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ENERGY STATISTICS: DEFINITIONS, UNITS OF MEASURE AND CONVERSION FACTORS

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ENERGY STATISTICS: DEFINITIONS, UNITS OF MEASURE AND CONVERSION FACTORS

Corrigendum

Page 24, table 8, first row (Crude oil)

The entry under "Gigacalories" should read 10.00

The entry under "Tons oil equivalent" should read 1.000

Page 29, table 13

The last column should read

0.086
0.115
0.172
0.215
0.246
0.287
0.344
0.433

Page 41, Volume

The third line should read

One cubic foot = 1 ft^3 = 0.0283168 m^3

Litho in United Nations, New York
91-38552 2643c (E)

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INTRODUCTION

When energy issues were thrust to the fore in the 1970s there was a concomitant burst of energy research and analysis. One result of this was the discovery of the inadequacy of most energy data. Most data of that time pertained only to supply and avoided addressing the transformation sector and final consumption. It also became apparent that there was little standardization in the methodologies for the collection and compilation of basic data. There were problems with definitions. There was debate as to what should be the common units for presentation.

One of the foremost problems was and continues to be the diversity of systems adopted by countries for the collection and assemblage of energy data. As a result, a user of energy statistics today must be prepared to compare joules to Btu's and calories, barrels to metric tons, oil equivalent to coal equivalent, and electricity to all the above.

The purpose of this handbook is to serve as a guide for the energy planners, economists and statisticians who must make some sense out of energy data. For the various energy sources, disparate units and different terminologies used to describe them, this book provides internationally adopted definitions, conversion factors and descriptive tables. It presents a compatible set of factors using available information and incorporating the practices developed by those who have advanced energy research the farthest.

I. DEFINITIONS

A. Energy sources and commodities

To understand how energy is measured and converted, one must understand the nature of the various energy sources and commodities. The multiple outputs of the mine, the well-head and the refinery must be precisely defined for modern commercial usage. These outputs can vary significantly with geographical location, so it is important that ranges of values be established for these products.

One must also learn something about biological processes since most fuels result from the action of biological forces over time. For example, peat, lignite and hard coal are three fuel commodities resulting from different degrees of coalification, a biological process, of plant biomass.

At the same time, man has exerted tremendous influence over the characteristics of fuels through processing of one type or another. The different types of petroleum products testify to our inventiveness in creating products for specific needs: light spirits to dry clean clothing, gasoline to power automobiles, heavy fuels to heat boilers and lubricants to grease bearings.

All energy sources and commodities must be accurately defined according to internationally accepted standards. Whether that definition is a chemical formula, a specific gravity, a calorific value or a viscosity, a consumer should be able to specify and receive the energy product required, even if it is procured from some far corner of the world.

The following are the standard definitions of energy sources and commodities as employed by the Statistical Office of the United Nations Secretariat. A glossary of technical terms used in some of these definitions is given on page 6.

1. Solid fuels

Hard coal is coal that has a high degree of coalification with a gross calorific value above 24 MJ/kg (5700 kcal/kg) on an ash-free but moist basis, and with a reflectance index of vitrinite of 0.5 and above. Slurries, middlings and other low-grade coal products, which cannot be classified according to the type of coal from which they are obtained, are included under hard coal.

Brown coal or lignite is coal with a low degree of coalification that has retained the anatomical structure of the vegetable matter from which it was formed. Its gross calorific value is less than 24 MJ/kg (5700 kcal/kg) on an ash-free but moist basis, and its reflectance index of vitrinite is less than 0.5.

Peat is a solid fuel formed from the partial decomposition of dead vegetation under conditions of high humidity and limited air access (the initial stage of coalification). Included is only that portion of peat used as fuel.

Patent fuel is another name for hard coal briquettes. In the briquetting process, coal fines are moulded into artifacts of even shape under the influence of pressure and temperature with the admixture of binders.

Lignite briquettes are made from lignite which, after crushing and drying, is moulded under high pressure without the admixture of binders to form artifacts of even shape.

Peat briquettes are made from raw peat which, after crushing and drying, is moulded under high pressure and without the admixture of binders to form artifacts of even shape.

Coke is the solid residue obtained from the dry distillation of hard coal or lignite in the total absence of air (carbonization). There are two types of coke: gas coke - a by-product of coal used for the production of manufactured gas in gas works; and coke-oven coke - which includes all other coke produced from hard coal.

Brown coal coke is a solid product obtained from the carbonization of brown coal briquettes.

Oil shale refers to sedimentary rock containing a high proportion of organic matter (kerogen), which can be converted to crude oil or gas by heating.

Bituminous sands are sands or sandstones (bitumens) containing a high proportion of tarry hydrocarbons, capable of yielding oil through heating or other extractive processes. Also included are heavy oils and tars which are so dense and viscous that they cannot be extracted commercially by conventional methods, that is, by natural flow or pumping. Since they do not naturally flow and must be separated by extraordinary means, such as heat, from the rock structures which they permeate, heavy crude oils are grouped with solid fuels. Viscosity should be used as a determinant to differentiate between crude oils and bitumens. Subsequently, density should be used to differentiate among extra-heavy crude oils, heavy crude oils and other oils.

Bitumens have viscosities greater than 10,000 centipoise. Crude oils have viscosities less than or equal to 10,000 centipoise. These viscosities are gas-free as measured and referenced to original reservoir temperature.

Extra-heavy crude oils have densities greater than 1000 kg/m^3 (API gravities less than 10°API). Heavy crude oils have densities from 934 to 1000 kg/m^3 (API gravities from 20° to 10°) inclusive. These densities (API gravities) are referenced to 15.6°C and atmospheric pressure.

2. Liquid fuels

Crude petroleum is mineral oil consisting of a mixture of hydrocarbons of natural origin, yellow to black in colour, of variable specific gravity and viscosity. Also included under this heading are crude mineral oils extracted from bituminous minerals (shale, bituminous sand, etc.). Data for crude petroleum include lease (field) condensate which is recovered from gaseous hydrocarbons in lease separation facilities.

Alcohol in the energy context generally refers to ethanol (ethyl alcohol) and methanol (methyl alcohol) used as fuel. Ethanol can be produced from sugar, starch and cellulose and is used mainly in transport (on its own or blended with gasoline). Methanol can be produced from wood, crop residues, grass, and the like and can be used in internal combustion engines.

Natural gas liquids are liquid or liquefied hydrocarbons produced in the manufacture, purification and stabilization of natural gas. Their characteristics vary, ranging from those of butane and propane to heavy oils. Specifically included are natural gasoline, LPG and plant condensate.

Plant condensate is made up of liquid hydrocarbons condensed from wet natural gas in natural gas processing plants. It is used as a petroleum refinery input.

Natural gasoline is light spirit extracted from wet natural gas, often in association with crude petroleum. It is used as a petroleum refiner and petrochemical plant input and is also used directly for blending with motor spirit without further processing.

Petroleum products comprise the liquid fuels, lubricating oils and solid and semi-solid products obtained by distillation and cracking of crude petroleum, shale oil or semi-refined and unfinished petroleum products. Excluded are oil products obtained from natural gas, coal, lignite and their derivatives.

Aviation gasoline is motor spirit prepared especially for aviation piston engines, with an octane number varying from 80 to 145 RON and a freezing point of -60°C.

Motor gasoline is light hydrocarbon oil used in positive (spark) ignition engines other than aircraft. It distills between 35° and 200°C and is treated to reach a sufficiently high octane number of generally between 80 and 100 RON. Treatment may be by reforming, blending with an aromatic fraction, or the addition of benzole or other additives (such as tetraethyl lead).

Jet fuel consists of gasoline-type and kerosene-type jet fuels. Gasoline-type jet fuel refers to all light hydrocarbon oils for use in aviation gas-turbine engines distilling between 100° and 250°C, with at least 20 per cent of volume distilling at 143°C. It is obtained by blending kerosene and gasoline or naphtha in such a way that the aromatic content does not exceed 25 per cent in volume. Additives are included to reduce the freezing point to -58°C and to keep the Reid vapour pressure between 0.14 and 0.21 kg/cm^2. Kerosene-type jet fuel refers to medium oils for use in aviation gas-turbine engines. It has the same distillation characteristics and flash point as kerosene, with a maximum aromatic content of 20 per cent in volume. It is treated to give a kinematic viscosity of less than 15 cSt at -34°C and a freezing point below -50°C.

Kerosene is a medium oil distilling between 150° and 300°C, with at least 65 per cent of volume distilling at 250°C. Its specific gravity is around 0.80 and its flash point is above 38°C. It is used as an illuminant and as a fuel in certain types of spark-ignition engines, such as those used for agricultural tractors and stationary engines.

Gas-diesel oil (distillate fuel oil) consists of those heavy oils distilling between 200° and 380°C, but distilling less than 65 per cent in volume at 250°C and 85 per cent or more at 350°C. Its flash point is always above 50°C and its specific gravity is higher than 0.82. Heavy oils obtained by blending are grouped together with gas oils on the condition that their kinematic viscosity does not exceed 27.5 cSt at 38°C. Also included are middle distillates intended for the petrochemical industry. Gas-diesel oils are used as a fuel for internal combustion in diesel engines, as a burner fuel in heating installations, such as furnaces, and for enriching water gas to increase its luminosity. Other names for this product are diesel fuel, diesel oil and gas oil.

Residual fuel oil is a heavy oil that makes up the residue of atmospheric distillation. It consists of all fuels (including those obtained by blending) with a kinematic viscosity above 27.5 cSt at 38°C. Its flash point is always above 50°C and its specific gravity is higher than 0.90. It is commonly used by ships and industrial large-scale heating installations as a fuel in furnaces or boilers. Another name for this product is mazout.

Liquified petroleum gas (LPG) refers to hydrocarbons which are gaseous under conditions of normal temperature and pressure but are liquified by compression or cooling to facilitate storage, handling and transportation. They are (1) extracted by the stripping of natural gas at crude petroleum and natural gas sources; (2) extracted by the stripping of imported natural gas in installations of the importing country and (3) produced both in refineries and outside refineries in the course of processing crude petroleum or its derivatives. Those liquids extracted as in (1) and (2) above are included under the classification of natural gas liquids. LPG is generally made up of propane (C_3H_8), butane (C_4H_{10}), or a mixture of these two hydrocarbons. It also includes ethane (C_2H_6) from petroleum refineries or natural gas producers' separation and stabilization plants.

Refinery gas is a non-condensable gas collected in petroleum refineries which is generally used wholly as refinery fuel. It is also known as still gas.

Feedstocks are products or a combination of products derived from crude oil destined for further processing in the refining industry other than blending. They are transformed into one or more components or finished products. This definition covers naphtha imported for refinery intake and naphtha returned from the chemical industry to the refining industry.

Naphtha comprises light or medium oil distilling between 30° and 210°C for which there is no official definition, but which does not meet the standards laid down for motor spirit. The properties depend upon consumer specification. The carbon:hydrogen ratio is usually 84:14 or 84:16, with a very low sulphur content. Naphtha may be further blended or mixed with other materials to make high-grade motor gasoline or jet fuel, or may be used as a raw material for manufactured gas. Naphtha is sometimes used as input to feedstocks to make various kinds of chemical products or may be used as a solvent.

White spirit/industrial spirit is a highly refined distillate with a boiling point ranging of from 135° to 200°C used as a paint solvent and for dry-cleaning purposes.

Lubricating oils are viscous, liquid hydrocarbons rich in paraffin waxes, distilling between 380° and 500°C obtained by vacuum distillation of oil residues from atmospheric distillation. Additives may be included to alter their characteristics. They have a flash point greater than 125°C, a pour point between -25° and +5°C, a strong acid number (0.5 mg/g), a low ash content and a low water content. Included are cutting oils, white oils, insulating oils, spindle oils and lubricating greases.

Bitumen is a solid or viscous hydrocarbon with a colloidal structure, brown or black in colour, which is obtained as a residue by vacuum distillation of oil residues from atmospheric distillation. It is sometimes soluble in carbon bisulphite, non-volatile, thermoplastic between 150° and 200°C, and often has insulating and adhesive properties. It is generally used for sealing and waterproofing such things as roadways and rooftops.

Petroleum wax refers to saturated aliphatic hydrocarbons obtained as residues extracted when dewaxing lubricant oils. Their main characteristics are as follows: they are colourless and in most cases odourless and translucent; they have a melting point above 45°C, a specific gravity of about 0.77 at 80°C and a kinematic viscosity between 3.7 and 5.5 cSt at 99°C. These waxes are used for candle manufacture, polishes and waterproofing of containers, wrappings, and the like.

Petroleum coke is a shiny black residue obtained by cracking and carbonization in furnaces. It consists mainly of carbon (90 to 95 per cent) and generally burns without leaving any ash. It is used principally in metallurgical processes and it excludes those solid residues obtained from carbonization of coal.

Other petroleum products refers to those products of petroleum origin (including partially refined products) not otherwise specified.

3. Gaseous fuels

Natural gas is a mixture of hydrocarbon compounds and small quantities of non-hydrocarbons existing in the gaseous phase, or in solution with oil in natural underground reservoirs. It may be subclassified as associated gas (that originating from fields producing both liquid and gaseous hydrocarbons), dissolved gas, or non-associated gas (that originating from fields producing only hydrocarbons in gaseous form). Included are methane (CH_4) recovered from coal mines, sewage gas and natural gas liquefied for transportation. Excluded, however, are gas used for re-pressuring and re-injection, as well as gas flared, vented or otherwise wasted, and shrinkage accruing to processing for the extraction of natural gas liquids.

Gasworks gas is gas produced by carbonization or total gasification with or without enrichment with petroleum products. It covers all types of gas produced by undertakings whose main purpose is the production of manufactured gas. It includes gas produced by cracking of natural gas and by reforming and simple mixing of gases.

Coke-oven gas is a by-product of the carbonization process in the production of coke in coke ovens.

Blast furnace gas is a by-product in blast furnaces recovered on leaving the furnace.

Biogas is a by-product of the fermentation of biomass, principally animal wastes, by bacteria. It consists mainly of methane gas and carbon dioxide.

4. Electricity and other forms of energy

Electricity production may be recorded in either gross or net terms. Gross production includes the consumption by station auxiliaries and any losses in the transformers that are considered integral parts of the station. Net production excludes the above-mentioned consumption and losses. Both gross and net production exclude electricity produced from pumped storage.

Primary electricity is produced from geothermal, hydro, nuclear, solar, tidal, wave and wind generation.

Uranium production covers the uranium content of uranium ores and concentrates intended for treatment for uranium recovery.

Steam and hot water refer to steam and hot water obtained from (a) geothermal sources and distributed as such for final consumption and (b) public supply thermal power plants for combined generation of electrical energy and heat. Also included is heat produced by pure heating plants and by self-producers which produce heat, to meet all or some of their own needs.

5. Traditional forms of energy

Fuelwood refers to all wood in the rough used for fuel purposes. Production data include the portion used for charcoal production, using a factor of 6 to convert from a weight basis to the volumetric equivalent (metric tons to cubic metres) of charcoal.

Charcoal is a solid residue consisting mainly of carbon obtained by the destructive distillation of wood in the absence of air.

Bagasse is the cellulosic residue left after sugar is extracted from sugar cane. It is often used as a fuel within the sugar milling industry.

Vegetal wastes are mainly crop residues (cereal straw from maize, wheat, paddy rice, etc.) and food processing wastes (rice hulls, coconut husks, ground-nut shells, etc.) used for fuel. Bagasse is excluded.

Animal wastes refer to dung and other non-dried excreta of cattle, horses, pigs, poultry, and the like and, in principle, humans. It can be dried and used directly as a fuel or converted to methane by methods of fermentation or decomposition.

Other wastes refer to all forms of energy not specifically defined above, such as municipal wastes and pulp and paper wastes.

Draft animal power refers to the energy produced by animal muscle power when involved in a tractive effort to accomplish work.

6. Technical terms employed in preceding definitions

Acid number - the amount of potassium hydroxide necessary to neutralize the acidity of oil, i.e. the number of milligrams of neutralizer per gram of oil.

Aromatic content - that fraction of an oil consisting of benzene or its derivatives.

Blending - the mixing of various petroleum products to secure a desired, homogeneous end product.

Carbonization - the destructive distillation of organic substances in the absence of air resulting in the removal of volatile constituents and leaving a residue high in carbon, e.g. coke, charcoal.

Coalification - the metamorphosis of vegetal matter into coal.

Cracking - a method by which heavier hydrocarbons are converted into lighter oils.

Distillation - the process of separating volatile fluids from heavier fractions by evaporation and then condensation.

Flash point - the temperature at which a petroleum product will suddenly ignite.

Kinematic viscosity - the ratio of viscosity to density.

Octane number - a designation adopted to show the anti-knock value of motor fuel, i.e. the percentage of iso-octane, in a blend of iso-octane and heptane, which will give the same anti-knock characteristics as the fuel in question.

Pour point - the lowest temperature at which an oil will pour or flow when chilled without disturbance.

Reflectance index - the ratio of light reflected from a surface to the total incident light.

Reforming - a cracking process which utilizes a straight-run gasoline or naphtha as input.

Reid vapour pressure - a measure of the pressure exerted on the interior of a special container (Reid vapour pressure apparatus) by the tendency of the product to vaporize.

RON - research octane number.

Vacuum distillation - distillation below atmospheric pressure, which lowers the temperatures at which fluids will evaporate and effectively increases the number of products distilling at high temperatures.

Viscosity - measurement of a liquid referring to its resistance to flow. It is usually measured by the time required for a given quantity of the liquid to flow through a measured aperture at a given temperature.

B. Energy transactions

Production of primary energy refers to the quantities of energy extracted, calculated after any operation for removal of inert matter contained in fuels. In general, it includes the quantities consumed in this process as well as supplies to other producers of energy for transformation or other uses. Production of hard coal and lignite comprises the sum of sales, consumption by mines, issues to miners, issues to coking, briquetting and other ancillary plants at mines, and changes in pithead stocks. Data for natural gas exclude the amount re-injected, re-pressured, flared, vented and wasted, as well as the amount corresponding to natural gas liquids extracted (shrinkage). Production of NGL is grouped with crude petroleum. Gross production of nuclear, hydro and geothermal electricity can be shown as the amount of electricity produced, the conventional fuel equivalent or in terms of the primary energy input.

Imports and exports refer to the amount of primary and derived energy obtained from, or supplied to, other countries. Imports and exports of crude petroleum also include imports and exports of feedstocks, unrefined and semi-refined oils and components derived from crude petroleum. Fuels used in transit are excluded from imports and exports and are included under bunkers.

Marine/aviation bunkers refer to the amounts of fuels delivered to ocean-going ships or aircraft of all flags engaged in international traffic. Deliveries to ships engaged in transport in inland and coastal waters or to aircraft engaged in domestic flights are not included.

Stock change (for producers, importers and industrial consumers) refers to the difference between the amounts of energy in stocks at the beginning and end of the year.

Energy converted shows the net input of primary or derivative energy into conversion as well as the net output of derivative energy. Outputs relate to gross production.

Net transfers are the net movements of energy products between processes in different sectors, for example, the blending of natural gas in the manufactured gas stream, the diversion of products (feedstocks) for further processing in the refining industry or the transfer of products for blending. Transfers also include backflows which are the petroleum products returned to refineries by the chemical and petrochemical industries.

Consumption by energy sector refers to the consumption of energy by producers and transformers of energy for operating their installations. It includes the consumption of compressor and pumping stations of pipelines, as well as the station use and loss of electric power plants (including electricity used for pumping at pumped storage installations).

Losses in transport and distribution refer to the losses of electrical energy, natural gas and derived gases which occur outside the utilities or plants before reaching the final consumer.

Consumption by industry and construction excludes consumption by the energy sector and all inputs into energy conversion, such as fuels used by industrial/self producers of thermal electricity. Consumption in the chemical industry includes use as fuel only.

Consumption by transport includes all fuel consumed by road traffic as well as deliveries to ships engaged in transport in inland and coastal waters and aircraft engaged in domestic flights. Fuels consumed by agricultural equipment are included in agricultural consumption.

Consumption by households and other consumers covers households (including free issues to employees), agriculture and all other sectors not included elsewhere. Agriculture includes hunting, forestry and fishing. Other consumers specifically include trade, communications and services, such as public lighting.

C. Energy resources

Hard coal, lignite and peat

Proved reserves in place represent the fraction of total resources that has not only been carefully measured, but has also been assessed as being exploitable under present and expected local economic conditions (or at specified cost) with existing available technology.

Proved recoverable reserves are the fraction of proved reserves in place that can be recovered (extracted from the earth in raw form) under the above economic and technological limits.

Additional resources embrace all resources, other than proved reserves, that are of at least foreseeable economic interest. The estimates provided for additional resources reflect, if not certainty about the existence of the entire quantities reported, at least a reasonable level of confidence, inferred through knowledge of geological conditions favourable for the occurrence of the resources. Resources whose existence is entirely speculative are not included.

Crude oil and natural gas liquids

Proved recoverable reserves are the fraction of proved reserves-in-place that can be extracted in raw form under present and expected local economic conditions with existing available technology.

Oil shale and bituminous sands

Proved recoverable reserves represent the fraction of total resources that has not only been carefully measured but has also been assessed as being exploitable under present and expected local economic conditions (or at specified cost) with existing available technology.

Raw natural gas

Proved recoverable reserves are the fraction of proved reserves-in-place that can be extracted from the earth in raw form under present and expected local economic conditions (or at specified costs) with existing available technology. It excludes those portions of reservoir gas recovered in liquid form in surface separators or plant facilities and reported as natural gas liquids.

Uranium

Reasonably assured resources refer to uranium that occurs in known mineral deposits of such size, grade and configuration that it can be recovered within the given production cost ranges with currently proven mining and processing technology.

Estimated additional resources refer to uranium, in addition to reasonably assured resources, that is expected to occur on the basis of direct geological evidence.

Falling water

Gross theoretical capability of hydraulic resources represents the energy potentially available if all natural flows estimated on the basis of atmospheric precipitation and water runoff were turbined down to sea level with 100 per cent efficiency from the machinery and driving water works.

Woody biomass

Forest/woodland and plantation resources include all standing biomass in closed natural forests, woodland and commercial tree plantations. This category also includes all residues derived exclusively from such woody vegetation.

Agro-industrial plantation resources are distinguished from forestry plantations in that they produce agro-industrial raw materials and have woody biomass collected as by-products. Examples include materials from tea, coffee, rubber trees, oil and coconut palms and bamboo plantations.

On-farm tree resources refer to trees that grow outside forest/woodland formations.

Non-woody vegetable biomass

Agricultural crop resources refer to crops that are grown specifically for food, fodder, fibre or energy production.

Crop residue resources include crop and plant residues produced in the field. Examples include cereal straw, leaves and plant stems.

Processing residue resources include residues resulting from the agro-industrial conversion or processing of crops (including tree crops), such as sawdust, sawmill offcuts, bagasse, nut shells and husks.

Animal waste

Resources refer to wastes from intensive and extensive animal husbandry.

II. UNITS OF MEASURE

Energy sources and commodities are measured by their mass or weight, volume, heat content, power and work. Standardization in the recording and presentation of original units is a primary task of an energy statistician before quantities can be analysed or compared.

It is recommended that for international reporting, and as far as possible in national accounting procedures, energy statisticians should use the International System of Units, officially abbreviated SI. The SI is a modernized version of the metric system established by international agreement. It provides a logical and interconnected framework for all measurements in science, industry and commerce. The SI is built upon a foundation of seven base units plus two supplementary units. Multiples and sub-multiples are expressed in the decimal system. A selective listing of the SI, as it pertains to energy, is presented in annex I of this document.

A. Mass

Most solid fuels are measured in units of mass, as are many liquid fuels. The principal units of mass used to measure energy commodities include the kilogram, the metric ton, the pound, the short ton and the long ton.

Tons are used very commonly to measure coal, oil and their derivatives as well as many non-commercial fuels. The metric ton (1000 kg) is the most widely adopted. The short ton (2000 lb) is used by the United States and Canada and a few other countries. The long ton (2240 lb) is used in the British system of measures. Most countries utilizing this system have either converted to the metric system or supply figures in metric units as well.

B. Volume

Units of volume are original units for most liquid and gaseous, as well as some traditional, fuels. The basic SI units of volume are the litre and the kilolitre, which is equivalent to the cubic metre. The British system, using the British or Imperial gallon, is employed in many countries of the Commonwealth. The United States system is employed throughout North America and parts of Central and South America. It uses the United States gallon and the barrel. The barrel is commonly used in many parts of the world as a measure of liquid fuel production. It is equivalent to 42 U.S. gallons or 34.97 Imperial gallons. The barrel per day is commonly used within the petroleum sector (e.g. official OPEC crude oil production was 19 million b/d in 1982, but only 17 million b/d in December of that year).

C. Specific gravity and density

Since liquid fuels can be measured by either weight or volume it is essential to be able to convert one into the other. This is accomplished by using either the specific gravity or the density of the liquid. Specific gravity is the ratio of the mass of a given volume of oil at 15°C to the mass of the same volume of water at that temperature. Density is the mass per unit volume.

$$\text{Specific gravity} = \frac{\text{mass}_{\text{oil}}}{\text{mass}_{\text{water}}} \qquad \text{Density} = \frac{\text{mass}}{\text{volume}}$$

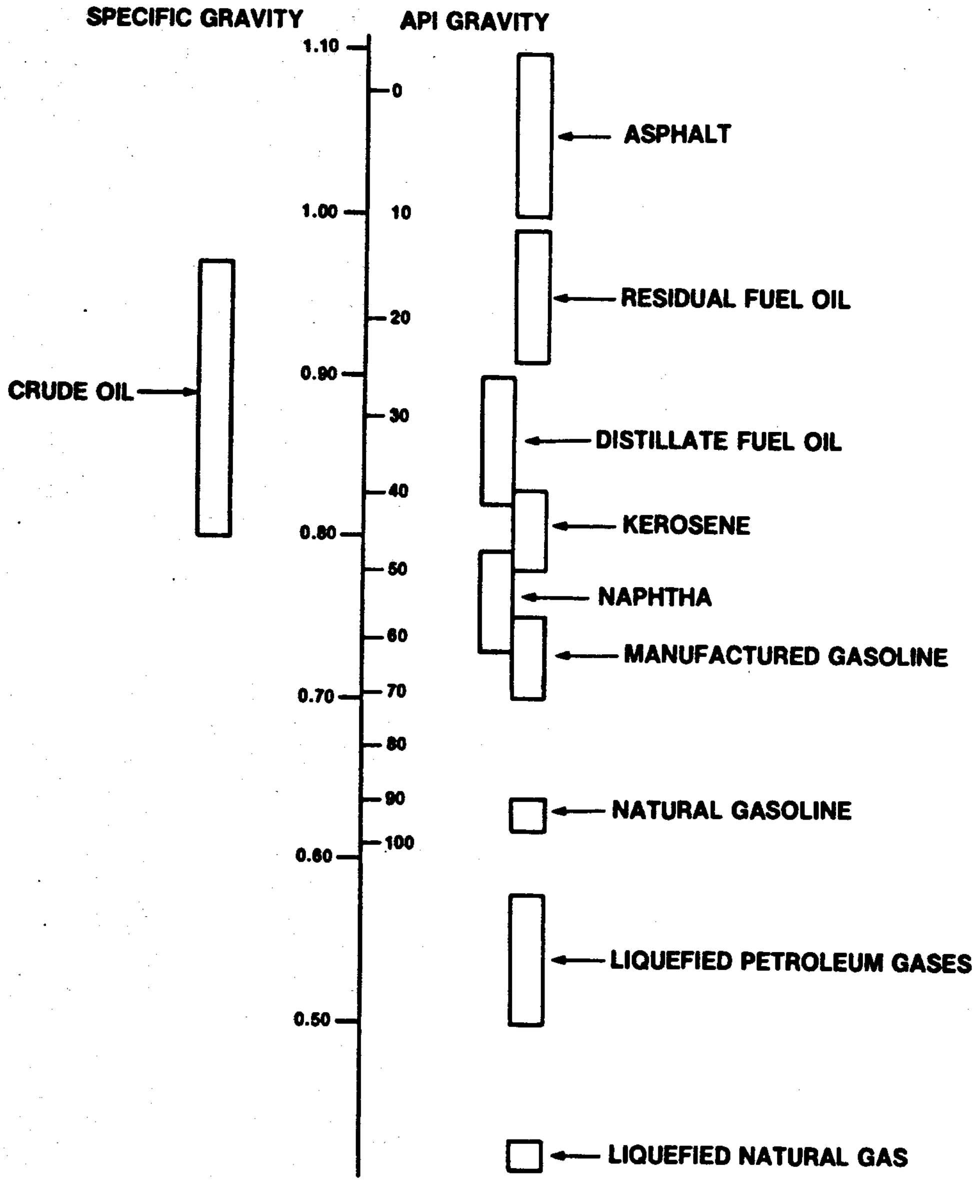
When density is expressed in kilograms per litre, it is equivalent to the specific gravity. When using the SI or metric system, in order to calculate volume, mass is divided by the specific gravity or density; and, vice versa, to obtain mass, volume is multiplied by the specific gravity or density. When using other measurement systems, one must consult tables of conversion factors to move between mass and volume measurements.

Another frequently used measure to express the gravity or density of liquid fuels is API gravity, a standard adopted by the American Petroleum Institute. API gravity is related to specific gravity by the following formula:

$$\text{API gravity} = \frac{141.5}{\text{specific gravity}} - 131.5$$

Thus specific gravity and API gravity are inversely related. They are both useful in that specific gravity increases with energy content per unit volume (e.g. barrel), while API gravity increases with energy content per unit mass (e.g. ton).

Specific gravity and API gravity related to particular petroleum products at 60°F



Source: United States of America Federal Energy Administration, Energy Interrelationships (Springfield, Virginia, National Technical Information Service, 1977).

D. Viscosity

The viscosity of a liquid is a measure of its internal friction or its resistance to flow. It is usually measured by the number of seconds required for a given quantity of the liquid to flow through a standard orifice at a given temperature. The poise is the SI unit of viscosity. The viscosity of a liquid is also commonly measured relative to the viscosity of water. Other units sometimes employed by industry are Redwood seconds and Saybolt universal seconds.

Another internationally used measure of viscosity is kinematic viscosity, which is the ratio of viscosity to density. There are several units in usage for kinematic viscosity. The SI uses the stoke or centistoke (mm^2/sec).

E. Energy, heat, work and power

Energy, heat, work and power are four concepts that are often confused. If force is exerted on an object and moves it over a distance, work is done, heat is released (under anything other than ideal conditions) and energy is transformed. Energy, heat and work are three facets of the same concept. Energy is the capacity to do (and often the result of doing) work. Heat can be a by-product of work, but is also a form of energy. Consider an automobile with a full tank of gasoline. Embodied in that gasoline is chemical energy with the ability to create heat (with the application of a spark) and to do work (the gasoline combustion powers the automobile over a distance).

The SI unit of energy, heat and work is the joule (J). The metric system utilizes the kilogram calorie (kcal) or one of its multiples. The British and American systems show the British thermal unit (Btu) or one of its multiples. Another unit is the kilowatt hour (kWh).

Power is the rate at which work is done (or heat released, or energy converted). A light bulb draws 100 joules of energy per second of electricity, and uses that electricity to emit light and heat (both forms of energy). The rate of one joule per second is called a watt. The light bulb, operating at 100 J/s, is drawing power of 100 Watts. Common units for power are multiples of the watt, the horsepower, the metric horsepower, the foot-pound per second and the kilogram force per second.

F. Energy units

The gram calorie is a precise measure of heat energy and is equal to the amount of heat required to raise the temperature of 1 gram of water at 14.5°C by 1 degree Celsius. It may also be referred to as an International Steam Table calorie (IT calorie). The kilocalorie and the teracalorie are its two multiples which find common usage in the measurement of energy commodities.

The British thermal unit is a precise measure of heat and is equal to the amount of heat required to raise the temperature of 1 pound of water at 60°F by 1 degree Fahrenheit. Its multiples are the therm ($1x10^5$ Btu) and the quad ($1x10^{15}$ Btu).

The kilowatt hour is a precise measure of heat and work. It is the work equivalent to 1000 watts (joules per second) over a one hour period. Thus 1 kilowatt-hour equals $3.6x10^6$ joules.

The joule is a precise measure of energy and work. It is defined as the work done when a constant force of 1 Newton is exerted on a body with mass of 1 gram to move it a distance of 1 metre. One joule of heat is approximately equal to one fourth of a calorie and one thousandth of a Btu. Common multiples of the joule are the megajoule, gigajoule, terajoule and petajoule.

G. Calorific values of fuels

The expression of original units of energy sources in terms of a selected single unit of account, such as the Btu, calorie or (preferably) the joule, may be made on one of two bases arising from the fact that energy stored in fossil fuels may be measured in two stages. The gross calorific value (GCV), or high heat value, measures the total amount of heat that will be produced by combustion. However part of this heat will be locked up in the latent heat of evaporation of any water present in the fuel during combustion. The net calorific value (NCV), or low heat value, excludes this latent heat. NCV is that amount of heat which is actually available from the combustion process for capture and use. The higher the moisture content of a fuel, the greater the difference between GCV and NCV.

Several practical considerations argue for using NCV. With present technologies, the latent heat from the evaporation process cannot be recovered from exhaust gases. If these gases were to be cooled below a certain level, they would not rise out of a boiler chimney and the reduced air current would either reduce boiler efficiency or would call for the use of energy in driving a fan to force the gases out of the chimney. Condensation of water would cause corrosion problems with sulphur dioxide and other residues. Another practical consideration is that the natural moisture content of solid fuels depends greatly on the occurrence of rainfall during transport and storage, so that NCV is a better indication of the energy effectively obtainable from combustible fuels.

The notion of NCV *per se* is as old as GCV, but its adoption in energy statistics has lagged far behind GCV until the early 1970s. Consequently, information on a set of both GCV and NCV is available for at best a decade, and only estimates can be made for earlier periods. Much the same is true for natural and manufactured gases. NCVs of crude oil and petroleum products are known better, although there is room for improvement in terms of their geographical coverage.

In terms of magnitude, the difference between gross and net calorific values of commercial energy sources (coal, oil, products, and gas) is less than 10 per cent while that of traditional energy (fuelwood, bagasse) is usually more than 10 per cent. Figures for the main energy commodities are presented below in table 1.

Those seeking further treatment of the issue of gross and net calorific values of fuels are referred to *Concepts and Methods in Energy Statistics, with Special Reference to Energy Accounts and Balances*, a United Nations publication.

Table 1. Difference between net and gross calorific values for selected fuels

Fuel	Percentage
Coke	0
Charcoal	0 - 4
Anthracite	2 - 3
Bituminous coals	3 - 5
Sub-bituminous coals	5 - 7
Lignite	9 - 10
Crude oil	8
Petroleum products	7 - 9
Natural gas	9 - 10
Liquified natural gas	7 - 10
Gasworks gas	8 - 10
Coke-oven gas	10 - 11
Bagasse (50% moisture content)	21 - 22
Fuelwood (10% moisture content)	11 - 12
(20% moisture content)	22 - 23
(30% moisture content)	34 - 35
(40% moisture content)	45 - 46

Sources: T. T. Baumeister and others, eds., Marks Standard Handbook for Mechanical Engineers (McGraw Hill, New York, 1978); United States of America, Federal Energy Administration, Energy Interrelationships (Springfield, Virginia, National Technical Information Service, 1977); United Nations, Economic Commission for Europe, Annual Bulletin of Gas Statistics for Europe, 1983 (United Nations publication, Sales No. E.F.R.84.II.E.28).

H. Accounting units

The original units in which fuels and electricity are most naturally measured are very disparate (tons, barrels, kilowatt hours, therms, calories, joules, cubic metres). Nevertheless, any one of these could be used as a basis for recording the other fuels if suitable conversion factors were available. For most purposes, the most useful basis from which to derive conversion factors is the energy derivable from one original quantity unit of each source of energy.

Several common accounting units have been adopted but their degree of use over time has varied according to economic realities. The ton of coal equivalent (TCE) was established when coal was the principal commercial fuel. At that time it was only natural that economists would formulate a unit which would allow them to perceive all their fuel requirements in terms of coal. When requirements changed and oil was in more demand than coal, oil became the principal commercial fuel. The ton of oil equivalent (TOE) was the result, along with the barrel per day, and their use has increased over that of the TCE for a generation. During the past decade, another unit, the joule, has been gaining increasing acceptance.

Ease of use is a primary consideration when selecting an accounting unit. One TCE has traditionally been defined as comprising 7×10^6 kcal and one TOE as 1×10^7 kcal. These are convenient presentation units for planners who must prepare and make policy decisions.

The conversion from original units into TCE or TOE implies choosing coefficients of equivalence between different forms and sources of primary energy. This problem can be approached in several ways. For example, one could adopt the same single equivalence in all countries, for instance, 7000 kcal per kg of coal, unspecified as to GCV or NCV.

The main objection to this method is that it results in distortions since there is a wide spread in calorific values among types of coal and individual petroleum products, and between calorific values of coals and crude oils in different countries. It is therefore necessary to adopt separate factors for each type of fuel and for each country of origin in order to be able to convert to a single presentation unit, such as TCE or TOE. These factors would take into account the specific energy values of the fossil fuels.

Consideration will now be given to the most commonly used accounting units and their means of computation.

1. Ton of coal equivalent

The Statistical Office of the European Communities (EUROSTAT), the Statistical Office of the United Nations Secretariat, and the Council for Mutual Economic Assistance (CMEA) have all been using the TCE as a common accounting unit. All three define the TCE as yielding 7 Gcal net calorific value.

However, some differences exist in computation methods. The route used for converting coal to TCE in EUROSTAT is quite complicated and consists of adjusting each grade of coal separately, according to its water and ash content, to a standard grade of coal having the specified calorific value. For the United Nations and the CMEA, all bituminous coal (including anthracite) is assumed to have the defined calorific value (net wherever possible). This is equivalent to treating physical tons of coal as already expressed in coal equivalent. In all cases, other solid fuels and other energy sources are converted to TCE by using factors that reflect the relative energy values of the defined grade of coal and the energy source in question.

The coal replacement ton used by India is defined as the quantity of coal yielding the same amount of energy as one unit of any given energy source when employed for a particular purpose (e.g. cooking).

2. Ton of oil equivalent

The International Energy Agency of the Organisation for Economic Co-operation and Development (IEA/OECD) uses the TOE as a common accounting unit. For IEA/OECD, the TOE is defined as having an NCV of 10 Gcal (41.9 GJ).

In the IEA/OECD the basic unit of thousand TOE is achieved by first expressing all energy sources in terms of their NCV in teracalories and then dividing by 10. In contrast to EUROSTAT's detailed adjustment of each grade of coal to a notional standard grade and the aggregated treatment of petroleum products when converting original units to TCE, the IEA/OECD uses the aggregated basis for coal and a product-by-product basis for petroleum products when it converts original units to TOE. Other solid fuels and other energy sources are converted to TOE each by its own coefficient.

In 1978 EUROSTAT ceased using the TCE and adopted the TOE as a presentation unit, while using the joule as the rigorous accounting unit. In the same year it also began converting original units of petroleum products to joules, separately for each main product. EUROSTAT publishes its overall energy balance in terms of terajoules.

The Statistical Office of the United Nations Secretariat had defined one TOE as 1.018×10^7 kcal, which was an attempt at precision, since that is the heat value of crude oil with a specific gravity of 0.86. However, since the TOE is a relative unit and is intended for ease of use by energy planners, the Statistical Office has decided to change its definition to 1.0×10^7 kcal and thus also be in accord with the international agencies.

3. Joule

Many countries use a large multiple of the joule as a common accounting unit, including the member countries of the European Economic Community (EEC). The Statistical Office of the United Nations Secretariat has adopted the joule as the accounting unit for the overall energy balances that it publishes, as has the Economic Commission for Europe (ECE).

The joule is the only energy unit recognized in the SI system. It was first promulgated as the SI unit of energy in 1946, and then as the SI unit of heat in 1948, by the General Conference on Weights and Measures. Energy analysts who have a physics background have welcomed the joule, but there is some resistance to its universal adoption in some countries. The main objection is to its small size and the consequent need for countries of any importance as energy producers or consumers to use a very high power of 10 as a multiplier. Suitable prefixes have been incorporated in the SI and by using them, large numbers of digits can be avoided.

4. British thermal unit

The British thermal unit (Btu) is used in Canada, the United States and other former British colonies. It is a small unit (1 Btu = 0.252 kcal = 1055.1 joule) and of the two countries that use the Btu, Canada shows up to 9 or more digits in its published energy balance and the United States uses 10^{12} and 10^{15} as multipliers in its published balance. The United Kingdom uses the therm as a rigorous accounting unit (1 therm = 10^5 Btu = 25.2 megacalories = 105.5 megajoules).

5. Calorie

The teracalorie (Tcal), a multiple of the calorie, has been used by many countries as an accounting unit. However there are five different heat values associated with the calorie, ranging in energy from 4.184 joules to 4.205 joules. The teracalorie is based on the kilogram calorie, which is also referred to as the International Steam Table calorie. The Tcal (equal to 4.1868 TJ) was the rigorous accounting unit of EUROSTAT until it was dropped in 1978 in favour of the terajoule. The OECD continues to use the Tcal and does not envisage dropping it, given their very conveniently defined relationship of 10:1 between Tcal and thousand TOE (that is, 10,000 kcal per kg).

6. Treatment of primary electricity in energy balances

When compiling an energy balance, it is possible to account for primary electricity, that is, electricity produced from nuclear, hydro, geothermal, solar, wind or tidal sources, in two distinct ways. One way is called the conventional fuel equivalent. This corresponds to the quantity of fossil fuel which would have been required for the generation of an identical quantity of electricity in a conventional thermal power plant. The other method of accounting is termed the physical energy input. The physical energy input varies according to the means of electricity production and is described below.

(a) Nuclear electricity

The physical energy input to nuclear electricity should, in principle, be defined as the heat released by reactors during the accounting period. In practice, a proxy for this may need to be used, namely the figure obtained by dividing generation of nuclear electricity by the average efficiency of all nuclear power stations.

(b) Hydro-electricity

The physical energy input to hydro-electricity should be defined as the energy value of the electricity itself or the energy value obtained by dividing the electricity generation by the average efficiency of all hydro power stations.

(c) Geothermal electricity

The physical energy input to geothermal electricity should be defined as the heat output of the capturing device or the heat output obtained by dividing the electricity generation by the average efficiency of all geothermal power stations.

(d) Solar, wind and tidal electricity

The physical energy input to these new sources of electricity would be defined as the mechanical, heat or electrical output of the capturing device.

III. CONVERSION FACTORS

A. International units of mass, volume, energy, work and power

1. Mass and volume

Because different systems of measurement have been adopted over time in various parts of the world, there is considerable variety in the units in which energy is expressed. This is particularly true in the case of mass and volume. Tables 2 and 3 facilitate conversion between these units. Mass and volume equivalents for specific energy sources are dealt with in later sections of this chapter categorized by type of energy source, such as solids, liquids, gases, and so on.

Table 2. Mass equivalents

FROM \ INTO	Kilograms	Metric tons	Long tons	Short tons	Pounds
	MULTIPLY BY				
Kilograms	1.0	0.001	0.000984	0.001102	2.2046
Metric tons	1000.	1.0	0.984	1.1023	2204.6
Long tons	1016.	1.016	1.0	1.120	2240.0
Short tons	907.2	0.9072	0.893	1.0	2000.0
Pounds	0.454	0.000454	0.000446	0.0005	1.0

Note: The units of the columns can be converted into the units of the rows by dividing by the conversion factors in the table.

Example: Convert metric tons into long tons. mt / 1.016 = lt.

Table 3. Volume equivalents

FROM \ INTO	U.S. gallons	Imperial gallons	Barrels	Cubic feet	Litres	Cubic metres
	MULTIPLY BY					
U.S. gallons	1.0	0.8327	0.02381	0.1337	3.785	0.0038
Imp. gallons	1.201	1.0	0.02859	0.1605	4.546	0.0045
Barrels	42.0	34.97	1.0	5.615	159.0	0.159
Cubic feet	7.48	6.229	0.1781	1.0	28.3	0.0283
Litres	0.2642	0.220	0.0063	0.0353	1.0	0.001
Cubic metres	264.2	220.0	6.289	35.3147	1000.0	1.0

Note: The units of the columns can be converted into the units of the rows by dividing by the conversion factors in the table.

Example: Convert barrels into kilolitres. barrels / 6.289 = kl.

2. Energy, work and power

After units of mass and volume, units of energy are the next most common means of recording quantities of energy sources. Energy units are also units of work. Table 4 relates these units of energy and work to each other. Energy equivalents for specific energy sources are dealt with in later sections of this chapter categorized by type of energy source, that is, solids, liquids, gases, and so on.

Power and work are related in that power multiplied by the time over which it is applied equals work. Table 5 provides conversion factors allowing movement from one unit of power to another.

Table 4. Energy and work equivalents

FROM \ INTO	Joule	Btu	Calorie	Kilowatt hour	Kilogram force metre
	MULTIPLY BY				
Joule	1.0	947.8×10^{-6}	0.23884	277.7×10^{-9}	0.10197
Gigajoule	$1. \times 10^{9}$	947.8×10^{3}	238.84×10^{6}	277.7	101.97×10^{6}
Terajoule	$1. \times 10^{12}$	947.8×10^{6}	238.84×10^{9}	277.7×10^{3}	101.97×10^{9}
Btu	1.0551×10^{3}	1.0	252.0	2.9307×10^{-6}	107.6
Therm	0.10551×10^{9}	1×10^{5}	$252. \times 10^{5}$	29.307	10.76×10^{6}
Quad	1.0551×10^{18}	1×10^{15}	$252. \times 10^{15}$	2.9307×10^{9}	107.6×10^{15}
Calorie	4.1868	3.968×10^{-3}	1.0	1.163×10^{-6}	0.4269
Kilocalorie	4.1868×10^{3}	3.968	1×10^{3}	1.163×10^{-3}	426.9
Thermie	4.1868×10^{6}	3.968×10^{3}	1×10^{6}	1.163	426.9×10^{3}
Teracalorie	4.1868×10^{12}	3.968×10^{9}	1×10^{12}	1.163×10^{6}	426.9×10^{9}
Kilowatt hour	3.6×10^{6}	3412.0	$860. \times 10^{3}$	1.0	367.1×10^{3}
Megawatt hour	3.6×10^{9}	$3412. \times 10^{3}$	$860. \times 10^{6}$	1×10^{3}	367.1×10^{6}
Gigawatt hour	3.6×10^{12}	$3412. \times 10^{6}$	$860. \times 10^{9}$	1×10^{6}	367.1×10^{9}
Terawatt hour	3.6×10^{15}	$3412. \times 10^{12}$	$860. \times 10^{12}$	1×10^{9}	367.1×10^{12}
Foot pound	1.3558	1.285×10^{-3}	0.3238	376.6×10^{-9}	0.13825
Kg force metre	9.807	9.295×10^{-3}	2.342	2.724×10^{-6}	1.0
Horsepower hour	26.845×10^{3}	2544.43	641.2×10^{3}	0.7457	273.7×10^{3}
Metric hp hour	26.478×10^{3}	2509.62	632.4×10^{3}	0.7355	$270. \times 10^{3}$

Note: The units of the columns can be converted into the units of the rows by dividing by the conversion factors in the table.

Example: Convert kilowatt hours into gigajoules. kWh / 277.7 = GJ.

Table 5. Power equivalents

FROM \ INTO	Foot pound per second	Kilogram-force metre per second	Kilowatt	Horsepower	Metric horsepower
	MULTIPLY BY				
Foot pound per second	1.0	0.1383	1.355×10^{-3}	1.818×10^{-3}	1.843×10^{-3}
Kilogram-force metre per second	7.233	1.0	9.803×10^{-3}	13.15×10^{-3}	13.33×10^{-3}
Kilowatt	738.0	102.0	1.0	1.341	1.360
Horsepower	550.0	76.04	0.7457	1.0	1.014
Metric horsepower	542.6	75.0	0.7353	0.9862	1.0

Note: The units of the columns can be converted into the units of the rows by dividing by the conversion factors in the table.

Example: Convert kilowatts into horsepower. kW / 0.7457 = Hp

B. Conversion from original to common units

For energy balances and other forms of analysis it is useful to convert quantities from original physical units into a common accounting unit for the purpose of aggregating diverse energy sources. Assuming standard calorific values for the various forms of energy, the following tables offer specific conversion factors to convert the data from original units to any common accounting unit. In addition, it allows for moving between accounting units.

1. Solid fuels

Table 6. Solid fuel equivalents a/

FROM Metric tons \ INTO	Giga-joules	Million Btus	Giga-calories	Megawatt hours	Barrels oil	Tons coal equivalent	Tons oil equivalent
	MULTIPLY BY						
Hard coal b/	29.31	27.78	7.00	8.14	4.9	1.000	0.700
Lignite b/	11.28	10.70	2.70	3.13	2.5	0.385	0.270
Peat	9.53	9.03	2.28	2.65	2.3	0.325	0.228
Oil shale	9.20	8.72	2.20	2.56	1.8	0.314	0.220
Coal briquettes	29.31	27.78	7.00	8.14	4.9	1.000	0.700
Lignite briquet.	19.64	18.61	4.69	5.45	3.3	0.670	0.469
Peat briquettes	14.65	13.89	3.50	4.07	2.5	0.500	0.350
Gas coke	26.38	25.00	6.30	7.33	4.4	0.900	0.630
Oven coke	26.38	25.00	6.30	7.33	4.4	0.900	0.630
Brown coal coke	19.64	18.61	4.69	5.45	3.4	0.670	0.469
Petroleum coke	35.17	33.33	8.40	9.77	5.9	1.200	0.840
Charcoal c/	28.89	27.38	6.90	8.02	4.8	0.985	0.690
Fuelwood c/	12.60	11.94	3.01	3.50	2.1	0.430	0.301

Note: Metric tons can be derived from units represented in the above columns by dividing by the conversion factors in the table.

Example: Convert hard coal in GJ into metric tons. GJ / 29.31 = metric tons.

a/ All heat values correspond to net calorific value.

b/ The calorific values of hard coal and lignite (or brown coal) can vary greatly by geographic or geologic location and over time. Illustrating this are the following examples of reported average energy values for hard coal and lignite in Gcal/metric ton.

c/ For a more thorough treatment, see section 2.E.

Table 7. Variation in calorific value of coal and lignite a/

Year	Hard Coal		Lignite	
	U.K.	U.S.A.	Czechoslovakia	U.S.S.R.
1970	5975	6490	3224	3267
1975	5810	6120	3133	2776
1980	5841	5977	2979	2521

a/ Net calorific value in kcal/kg.

2. Liquid fuels

Tables 8, 9, 10 and 11 provide conversion factors for liquid fuels. Table 8 presents conversion factors for various units of heat values and assumes standard calorific values for the various liquid fuels. The other tables deal with conversion of liquids expressed in units of mass and volume because liquid fuels are generally recorded in such units. Since the density, or specific gravity, of each petroleum product is unique, it is necessary to have a table of conversion factors to convert from units of volume to mass, or vice versa. Table 9 presents the conversion factors for liquid fuels having a given average specific gravity. Table 10 makes no assumption about average specific gravities of liquid fuels and proceeds to list the volume per weight conversion factors for each number of specific gravity. Table 11 lists the weight per volume conversion factors for each number of specific gravity. Tables relating density, specific gravity and API gravity can be found in annex II.

Table 8. Liquid fuel equivalents a/

INTO / FROM Metric tons	Giga-joules	Million Btus	Giga-calories	Megawatt hours	Barrels oil	Tons coal equivalent	Tons oil equivalent
	MULTIPLY BY						
Crude oil	42.62	40.39	10.18	11.84	7.32	1.454	1.018
Nat. gas liquids	45.19	42.83	10.79	12.55	10.40	1.542	1.079
LPG/LRG	45.55	43.17	10.88	12.65	11.65	1.554	1.088
Propane	45.59	43.21	10.89	12.67	12.34	1.556	1.089
Butane	44.80	42.46	10.70	12.44	10.85	1.529	1.070
Natural gasoline	44.91	42.56	10.73	12.47	10.00	1.532	1.073
Motor gasoline	43.97	41.67	10.50	12.21	8.50	1.500	1.050
Aviation gasoline	43.97	41.67	10.50	12.21	8.62	1.500	1.050
Jet fuel gas type	43.68	41.39	10.43	12.13	8.28	1.490	1.043
Jet fuel kero type	43.21	40.95	10.32	12.00	7.77	1.474	1.032
Kerosene	43.21	40.95	10.32	12.00	7.77	1.474	1.032
Gas-diesel oil	42.50	40.28	10.15	11.81	7.23	1.450	1.015
Residual fuel oil	41.51	39.34	9.91	11.53	6.62	1.416	0.991
Lubricating oil	42.14	39.94	10.07	11.70	6.99	1.438	1.007
Bitumen/Asphalt	41.80	39.62	9.98	11.61	6.05	1.426	0.998
Petroleum coke	36.40	34.50	8.69	10.11	5.52	1.242	0.869
Petroleum wax	43.33	41.07	10.35	12.03	7.86	1.479	1.035
Plant condensate	44.32	42.01	10.59	12.31	8.99	1.512	1.059
White spirit	43.21	40.95	10.32	12.00	7.77	1.474	1.032
Naphtha	44.13	41.83	10.54	12.26	8.74	1.506	1.054
Feedstocks	43.94	41.65	10.50	12.20	8.50	1.499	1.050
Other pet. prods	42.50	40.28	10.15	11.80	6.91	1.450	1.015
Ethyl alcohol	27.63	26.19	6.60	7.68	4.60	0.94	0.660
Methyl alcohol	20.93	19.84	5.00	5.82	3.50	0.71	0.500

Note: Metric tons can be derived from the units represented in the above columns by dividing by the conversion factors in the table.

Example: Convert crude oil in barrels into metric tons. barrels / 7.32 = metric tons.

a/ All heat values correspond to net calorific value.

Table 9. Volume equivalents of liquid fuels

FROM Metric tons at sp. gravity (INTO)		Litres	Kilo-litres	U.S. gallons	Imperial gallons	Barrels	Barrels per day a/
		MULTIPLY BY					
Crude oil	0.86	1164	1.164	308	256	7.32	0.02005
Nat. gas liquids	0.55	1653	1.653	437	364	10.40	0.02849
LPG/LRG	0.54	1852	1.852	489	407	11.65	0.03192
Propane	0.51	1962	1.962	518	432	12.34	0.03381
Butane	0.58	1726	1.726	456	380	10.85	0.02974
Natural gasoline	0.63	1590	1.590	420	350	10.00	0.02740
Motor gasoline	0.74	1351	1.351	357	297	8.50	0.02329
Aviation gasoline	0.73	1370	1.370	362	301	8.62	0.02362
Jet fuel gas type	0.76	1317	1.317	348	290	8.28	0.02270
Jet fuel kero type	0.81	1235	1.235	326	272	7.77	0.02129
Kerosene	0.81	1235	1.235	326	272	7.77	0.02129
Gas-diesel oil	0.87	1149	1.149	304	253	7.23	0.01981
Residual fuel oil	0.95	1053	1.053	278	232	6.62	0.01814
Lubricating oils	0.90	1111	1.111	294	244	6.99	0.01915
Bitumen/Asphalt	1.04	962	0.962	254	212	6.05	0.01658
Petroleum coke	1.14	877	0.877	232	193	5.52	0.01512
Petroleum wax	0.80	1250	1.250	330	275	7.86	0.02153
Plant condensate	0.70	1429	1.429	378	314	8.99	0.02463
White spirit	0.81	1235	1.235	326	272	7.77	0.02129
Naphtha	0.72	1389	1.389	367	306	8.74	0.02395
Other pet. prods	0.91	1099	1.099	290	241	6.91	0.01893

Note: Metric tons can be derived from the units represented in the above columns by dividing by the conversion factors in the table.

Example: Convert crude oil in barrels into metric tons. barrels / 7.32 = metric tons.

a/ On an annualized basis.

Table 10. Volume of liquids of different specific gravities contained in one metric ton

Specific gravity	API gravity	Litres	Kilo-litres	Imperial gallons	U.S. gallons	Barrels	Barrels per day (annualized)
0.65	86.19	1540	1.540	339	407	9.69	0.0265
0.66	82.89	1516	1.516	334	401	9.54	0.0261
0.67	79.69	1494	1.494	329	395	9.40	0.0257
0.68	76.59	1472	1.472	324	389	9.26	0.0254
0.69	73.57	1450	1.450	319	383	9.12	0.0250
0.70	70.64	1430	1.430	315	378	8.99	0.0246
0.71	67.80	1410	1.410	310	372	8.87	0.0243
0.72	65.03	1390	1.390	306	367	8.74	0.0240
0.73	62.34	1371	1.371	302	362	8.62	0.0236
0.74	59.72	1352	1.352	298	357	8.51	0.0233
0.75	57.17	1334	1.334	294	353	8.39	0.0230
0.76	54.68	1317	1.317	290	348	8.28	0.0227
0.77	52.27	1300	1.300	286	343	8.18	0.0224
0.78	49.91	1283	1.283	282	339	8.07	0.0221
0.79	47.61	1267	1.267	279	335	7.97	0.0218
0.80	45.38	1251	1.251	275	331	7.87	0.0216
0.81	43.19	1236	1.236	272	326	7.77	0.0213
0.82	41.06	1220	1.220	269	323	7.68	0.0210
0.83	38.98	1206	1.206	265	319	7.59	0.0208
0.84	36.95	1191	1.191	262	315	7.50	0.0205
0.85	34.97	1177	1.177	259	311	7.41	0.0203
0.86	33.03	1164	1.164	256	308	7.32	0.0201
0.87	31.14	1150	1.150	253	304	7.24	0.0198
0.88	29.30	1137	1.137	250	301	7.15	0.0196
0.89	27.49	1124	1.124	247	297	7.07	0.0194
0.90	25.72	1112	1.112	245	294	7.00	0.0192
0.91	23.99	1100	1.100	242	291	6.92	0.0190
0.92	22.30	1088	1.088	239	287	6.84	0.0189
0.93	20.65	1076	1.076	237	284	6.77	0.0186
0.94	19.03	1065	1.065	234	281	6.70	0.0184
0.95	17.45	1053	1.053	232	278	6.63	0.0182
0.96	15.90	1043	1.043	229	275	6.56	0.0180
0.97	14.38	1032	1.032	227	273	6.49	0.0178
0.98	12.89	1021	1.021	225	270	6.42	0.0176
0.99	11.43	1011	1.011	222	267	6.36	0.0174
1.00	10.00	1001	1.001	220	264	6.30	0.0173
1.01	8.60	991	0.991	218	262	6.23	0.0171
1.02	7.23	981	0.981	216	259	6.17	0.0169
1.03	5.88	972	0.972	214	257	6.11	0.0168
1.04	4.56	962	0.962	212	254	6.05	0.0166
1.05	3.26	953	0.953	210	252	6.00	0.0164

Source: United States of America, Federal Energy Administration, Energy Interrelationships (Springfield, Virginia, National Technical Information Service, 1977).

Table 11. Weights of liquids of different specific gravities in kilograms

Specific gravity	API gravity	Kilograms per litre	Kilograms per kilolitre	Kilograms per Imperial gallon	Kilograms per U.S. gallon	Kilograms per barrel
0.65	86.19	0.651	651	2.957	2.462	103.4
0.66	82.89	0.661	661	3.003	2.500	105.0
0.67	79.69	0.671	671	3.048	2.538	106.6
0.68	76.59	0.681	681	3.094	2.576	108.2
0.69	73.57	0.691	691	3.139	2.614	109.8
0.70	70.64	0.701	701	3.185	2.652	111.4
0.71	67.80	0.711	711	3.230	2.689	112.9
0.72	65.03	0.721	721	3.276	2.727	114.5
0.73	62.34	0.731	731	3.321	2.765	116.1
0.74	59.72	0.741	741	3.367	2.803	117.7
0.75	57.17	0.751	751	3.412	2.841	119.3
0.76	54.68	0.761	761	3.458	2.879	120.9
0.77	52.27	0.771	771	3.503	2.917	122.5
0.78	49.91	0.781	781	3.549	2.955	124.1
0.79	47.61	0.791	791	3.594	2.993	125.7
0.80	45.38	0.801	801	3.640	3.030	127.3
0.81	43.19	0.811	811	3.685	3.068	128.9
0.82	41.06	0.821	821	3.731	3.106	130.5
0.83	38.98	0.831	831	3.776	3.144	132.0
0.84	36.95	0.841	841	3.822	3.182	133.6
0.85	34.97	0.851	851	3.867	3.220	135.2
0.86	33.03	0.861	861	3.913	3.258	136.8
0.87	31.14	0.871	871	3.958	3.296	138.4
0.88	29.30	0.881	881	4.004	3.333	140.0
0.89	27.49	0.891	891	4.049	3.371	141.6
0.90	25.72	0.901	901	4.095	3.409	143.2
0.91	23.99	0.911	911	4.140	3.447	144.8
0.92	22.30	0.921	921	4.186	3.485	146.4
0.93	20.65	0.931	931	4.231	3.523	148.0
0.94	19.03	0.941	941	4.277	3.561	149.6
0.95	17.45	0.951	951	4.322	3.599	151.2
0.96	15.90	0.961	961	4.368	3.637	152.8
0.97	14.38	0.971	971	4.413	3.674	154.3
0.98	12.89	0.981	981	4.459	3.712	155.9
0.99	11.43	0.991	991	4.504	3.750	157.5
1.00	10.00	1.001	1001	4.550	3.788	159.1
1.01	8.60	1.011	1011	4.595	3.826	160.7
1.02	7.23	1.021	1021	4.641	3.864	162.3
1.03	5.88	1.031	1031	4.686	3.902	163.9
1.04	4.56	1.041	1041	4.732	3.940	165.5
1.05	3.26	1.051	1051	4.777	3.977	167.0

Source: United States of America, Federal Energy Administration, Energy Interrelationships (Springfield, Virginia, National Technical Information Service, 1977).

3. Gaseous fuels

Table 12. Gaseous fuel equivalents a/

INTO / FROM Thousand cubic metres b/	Giga-joules	Million Btus	Megawatt hours	Giga-calories	Barrels oil	Tons coal equivalent	Tons oil equivalent
	M U L T I P L Y	B Y					
Natural gas	39.02	36.98	10.84	9.32	6.50	1.331	0.932
Coke oven gas	17.59	16.67	4.88	4.20	2.94	0.600	0.420
Blast furnace gas	4.00	3.79	1.11	0.96	0.66	0.137	0.096
Refinery gas c/	46.1	43.7	12.8	11.0	7.69	1.571	1.100
Gasworks gas	17.59	16.67	4.88	4.20	2.94	0.600	0.420
Biogas	20.0	19.0	5.6	4.8	3.36	0.686	0.480
Methane	33.5	31.7	9.30	8.0	5.59	1.143	0.800
Ethane	59.5	56.3	16.5	14.2	9.92	2.029	1.420
Propane	85.8	81.3	23.8	20.5	14.33	2.929	2.050
Isobutane	108.0	102.0	30.0	25.8	18.0	3.686	2.580
Butane	111.8	106.0	31.0	26.7	18.6	3.814	2.670
Pentane	134.0	127.0	37.2	32.0	22.36	4.571	3.200

Note: Cubic metres can be derived from the units represented in the above columns by dividing by the conversion factors in the table. 1 cubic meter = 35.31467 cubic feet.

Example: Convert natural gas in TJ into thousand m^3. GJ / 39.02 = thousand m^3.

a/ All heat values correspond to net calorific value.

b/ Under standard reference conditions. To convert from standard reference conditions to standard temperature and pressure, multiply by 1.0757.

c/ A factor of 0.02388 is used to convert refinery gas in terajoules to a weight basis of metric tons.

4. Electricity

Table 13. Electricity equivalents a/

FROM Megawatt hours / INTO	Giga-joules	Million Btus	Giga-calories	Barrels oil	Tons coal equivalent	Tons oil equivalent
	MULTIPLY BY					
Efficiency						
100%	3.600	3.412	0.860	0.601	0.123	0.086
75%	4.800	4.549	1.147	0.801	0.164	0.115
50%	7.200	6.824	1.720	1.202	0.246	0.172
40%	9.000	8.530	2.150	1.503	0.307	0.215
35%	10.285	9.748	2.457	1.717	0.351	0.246
30%	12.000	11.373	2.867	2.003	0.409	0.287
25%	14.400	13.468	3.440	2.404	0.491	0.344
20%	18.000	17.060	4.330	3.005	0.614	0.433

Note: Gigawatt hours can be derived from the units represented in the above columns by dividing by the conversion factors in the table.

Example: Convert electricity in GJ at 100 per cent efficiency into MWh. GJ / 3.600 = MWh.

Since the different types of plants which produce electricity do so at various efficiencies, Table 13 presents conversion factors for selected values of efficiency from original units of gigawatts to any common accounting unit, or to move between accounting units. Direct conversion from gigawatts to any accounting unit is possible assuming the 100 per cent efficiency.

a/ All heat values correspond to net calorific value.

5. Biomass and animate power

Biomass and animate power plav an important role in the enerqy mix of manv countries. This is particularly true in develooina countries where fuelwood and drauaht animals may be the principal sources of enerav and power in rural areas. Biomass refers to several enerqy sources which are typically found in the informal sector. This list includes fuelwood, charcoal, baqasse, and animal and veqetal wastes.

(a) Fuelwood

In rural areas of many developing countries the principal source of enerav for cookinq and heatinq is fuelwood, in some instances makina up more than 70 per cent of the national enerav mix; yet statistics on fuelwood in general are poor. This is due larqely to the fact that fuelwood is produced and traded in the informal sector.

Fuelwood can be measured by either volume or weiaht. If it is measured by volume, it can be either stacked volume or solid volume. Measures of stacked fuelwood are the stere or stacked cubic metre and the cord (128 stacked cubic feet). Solid volume is obtained by the water displacement method. One advantage of measurement by volume is the relatively small influence of the moisture content of the wood on the measurement results. The weiaht of fuelwood is hiahly dependent on moisture content, and this is true for all biomass. The more water per unit weiaht, the less fuelwood. Therefore it is imperative that the moisture content be accurately specified when fuelwood is measured by weiaht.

There are two ways of measurina moisture content (mc). They are the so-called "dry basis" and "wet basis" and are defined below.

Dry basis

$$mc\% = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

Wet basis

$$mc\% = \frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} \times 100$$

When biomass is very wet there is a larqe difference between the two moisture contents (eq. 100 per cent mc dry basis = 50 per cent mc wet basis), but when the biomass is air-dry, the difference is small (15 per cent mc dry basis = 13 per cent mc wet basis). It is important to state on which basis the moisture content is measured. Most fuelwood is measured on the dry basis, but some is measured on the wet basis.

Another important determinant of the enerqy content of fuelwood is ash content. While the ash content of fuelwood is qenerally around 1 per cent, some species can reqister an ash content of up to 4 per cent. This affects the enerqy value of the wood since the substances that form the ashes qenerally have no enerqy value. Thus wood with 4 per cent ash content will have 3 per cent less enerqy than wood with 1 per cent ash content.

Tables 14, 15 and 16 provide factors for volumetric and calorific conversion of fuelwood.

Table 14. Fuelwood conversion table

(Wood with 20-30 per cent moisture content)

Fuelwood	Metric tons per cubic metre	Metric tons per cord	Cubic metres per metric ton	Cubic feet per metric ton
General	0.725	1.54	1.38	48.74
Coniferous	0.625	1.325	1.60	56.50
Non-Coniferous	0.750	1.59	1.33	46.97

Source: Food and Agriculture Organization of the United Nations, Yearbook of Forest Products, 1983 (Rome, 1985).

Note: 1 cord of wood = 3.624556 cubic metres = 128 cubic feet
1 stere (stacked wood) = 1 stacked m^3 = 35.31467 stacked cubic feet
1 board foot of wood = 2.359737×10^{-3} m^3 = 0.08333 cubic feet

Table 15. Influence of moisture on solid volume and weight of fuelwood

	Percentage moisture content of fuelwood								
	100	80	60	40	20	15	12	10	0
Solid volume in m^3 per ton	0.80	0.89	1.00	1.14	1.33	1.39	1.43	1.45	1.60
Weight in tons per m^3	1.25	1.12	1.00	0.88	0.75	0.72	0.70	0.69	0.63

Source: Food and Agriculture Organization, Wood Fuel Surveys, (Rome, 1983).

Discrepancies do exist between the above two tables and this reflects much of the literature on fuelwood measurement. It occurs in this case largely because table 14 is based on information contained in standardized tables while Table 15 presents results of more current research.

Table 16. Influence of moisture on net calorific values of fuelwood

(Wood with 1 per cent ash content)

	Percentage moisture content		Kilocalories per kilogram	Btus per pound	Megajoules per kilogram
	dry basis	wet basis			
Green wood	160	62	1360	2450	5.7
	140	59	1530	2750	6.4
	120	55	1720	3100	7.2
	100	50	1960	3530	8.2
	80	45	2220	4000	9.3
	70	41	2390	4300	10.0
Air-dried wood	60	38	2580	4640	10.8
	50 a/	33 a/	2790	5030	11.7
	40	29	3030	5460	12.7
	30	23	3300	5930	13.8
	25 b/	20 b/	3460	6230	14.5
	20	17	3630	6530	15.2
	15	13	3820	6880	16.0
Oven-dried wood	10	9	4010	7220	16.8
	5	5	4230	7610	17.7
	0	0	4470	8040	18.7

Sources: Food and Agriculture Organization, A New Approach to Domestic Fuelwood Conservation, (Rome, 1986); D. A. Tillman, Wood as an Energy Resource (New York, Academic Press, 1978); and United Nations, Concepts and Methods for the Collection and Compilation of Statistics on Biomass Used as Energy, by K. Openshaw (ESA/STAT/AC.3016).

a/ Average of as-received fuelwood on cordwood basis (4-foot lengths).

b/ Average of logged fuelwood.

(b) Charcoal

When statistically recording the conversion from fuelwood to charcoal, three principal aspects must be dealt with: wood density, moisture content of the wood and the means of charcoal production.

The principal factor in determining the yield of charcoal is parent wood density, since the weight of charcoal can vary by a factor of 2 for equal volumes. However, the moisture content of the wood also has an appreciable effect on yields; the drier the wood, the greater is the yield. The means of charcoal production is the third determinant of yield. Charcoal is produced in earth-covered pits, in oil drums, in brick or steel kilns and in retorts. The less sophisticated means of production generally involve loss of powdered charcoal (fines), incomplete carbonization of the fuelwood and combustion of part of the charcoal product, resulting in lower yields.

There is always an amount of powdered charcoal produced in the manufacture and transport of charcoal. If powdered charcoal undergoes briquetting, then the weight of the briquettes may be 50-100 per cent higher, per given volume of unpowdered charcoal, due to greater density.

The three variables which affect the energy value of charcoal are moisture content, ash content and degree of carbonization. The average moisture content of charcoal is 5 per cent. The average ash content of wood charcoal is 4 per cent, while that of charcoal produced from woody crop residues, such as coffee shrubs, is near 20 per cent. With the assumption of complete carbonization, the average energy value of wood charcoal with 4 per cent ash content and 5 per cent moisture content is approximately 30.8 MJ/kg. The average energy value of crop residue charcoal with 20 per cent ash content and 5 per cent moisture content is 25.7 MJ/kg.

Three tables are provided pertaining to charcoal production. Table 17 illustrates the effect of parent wood density and moisture content on charcoal yield. Table 18 supplies conversion factors for production of charcoal by the various kilns for selected percentages of wood moisture content. It assumes some standard hardwood as input to the process. Table 19 is a fairly exhaustive list of wood species and their densities.

Table 17. Fuelwood to charcoal conversion table

Influence of parent wood density on charcoal production
(Weight (kg) of charcoal produced per cubic metre fuelwood)

	Coniferous wood	Average tropical hardwoods	Preferred tropical hardwoods	Mangrove (rhizophora)
Charcoal	115	170	180	285

Influence of wood moisture content on charcoal production
(Quantity of wood required to produce 1 ton of charcoal)

Moisture content (dry basis)	100	80	60	40	20	15	10
Volume of wood required (cubic metres)	17.6	16.2	13.8	10.5	8.1	6.6	5.8
Weight of wood required (tons)	12.6	11.6	9.9	7.5	5.8	4.7	4.1

Sources: Wood Fuel Surveys, (Rome, 1983). D. E. Earl, Forest Energy and Economic Development (London, Oxford University Press, 1975); and the Food and Agriculture Organization of the United Nations.

Table 18. Fuelwood requirement for charcoal production by kiln type

(Cubic metres of fuelwood per ton of charcoal)

Kiln type	Percentage moisture content of fuelwood					
	15	20	40	60	80	100
Earth kiln	10	13	16	21	24	27
Portable steel kiln	6	7	9	13	15	16
Brick kiln	6	6	7	10	11	12
Retort	4.5	4.5	5	7	8	9

Source: Food and Agriculture Organization, Wood Fuel Surveys, (Rome, 1983).

Table 19. Densities of selected fuelwood species

(wood with 12 per cent moisture content)

Non-coniferous fuelwood	Density (kg/m^3)	Coniferous fuelwood	Density (kg/m^3)
All-inclusive standard	750	All-inclusive standard	625
Acacia, albida	633	Cedar, white, red	352
Acacia, nigrescens	1111	Cypress	465
Apple	705	Fir, Douglas	513
Ash, black	545	Fir, balsam	401
Ash, white	673	Hemlock	465
Bamboo	725	Pine, Oregon	513
Birch, sweet yellow	705	Pine, red	481
Cherry, wild red	433	Pine, white	433
Chestnut	481	Pine, southern	642
Elm, white	561	Pine, Norway	541
Erythrophleum africanum	1010	Redwood, California	417
Eucalyptus, microcorys	847	Spruce, white, red	449
Eucalyptus, paniculata	1000		
Hickory	769	For unknown species	725
Irvingia malayana	1099		
Locust	722		
Mahogany	705		
Mangrove, heriteria	901		
Mangrove, rhizophora	1176		
Mangrove, sonneratia	775		
Maple, sugar	689		
Maple, white	529		
Oak,chestnut	737		
Oak, live	866		
Oak, red, black	673		
Oak, white	770		
Poplar	433		
Tamarind	855		
Teak, African	994		
Teak, Indian	769		
Walnut, black	593		
Willow	449		

Sources: T. Baumeister and others, Marks' Standard Handbook for Mechanical Engineers, 8th ed. (New York, McGraw-Hill, 1978); J. Bryce, The Commercial Timbers of Tanzania (Dar es Salaam, Government Printers, 1967); P. Sono, Merchantable Timbers of Thailand (Bangkok, Forest Products Division, Royal Forest Department, 1974); United Nations, "Concepts and methods for the collection and compilation of statistics on biomass used as energy", by K. Openshaw (ESA/STAT/AC.30/6).

(c) Vegetal and animal wastes

Energy stored in agricultural wastes and waste products from food processing increasingly are being used to replace woody biomass in fuelwood deficient areas. These waste products can be burned as fuels to fulfil heating or cooking requirements.

There are two important determinants of the energy value of non-woody plant biomass-one is moisture content and the other is ash content. While the ash content of wood is generally around 1 per cent, that of crop residues can vary from 3 per cent to over 20 per cent, and this affects the energy value. Generally the substances that form the ashes have no energy value. Thus biomass with 20 per cent ash content will have 19 per cent less energy than a similar substance with 1 per cent ash content.

Data for these potential sources of energy are rarely collected directly but derived from crop/waste or end-product/waste ratios. Given the importance of the use of bagasse, the fibrous cane residue from the production of sugar from sugar cane, possible estimation procedures shall be outlined for this case. Bagasse is used as a fuel mostly for the sugar industry's own energy needs (at times excess electricity is also fed into the public grid) in many sugar-producing countries.

The availability of fuel bagasse can be estimated based on either (a) data on the input of sugar cane into sugar mills, or (b) production data on centrifugal cane sugar.

Method (a): Studies based on experiences in Central American countries, found that the yield of fuel bagasse is approximately 280 kilograms per ton of sugar cane processed. Assuming a 50 per cent moisture content at the time of use, 1 ton of bagasse yields 7.72 GJ (factor used in the publications of the Statistical Office of the United Nations). The energy values for bagasse corresponding to 1 ton of processed sugar cane are, therefore, as follows:

2.16 GJ = 0.516 Gcal = 0.074 TCE = 0.051 TOE.

Method (b): Based on observations, the Economic Commission for Latin America and the Caribbean (ECLAC) proposed the use of 3.26 kg bagasse yield per kilogram of centrifugal sugar produced (adopted by the Statistical Office of the United Nations until firm data become available). Calorific equivalents for bagasse corresponding to the production of 1 ton of sugar are as follows:

25.2 GJ = 6 Gcal = 0.86 TCE = 0.59 TOE.

Animal waste or dung is another important by-product of the agricultural sector. It can be dried and burned directly as a fuel for space heating, cooking or crop drying. It can also be spread in the fields as fertilizer. When used as an input to biogas digestors, the outputs are gas for cooking, heating and lighting, and a solid residue for use as fertilizer.

Table 20 presents various animal and vegetal wastes and indicates the approximate calorific values recoverable from them when used as fuels.

Table 20. Energy values of selected animal and vegetal wastes

Wastes	Average moisture content: dry basis (percentage)	Approximate ash content (percentage)	Net calorific value (MJ/kg)
Animal dung	15	23-27	13.6
Groundnut shells	3-10	4-14	16.7
Coffee husks	13	8-10	15.5-16.3
Bagasse	40-50	10-12	8.4-10.5
Cotton husks	5-10	3	16.7
Coconut husks	5-10	6	16.7
Rice hulls	9-11	15-20	13.8-15.1
Olives (pressed)	15-18	3	16.75
Oil-palm fibres	55	10	7.5-8.4
Oil-palm husks	55	5	7.5-8.4
Bagasse	30	10-12	12.6
Bagasse	50	10-12	8.4
Bark	15	1	11.3
Coffee husk, cherries	30	8-10	13.4
Coffee husk, cherries	60	8-10	6.7
Corncobs	15	1-2	19.3
Nut hulls	15	1-5	18.0
Rice straw & husk	15	15-20	13.4
Wheat straw & husk	15	8-9	19.1
Municipal garbage	..	..	19.7
Paper	5	1	17.6
Sawdust	50	1	11.7

Sources: G. Barnard and L. Kristoferson, Agricultural Residues as Fuel in the Third World, (London, Earth Scan, 1985); Commonwealth Science Council, Common Accounting Procedures for Biomass Resources Assessment in Developing Countries (London, 1986); Food and Agriculture Organization of the United Nations, Energy for World Agriculture (Rome, 1979); United States of America, Federal Energy Administration, Energy Interrelationships (Springfield, Virginia, National Technical Information Service, 1977).

Note: Two dots (..) indicate that data are not available.

(d) Draught animal power

The term draught (or draft) refers to the force required or exerted to pull, haul, draw, move, transport or lift an object. It is also denoted as a tractive effort or pull and refers essentially to the muscle power of the animal. Draught effort is directly proportional to the weight of the animal. Draught capacity, i.e. available power in horsepower of an animal, is determined by the species, genetic characteristics of the breed, body weight, state of health, food and nutrition, ambient temperature, and frequency and intensity of use. Among these, empirical data are available only for the body weight factor for some of the breeds of most species. Draught power is expressed as a force exerted by the animals. Draught horse power or tractive effort is obtained by:

$$\frac{\text{Draught power in pounds per second x speed in feet per second}}{\text{550 foot pounds per second}}$$

The following table presents the draught power of various animal species and, making an assumption about work hours, provides figures for annual amounts of energy generated.

Table 21. Animate power and energy

Work done by	Power developed hp	Power developed kW	Working hours per year	Animate energy generated kWh/y	Animate energy generated GJ/y
Draught animals					
Elephant	2	1.5	800	1200	4.32
Horse	1	0.75	800	600	2.16
Buffalo	0.75	0.56	800	448	1.61
Camel	0.75	0.56	800	448	1.61
Ox (bullock)	0.75	0.56	800	448	1.61
Mule	0.70	0.52	800	416	1.50
Cow	0.45	0.34	800	272	0.99
Donkey	0.35	0.26	800	208	0.75
Dog	0.1	0.075	800	60	0.22
Man (long duration muscular labor)	0.1	0.075	2000	150	0.54

Sources: R. E. McDowell, Report of National Dairy Research Institute (1975); and, United States of America, Federal Energy Administration, Energy Interrelationships (Springfield, Virginia, National Technical Information Service, 1977).

Note: For man, work scheduling in terms of rest stops, the temperature and humidity of the environment, the nature of the labourer's diet, and perhaps the sex are factors which influence ability to generate and maintain the above nominal horsepower values. These considerations should be factored in for specific work situations.

The calculation for a strong man of 35 years of age working 8 hours (480 minutes) a day yields:

hp = 0.35 - 0.092 log 480 = 0.1
0.1 hp x 0.75 hph/kWh x 8 h/d = 0.6 kWh/d
2000 h/y / 8 h/d = 250 d/y
0.6 kWh/d x 250 d/y = 150 kWh/y

Annex I

INTERNATIONAL SYSTEM OF UNITS

The International System of Units, officially abbreviated SI, is a modernized version of the metric system established by international agreement. It provides a logical and interconnected framework for all measurements in science, industry and commerce. The SI is built upon a foundation of seven base units plus two supplementary units. Multiples and sub-multiples are expressed in a decimal system.

The SI comprises the following:

Base units

Quantity	Name of unit	Unit symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
luminous intensity	candela	cd
amount of substance	mole	mol

Supplementary units

plane angle	radian	rad
solid angle	steradian	sr

The above units are all internationally defined.

The term principal units is adopted here for the members of the set of units comprising the above base units, supplementary units and coherent units derived from these. For example, metre per second, m/s, is the principal SI unit of velocity.

Principal units having special names

Name	Symbol	Definition
hertz	Hz	1 Hz = 1 s^{-1}
newton	N	1 N = 1 kg·m/s^2
pascal	Pa	1 Pa = 1 N/m^2
joule	J	1 J = 1 N·m
watt	W	1 W = 1 J/s
coulomb	C	1 C = 1 A·s
volt	V	1 V = 1 J/C
ohm	Ω	1 Ω = 1 V/A
siemens	S	1 S = 1 A/V
farad	F	1 F = 1 C/V
weber	Wb	1 Wb = 1 V/s
henry	H	1 H = 1 Wb/A
tesla	T	1 T = 1 Wb/m^2
lumen	lm	1 lm = 1 cd·sr
lux	lx	1 lx = 1 lm/m^2

Prefixes

Larger or smaller units may be derived from other units by means of the following prefixes:

Multiplication factor	Prefix	Symbol
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	u
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10^{1}	deka	da
10^{2}	hecto	h
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P

Prefixes are attached only to units having a single-word name and a single symbol (such as m, and not a compound symbol such as m/s) not already modified by either a prefix or an index.. Thus one prefix can never immediately precede another. In units such as km^2 the prefix is attached to m and the index applies to km, i.e., 1 km^2 = $(1000\ m)^2$ = $10^6\ m^2$.

The factors in compound unit symbols should be separated by a space or a half-high dot. For example, mN means millinewton while metre newton is m·N or m N.

Other Units

For each of the quantities given below the base or principal SI unit is given first, followed by definitions of other units.

Length

one metre	=1 m
one inch	=1 in = 25.4 mm
one foot	=1 ft = 12 in = 0.3048 m
one yard	=1 yd = 3 ft = 0.9144 m
one mile	=5280 ft = 1609.344 m

Mass

one kilogram	=1 kg
one pound	=1 lb = 0.45359237 kg
one ton	=1 t = 1000 kg
one UK ton	=2240 lb = 1016.05 kg
one US ton	=2000 lb = 907.185 kg

Time

one second	=1 s
one minute	=1 min = 60 s
one hour	=1 h = 60 min = 3600 s

Temperature

one kelvin	=1 K (formerly referred to as degrees Centigrade, Celsius and Kelvin)
one rankine	=(5/9) K (also referred to as degree Fahrenheit)

Area

one square metre	=1 m^2
one square foot	=1 ft^2 = 0.09290304 m^2
one square yard	=1 yd^2 = 0.83612736 m^2
one acre	=43560 ft^2 = 4046.86 m^2
one hectare	=10000 m^2

Volume

one cubic metre	=1 m^3
one litre	=1 l = 0.001 m^3
one cubic foot	=1 ft^3 = 0.0283168 m^3
one cubic yard	=1 yd^3 = 0.764555 m^3
one UK gallon	=0.0045460919 m^3
one US gallon	=0.003785411784 m^3
one US barrel	=42 US gallons = 0.158988 m^3

Velocity

one metre per second	=1 m/s
one foot per second	=1 ft/s = 0.3048 m/s
one mile per hour	=1 mile/h = 0.44704 m/s

Density

one kg per cubic metre	$=1\ kg/m^3$
one pound per cubic foot	$=1\ lb/ft^3 = 16.0185\ kg/m^3$

Force

one newton	$=1\ N = 1\ kg\cdot m/s^2$
one dyne	$=1\ dyn = 1\ g\cdot cm/s^2 = 10^{-5}\ N$
one kilogram-force	=1 kgf = 9.80665 N

Pressure, stress

one pascal	$=1\ Pa = 1\ N/m^2$
one bar	$=10^5\ Pa = 10^5\ N/m^2$
one dyn/cm^2	$=0.1\ Pa = 0.1\ N/m^2$
one standard atmosphere	=1 atm = 1.01325 bar
one millimetre of mercury	$=133.322\ N/m^2$

Viscosity (dynamic)

one $N\cdot s/m^2$	$=1\ Pa\cdot s = 1\ kg/m\cdot s$
one poise	$=1\ P = 1\ dyn\cdot s/cm^2 = 1\ g/cm\cdot s$
one centipoise	$=0.01\ P = 0.001\ kg/m\cdot s$

Viscosity (kinematic)

one m^2 per second	$=1\ m^2/s$
one stoke	$=1\ St = 1\ cm^2/s$
one centistoke	$=1\ cSt = 1\ mm^2/s$

Energy, work, heat

one joule	$=1\ J = 1\ N\cdot m = 1\ kg\cdot m^2/s^2 = 1\ Pa\cdot m^3$
one kilowatt hour	$1\ kW\cdot h = 3.6x10^6\ J$
one calorie	1 cal = 4.1868 J
one kilocalorie	1 kcal = 4186.8 J
one thermie	$4.1855x10^6\ J$
one British thermal unit	=1 Btu = 1055.06 J
one therm	$=10^5\ Btu = 1.05506x10^8\ J$
one horsepower hour	$2.68452x10^6\ J$

Power

one watt	=1 W = 1 J/s
one kilowatt	$=1\ kW = 10^3\ J/s$
one $kgf\cdot m/s$	9.80665 W
one metric horsepower	=1 CV (cheval vapeur) = 1 ch = 1 PS = 735.499 W
one horsepower	$=1\ hp = 550\ ft\cdot lbf/s = 745.7\ W$

Energy per mass (calorific value, specific enthalpy)

one joule per kilogram	=1 J/kg
one calorie per gram	=4.1868 J/g
one Btu per pound	=2326 J/kg

Energy per mass·temperature (specific entropy, specific heat-capacity)

1 joule per kg·kelvin	=1 J/kg·K
1 calorie per kg·kelvin	=4.1868 J/kg·K
1 Btu per lb·rankine	=4187 J/kg·K

Energy per volume·temperature

one joule per m^3·kelvin	=1 $J/m^3 \cdot K$
one joule per cm^3·kelvin	=10^6 $J/m^3 \cdot K$
1 $cal/cm^3 \cdot K$	=4.1868×10^6 $J/m^3 \cdot K$
1 cal/l·K	=4.1868×10^3 $J/m^3 \cdot K$
1 $kcal/m^3 \cdot K$	=4.1868 $J/m^3 \cdot K$
1 Btu/ft^3·rankine,	67066.1 $J/m^3 \cdot K$

Energy flux density (power per area)

one watt per m^2	=1 W/m^2 = 1 $J/m^2 \cdot s$
one calorie/$m^2 \cdot s$	=4.1868 W/m^2
one $kcal/m^2 \cdot h$	=1.163 W/m^2
one $Btu/ft^2 \cdot h$	=3.15459 W/m^2

Heat-transfer coefficient (thermal conductance)

one watt/$m^2 \cdot K$	=1$W/m^2 \cdot K$ = 1 $J/m^2 \cdot s \cdot K$
one $cal/m^2 \cdot s \cdot K$	=4.1868 $W/m^2 \cdot K$
one $kcal/m^2 \cdot h \cdot K$	=1.163 $W/m^2 \cdot K$
one $Btu/ft^2 \cdot h$·rankine	=3.15459 $W/m^2 \cdot K$

Thermal conductivity

one watt/m·K	=1W/m·K = 1 J/m·s·K
one cal/cm·s·K	=418.68 W/m·K
one kcal/m·h·K	=1.163 W/m·K
one Btu/ft·h·rankine	=1.73073 W/m·K

Annex II

TABLES FOR SPECIFIC GRAVITY, DENSITY AND VISCOSITY

Density and specific gravity

The following tables have been extracted from the ASTM-IP Petroleum Measurement Tables, prepared jointly by the American Society for Testing Materials and the Institute of Petroleum (United Kingdom). The definitions of the gravities and the density are given by the ASTM-IP as follows:

Specific gravity: the ratio of the mass of a given volume of oil at 60°F to the mass of the same volume of water at 60°F.

Density: mass per unit volume at 15°C expressed in kilograms per litre.

API gravity: based on a standard temperature of 60°F and related to specific gravity as follows:

$$\text{API gravity} = \frac{141.5}{\text{sp.gr. } 60°/60°\text{F}} - 131.5$$

In using the tables, the weight of water in air at 60°F may be taken as:

1 kg		per litre
8.3283	lb.	per US gallon
10.002	lb.	per Imperial gallon
62.3	lb.	per cubic foot
349.7886	lb.	per US petroleum barrel

Table 22. Equivalents of specific gravity

Specific Gravity	API Gravity	Density	Specific Gravity	API Gravity	Density	Specific Gravity	API Gravity	Density
0.60	-	0.6000	0.75	57.17	0.7497	0.90	25.72	0.8995
0.61	-	0.6100	0.76	54.68	0.7597	0.91	23.99	0.9095
0.62	96.73	0.6200	0.77	52.27	0.7697	0.92	22.30	0.9195
0.63	93.10	0.6299	0.78	49.91	0.7797	0.93	20.65	0.9295
0.64	89.59	0.6399	0.79	47.61	0.7897	0.94	19.03	0.9395
0.65	86.19	0.6499	0.80	45.38	0.7996	0.95	17.45	0.9495
0.66	82.89	0.6599	0.81	43.19	0.8096	0.96	15.90	0.9594
0.67	79.69	0.6699	0.82	41.06	0.8196	0.97	14.38	0.9694
0.68	76.59	0.6798	0.83	38.98	0.8296	0.98	12.89	0.9794
0.69	73.57	0.6898	0.84	36.95	0.8396	0.99	11.43	0.9894
0.70	70.64	0.6998	0.85	34.97	0.8496	1.00	10.00	0.9994
0.71	67.80	0.7098	0.86	33.03	0.8596	1.01	8.60	1.0094
0.72	65.03	0.7198	0.87	31.14	0.8695	1.02	7.23	1.0194
0.73	62.34	0.7298	0.88	29.30	0.8795	1.03	5.88	1.0294
0.74	59.72	0.7397	0.89	27.49	0.8895	1.04	4.56	1.0394

Note: Measured at standard temperatures of 60°F for API and specific gravities and 15°C for density.

Table 23. Equivalents of API gravity

API Gravity	Specific Gravity	Density	API Gravity	Specific Gravity	Density	API Gravity	Specific Gravity	Density
0.0	1.0760	1.0754	33.0	0.8602	0.8597	66.0	0.7165	0.7162
1.0	1.0679	1.0673	34.0	0.8550	0.8545	67.0	0.7128	0.7126
2.0	1.0599	1.0593	35.0	0.8499	0.8494	68.0	0.7093	0.7091
3.0	1.0520	1.0514	36.0	0.8448	0.8443	69.0	0.7057	0.7055
4.0	1.0443	1.0436	37.0	0.8398	0.8393	70.0	0.7022	0.7020
5.0	1.0366	1.0360	38.0	0.8348	0.8344	71.0	0.6988	0.6986
6.0	1.0291	1.0285	39.0	0.8299	0.8295	72.0	0.6953	0.6952
7.0	1.0217	1.0210	40.0	0.8251	0.8247	73.0	0.6919	0.6918
8.0	1.0143	1.0137	41.0	0.8203	0.8199	74.0	0.6886	0.6884
9.0	1.0071	1.0065	42.0	0.8156	0.8152	75.0	0.6852	0.6851
10.0	1.0000	0.9994	43.0	0.8109	0.8105	76.0	0.6819	0.6818
11.0	0.9930	0.9924	44.0	0.8063	0.8059	77.0	0.6787	0.6785
12.0	0.9861	0.9855	45.0	0.8017	0.8013	78.0	0.6754	0.6753
13.0	0.9792	0.9787	46.0	0.7972	0.7968	79.0	0.6722	0.6721
14.0	0.9725	0.9719	47.0	0.7927	0.7924	80.0	0.6690	0.6689
15.0	0.9659	0.9653	48.0	0.7883	0.7880	81.0	0.6659	0.6658
16.0	0.9593	0.9588	49.0	0.7839	0.7836	82.0	0.6628	0.6626
17.0	0.9529	0.9523	50.0	0.7796	0.7793	83.0	0.6597	0.6596
18.0	0.9465	0.9459	51.0	0.7753	0.7750	84.0	0.6566	0.6565
19.0	0.9402	0.9397	52.0	0.7711	0.7708	85.0	0.6536	0.6535
20.0	0.9340	0.9335	53.0	0.7669	0.7666	86.0	0.6506	0.6505
21.0	0.9279	0.9273	54.0	0.7628	0.7625	87.0	0.6476	0.6475
22.0	0.9218	0.9213	55.0	0.7587	0.7584	88.0	0.6446	0.6446
23.0	0.9159	0.9153	56.0	0.7547	0.7544	89.0	0.6417	0.6416
24.0	0.9100	0.9095	57.0	0.7507	0.7504	90.0	0.6388	0.6387
25.0	0.9042	0.3753	58.0	0.7467	0.7464	91.0	0.6360	0.6359
26.0	0.8984	0.8979	59.0	0.7428	0.7425	92.0	0.6331	0.6330
27.0	0.8927	0.8923	60.0	0.7389	0.7387	93.0	0.6303	0.6302
28.0	0.8871	0.8867	61.0	0.7351	0.7348	94.0	0.6275	0.6274
29.0	0.8816	0.8811	62.0	0.7313	0.7310	95.0	0.6247	0.6247
30.0	0.8762	0.8757	63.0	0.7275	0.7273	96.0	0.6220	0.6219
31.0	0.8708	0.8703	64.0	0.7238	0.7236	97.0	0.6193	0.6192
32.0	0.8654	0.8650	65.0	0.7201	0.7199	98.0	0.6166	0.6165

Note: Measured at standard temperatures of 60°F for API and specific gravities and 15°C for density.

Table 24. Equivalents of density

Density	Specific Gravity	API Gravity	Density	Specific Gravity	API Gravity	Density	Specific Gravity	API Gravity
0.50	0.4996	-	0.69	0.6902	73.52	0.88	0.8805	29.21
0.51	0.5097	-	0.70	0.7002	70.59	0.89	0.8905	27.40
0.52	0.5197	-	0.71	0.7102	67.74	0.90	0.9005	25.64
0.53	0.5298	-	0.72	0.7202	64.97	0.91	0.9105	23.91
0.54	0.5398	-	0.73	0.7302	62.27	0.92	0.9205	22.22
0.55	0.5498	-	0.74	0.7403	59.65	0.93	0.9305	20.56
0.56	0.5599	-	0.75	0.7503	57.10	0.94	0.9405	18.95
0.57	0.5699	-	0.76	0.7603	54.61	0.95	0.9505	17.36
0.58	0.5799	-	0.77	0.7703	52.19	0.96	0.9606	15.81
0.59	0.5900	-	0.78	0.7803	49.83	0.97	0.9706	14.29
0.60	0.6000	-	0.79	0.7903	47.53	0.98	0.9806	12.80
0.61	0.6100	-	0.80	0.8004	45.29	0.99	0.9906	11.34
0.62	0.6200	96.71	0.81	0.8104	43.11	1.00	1.0006	9.92
0.63	0.6301	93.08	0.82	0.8204	40.98	1.01	1.0106	8.52
0.64	0.6401	89.57	0.83	0.8304	38.90	1.02	1.0206	7.14
0.65	0.6501	86.16	0.84	0.8404	36.87	1.03	1.0306	5.79
0.66	0.6601	82.86	0.85	0.8504	34.89	1.04	1.0406	4.47
0.67	0.6701	79.65	0.86	0.8605	32.95	1.05	1.0507	3.18
0.68	0.6802	76.54	0.87	0.8705	31.06			

Note: Measured at standard temperatures of 60°F for API and specific gravities and 15°C for density.

Table 25. Densities of selected fuels

Fuel	Average density (kg/m^3)
Solids	
Anthracite	1554
Bituminous coal	1346
Lignite	1250
Coke	1201
Peat, dry	753
Charcoal, oak	481
Charcoal, pine	369
Liquids	
Crude oil	840-860
LPG/LRG	540
Propane	510
Butane	580
Natural gasoline	630
Motor gasoline	740
Aviation gasoline	730
Jet fuel gas-type	760
Jet fuel kero-type	810
Kerosene	810
Gas-diesel oil	870
Residual fuel oil	950
Lubricating oil	900
Bitumen/Asphalt	1040
Petroleum coke	1140
Petroleum wax	800
Plant condensate	700
White/Industrial spirit	810
Naphtha	720
Other petroleum products	910
Gases	
at 1 atm and 15°C	
Natural Gas	0.720-0.785
Propane	1.869
Butane	2.383
Blast furnace gas	1.270
Manufactured gas	1.070

Sources: J. W. Rose and J. R. Cooper, Technical Data on Fuel, 7th ed. (Edinburgh, Scottish Academic Press, 1977); and United Kingdom, Department of Energy, Digest of U.K. Energy Statistics (London, 1980).

Table 26. Kinematic viscosity conversions

Kinematic viscosity in centistokes	Redwood No. 1 viscosity seconds at 38°C	Saybolt Universal viscosity seconds at 38°C	Engler viscosity degrees all temp.	Saybolt Furol viscosity seconds at 50°C
2	30.65	32.62	1.141	-
3	33.15	36.03	1.225	-
4	35.65	39.14	1.309	-
5	38.25	42.35	1.401	-
6	40.85	45.56	1.482	-
7	43.55	48.77	1.565	-
8	46.25	52.09	1.655	-
9	49.05	55.50	1.749	-
10	51.95	58.91	1.840	-
12	58.07	66.04	2.024	-
14	64.54	73.57	2.224	-
16	71.39	81.30	2.439	-
18	78.40	89.44	2.650	-
20	85.75	97.77	2.877	-
22	93.28	106.4	3.108	-
24	100.8	115.0	3.344	-
26	108.6	123.7	3.584	-
28	116.3	132.5	3.830	-
30	124.1	141.3	4.081	-
35	144.0	163.7	4.708	-
40	164.1	186.3	5.350	-
45	184.3	209.1	5.993	-
50	204.4	232.1	6.650	26.1
55	224.6	255.2	7.260	28.3
60	244.8	278.3	7.920	30.6
65	265.0	301.4	8.580	32.8
70	285.4	324.4	9.240	35.1
75	305.4	347.6	9.900	37.4
80	325.5	370.5	10.550	39.6
90	-	-	-	44.1
100	-	-	-	48.6
120	-	-	-	57.8
140	-	-	-	67.0
160	-	-	-	76.3
180	-	-	-	85.6
200	-	-	-	95.0

Source: J. W. Rose and J. R. Cooper, Technical Data on Fuel, 7th ed. (Edinburgh, Scottish Academic Press, 1977).

EFFICIENCIES OF ENERGY CONVERSION DEVICES

Energy conversion

All processes of life require the conversion of energy from one form to another. The radiant energy of the sun is converted by plants into stored chemical energy. Plants are then consumed by animals and their energy is transformed into mechanical energy to move muscles and create heat. The chemical energy stored in plants over time has also been accumulating in deposits of coal, petroleum and natural gas which are used in devices to convert this energy into heat, mechanical and radiant energy. Additionally, electrical energy can be produced from mechanical energy so that energy may be transported over long distances and then utilized by the appliances of the final consumers.

Table 27 examines the efficiency of the conversion process in the various devices and appliances. Most of the conversion efficiencies of the appliances listed in the table were developed by the Statistical Office of the European Communities (EUROSTAT) for the calculation of useful energy balances. Useful energy balance-sheets, in addition to recording other losses, take account of the transformation of energy in the appliances of the final consumer.

The measurement of useful energy requires that the following be recorded:

(a) The main types of appliances used by final energy consumers;

(b) The amount of energy actually used by these various appliances;

(c) The average efficiencies of these appliances when in normal use.

Employing these, the useful energy balance-sheet is able to present a fifth category of energy losses - those at the final consumer stage. Thus, from primary input to final consumer offtake, the losses recorded are:

(a) Losses in the primary production/extraction process (gas flared, coal fines lost, etc.);

(b) Transformation losses from primary to secondary sources of energy;

(c) Distribution losses which largely affect gaseous fuels and electricity;

(d) Consumption by the energy sector for plant operations;

(e) Losses at the final consumer stage due to the operating efficiencies of the appliances which transform the energy for the last time.

Table 27. Average efficiencies of appliances at the final consumption stage

Appliances	Percentage
Three stone wood fire	10 - 15
Charcoal stove	20 - 30
Cement kilns	30 - 40
Glassworks radiation furnace	40
Blast furnace	70 - 77
Gas engine	22
Diesel engine	35
Jet engine	25
Coal-fired industrial furnaces and boilers	60
Coal-fired cooker	25
Coal-fired domestic heating boiler and coal - fired stove	55 - 65
Oil-fired industrial furnaces and boilers	68 - 73
Oil-fired domestic heating boiler	68 - 73
District heating boilers fired with residual fuel oil	66 - 73
Parafin burners	55
Gas-fired industrial furnaces and boilers	70 - 75
Gas cooker	37
Gas-fired water heater	62
Gas-fired domestic heating boiler	67 - 80
LPG cooker	37
Space heating with LPG	69 - 73
Electric motors	95
Electric furnaces	95
Electrolysis	30
Electric rail haulage	90
Electric cooker	75
Electric water heater	90
Direct electric heating	100
Incandescent electric lighting	6
Fluorescent electric lighting	20

Sources: European Economic Community, Statistical Office of the European Communities (EUROSTAT), Useful Energy Balance Sheets, Supplement to Energy Statistics Yearbook (Brussels, 1983); and United Nations, "Concepts and methods for the collection and compilation of statistics on biomass used as energy", by K. Openshaw (ESA/STAT/AC.30/6).

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