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Units of Measurement and Conversion Factors

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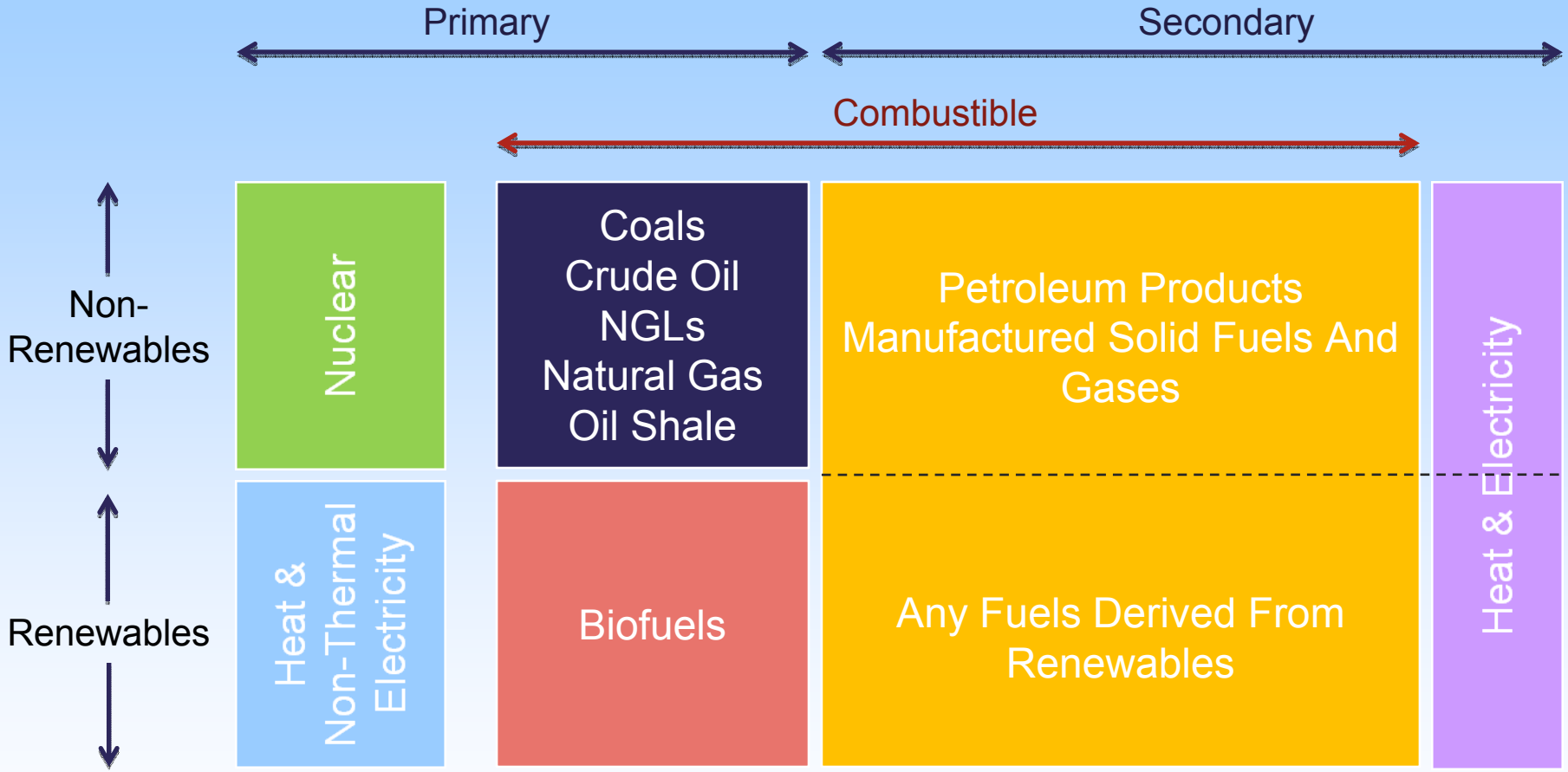
Units of Measurement and Conversion Factors

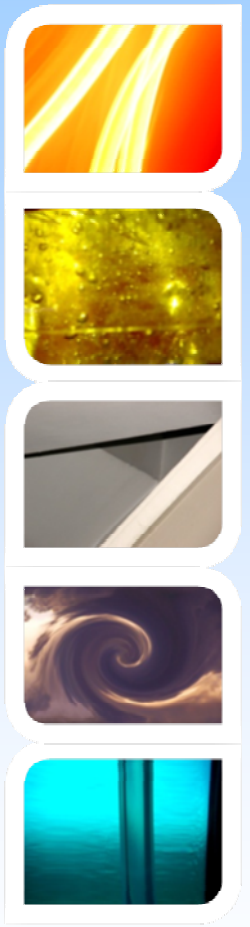
- How to measure quantities and heating values
- Why use conversion factors?
- Difference between gross and net calorific values
- Issues relating to various energy sources
- Manuals available

Fossil Fuels & Renewable Energy Forms



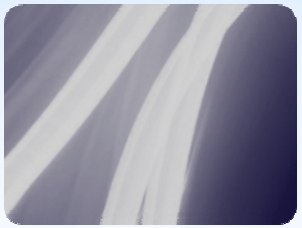
How To Measure Quantities and Heating Values

- At the point of measurement of the fuel flow, the units measured should be the best suited to its physical state (solid, liquid or gas) .
- This is termed the natural or physical units.
- Examples include:
  - Mass units for solid fuels (e.g. kilograms or tonnes)
  - Volume units for liquids and gases (e.g. litres or cubic metres)
  - Energy units for electricity (e.g. kilowatt-hour) and heat (e,g. calories or joules). Note that heat from steam flows is rarely measured but typically inferred from the fuel used to produce them.
- Common for liquid fuels to be converted to intermediate units (e.g. from litres or gallons to tonnes)



Why Use Conversion Factors?

- Natural units are often converted to a common unit to enable comparison between fuels, estimating efficiencies etc.
- Typically this is an energy unit (e.g. megajoule or tonne of oil equivalent).
- For thermal fuels, this requires a conversion factor that expresses the heat obtained from one unit of the fuel. This is called the *calorific value* of the fuel (it is also widely referred to as the heating value).
- Example calorific values (CVs) include:
  - gigajoule/tonne (GJ/t) for coal
  - megajoule/cubic metre (MJ/m^3) for gas



- Calorific values vary between products and also countries!

Difference between Gross & Net Calorific Values

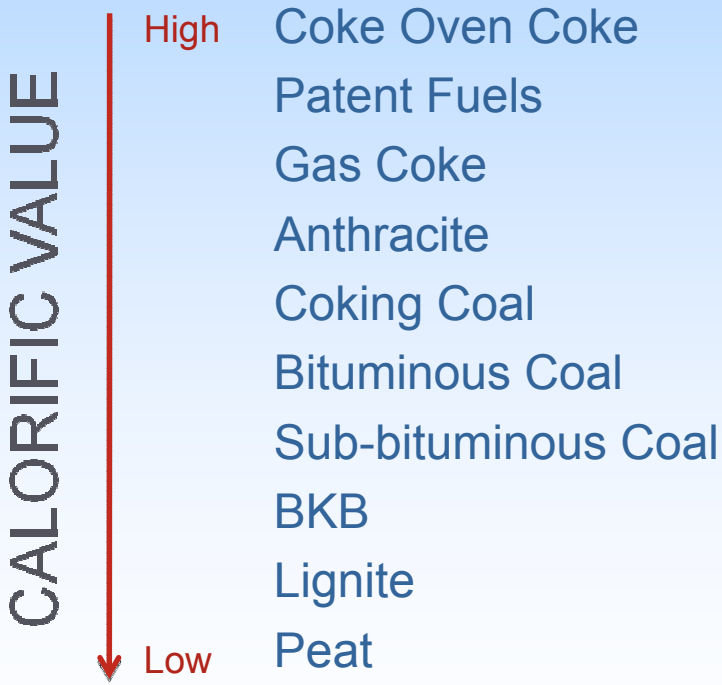
- Calorific values may be expressed in **gross** or **net** terms. The difference is due to latent heat of vaporisation of the water produced during combustion.
- IEA typically uses **net** calorific values (or lower heating value) in its energy balances. For reporting purposes, some data (e.g. manufactured gases) may be collected on a gross basis while other data (e.g. wastes and biogases) are on a net basis.
- Net calorific values are typically 5% to 6% less than the gross calorific value for solid and liquid fuels and about 10% less for natural gas.

Coal & Coal Products

- Solid fuels are typically reported in thousand metric tonnes (kt).
- The type and quality of coal produced and/or consumed varies significantly by country. Consequently, the range of calorific values may be hugely variable and will differ depending on use.
- For example, coal combusted in a power station will have completely different characteristics from coal used as a reductant in a steel-making process.
- Separate calorific values for *each* country for *each* grade of coal (e.g. anthracite, coking, other bituminous, sub-bituminous, lignite) and within *each* grade specific values for production, imports, exports, inputs to electricity/heat generation and coal used in coke ovens, blast furnaces, and industry.
- Coal products such as patent fuel, coke oven coke, coal tar, BKB, and charcoal also have their own CVs.

Coal and Peat Calorific Values

> Gross calorific values for coal can be estimated from net values by adding 5% to the net calorific value.

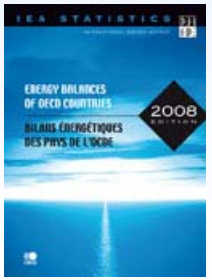


Country Specific Net Calorific Factors

	Australia	Austria	Belgium	Canada	Czech Republic
Coking coal					
Production	28500	-	-	24890	28621
Imports	-	29074	29308	28329	27046
Exports	28500	-	29308	24890	27600
Coke ovens	28500	29074	29308	28329	29148
Electricity generation	-	-	-	-	-
Indu					-
Othe					29148
Other					
Prod					-
Impo					-
Exports	25700	-	25781	25514	-
Coke ovens	-	-	-	-	-
Electricity generation	27000	27804	25056	25514	-
Industry	25700	28778	29308	25514	-
Other uses	25700	28066	25781	25514	-
Sub-bituminous coal					
Production	18478	-	21967	17799	23857
Imports	-	22200	-	17799	28175
Exports	-	-	18662	17799	24658
Electricity generation	18914	-	-	17799	23500
Industry	19195	22200	18900	-	22221
Other uses	18478	22200	21967	17799	22493

Note the significant difference (14%) between indigenous production and imported coking coal

Source: Energy Balances of OECD Countries – 2008 Edition, IEA



Manufactured Gases

- Quantities of gases have been historically collected in terms of their **gross** energy (heat) content in terajoules (TJ).
- In balance tables, this is then converted to net terms.

Difference between Gross and Net Calorific Values

Gas	Gross to Net ratio
Gas-work gas	0.9
Coke-oven gas	0.9
Blast-furnace gas	1.0
Oxygen steel-furnace gas	1.0

Natural Gas

- Natural gas data are reported in two units:
  - Units of energy: terajoules (TJ)
  - Units of volume: million cubic metres (Mm^3)
- Calorific values are typically reported in MJ/m^3 or $kcal/m^3$
- Net calorific value of natural gas is on average 10% less than the gross value.

Note that gross and net calorific values should not be confused with gross and net gas production. Gross gas production is measured before extraction losses and quantities reinjected, vented or flared while net gas production is measured after (net production is also sometimes referred to as marketable gas).

Oil

- Several units are used within the oil industry:
  - mass (weight) using the metric tonne (or tonne)
  - volume measured by the litre (l), the barrel (bbl) or cubic metre (m^3)
- To convert to between mass and volume it is important to know the ***specific gravity*** or ***density*** of the liquid.
- Net calorific values are typically 5% to 6% less than the gross calorific value.

Note: Many countries and organisations use the tonne of oil equivalent (toe). This is based on calorific properties and is used to compare oil with other energy forms and should not be confused with the mass measurement tonnes.

Oil - Regional NCV's for petroleum products

Petroleum products	Europe kJ/kg	North America kJ/kg	Pacific kJ/kg
Refinery gas	49 500	48 100	48 100
Ethane	49 500	49 400	49 400
Liquefied petroleum gases	46 000	47 300	47 700
Motor gasoline	44 000	44 800	44 600
Aviation gasoline	44 000	44 800	44 600
Gasoline type jet fuel	43 000	44 800	44 600
Kerosene type jet fuel	43 000	44 600	44 500
Kerosene	43 000	43 800	42 900
Gas/diesel oil	42 600	42 600	42 600
Residual fuel oil	40 000	40 200	42 600
Naphtha	44 000	45 000	43 200
White spirit	43 600	43 000	43 000
Lubricants	42 000	42 000	42 900
Bitumen	39 000	40 000	38 800
Paraffin Waxes	40 000	40 000	40 000
Petroleum Coke	32 000	32 000	33 800
Non-specified petroleum products	40 000	40 000	40 000

Renewables and Waste

> Due to their diverse forms, renewables and wastes are measured in a variety of units

- Solid products like wood and wood waste in volume such as cubic metres (m^3) and mass like tonnes (t).
- Biogases on volume basis such as cubic metres (m^3) or energy content basis like kilowatt-hours (kWh)
- Bioliquids in terms of volume like litres (l), mass in tonnes (t) and/or energy content like megajoules (MJ)
- Electricity-only renewable sources and technologies like hydro, solar-photovoltaic, wind, tide, ocean and wave are measured by their electricity output (typically gigawatt-hours)

Electricity & Heat

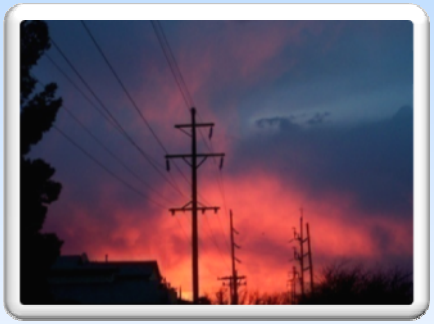
- Electricity is reported in gigawatt-hours (GWh)
- Heat is reported in terajoules (TJ)
- Electricity-generating capacity is reported in megawatts (MW).
- Gross electricity is before losses while net electricity is after losses in the plant. Default multipliers for computing net to gross are:
  - Non-combustible renewables (excl. geo) 1.01
  - Geothermal 1.06
  - Thermal Fuels 1.07

Note gross and net generation should not be confused with the gross and net calorific value of the fuel input for thermal generation

Calculating Fuel Input for Electricity & Heat

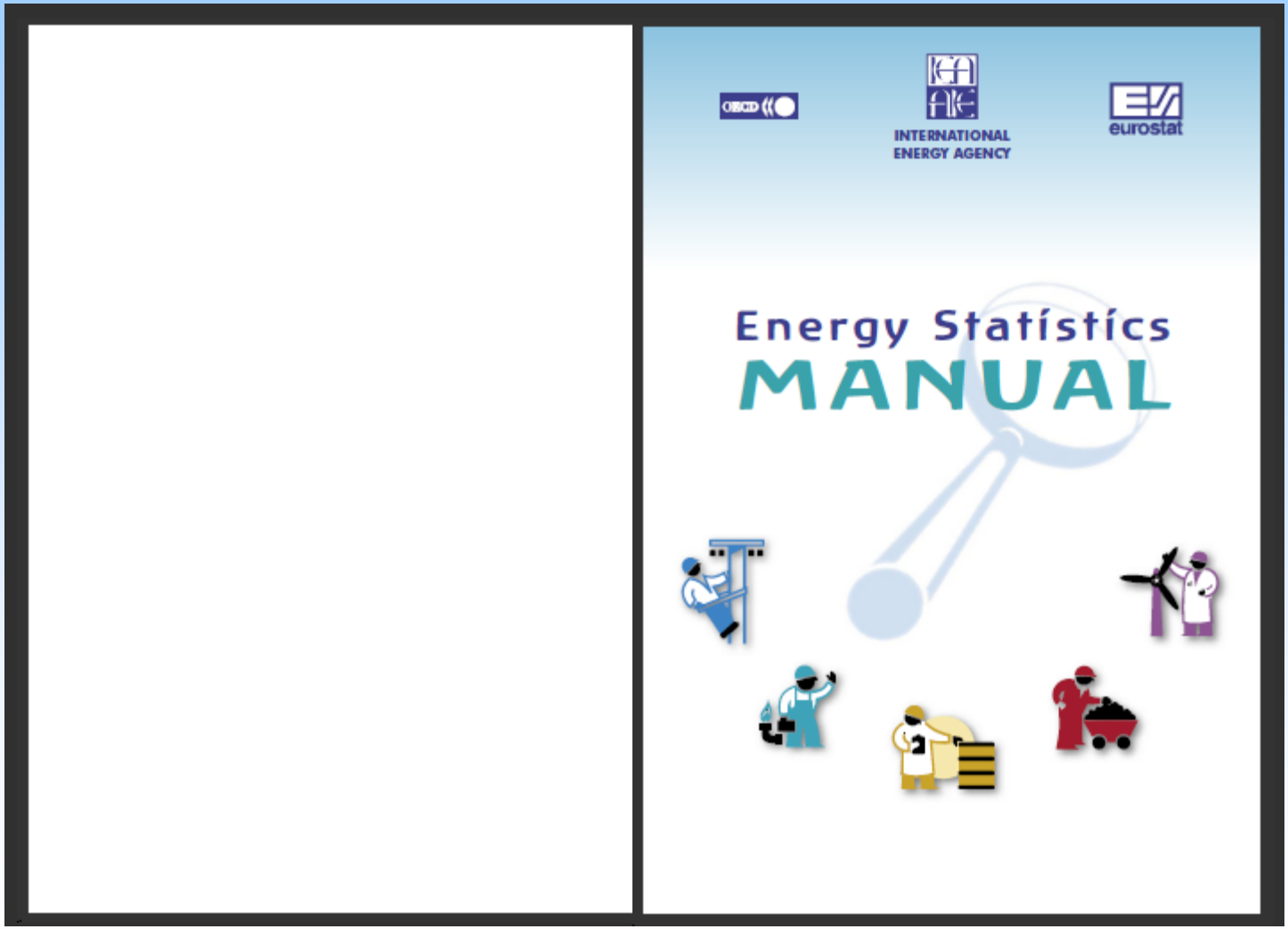
> For renewable fuels where only the electricity output is measured we can derive the primary energy equivalent using standard conversion efficiencies:

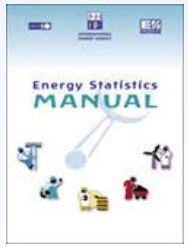
Fuels	Efficiency
Non-combustible renewables excluding geothermal e.g. (wind, hydro)	100%
Nuclear	33%
Geothermal	10%



> For geothermal heat, where no other information is available, then an efficiency of 50% is assumed.

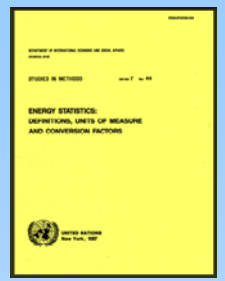
IEA/Eurostat Energy Statistics Manual





http://www.iea.org/textbase/nppdf/free/2005/statistics_manual.pdf

What is currently in the UN Manual: Differences between Gross and Net CVs

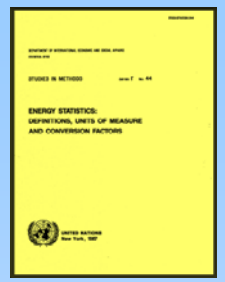


Fuel	Percentage
Coke	0%
Charcoal	0-4%
Anthracite	2-3%
Bituminous coals	3-5%
Sub-bituminous coals	5-7%
Lignite	9-10%
Crude oil	8%
Petroleum products	7-9%
Natural gas	9-10%

Fuel	Percentage
Liquefied natural gas	7-10%
Gasworks gas	8-10%
Coke-oven gas	10-11%
Bagasse (50% moisture)	21-22%
Fuelwood (10% moisture)	11-12%
(20% moisture)	22-23%
(30% moisture)	34-35%
(40%) moisture)	45-45%

Source: *Energy Statistics: Definitions, Units of Measure and Conversion Factors*, UN, 1987
http://unstats.un.org/unsd/pubs/gesgrid.asp?ID=37

What is currently in the UN Manual: *RECOMMENDATION*



> 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.

may need to be reconsidered…

Has the Situation Changed?

- Can a significant part of the latent heat now be recuperated from the exhaust gases?
- Apparently Belgium and Norway are recuperating at least some of the latent heat in their natural gas CHP plants. This can lead to efficiencies over 100% in some instances when the inputs are calculated using the NCVs.
- However, what about other fuels such as coal and oil and other types of plants such as electricity only or heat only. Also, what about other types of transformation and final consumption.

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

Summary

- Natural units: at the point of measurement of the fuel flow, the units measured should be the best suited to its physical state (solid, liquid or gas).
- Energy units: a common unit (e.g. Joule or toe) to enable comparison between fuels, estimating efficiencies etc.

- Calorific values may be expressed in gross or net terms. When significant quantities of the latent heat can be recovered, the international community may wish to reconsider it's recommendation to show energy balances on a NCV basis.