CDP Technical Note: Conversion of fuel data to MWh

CDP Climate Change Questionnaire

Contents

Version

Version	Revision date	Revision summary
1.0	2013	First published version.
2.0	January, 2014	Updated and worked examples added.
2.1	2015	Question numbers updated to align with the 2015 CDP climate change questionnaire.
2.2	2016	Question numbers updated to align with the 2016 CDP climate change questionnaire.
2.3	2017	CDP logo updated.
3.0	2018	Question numbers and formatting updated to align with the 2018 CDP climate change questionnaire.
3.1	March, 2019	Updated to align with the 2019 CDP climate change questionnaire.
3.2	March 31, 2020	Question numbers updated to align with the 2020 CDP climate change questionnaire.
3.3	January 7, 2021	Minor editorial changes

Introduction

Questions C8.2a, C8.2c and C8.2d ask for energy and fuel inputs to be reported according to standardized units commonly used for measuring electricity consumption, i.e.: MWh. Energy and fuel inputs mean the energy content of:

- Fuels before combustion in operations/assets within your reporting boundary; and
- The amount of purchased energy inputs which include electricity, heat, steam and cooling for use by those operations/assets.

Some information about how to convert purchased energy inputs (electricity, heat, steam and cooling) to MWh is provided in the guidance for Module C8. Cooling is included in this list because when cooling services are purchased using a district system, the compressor system that produces the cooling may be driven by either electricity or fossil fuel combustion.

This technical note provides guidance on how to convert fuel data to MWh.

Fuel can be measured in terms of:

- Energy content e.g. in kilojoules (kJ), British thermal units (Btu) or therms;
- Volume e.g. in m3 or liters; and
- Mass e.g. in metric tonnes or short tons.

The way in which fuel data may be converted to MWh depends upon whether information about fuel is expressed in terms of energy content, volume or mass and guidance on conversion for each measurement is set out below. For fuel inputs, we ask for the energy content of fuels prior to combustion.

Please include in your calculations the energy content of any biomass and self-produced fuels that you use for stationary combustion. Self-produced fuels are fuels produced by assets or activities within your reporting boundary that are combusted for energy generation. This is common in the oil and gas sector, e.g. refinery fuel gas, associated gas, etc.

If you have your fuel data in energy units

If you have your fuel data in an energy unit, you can convert it to MWh using a conversion tool such as: www.onlineconversion.com. Additionally, there is a conversion table listed in this guidance document.

If your fuel data is in units of mass

You will generally have your fuel in mass if it is a solid (e.g. coal, wood, waste) or in the case of certain liquids (e.g. fuel oil).

1. If your fuel consumption is measured by mass you need to obtain the energy content of the fuel in corresponding units, e.g. kJ/metric ton, TJ/Gg. This is usually called the calorific value or heating value. It may be obtained from your fuel supplier or you may have your own values generated by your own tests. You may also refer to typical values published by reliable sources. In this note you can find typical values as published and used by the IPCC.
2. Multiply the fuel mass by the calorific value (or heating value) in the appropriate units i.e. if the fuel data is in metric tons, then the calorific value must be expressed in energy units per metric tons. This gives you the energy content of the fuel used.
3. Then take the resulting figure and convert it to MWh using a conversion tool.

Worked example (Mass)

A company has consumed 1245345 tons of coal (lignite) and wishes to obtain an estimate of the energy equivalent of that amount of coal. For this consumption it would be expected that analysis of the calorific value of lignite would have been made and is available. However, for the sake of the example the Calorific Value of lignite presented in Table 1 (below) is used.

Step 1 - Existent Data

Coal = 1245345 tonnes (t) of coal

Net Calorific Values (NCV) = 11.9 TJ/Gg

Expression to calculate Energy: Energy = Mass * NCV

Step 2 – Analyzing the units of the parameters in the equation

Coal is expressed in metric tons and we want to obtain Energy in MWh. The NCV is given in TJ/Gg, so we need to transform it to MWh/t. For that the following reasoning can be applied:

Convert TJ into MWh:

1 TJ = 10^{12} J = 277.778 MWh

[Note 1 MWh = 10^{6} (M) * 1 (W=J/s) * 3600 (s) = 3.6 * 10^{9} J, so you can know how many MWh there are in 1TJ by dividing 1 TJ = 10^{12} J by 3.6 * 10^{9} J that there are in 1 MWh]

Convert Gg into ton:

1 Gg = 10^{9} g = 1000 t

[Note 1 ton = 1000 kg = 10^{6} g, so 1 Gg = 10^{9} g which divided by 10^{6} g of one tonne equals that 1 Gg = 1000 t]

Conversion of NCV:

11.9 TJ/Gg = 11.9 * 277.778/1000 t = 3.306 MWh/ton

Step 3 – Calculate energy

Now that the conversion has been made, to calculate the energy content of the mass of coal is straightforward, given the expression:

Energy [MWh]= Mass [t] * NCV [MWh/t]

Energy [MWh] = 1245345 t * 3.306 MWh/ton = 4117111 MWh

Note 1: Step 2 could have been done differently. One could have transformed NCV as TJ/t and then convert from TJ to MWh in a Step 4, after calculating the energy in step 3. See "Worked example (Liquid)".

Note 2: As illustrated by this example, the critical factor is to be sure that the parameters we multiply all have the same units to guarantee the homogeneity of the final result. This is usually called "Dimensional Analysis" and you can learn more about it if you want here http://en.wikipedia.org/wiki/Dimensional_analysis.

If your fuel data is a liquid expressed in units of volume

If your fuel is a liquid, you might get your fuel data either as a mass or a volume. If you do get it as a volume, the calculation is entirely similar to the worked example for mass, with the exception that you need to convert the volume of the fuel into a mass – or have the NCV expressed in terms of volume. Usually, a step will be required to convert mass in volume and this is done by using a conversion parameter known as density that expresses the mass per a unit of volume (e.g. kg/m^3). You can find some density values in Table 2, below.

Worked example (Volume; Liquid)

A company has consumed 4456 m^3 of Diesel and wishes to obtain an estimate of the energy equivalent of that amount. In case the supplier has not given information about both the density of the diesel and its NCV, the values in Table 1 and Table 2 could be used, as done in this example.

Step 1 - Existent Data

Diesel = 4 456 m^3 of Diesel

Net Calorific Values (NCV) = 43 TJ/Gg

Diesel density = 0.84 kg/l (same as Distillate Fuel Oil N.o 1)

Expression to calculate Energy: Energy = Mass * NCV

Step 2 – Convert volume into mass

Diesel = 4 456 m^3 = 4 456 000 l

Mass of Diesel = Volume * Density

= 4 456 000 (l) * 0.84 (kg/l) = 3 743 040 kg = 3 743 t

Step 3 – Calculate energy

Energy = Mass * NCV = 3 743 [t] * 43 [TJ/Gg] = 3 743 t * 43 TJ/(1000 [t])

= 160.949 [TJ]

Step 4 – Convert TJ to MWh

1 TJ = 10^{12} J = 277.778 MWh, so

160.949 [TJ] = 277.778 [MWh/TJ] * 160.949 [TJ] = 44 708 MWh

If your fuel data is a gas expressed in units of volume

If your fuel is a gas expressed in volume, you can calculate energy by using a similar approach to the one used for liquids. The main exception is that you will have to be particularly careful related to the conditions (pressure and temperature) in which you are measuring your volume of gas, because the density of gases can vary widely depending on temperature and pressure[1].

Worked example (Gas; Volume)

A company has bought 5000 m^3 of Natural Gas and wishes to obtain an estimate of the energy equivalent of that amount. To first start addressing this question, you need to know what the conditions are of this 5000 m^3 of Natural Gas. Usually, this will refer to either Standard Temperature and Pressure (STP), which is 0ºC and 100 kPa or to Normal Temperature and Pressure (NTP), which will be 25ºC and 101.325 kPa.

Fortunately, there is a simple approximate relationship between the state of a gas and its density, pressure and temperature, which is given by the ideal gas law

$$PV = nRT$$

You can learn more about it here http://en.wikipedia.org/wiki/Ideal_gas_law. You should remember that this can be used for the purpose of calculating density of gases at different conditions of temperature and pressure.

Instead of using the equation you can use the following link http://www.enggcyclopedia.com/calculators/physical-properties/gas-density/ for an online calculation of gas density, based on certain characteristics such as its Molecular Weight, Compressibility, Temperature and Pressure . In this site, if you define the compressibility of the gas as 1 (compressibility of an ideal gas) you will be using in practice the ideal gas law.

Natural Gas varies in composition, but is basically a mixture of Methane, Ethane, Water and with other combustible gases of higher molecular weight, but in much smaller amounts. For this reason you should contact your suppliers and ask them to provide you with information about the energy density of the gas (kJ/m^3) (or its NCV/HCV) and the molecular composition/molecular weight or its density.

If you don't have this information, you may wish to find values in other sources information, such as online. For instance, for the sake of this example we will use the following reference https://roymech.org/Useful_Tables/Matter/Prop_Gas.html.

In here, Natural Gas is characterized as having a Molecular Weight of 19.5 and density of 0.8034 kg/m^3 at NTP (25ºC, 1 atm). If we introduce this information in the gas calculator http://www.enggcyclopedia.com/calculators/physical-properties/gas-density/ we can see we obtain a density of 0.7971 kg/m^3, which is close enough. Notice that this is considerable different from the value provided in Table two as middle of the range (0.7).

Once you have the density of the Natural Gas, all the rest is similar to the example of calculating the energy of a liquid.

Please note that just as density will vary significantly with the specific composition of the natural gas – which changes its molecular weight – so will the NCV, which is determined in part by the individual NCV's of the species that constitute the Natural Gas.

[1] Densities of liquid will actually also vary, however, it can be approximated that for the range of usual ambient temperatures, this variation is negligible. You can find a "density calculator" for common liquid compounds in here http://www.enggcyclopedia.com/calculators/physical-properties/liquid-density/

Step 1 - Existent Data

Natural Gas = 5 000 m^3 (NPT) of Natural Gas

Net Calorific Values (NCV) = 47 TJ/Gg

Natural Gas density (NPT) = 0.7971 kg/m^3

Expression to calculate Energy: Energy = Mass * NCV

Step 2 – Convert volume into mass

Natural Gas = 5 000 m^3

Mass of Diesel = 0.7971*5000 = 3985.5 kg

Step 3 – Calculate energy

Energy = Mass * NCV = 3.9855 [t] * 47 [TJ/Gg] = 3.9855 t * 47 TJ/(1000 [t])

= 0.18732 [TJ]

Step 4 – Convert TJ to MWh

1 TJ = 10^{12} J = 277.778 MWh, so

0.18732 [TJ] = 277.778 [MWh/TJ]* 0.18732 [TJ] = 52.03 MWh

If you do not know the energy content of the fuel

If you cannot obtain a calorific value (or heating value) specific to the fuel you purchase, default heating values may be used. Default heating values are reproduced from the GHG Protocol's stationary combustion Excel spreadsheet 3.1(1). Please note: These default values are meant only to provide guidance for users who are developing their own values. Users are encouraged to develop their own values based on the actual characteristics of the fuel being combusted. The GHG Protocol has produced a new tool version 4.1. Its simpler and clearer user interface means that some reference data such as the figures below are no longer visible.

Fuel Type		Higher Heating Values (HHV) / Gross Calorific Values (GCV) units TJ/Gg	Lower Heating Values (LHV) / Net Calorific Values (NCV) units TJ/Gg
Crude oil & derived substances	Crude oil	44.53	42.3
	Orimulsion	28.95	27.5
	Natural Gas Liquids	46.53	44.2
	Motor Gasoline	46.63	44.3
	Aviation Gasoline	46.63	44.3
	Jet Gasoline	46.63	44.3
	Jet Kerosene	46.42	44.1
	Other Kerosene	46.11	43.8
	Shale oil	40.11	38.1
	Gas/Diesel oil	45.26	43
	Residual Fuel oil	42.53	40.4
	Liquefied Petroleum Gases	49.79	47.3
	Ethane	48.84	46.4
	Naphtha	46.84	44.5
	Bitumen	42.32	40.2
	Lubricants	42.32	40.2
	Petroleum coke	34.21	32.5
	Refinery feedstocks	45.26	43
	Refinery Gas	55.00	49.5
	Paraffin waxes	42.32	40.2
	White Spirit & SBP	42.32	40.2
	Other petroleum products	42.32	40.2
Coal & derived substances	Anthracite	28.11	26.7
	Coking coal	29.68	28.2
	Other bituminous coal	27.16	25.8
	Sub-bituminous coal	19.89	18.9
	Lignite	12.53	11.9
	Oil shale and tar sands	9.37	8.9
	Brown coal briquettes	21.79	20.7
	Patent fuel	21.79	20.7
	Coke oven coke & lignite coke	29.68	28.2
	Gas coke	29.68	28.2
	Coal tar	29.47	28
	Gas works gas	43.00	38.7
	Coke oven gas	43.00	38.7
	Blast furnace gas	2.74	2.47

	Oxygen steel furnace gas	7.84	7.06
Natural gas	Natural Gas	53.33	48
Non-biomass waste fuels	Municipal wastes (non-biomass fraction)	10.53	10
	Industrial wastes	NA	NA
	Waste oils	42.32	40.2
Peat	Peat*	10.27	9.76
Biomass fuels	Wood/Wood waste	16.42	15.6
	Sulphite lyes (Black liquor)	12.42	11.8
	Other primary solid biomass fuels	12.21	11.6
	Charcoal	31.05	29.5
	Biogasoline	28.42	27
	Biodiesels	28.42	27
	Other liquid biofuels	28.84	27.4
	Landfill gas**	56.00	50.4
	Sludge gas**	56.00	50.4
	Other biogas	56.00	50.4
	Municipal wastes (biomass fraction)	12.21	11.6

Table 1: HHV's and LHV's by fuel type

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The IPCC values were originally on a NCV (LHV) basis and have been converted to a GCV (HHV) basis. They have been published by the World Resources Institute/World Business Council for Sustainable Development in their stationary combustion calculation tool version 3.1(1)

*Value can be significantly affected by moisture content of fuel

**Value can be significantly affected by fraction of air, CO_2, and moisture in gas.

Please note that the heating values in Table 1 are given in units of TJ/Gg, where the prefixes T and G stand for "tera" and "giga" and correspond respectively to multiplication factors of 10^{12} and 10^9. When using the tabulated values for heating values, please ensure that your fuel use figures are in the correct units. You can find below standard prefixes for the System International (SI) units of measure (source: http://en.wikipedia.org/wiki/International_System_of_Units)

Standard prefixes for the System International (SI) units of measure

Multiples	Name	deca-	hecto-	kilo-	mega-	giga-	tera-	peta-
	Symbol	da	h	k	M	G	T	P
	Factor	10^1	10^2	10^3	10^6	10^9	10^{12}	10^{15}
Fractions	Name	deci-	centi-	milli-	micro-	nano-	pico-	femto-
	Symbol	d	c	m	μ	n	p	f
	Factor	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-12}	10^{-15}

Fuel Type	Gaseous (kg/m³)[a,b]		Liquid (kg/L)[b]		Gaseous (lb/ft³)[a,b]		Liquid (lb/gal)[b]	
	Range	Typical	Range	Typical	Range	Typical	Range	Typical
Coal-based fuels								
Anthracite coal								

Fuel Type	Gaseous (kg/m³)[a,b]		Liquid (kg/L)[b]		Gaseous (lb/ft³)[a,b]		Liquid (lb/gal)[b]	
	Range	Typical	Range	Typical	Range	Typical	Range	Typical
Bituminous coal								
Sub-bituminous coal								
Lignite coal								
Coal coke								
Patent fuel								
BKB								
Natural gas-based fuels[c]								
Natural gas	0.6-0.9	0.7			0.037-0.055	0.043		
Natural gas (dry)	0.6-0.9	0.7			0.037-0.056	0.043		
Methane	-	0.67			-	0.042		
Ethane	-	1.3			-	0.079		
Propane	-	1.9			-	0.12		
Butane	-	2.5			-	0.16		
Isobutane	-	2.5			-	0.16		
n-Butane	-	2.5			-	0.16		
Natural gas liquids (LNG)			0.42-0.54	0.47			3.5-4.5	3.9
Petroleum-based fuels								
Crude oil			0.7-0.9	0.8			5.8-7.5	6.7
Motor gasoline / petrol			0.73-0.76	0.74			6.1-6.3	6.2
Aviation gasoline			0.7-0.72	0.71			5.8-6.0	5.9
Distillate Oil			0.82-0.95	0.84			6.8-7.9	7.0
Distillate fuel oil No.1			0.82-0.85	0.84			6.8-7.1	7.0
Distillate fuel oil No.2			0.82-0.85	0.85			6.8-7.1	7.1
Distillate fuel oil No.4			0.91-0.95	0.93			7.6-7.9	7.8
Residual Oil			0.93-1.03	0.94			7.8-8.6	7.8
Residual fuel oil No.5			0.93-0.95	0.94			7.8-7.9	7.8
Residual fuel oil No.6			0.89-1.01	0.94			7.4-8.5	7.8
Jet kerosene			0.76-0.83	0.79			6.3-6.9	6.6
Kerosene (other)			0.79-0.82	0.80			6.6-6.8	6.7
Petroleum Coke								
LPG			0.53-0.55	0.54			4.5-4.6	4.5
Naphtha			0.75-0.82	0.77			6.3-6.8	6.4
Asphalt / bitumen								
Pitch								
Lubricants			0.8-1.1	1.0			6.7-9.2	8.3
Waxes								
Shale oil (liquid)			0.96-1.00	1.0			8.0-8.3	8.3
Oil shale								
Other Fuels								
Peat								
Waste plastics								
Tar								
Waste tire derived fuels								
Biomass								
Wood (dry)								

Fuel Type	Gaseous (kg/m^3)[a,b]		Liquid (kg/L)[b]		Gaseous (lb/ft^3)[a,b]		Liquid (lb/gal)[b]	
	Range	Typical	Range	Typical	Range	Typical	Range	Typical
Wood (wet)								
Fuelwood (approx. 20% moisture)								
Black liquor								
Landfill gas	0.67-1.2	0.9			0.042-0.075	0.056		
Waste water treatment biogas	0.67-1.2	0.9			0.042-0.076	0.056		
Biodiesel			0.96-1.00	0.85			6.9-7.2	7.0
Turpentine			-	0.87			-	7.2
Vegetable oils			0.96-1.00	0.90			7.4-7.5	7.5

Table 2: Gaseous and liquid ranges and typical values by fuel type

Source: World Resources Institute/World Business Council for Sustainable Development stationary combustion calculation tool version 3.3(1)

a. Density values are highly sensitive to changes in temperature and pressure. Values indicated are based on room temperature and standard atmospheric pressure.

b. Dry unless otherwise noted.

c. At room temperature and standard atmospheric pressure.

Reference:

Typical values are based on a compilation of commonly accepted sources such as US DOE/EIA, national inventory reports to the UNFCCC and other sources.

Other sources of information

You can find lots of useful information, namely on NCV's, density, emission factors, etc, in the national inventories submitted to UNFCCC. Furthermore, these figures will be specific and more representative to a certain country and year. To check the National Inventory Reports see http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php