Chapter 4 Measurement units and conversion factors

This is a preliminary text for the chapter. The Oslo Group is invited to provide comments on the general structure and coverage of the chapter (for example, if it covers the relevant aspects related to measurement units and conversion factors, and if there are additional topics that should be covered in this chapter), and on the recommendations to be contained in IRES.

The current text presents the recommendations from the UN Manual F.29 as well as some points that were raised during the last OG meeting. The issue of "harmonization" of standard/default conversion factors still needs to be addressed. It was suggested that tables be moved to an annex. Please provide your views on which ones should be retained in the chapter.

A. Introduction

4.1. Energy products are measured in physical units by their weight or mass, volume, and energy. The measurement units that are specific to an energy product and are employed at the point of measurement of the energy flow are often referred to as "original" or "natural" units (IEA/Eurostat Manual page 19). Coal, for example, is generally measured by its mass or weight and crude oil by its volume. In cross-fuel tabulations such as the energy balances energy sources and commodities are also displayed in a "common unit" to allow comparison across sources. These "common" units are usually energy units and require the conversion of a quantity of a product from its original units through application of appropriate conversion factors.

4.2. When different units are used to measure a product, the compiler is left with the task of converting units which, in absence of specific information on the products (such as density, gravity and calorific value), may lead to different figures.

4.3. This chapter provides a review of the physical measurement units used for energy statistics, explains the concepts of original and common units, discusses the importance of conversion factors for the conversion from original to common units and presents standard conversion factors to use in absence of country- or region-specific conversion factors.

B. Measurement units

4.4. Energy sources and commodities are measured by their mass or weight, volume, and energy. This section covers the "original" or "natural" units as well as the common units. It also makes reference to the International System of Units – often abbreviated as SI from the French "*Système International d'Unités"* – which 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. See Box 4.1for more details on SI.

4.5. Standardization in the recording and presentation of original units is a primary task of an energy statistician before quantities can be analyzed or compared. (UN Manual F.44 page 11).

Box 4.1: International System of Units

DESCRIPTION TO BE INSERTED

1. Original units

4.6. As mentioned in para 4.1, original units are the units of measurement employed at the point of measurement of the product flow that are those best suited to its physical state (solid, liquid or gas) and that require the simplest measuring instruments (IEA/Eurostat Manual page 19). Typical examples are mass units for solid fuels (e.g. kilograms or tons) (with some exceptions, for example, for fuelwood which is usually sold in stacks and measured in a local volume unit, then converted to cubic metres) and volume units for liquids and gases (e.g. litres or cubic metres). The actual units used nationally vary according to country and local condition and reflect historical practice in the country, sometimes adapted to changing fuel supply conditions (IEA/Eurostat Manual page 177).

4.7. Electricity is measured in kilowatt-hour (kWh), an energy unit (although it is rather a unit of work) which allows one to perceive the electrical energy in terms of the time an appliance of a specified wattage takes to “consume” this energy. Heat quantities in steam flows are calculated from measurements of the pressure and temperature of the steam and may be expressed in calories or joules. Apart from the measurements to derive the heat content of steam, heat flows are rarely measured but inferred from the fuel used to produce them.

4.8. It should be noted that it may occur that, in questionnaires for the collection of energy statistics, data may be required to be reported in different units from the original/natural unit for certain classes of fuels. For example, statistics on crude oil and oil products may be requested in a mass or weight basis since the heating value of oil products by weight displays less variation than the heating value by volume. Statistics on gases, as well as wastes, can be requested in terajoules or other energy unit in order to ensure comparability, since gases (and wastes) are usually defined on the basis of their production processes, rather than their chemical composition and different compositions of the same type of gas (or waste) entail different energy contents by volume. Collection of statistics on wastes in an energy unit should be based on the measured or inferred heat output. It is important to note that energy statistics on waste refer only to the portion used for energy purposes.

Mass units

4.9. Solid fuels, such as coal and coke, are generally measured in mass units. The SI unit for mass is the *kilograms*, kg. Metric tons (tons) are most commonly used - for example, to measure coal, oil and their derivatives. One ton corresponds to 1000 kg. Other units of mass used by countries include: pound (0.4536 kg), short ton (907.185 kg) and long ton (1016.05 kg). Table 1 presents the equivalent factors to convert different mass units.

Table 1: 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 from metric tons (ton) into long tons: 1 ton = 0.984 long ton.

Volume units

4.10. Volume units are original units for most liquid and gaseous, as well as for some traditional fuels. The SI unit for volume is the *cubic metre* which is equivalent to a kilolitre or one thousand litres. Other volume units include: the British or Imperial gallon (4.546 litres), United States gallon (3.785 litres), the barrel (159 litres) and the cubic feet, which is also used to measure volumes of gaseous fuels. Given the preference from oil markets for the barrel as a volume unit, the barrel per day is commonly used within the petroleum sector so as to allow direct data comparison across different time frequencies (e.g., monthly versus annual crude oil production). However, in principle other units of volume per time can be used for the same purpose. Table 2 shows the equivalent factors to convert volume units.

Table 2: 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 from barrels into cubic meters. 1 barrel = 0.159 cubic meter.

Conversions between mass and volume - Specific gravity and density

4.11. 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 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.

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

4.12. 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.

4.13. 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:

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

4.14. 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).

Energy units

4.15. 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 unrealistically 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).

4.16. The SI unit of energy, heat and work is the *joule* (J). Other units include: the kilogram calorie in the metric system, or kilocalorie, (kcal) or one of its multiples; the British thermal unit (Btu) or one of its multiples; and the kilowatt hour (kWh).

4.17. 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.

4.18. 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.

4.19. 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.

4.20. 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 most used multiples are the *therm* (10^5 Btu) and the *quad* (10^{15} Btu).

4.21. 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 $3.6 \text{x} 10^{6}$ joules. Electricity is generally measured in kilowatt hour.

2. Common units

4.22. The original units in which energy sources and commodities are most naturally measured vary (e.g. tons, barrels, kilowatt hours, therm, calories, joules, cubic metres), thus quantity of energy sources and commodities are generally converted into a common unit to allow, for example, comparisons of fuel quantities and estimate efficiencies. The conversion from different units to a common unit requires some conversion factors for each product. This is addressed in Section C of this chapter.

4.23. The energy unit in the International System of Units is the *joule* which is very commonly used in energy statistics. Other energy units are also used such as: the *ton of oil equivalent* (TOE) (41.868 gigajoules), the *Gigawatt-hour* (GWh), the *British thermal unit* (Btu) (1055.1 joules) and its derived units – therm (10^{15} Btu) and quad (10^{5} Btu) - and the teracalorie (4.205 joules).

4.24. In the past, when coal was the principal commercial fuel, the ton of coal equivalent (TCE) was commonly used. However, with the increasing importance of oil, it has been replaced by the ton of oil equivalent. Table 3 shows the conversion equivalents between the common units.

Table 3: Conversion equivalents between energy units

INTO / FROM	TJ	Million Btu	GCal	GWh	MTOE
	MULTIPLY BY				
Terajoule	1	947.8	238.84	0.2777	$2.388 \text{x} 10^{-5}$
Million Btu	$1.0551 \text{x} 10^{-3}$	1	0.252	$2.9307 \text{x} 10^{-4}$	$2.52 \text{x} 10^{-8}$
GigaCalorie	$4.1868 \text{x} 10^{-3}$	3.968	1	$1.163 \text{x} 10^{-3}$	10^{-7}
Gigawatt hour	3.6	3412	860	1	$8.6 \text{x} 10^{-5}$
MTOE	$4.1868 \text{x} 10^{4}$	$3.968 \text{x} 10^{7}$	10^{-7}	11630	1

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 from Gigawatt-hours (GWh) into Terajoules (TJ): 1 GWh = 3.6 TJ.

C. Calorific values

[the standard factors displayed in the tables are from the UN manual F. 44. They need to be reviewed and discussed]

4.25. The compilation of overall energy balances, as opposed to the balance of a single energy product (also referred to in energy statistics as a commodity balance), requires conversion of the original units in which the fuel are measured to a common unit of measurement. In addition, it may also be necessary to apply some form of conversion for certain individual fuels (e.g. to express different grades of coal in terms of coal of a standard calorific content). Even though conversion factors are often considered in the context of the preparation of energy balances, they have wider application in the preparation of any tables designed to show energy in an aggregated form or in the preparation of inter-fuel comparative analyses.

4.26. *Calorific value* or *heating value* of a fuel express the heat obtained from one unit of the fuel. They are obtained by measurements in a laboratory specializing in fuel quality determination. They should preferably be in terms of joules (or any of its multiples) per original unit, for example gigajoule/ton (GJ/t) or gigajoule/cubic metre (GJ/m^3). Major fuel producers (mining companies, refineries, etc.) measure the calorific value and other qualities of the fuels they produce.

4.27. There are two ways of expressing calorific values: gross or net of the latent heat of the water formed during combustion and previously present in the form of moisture. Also, the calorific values depend on the quality of the energy product: the calorific value of a ton of hard coal may vary greatly by geographic and geological location; thus they are specific to the fuel and transaction in question. These two issues are discussed in detail in the next two sections.

1. Gross and net calorific/ heating values

4.28. The expression of original units of energy sources in terms of a common unit may be made on two bases as the energy stored in 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 before combustion (moisture) or generated in the combustion process. This latter comes from the combination of hydrogen present in the fuel with the oxidant oxygen (O_2) present in the air to form H_2O. This combination itself releases heat, but this heat is partly used in the evaporation of the generated water.

4.29. 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 of a fuel or its hydrogen content, the greater is the difference between GCV and NCV. For some fuels with very little or no hydrogen content (e.g., some types of coke, blast furnace gas), this difference is negligible. The applied technology to burn a fuel can also play a role in determining the NCV of the fuel, depending for example on how much of the latent heat it can recover from the exhaust gases.

4.30. In 1982, in the UN Manual F.29, it was recommended that:

> "When expressing the energy content of primary and secondary fossil energy sources in terms of a common energy accounting unit, net calorific values (NCV) should be used in preference to gross calorific values (GCV). If and when recuperation of a significant part of the difference between GCV and NCV from exhaust gases becomes a practical possibility and seems likely to become a reality, this recommended basis may need to be reconsidered (para. 135, UN Manual F.29).

4.31. This recommendation was made based on practical considerations:

> "With present technologies, the latent heat from the condensation of water vapour 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 (SO_2) and other residues. Yet, 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 when making comparisons through time and between countries (unless the moisture content of solid fuels is reduced to a standard level before GCV is measured). (Para 133 UN Manual F.29)

4.32. Given that new technologies may have been developed in the generation of energy to capture the latent heat, for example in gas-fired condensing boilers, it may be possible to recommend the use of GCV instead of NCVs.

4.33. 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 4.

Table 4: 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: This is taken from the UN Manual F. 44 and the original source was :[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)].

2. Standard vs specific calorific values

4.34. Energy products with the same chemical composition will carry the same energy content. In practice, there are variations of the composition of the same energy product. For example, "premium" gasoline may have slightly different chemical formulations (and therefore have a different energy content); natural gas may contain variations in the proportions of ethane and methane; liquefied petroleum gas (LPG) may in fact be solely propane or solely butane or any combination of the two. Only those products which are single energy compounds, such as "pure" methane, or "pure" ethane, and electricity (which is an energy form rather than a product) have precise and unalterable energy contents. In addition, differences in energy content may also occur over time as the quality of the fuel may change due, for example, to a change in the source of that fuel.

4.35. *Standard calorific values* refer to the energy content of fuels with specific characteristics that are generally applicable to all circumstances (different countries, different flows, etc.). They are used as default values when specific calorific values are not available. *Specific calorific values*, on the other hand, are based on the specificity of the fuel in question and are measurable from the original data source. They are particularly important for fuels which present different qualities: coal, for example, presents a range of quality which makes it suitable for different uses. However, in using many different specific calorific values, caution should be applied to ensure consistency between the energy content on the supply side and on the consumption side for a same country-year.

4.36. Often there is a problem in energy statistics as the product produced may not be identical in composition to the product in subsequent processes, even though it is referred to by the same name. The coal extracted from a coal mine may well contain substantial quantities of waste material and be different in chemical composition and energy content from the coal finally supplied and consumed. Crude oil from an oil well may contain dissolved energy and non-energy gases and liquids, which are removed from the crude oil before or when it is processed at refineries. Natural gas, whether produced in association with crude oil or independently, may contain non-energy gases and dissolved energy liquids that have to be separated out before natural gas of defined chemical content can be marketed. Some of the apparent losses of energy that appear in national energy balances (and apparent gains) could be the result of not taking into account the changes in energy content of a particular product. In this case, flow-specific calorific values would allow for a more consistent energy balance.

4.37. An alternative to apply specific conversion factors for different flows (production, import, export, transformation, consumption) of a same fuel is to adjust the quantities of this fuel to meet the energy content of a grade of this fuel of a certain calorific value, constant across flows. While this approach would make no difference in an energy balance, if compared with the previous one, it would make the commodity balance in the original unit more consistent.

4.38. In any case, it is extremely important to provide metadata on all conversions between different energy units undertaken to arrive at the disseminated data, in order to ensure transparency and clarity, and to enable comparability. This would include displaying the conversion factors between original and presented units, informing whether they are on a gross or on a net calorific basis and also detailing the route utilized in each conversion. (base on Recommendation 25 of the UN Manual F.29)

[**Should there be a section describing how to calculate average (specific) calorific values?**

We have received different views on the need for this proposed section, so we will appreciate more feedback on the topic]

Standard calorific values for solid fuels

4.39. Since solid fuels are naturally measured by mass, Table 5 provides the standard calorific values to convert mass/weight units of solid fuels to energy units.

Table 5: Standard solid fuel equivalents a/

INTO FROM Metric tons	Giga-joules	Million Btus	Giga-calories	Megawatt hours	Barrels oil eq.	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 briquettes	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	28.89	27.38	6.90	8.02	4.8	0.985	0.690
Fuelwood	12.60	11.94	3.01	3.50	2.1	0.430	0.301

Source : UN Manual F.44

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 from GJ into metric tons. 1 GJ of hard coal = 1 / 29.31 metric ton of hard coal

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

Standard calorific values for liquid fuels

4.40. As liquid fuels are reported in mass basis, even though their original units are on a volumetric basis (see para. 4.8), two tables are provided with standard conversion factors; one with the standard energy contents by weight; and the other with standard densities, so that their calorific content can be derived from either mass or volume. Table 6 presents the standard calorific values from mass units to energy units; and Table 7 presents volume equivalents of liquid fuels from volume to mass units for a specific gravity.

Table 6: Standard liquid fuel equivalents a/

INTO FROM Metric tons	Giga-joules	Million Btus	Giga-calorie	Megawatt hours	Barrels oil eq.	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

Source : UN Manual F.44

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 metric tons of crude oil into Gigajoules: 1 metric ton of crude oil = 42.62 Gigajoules.

a/ All heat values correspond to net calorific value.

Table 7: Standard volume equivalents of liquid fuels

FROM Metric tons at sp. gravity	INTO	Litres	Cubic meters	US 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

Source : UN Manual F.44

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 from barrels into metric tons. 1 barrel of crude oil = 1 / 7.32 metric tons of crude oil

a/ On an annualized basis.

Standard calorific values for gaseous fuels

4.41. The original/natural unit for gaseous fuels is in volume units. Table 8 provides the standard calorific values to convert from volume units into energy content. It should be mentioned, however, that at international level data on gaseous fuels are generally collected from countries already in energy units.

Table 8: Standard 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
	MULTIPLY BY						
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

Source : UN Manual F.44

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 from Gigajoules (GJ) into thousand m^3. 1 GJ of natural gas = 1 / 39.02 thousand m^3 of natural gas.

a/ All heat values correspond to net calorific value.

b/ Under standard reference conditions of 15oC, 1,013.25 mbar, dry. Adjustments may be needed under different conditions.

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

Standard calorific values for electricity/heat

4.42. The original unit for electricity and heat is an energy unit (mass and volume are not applicable units in this case). Thus there is no need for standard conversion factors for electricity and heat, but rather a table of equivalence between energy units (e.g., GWh to TJ, TOE, Gcal, etc.), which is presented in Table 3. A table of transformation efficiencies is not necessary either, since it is straightforward to apply a, say, 50% efficiency to derive the energy content of entrants to a thermal (power) plant based on its electricity or heat output.

Standard calorific values for biomass fuels

4.43. Biomass plays an important role in the energy mix of many countries. This is particularly true in developing countries where biomass, and in particular fuelwood, is often the principal source of energy and power in rural areas. Biomass refers to several energy sources which are typically found in the informal sector. It includes fuelwood, charcoal, bagasse, and animal and vegetal wastes, but also to derived biofuels such as bioethanol and biodiesel.

4.44. *Fuelwood.* In rural areas of many developing countries the principal source of energy for cooking and heating is fuelwood; yet statistics on fuelwood in general are poor. This is due largely to the fact that fuelwood is produced and traded in the informal sector.

4.45. Fuelwood can be measured by either volume or weight. 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 weight of fuelwood is highly dependent on moisture content, and this is true for all biomass. The more water per unit weight, the less fuelwood. Therefore it is important that the moisture content be accurately specified when fuelwood is measured by weight.

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

Dry basis: $\text{mc\%} = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} x100$

Wet basis $\text{mc\%} = \frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} x100$

4.47. When biomass is very wet there is a large difference between the two moisture contents (e.g. 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 moisture is measured on the dry basis, but some is measured on the wet basis.

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

4.49. The standard calorific values from mass unit to energy units provided in the UN Manual F.44 are presented in Table 9. The table shows how the calorific values vary with different moisture content of green wood, air-dried wood and oven-dried wood.

Table 9: Influence of moisture on net calorific values of standard 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: from UN Manual F.44. the original source was: 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.

4.50. When fuelwood is collected in volume units, a conversion factor has to be used to obtain mass units. Table 10 shows the standard conversion factors to go from volume units to mass units. Table 11 shows how the different moisture contents of fuelwood affect the conversion factors between cubic metres and metric tons.

Table 10: Standard fuelwood conversion table

(Wood with 20–30 per cent moisture content)

Fuel wood	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: from UN Manual F.44. The original source was: 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 11: Influence of moisture on solid volume and weight of standard 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: from UN Manual F.44. The original source was: Food and Agriculture Organization, Wood Fuel Surveys, (Rome, 1983).

4.51. These tables need to be updated and revised as even the UN Manual F.44 (page 31) mentions that

> "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 the former is based on information contained in standardized tables while the latter presents results of more current research"

4.52. *Charcoal*. The amount of fuelwood necessary to yield a given quantity of charcoal depends mostly on three factors: wood density, wood moisture content and the means of charcoal production.

4.53. 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.

4.54. 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.

4.55. 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.

4.56. Two tables are provided pertaining to charcoal production. Table 12 illustrates the effect of parent wood density and moisture content on charcoal yield. Table 13 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 12: Fuelwood to charcoal conversion table

<table>
<tr><td colspan="8">Influence of parent wood density on charcoal production
(Weight (kg) of charcoal produced per cubic metre fuelwood)</td></tr>
<tr><td></td><td colspan="2">Coniferous wood</td><td colspan="2">Average tropical Hardwoods</td><td colspan="2">Preferred Tropical hardwoods</td><td>Mangrove (rhizophora)</td></tr>
<tr><td>Charcoal</td><td colspan="2">115</td><td colspan="2">170</td><td colspan="2">180</td><td>285</td></tr>
<tr><td colspan="8">Influence of wood moisture content on charcoal production
(Quantity of wood required to produce 1 ton of charcoal)</td></tr>
<tr><td>Moisture content (dry basis)</td><td>100</td><td>80</td><td>60</td><td>40</td><td>20</td><td>15</td><td>10</td></tr>
<tr><td>Volume of wood required (cubic metres)</td><td>17.6</td><td>16.2</td><td>13.8</td><td>10.5</td><td>8.1</td><td>6.6</td><td>5.8</td></tr>
<tr><td>Weight of wood required (tons)</td><td>12.6</td><td>11.6</td><td>9.9</td><td>7.5</td><td>5.8</td><td>4.7</td><td>4.1</td></tr>
</table>

Sources: from UN Manual F.44. The original source was: 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 13: 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: from UN Manual F.44. The original source was: Food and Agriculture Organization, Wood Fuel Surveys, (Rome, 1983).

4.57. *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 fulfill heating or cooking requirements.

4.58. 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 percent ash content will have 19 percent 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. Due to this wide of variability in composition, ash and moisture content of general animal and vegetal wastes across countries, it is recommended to report these products to international organizations in an energy unit (TJ preferably) rather than their natural units. Country authorities in general are able to assess and determine the energy content of these wastes. Alternatively, measuring the energy content can be accomplished by measuring the heat or electricity output of transformation devices and applying standard efficiency factors.

4.59. 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. Also, singling out this specific vegetal waste allows reporting quantities to international organizations in its natural unit (weight basis), since its composition does not allow much variation. This has been done by the international organizations who treat bagasse separately from ordinary vegetal waste. 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.

4.60. 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. 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

4.61. 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. 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

4.62. 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 14 presents various animal and vegetal wastes and indicates the approximate calorific values recoverable from them when used as fuels.

Table 14: Energy values of selected animal and vegetal wastes

Wastes	Average moisture content: dry basis (percentage)	Approximate ash content (percentage)	Net calorific value (MJ/ka)
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: from UN Manual F.44. The original source was: 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.

Efficiency(ies)/useful energy

[Note this section was discussed in the F.44 manual. However, we think that it is more appropriate and relevant to discuss this (if at all) with the context of data compilation strategies

and energy balances (as there is a mention to "Useful energy balance sheet". Also, the average efficiencies in the table refer to 1983 and need to be updated

One comment agreed to moving the section. Please provide your views.]

4.63. 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.

4.64. When assessing energy transformation/conversion devices, it is desirable to measure the energy input and output, from which one can derive the device's *conversion efficiency* and have a more accurate picture of the energy flows. However, when only energy input or energy output is available, standard efficient coefficients of similar devices could be used to estimating the missing variable (output in the first case, and input in the second).

4.65. The concept of *useful energy* tries to gauge how much of the energy content of the consumed product is not wasted, but rather is working for the end-use it is intended for. Unlike in the assessment of transformation devices, in surveying final-use appliances it is mostly impracticable to measure the *useful energy* output, particularly in households (e.g. the light emitted by an incandescent bulb, as opposed to the generated heat; or the useful heat generated by a residential boiler burning gas or fuel oil). In some cases, it is also difficult to measure the energy input individually (what percentage of the total electricity consumption of a household goes to lighting, for example). In this case, standard efficiencies, together with assessment of time-use of individual appliances in household surveys, can provide a picture of the useful energy by end-use. 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, or an estimate based on their utilization (time x average power input);

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

4.66. Table 15 examines present the average efficiencies of different devices and appliances. "Useful energy balance-sheets" [these should be explained], in addition to recording other losses, take account of the transformation of energy in the appliances of the final consumer.

Table 15: 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: from UN Manual F.44. The original source was: 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).

4.67. 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.

D. Recommendations

[TO BE DISCUSSED]

The recommendations on “accounting units and conversion” in the UN Manual F.29 are the following (they are taken verbatim and are presented here so that they can be reviewed and amended as needed).

(Rec. 25) Energy balances should contain in the column headings for each energy source the average conversion factor (appropriate for expressing the original units in (or underlying) that column in terms of the common accounting unit as shown in the balance). Such average factors should be complemented in foot-notes, or accompanying text; with clear descriptions of the routes and stages followed in any conversions that are not adequately defined by the average factors (para. 268).

(Rec. 5) National and international statistical offices, and bodies that advise them or undertake work for them, should always define clearly the accounting units or presentation units employed in published analyses. The conversion factors and the route used to convert original physical units into the chosen common accounting unit or units should also be stated, or readily available published sources where they may be found should be cited. It should also be made clear whether energy units are defined on a gross or net calorific basis (para.48; see also (19) and (20), below).

(19) When expressing the energy content of primary and secondary fossil energy sources in terms of a common energy accounting unit, net calorific values (NCV) should be used in preference to gross calorific values (GCV). If and when recuperation of a significant part of the difference between GCV and NCV from exhaust gases becomes a practical possibility and seems likely to become a reality, this recommended basis may need to be reconsidered (para. 135).

(20) Given that the joule, and multiples of it by raising it to powers of 10^3, is the only energy unit in the SI, international and national statistical offices should consider adopting the joule (1 joule = 0.239 calorie) as the rigorous accounting unit for energy balances. The TOE (1 TOE = 10^7 kcal NCV) and/or TCE (l TCE= 7 x 10^6 kcal NCV) may be used as supplementary presentation units. Whenever they are used, they should be clearly defined in terms of the joule, and the route used for converting original data to TOE or TCE should be clearly described (para. 157).

[THE FOLLOWING MAY BE RECOMMENDED – FOR DISCUSSION]

4.68. 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.

4.69. It is recommended to collect data in original and common units and on the specific conversion factors used in the conversion to the common units. Standard calorific values are to be used in absence of specific conversion factors.

4.70. The units to be recommended for data collection [**can this be recommended? If so, only to international data compilation or also to national statistics data collection and/or dissemination? For all products or might there be exceptions (e.g., waste)? We have received different views on the subject as a general question, and the Cslo Group is invited to provide further comments on the specifics; whether this can be recommended and for which fuels**] for each class of fuels are as displayed on Table 16. Where there is no mention, it applies to primary as well as derived fuels.

Table 16: Recommended(?) measurement units

	Dimension	Unit
Solid fossil fuels	Mass	Thousand tons
Liquid fuels (fossil and biofuels)	Mass	Thousand tons
Gases	Energy	Terajoules
Wastes	Energy	Terajoules
Fuelwood	Volume	Thousand cubic metres
Charcoal	Mass	Thousand tons
Electricity	energy (power x time)	GWh
Electricity installed capacity	Power	MW
Refinery capacity	mass/time	Thousand tons/year

Heat	Energy	Terajoules

4.71. When the type of waste is well-defined in its constitution, rather than only by the process by which it was generated, one can assume that there should not be great variation in specific conversion factors. In this case, data can be reported on a weight basis (thousand metric tons). Even so, if the specific conversion factors are available, they should be provided. Bagasse and black liquor (also referred to as pulp and paper waste) both fall in such case.

4.72. *Common units*. One TCE has traditionally been defined as comprising 7 x 10^6 kcal and one TOE as l x 10^7 kcal. The conversion from original units into TCE or TOE implies choosing coefficients of equivalence between different forms and sources of primary energy. When using TCE and TOE as common unit (or any other unit based on one particular fuel for the same effect), it should not be assumed that one ton of coal has one TCE or that one ton of oil has one TOE of energy content. This approach could lead to 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. Rather, it is recommended first to convert data to an energy unit (terajoules, for example), using the pertinent conversion factors, and then from this energy unit directly to TCE or TOE. This approach entails, for example, having different conversions factors for each grade of coal and treating them separately.

[**Do we need to give guidance on the conversion of toe and TCE to Tj? The consideration here is that country practices might define the toe or the TCE differently**]

4.73. *Net and Gross calorific values*. Net (rather than gross) calorific values (NCVs rather than GCVs) should be applied. In other words, the heat required to evaporate moisture, which is present in all fuels (except electricity) and is also produced in the combustion process, should not be treated as part of a fuel's energy providing capability

[The standard default conversion factors should be updated. The text below is from the presentation on net/gross calorific values at the 3rd OG meeting]

It would be helpful if countries that are recuperating the latent heat in CHP plants provide information on this process, including estimates of what proportion of total energy consumption is represented**. [Is it feasible to provide this proportion? Please provide comments]**

For now, technological advances have not gone far enough to justify changing from GCVs to NCVs for the balances.

The default gross/net ratios and fuel equivalents should be evaluated systematically (using "real" measurements) and probably updated.

We recommend that experts proceed with a campaign of tests and measurements in as many countries as possible. Analysis should be undertaken to determine whether region-specific NCVs are useful.

Comparison of solid fuel equivalents between organisations (GJ/t)

	UN defaults	IPCC defaults (2006 GLs)	IEA defaults			
			Old	Europe	N. Amer.	Pacific
Hard Coal	29.31	25.8-28.2	country-specific			
Lignite	11.28	11.9	country-specific			
Peat	9.53	9.76	8.374	9.76		

Oil Shale	9.2	8.9	9.399	9.40		
Coal briq.	29.31	20.7	20.097	20.00		
Lignite briq.	19.64					
Peat briq.	14.65					
Gas coke	26.38	28.2	country-specific			
Oven coke	26.38	28.2	country-specific			
Br. coal coke	19.64	28.2	country-specific			
Pet. coke	35.17	32.5	30.982	32.00	32.00	33.80
Charcoal	28.89	29.5	30.773	30.80		
Fuelwood	12.6	15.6	Na	na		

Comparison of selected liquid fuel equivalents between organisations (GJ/t)

	UN defaults	IPCC defaults (2006 GLs)	IEA defaults			
			Old	Europe	N. Amer.	Pacific
LPG	45.55	47.3	47.311	46.0	47.3	47.7
Gasoline	43.97	44.3	44.799	44.0	44.8	44.6
Jet fuel - gas	43.68	44.3	44.799	43.0	44.8	44.6
Jet fuel – kero	43.21	44.1	44.589	43.0	44.6	44.5
Kerosene		43.8	43.752	43.0	43.8	42.9
Gas-diesel oil	42.50	43.0	43.333	42.6		
Resid. fuel oil	41.51	40.4	40.193	40.0	40.2	42.6
Lubricants	42.14	40.2	40.193	42.0	42.0	42.9
Bitumen	41.80	40.2	40.193	39.0	40.0	38.8
Pet. coke	36.40	32.5	30.982	32.00	32.00	33.80
Petroleum	43.33	40.2	40.193	40.0		
White spirit	43.21	40.2	40.193	43.6	43.0	43.0
Naphtha	44.13	44.5	45.008	44.0	45.0	43.2