UNIT-I

TERMS AND UNITS USED IN BIOMASS PRODUCTION

1. Energy sources

Energy sources partly correspond to the energy forms of section 2, but not entirely. The following energy sources can be relevant for rural areas.

- Biomass. We distinguish between: woody biomass (stems, branches, shrubs, hedges, twigs), non-woody biomass (stalks, leaves, grass, etc.), and crop residues (bagasse, husks, stalks, shells, cobs, etc.). The energy is converted through combustion (burning), gasification (transformation into gas) or anaerobic digestion (biogas production). Combustion and gasification ideally require dry biomass, whereas anaerobic digestion can very well take wet biomass. Fuel preparations can include chopping, mixing, drying, carbonising (i.e. charcoal making) and briqueting (i.e. densification of residues of crops and other biomass).

- Dung from animals, and human excreta. The energy is converted through direct combustion orthrough anaerobic digestion.

- Animate energy. This is the energy which can be delivered by human beings and animals by doing work.

- Solar radiation, i.e. energy from the sun. We distinguish between direct beam radiation and diffuse (reflected) radiation. Direct radiation is only collected when the collector faces the sun. Diffuse radiation is less intense, but comes from all directions, and is also present on a cloudy day. Solar energy can be converted through thermal solar devices (generating heat) or through photovoltaic cells (generating electricity). Direct beam solar devices (whether thermal or photovoltaic) would need a tracking mechanism to have the device continuously facing the sun.
- Hydro resources, i.e. energy from water reservoirs and streams. We distinguish between: lakes with storage dams, natural heads (waterfalls), weirs, and run-of-river systems. Hydro energy canbe converted by waterwheels or hydro turbines.

- Wind energy, i.e. energy from wind. Wind machines can be designed either for electricity generating or for water lifting (for irrigation and drinking water).

- Fossil fuels, like coal, oil and natural gas. Unlike the previous energy sources, the fossil energysources are non-renewable.

- Geothermal energy, that is, the energy contained in the form of heat in the earth. A distinction is made between tectonic plates (in volcanic areas) and geopressed reservoirs (could be anywhere). Geothermal energy is, strictly speaking, non-renewable, but the amount of heat in the earth is so large that for practical reasons geothermal energy is generally ranked with the renewables. Geothermal energy can only be tapped at places where high earth temperatures come close to the earth's surface.

This list only contains primary energy sources. These are the energy sources which are present in our natural environment. Secondary energy sources, like batteries, are not included here.

We observe that the primary energy sources are not the ultimate sources of energy. For instance, animate energy comes from biomass, whereas biomass energy ultimately comes from the sun. Apart from geothermal and nuclear energy, all our so-called primary energy sources have ultimately got their energy from the sun!

2. Energy sources

Energy sources are sometimes classified according to characteristics like: renewable, traditional, commercial, etc. The terminology is rather ambiguous, as the meaning of the words often depends on the context. Some connotations are given below.

Renewable is generally contrasted with fossil. Renewable are biomass, animate, solar, water and wind energy, as well as geothermal energy. Fossil energy is contained in coal, oil and natural gas.

Traditional energy is often contrasted with non-traditional energy, and also with new energy. However, what is considered as traditional depends on what one is used to. In industrialised societies which are used to fossil fuels, renewable energies like biomass and animate energy are often called traditional. At the same time, engineers working on "new" energies like wind or solar energy often consider fossil fuels as traditional. Apparently, what people call traditional are the forms they are actually not used to.

New and renewable energy sources are often put together. They exclude fossil and nuclear energy.

Commercial energy is contrasted with non-commercial energy, and sometimes with traditional energy. Commercial energy certainly includes energy from fossil fuels which havebeen monetarized, but also some forms of new and renewable energies which are part of the cash economy. Biomass and some other sources of renewable energy (thermal solar energy) are sometimes considered non-commercial, because they are thought to be freely available. However, in many areas, biomass fuels have to be paid for!

3. Energy flow

As we have seen, generating and utilising energy means converting energy from one form into another. Often, intermediate steps are Implied. The energy flows through a number of forms, as well as conversion steps, between the source and the end-use. The costs increase accordingly. We distinguish between primary, secondary, final and useful energy.

An example is an energy flow which is related to charcoal. Here, the primary energy form is wood.The wood is converted into charcoal in a charcoal kiln. Charcoal is the secondary form of energy,and it is transported to the consumer. What the consumer buys at the market place is charcoal, and this is called final energy. The consumer eventually converts the charcoal into heat for cooking. The heat is the useful energy.

Another example of an energy flow is: primary energy in the form of a hydro resource, secondary energy in the form of electricity at the hydro power station, final energy in the form of electricity at a saw mill, and useful energy in the form of shaft power for sawing.

Energy	**Technology**	**Examples**
primary		coal, wood, hydro, dung, oil, etc.
	conversion	power plant, kiln, refinery, digester
secondary		refined oil, electricity, biogas
	transport/transmission	trucks, pipes, wires
final		diesel oil, charcoal, electricity, biogas
	conversion	motors, heaters, stoves
useful		shaft power, heat

<u>Primary energy</u> is the energy as it is available in the natural environment, i.e. the primary source of energy.

<u>Secondary energy</u> is the energy ready for transport or transmission.

<u>Final energy</u> is the energy which the consumer buys or receives.

<u>Useful energy</u> is the energy which is an input in an end-use application.

Note that useful energy is almost invariably either in the form of heat or in the form of shaft power. For a few end-uses (e.g. communication equipment), electricity is the form of useful energy.

Note that in some cases the primary energy is at the same time the secondary, and even the final energy (c.f. wood gathered for cooking purposes, or animate power for pulling).
The breakdown of primary to useful energy is relevant, because with each conversion step some energy is lost. In order to reduce costs and avoid unnecessary losses, we will always aim at eliminating unnecessary steps in the flow of energy.

4. Energy units and dimensions

So far, we have discussed energy in qualitative terms. In order to proceed, we must discuss energy quantitatively. That means, we need units for measuring quantities of energy and related concepts. We use the International system of units (SI units), which is based on the dimensions and basic units in Table 1.

Table 1. Basic SI units

dimension	**basic unit**	**symbol**
length	meter	m
mass	kilogram	kg
time	Second	s
electric current	ampere	A
temperature	kelvin	°K

The unit of energy in this unit system is joule (J), and the unit of power is watt (W). These and many other units can be derived from the basic SI units. The relationship between some derived SI units and the basic SI units is represented in Table 2.

Table 2. Derived SI units

dimension	unit	symbol
area	square meter	m^2
volume	cubic meter	m^3
speed	meter per second	m/s
acceleration	meter per second	m/s^2
pressure	pascal	Pa (=N/m)
volume flow	cubic meter per second	m^3/s
mass flow	kilogram per second	kg/s
density	kilogram per cubic meter	kg/m^3
force	newton (*)	$N(=kg.m/s^2)$
energy	joule (**)	J(=N.m)
power	watt	W (=J/s)
energy flux	watt per square meter	W/m^2
calorific value	joule per kilogram	J/kg
specific heat	joule per kilogram kelvin	J/kg.K
voltage	volt	V (=W/A)

(*) The force exerted by a mass of 1 kg equals ca. 10 N.(**) The energy required to lift 1 kg by 1 meter. Note that = W.s.

In some countries, or in a particular context, other units than SI units are also used. They can be converted into SI units, which are more convenient for calculations. The conversion of some non-SI units into SI units is given in Table 3, for energy and for power.

Table 3. Conversion of non-SI units

Non-SI unit for energy	symbol	equivalence in SI-units
erg	erg	10^{-7} J
foot pound force	ft.lbf	1.356 J
calorie	cal	4.187 J
kilogramforce meter	kgf.m	9.8 J
British thermal unit	Btu	1.055×10^{3} J
horsepower hour (metric)	hp.hr	2.646×10^{6} J
horsepower hour (GB)	hp.hr	2.686×10^{6} J
kilowatt hour	kWh	3.60×10^{6} J
barrel oil equivalent	b.o.e.	6.119×10^{9} J
ton wood equivalent	-	9.83×10^{9} J
ton coal equivalent	tee	29.31×10^{9} J
ton oil equivalent	toe	41.87×10^{9} J
quad (PBtu)	-	1.055×10^{18} J
tera watt year	TWy	31.5×10^{18} J

Non-SI unit for power	symbol	equivalence in SI-Units
foot pound per hour	ft.lb/h	0.377×10^{-3} W
calorie per minute	cal/min	69.8×10^{-3} W
British thermal unit per hour	Btu/h	0.293 W
British thermal unit per second	Btu/s	1.06×10^{3} W
kilocalorie per hour	kcal/h	1.163 W
foot poundforce per second	ft.lbf/s	1.356 W
calorie per second	cal/s	4.19 W
kilogramforce meter per second	kgf.m/s	9.8 W
horsepower (metric)	hp	735.49 W
horsepower (GB)	hp	746 W

The powers of ten are often abbreviated by writing prefixes before the unit. For instance, the symbol G stands for giga, which means 10 to the power 9, i.e. a billion. One billion W is then written as 1 GW (one giga Watt). Common prefixes are given in Table 4.

Table 4. SI prefixes

Prefix	Symbol	Multiplier
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9} (=1,000,000,000)
mega	M	10^{6} (= million)
kilo	k	10^{3} (= thousand)
hecto	h	10^{2} (= hundred)
deca	da	10^{1} (= ten)
deci	d	10^{-1} (= a tenth)
centi	c	10 (= a hundredth)
milli	m	10^{-3} etc....
micro	u	10^{-6}
nano	n	10^{-9}
pico	P	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

Magnitudes of energy forms

Now we have Introduced units for measuring energy, we can make quantitative comparisons and calculations. The following results give us some feeling of magnitudes of energy, as represented in different energy forms.

The examples are all equivalent to about 100 kJ;

- radiation from the sun on the roof of a house (of ca. 40 m^2) in 2.5 s

- energy released in burning 3.5 g coal or 2.9 g petrol; or the energy stored in 1/4 slice of bread

- a large object (1,000 kg) at a height of 10 m

- energy produced by a windmill of 3 m diameter in a wind speed of 5 m/s (a breeze) during 20 minutes; or the energy stored in the mass of a car (1,000 kg) moving at 50 km/h heat emanated in cooling three cups of coffee (0.4 kg) from 80°C to 20° C; or the energy needed to melt 0.3 kg ice

- an iron flywheel of 0.6 m diameter and 70 mm thick, rotating at 1,500 revolutions per second

- energy consumed by a 100 W electric light bulb in 17 minutes

5. Energy losses and efficiency

As has been stated in Section 3, energy conversions always imply energy losses. This leads us to the concept of efficiency, as follows. A quantity of energy in a certain form is put into a machineor device, for conversion into another form of energy. The output energy in the desired form is only a part of the Input energy. The balance is the energy loss (usually in the form of diffused heat). It means the converter has less than 100% efficiency.

The efficiency of an energy converter is now defined as the quantity of energy in the desired form(the output energy) divided by the quantity of energy put in for conversion (the input energy). The efficiency is usually expressed by the Greek letter η .

Hence: $$\eta = \frac{\text{output energy}}{\text{input energy}}$$

Table 5 gives some typical efficiencies of energy converters.

Table 5. Some typical efficiencies of energy converters

Converter	form of input energy	form of output energy	efficiency %
petrol engine	chemical	mechanical	20 - 25
diesel engine	chemical	mechanical	30 - 45
electric motor	electrical	mechanical	80 - 95
boiler & turbine	thermal	mechanical	7-40
hydraulic pump	mechanical	potential	40 - 80
hydro turbine	potential	mechanical	70 - 99
hydro turbine	kinetic	mechanical	30 - 70
generator	mechanical	electrical	80 - 95
battery	chemical	electrical	80 - 90
solar cell	radiation	electrical	8-15
solar collector	radiation	thermal	25 - 65
electric lamp	electrical	light	ca. 5

Water pump	mechanical	potential	ca. 60
water heater	electrical	thermal	90 - 92
gas stove	chemical	thermal	24 - 30

In some of these converters, intermediate forms of energy occur between the form of the input energy and the form of the output energy. For instance, with diesel engines, the intermediate form is thermal energy.

When thermal energy is Involved either as the input or as an intermediate form, the efficiency is generally low.

The energy converter can be a device, or a process, or a whole system. An example of the efficiency of an energy conversion system is given in Table 6. The overall efficiency equals the product of the efficiencies of the various components of the system. We see that it can be very low indeed.

Table 6

energy form	**energy converter**	**efficiency**
chemical energy		
	diesel engine	30%
mechanical energy		
generator		80%
electricity		
electric motor		80%
mechanical energy		
waterpump		60%
potential energy		

efficiency of the system = 30% x 80% x 80%x 60% = 12%

Efficiency of an energy conversion system: An example

Where energy is a scarce resource, we want the efficiency of conversion to be high, in order to save energy. But higher efficiency often implies higher costs for better equipment. Optimization with respect to, on the one hand, the costs of energy and, on the other hand, the costs of equipment, is a major task in energy planning. The problem of optimization is different when energy sources are free (like with wind, solar and some hydro sources). Energy efficiency has then a limited meaning, and the choice of technology will be guided by the cost effectiveness of the equipment.

A very high system efficiency can be obtained when heat losses from one converter are utilised as energy inputs in another. We call this waste heat utilisation. It is applicable, for instance, in agro-processing where heat from Industrial converters is utilised for drying of products. Cogeneration is another example, i.e. the utilisation of "waste" heat from electricity production, for purposes of process heat in Industry.