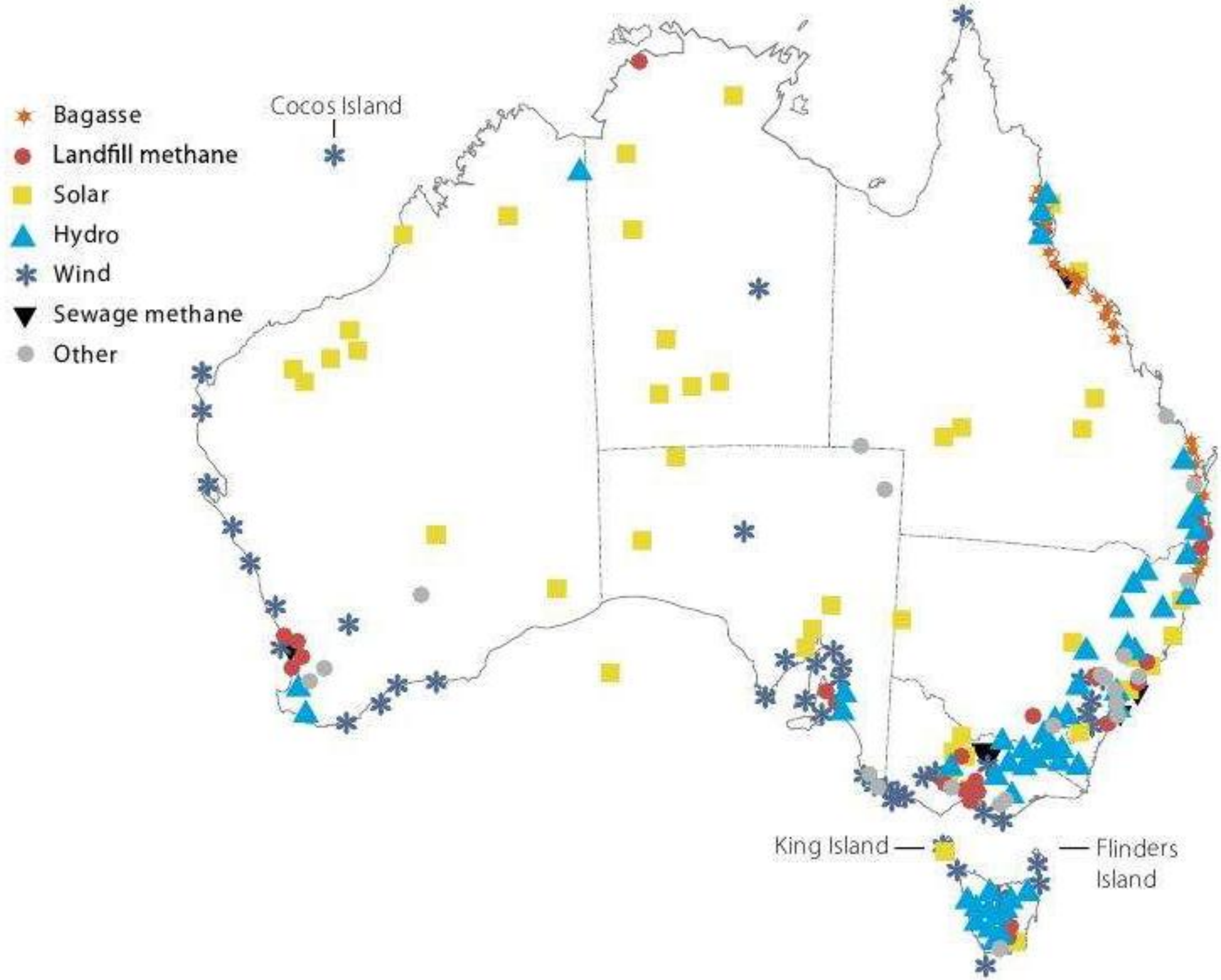
		Australia	Share of World	Resources to production[a]
		PJ	%	yrs
Coal[b]	Black coal	1 255 470	10.3	128
	Lignite	384 689	8.6	517
Petroleum	Oil	5 685	0.2[c]	9
	Condensate	12 413	na	38
	LPG	4 063	na	38
Gas	Conventional gas	113 373	1.6	66
	Coal seam gas	35 055	na	175
Uranium[d]		648 480	33.0	134

Table 15: Capacity of renewable electricity generation in Australia, 2010

	Hydro MW	Wind MW	Bioenergy MW	Solar PV[a] MW	Solar thermal MW	Geothermal MW	Wave MW	Total MW
NSW	4 677	234	166	328	3	0	0	5 408
Tas	2 316	142	5	8	0	0	0	2 471
Vic	803	432	113	152	0	0	0.2	1 500
Qld	669	12	429	256	0	0.1	0	1 366
SA	4	1 151	20	130	0	0	0	1 305
WA	30	204	33	141	0	0	0.1	408
ACT	1	0	4	19	0	0	0	25
NT	0	0	1	6	0	0	0	7
Australia	**8 501**	**2 175**	**772**	**1 041**	**3**	**0.1**	**0.3**	**12 492**

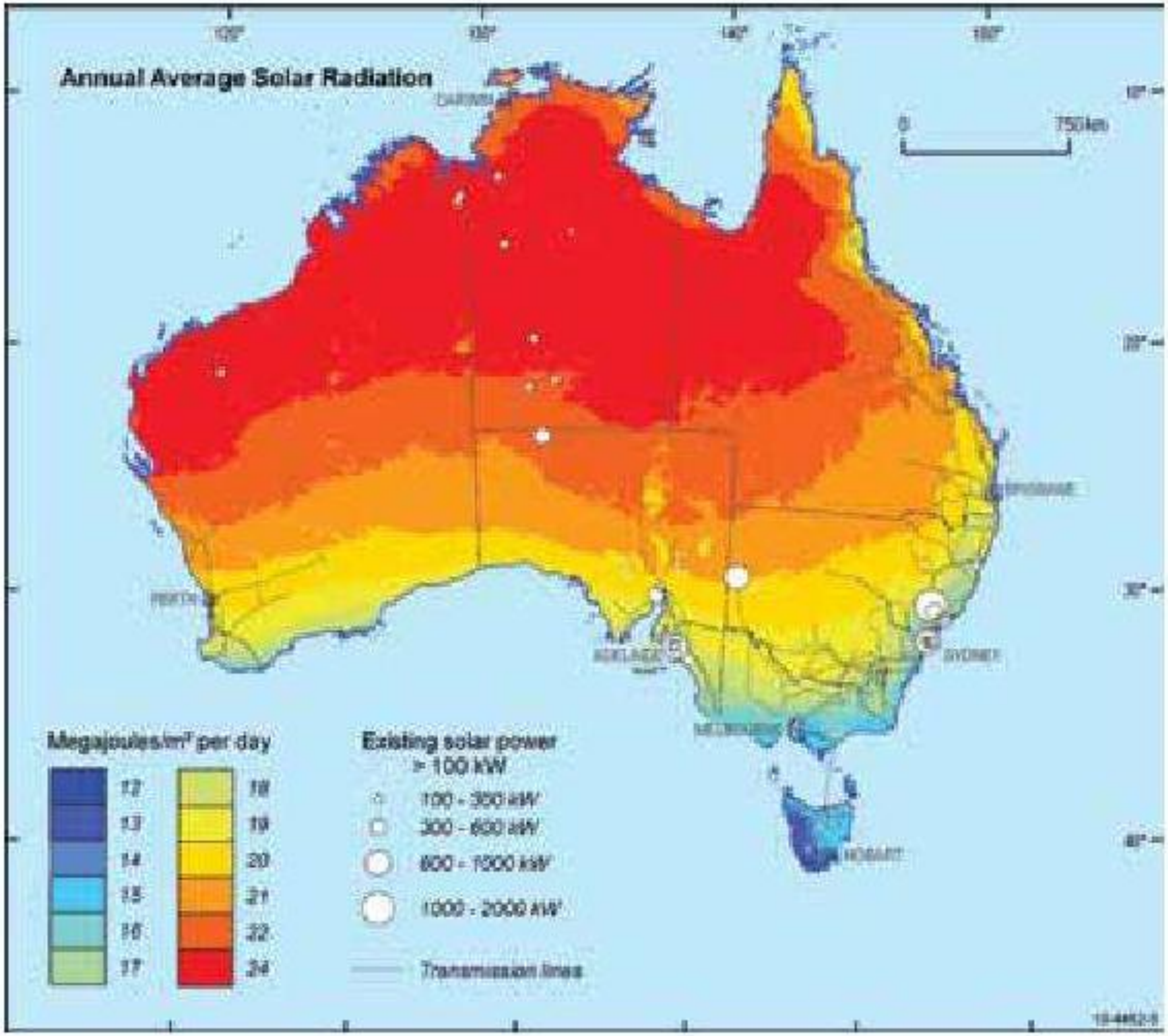
a Includes small-scale Solar PV.

Source: Clean Energy Council 2011, Clean Energy Australia Report 2011.



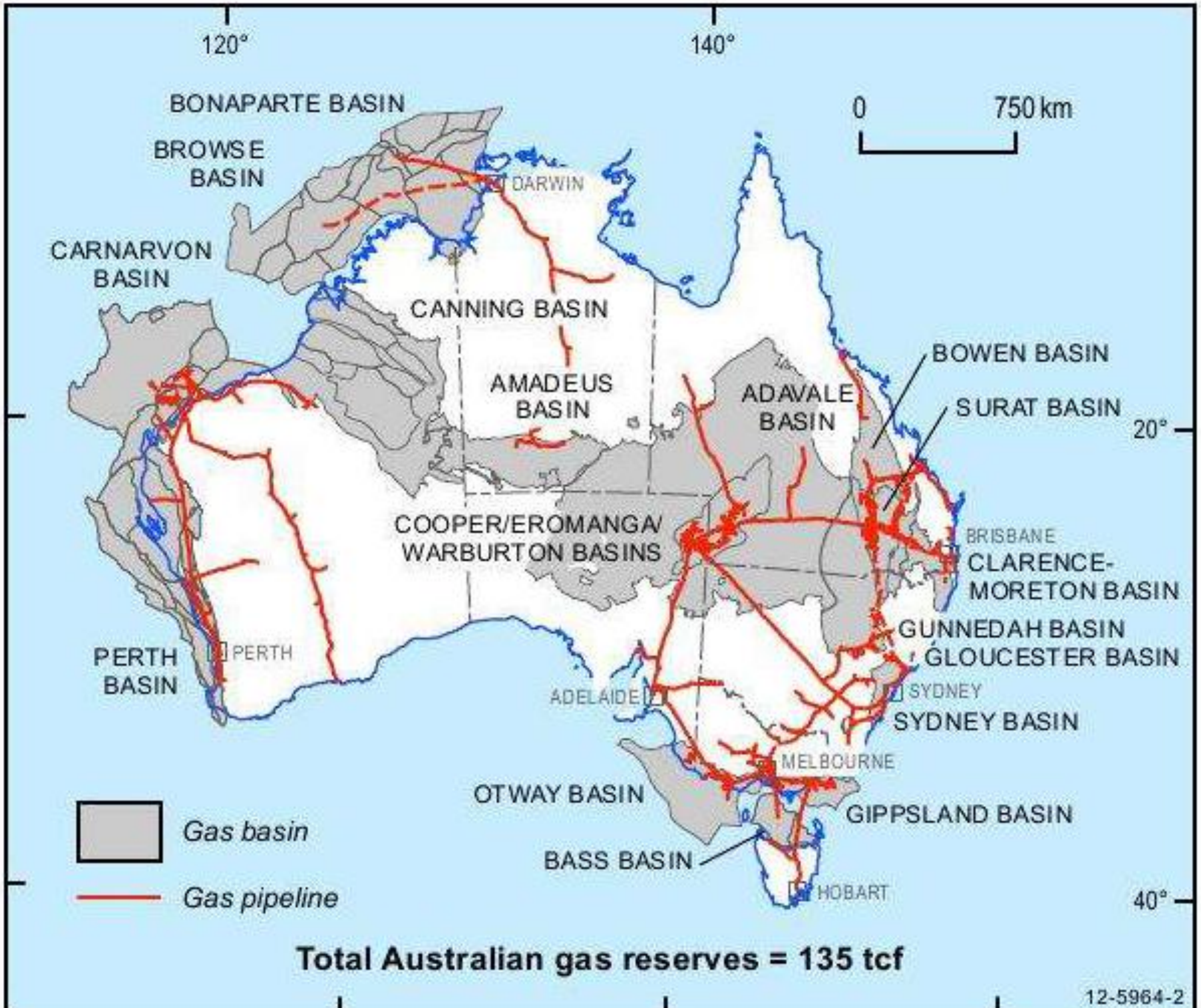
Bagasse
Landfill methane
Solar
Hydro
Wind
Sewage methane
Other
Cocos Island
King Island
Flinders Island

Map 3: Solar energy potential



Source: Geoscience Australia and ABARE 2010.

Map 5: Gas resources and infrastructure



$$\text{force (N)} = \text{mass (kg)} \times \text{acceleration (m s}^{-2}\text{)}.$$

Thus the derived unit, the newton, is equivalent to kg m s^{-2}.

In the real world, force is often needed to move an object even at a steady speed, but this is because there are opposing forces such as friction to be overcome.

Whenever a force is accelerating something or moving it against an opposing force, it must be providing energy. The unit of energy, the **joule (J)**, is defined as the energy supplied by a force of one newton in causing movement through a distance of 1 metre. In general:

$$\text{energy (J)} = \text{force (N)} \times \text{distance (m)}.$$

So a joule is dimensionally equivalent to one newton metre (N m).

Kinetic energy

The **kinetic energy** possessed by any moving object is equal to half the mass (m) of the object times the square of its velocity (v), i.e.:

kinetic energy = $\frac{1}{2}mv^2$

where energy is in joules (J), mass in kilograms (kg) and velocity in metres per second ($m\ s^{-1}$).

Less obvi

Gravitational energy

A second fundamental form of energy is **gravitational energy**. On Earth, an input of energy is required to lift an object because the gravitational pull of the Earth opposes that movement. If an object, such as an apple, is lifted above your head, the input energy is stored in a form called **gravitational potential energy** (often just 'potential energy' or 'gravitational energy'). That this stored energy exists is obvious if you release the apple and observe the subsequent conversion to kinetic energy. The gravitational force pulling an object towards the Earth is called the *weight* of the object, and is equal to its *mass*, m, multiplied by the acceleration due to gravity, g (which is $9.81\ \mathrm{m\ s^{-2}}$, although for rough calculations needing less than 2% precision a value of $10\ \mathrm{m\ s^{-2}}$ is often used). Note that although everyday language may treat mass and weight as the same, science does not. The potential energy (in joules) stored in raising an object of mass m (in kilograms) to a height H (in metres) is given by the following equation (see Figure 1.1):

$$\text{potential energy} = \text{force} \times \text{distance} = \text{weight} \times \text{height} = m \times g \times H.$$

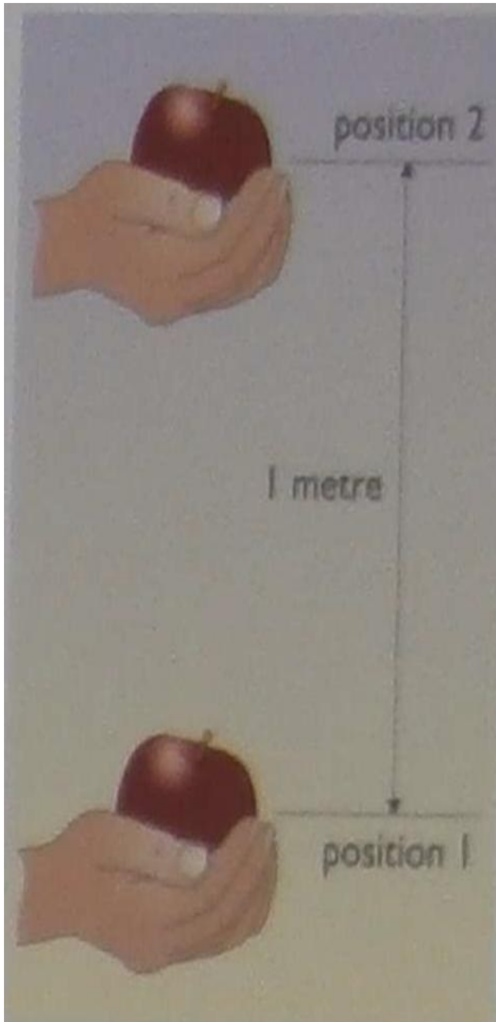


Figure 1.1 The amount of energy required to raise a 100 g apple vertically through 1 m is approximately one joule (1 J)

Electrical energy

Gravity is not the only force influencing the objects around us. On a scale far too small for the eye to see, electrical forces hold together the atoms and molecules of all materials; gravity is an insignificant force at the molecular level. The **electrical energy** associated with these forces is the third of the basic forms. Every atom can be considered to consist of a cloud of electrically charged particles, electrons, moving incessantly around a central nucleus. When atoms bond with other atoms to form molecules, the distribution of electrons is changed, often with dramatic effect. Thus **chemical energy**, viewed at the atomic level, can be considered to be a form of electrical energy. When a fuel is burned, the energy liberated (the chemical energy) is converted into heat energy. Essentially, the electrical energy released as the electrons are rearranged (that is, the net release of energy from the breaking and forming of bonds) is converted to the kinetic energy of the molecules of the combustion products.

$$\text{power (W)} = \text{voltage (V)} \times \text{current (I)}.$$

The largest contribution is an estimated value of 30 EJ from 'traditional biomass' (wood, straw, dung, etc.) mainly used in developing countries. Since most of this isn't traded, it often doesn't enter into national economic statistics and its true magnitude is only known approximately. The next largest category is 'new biomass'. This includes wood and other crops specifically grown for energy purposes, biogas, and biofuels such as ethanol and biodiesel. This is a commodity that is likely to be traded and so its magnitude is more certain. Hydro power is the next largest category, supplying over 2% of the world's primary energy. 'New biomass', together with energy from wastes, geothermal energy, solar energy and energy from wind, wave and tidal power make up the 'other sources' shown in Figure 1.2.

In practice, many electricity-generating fossil fuelled and renewable energy technologies produce large amounts of unused 'waste' heat. Renewable energy proportions based on *primary* energy may thus give a misleading picture. Proportions of renewable energy in national (and global) statistics are now often quoted in terms of *gross final energy consumption* (see Box 1.1).

According to a study of global oil depletion by the UK Energy Research Centre:

> a peak of conventional oil production before 2030 appears likely and there is a significant risk of a peak before 2020.
>
> (Sorrell et al., 2009)

So although large worldwide reserves of oil will remain, the overall production of *conventional* oil seems likely to 'plateau' or even decline. This has serious implications for the UK, where oil production peaked in 1999 and gas production peaked in 2000.

Renewable energy can be defined as:

> *energy obtained from the continuous or repetitive currents of energy recurring in the natural environment*
>
> (Twidell and Weir, 1986)

or as

> *energy flows which are replenished at the same rate as they are 'used'*
>
> (Sorensen, 2000)

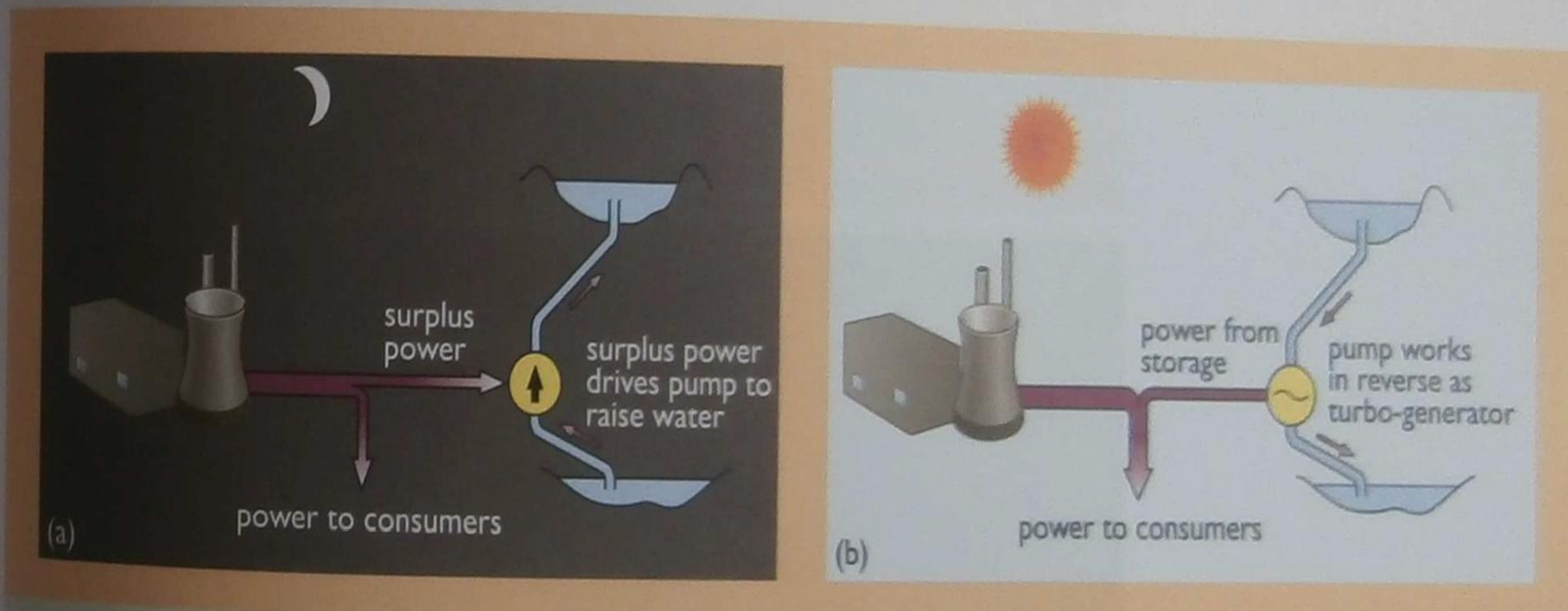
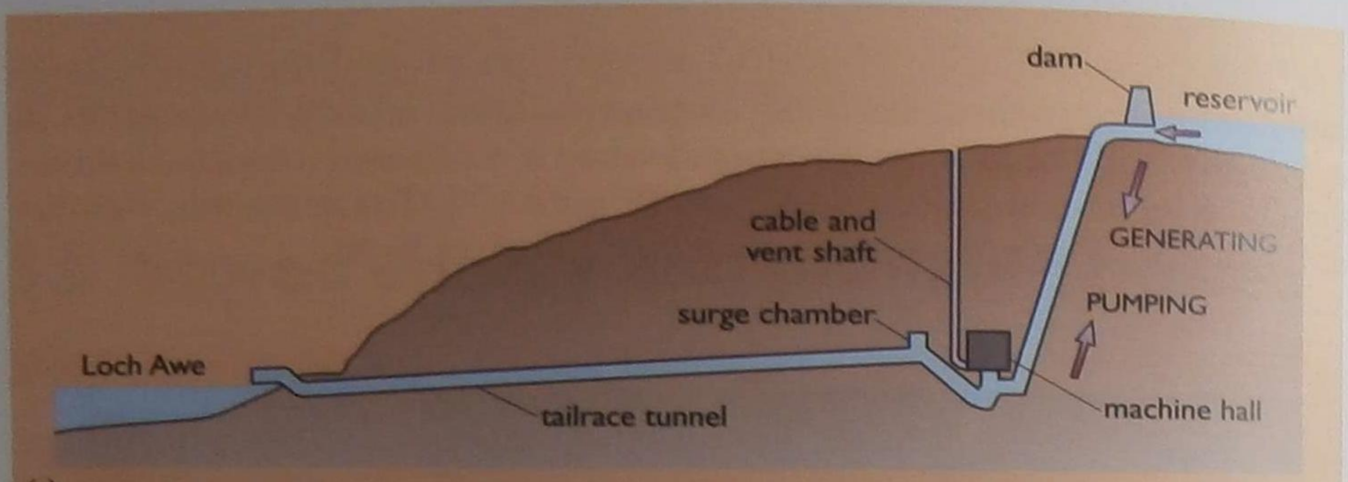
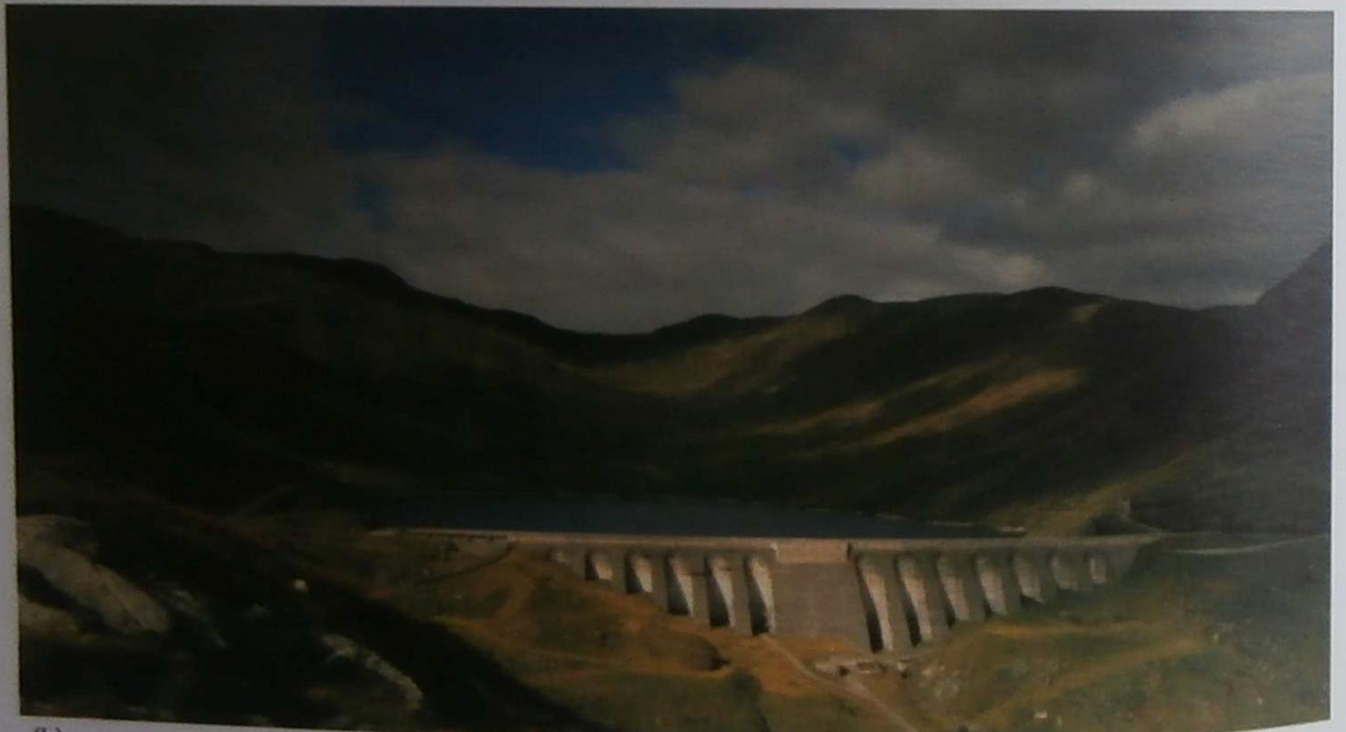


Figure 5.7 Pumped storage system (a) at time of low demand, (b) at time of high demand


dam
reservoir
GENERATING
PUMPING
cable and
vent shaft
surge chamber
Loch Awe
tailrace tunnel
machine hall

(a)



(b)

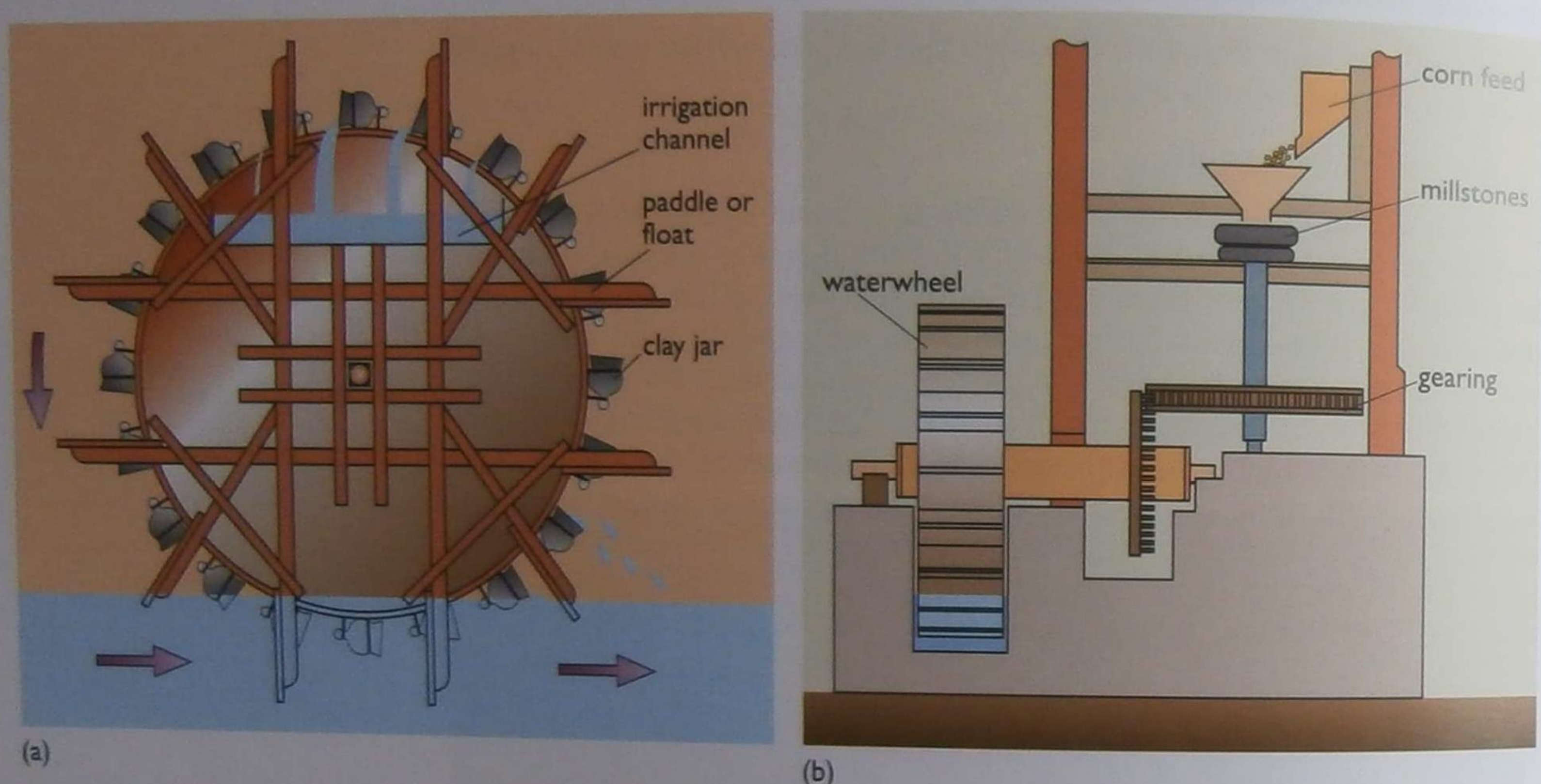


Figure 5.9 (a) A noria – in this earliest waterwheel the paddles dip into the flowing stream and the rotating wheel lifts a series of jars, raising water for irrigation, (b) A Roman mill – this corn mill with its horizontal-axis wheel was described by Vitruvius in the first century BC (note the use of gears)

shows the main features of the three types.

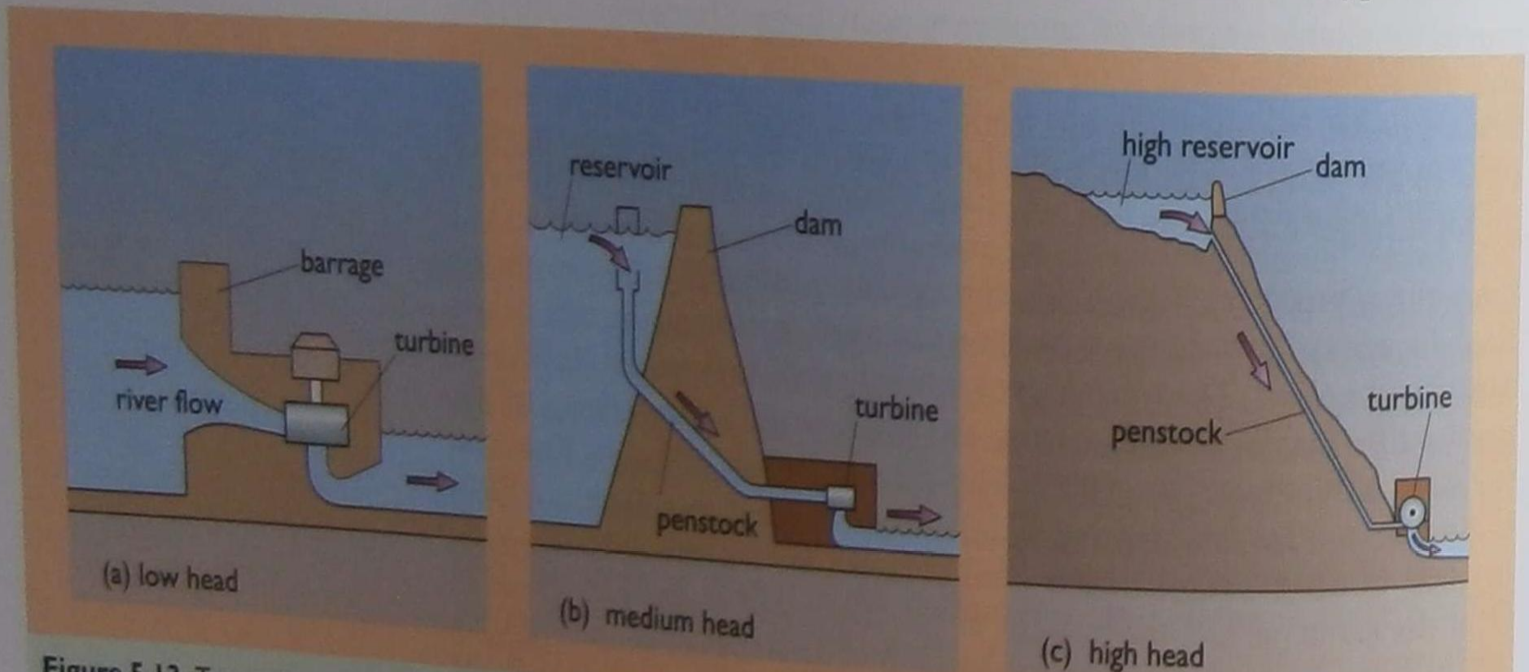


Figure 5.13 Types of hydroelectric installation