BS 8609:2014

BSI Standards Publication

Natural gas – Calculation of carbon dioxide emission factors from composition

bsi.

...making excellence a habit.™

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

Publishing and copyright information

The BSI copyright notice displayed in this document indicates when the document was last issued.

© The British Standards Institution 2014

Published by BSI Standards Limited 2014

ISBN 978 0 580 83913 9

ICS 75.060

The following BSI references relate to the work on this document:
Committee reference PTI/15
Draft for comment 14/30287938 DC

Publication history

First published July 2014

Amendments issued since publication

Date

Text affected

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013 Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to ii, pages 1 to 12, an inside back cover and a back cover.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013 Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 July 2014. It was prepared by Technical Committee, PTI/15, *Natural Gas and Gas Analysis*. A list of organizations represented on this committee can be obtained on request to its secretary.

Relationship with other publications

The methods of calculation in this British Standard require a value of the atomic index for carbon of each component comprising the gas mixture, together with the relevant molar property of the gas mixture. All of these values are either obtained from or calculated according to BS EN ISO 6976.

The method of calculation in this British Standard is applicable to any gas mixture for which BS EN ISO 6976 is applicable.

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its methods are expressed as a set of instructions, a description, or in sentences in which the principal auxiliary verb is “shall”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

1 Scope

This British Standard gives methods for the calculation of the carbon dioxide emission factor of natural gases, natural gas substitutes and other combustible gaseous fuels, when the composition of the gas by mole fraction is known. The method provides for the calculation of the carbon dioxide emission factor at the commonly used reference conditions of temperature and pressure and on the four common quantity bases:

- mole;
- mass;
- volume (at the reference conditions of temperature and pressure); and
- energy (gross or net).

Annex A provides example calculations for carbon dioxide emission factors on all the above bases and their uncertainties.

This standard requires use of complete compositional data in the form of mole fractions that, by definition, sum to unity. If this is not so then the raw mole fraction data is to be normalized and the normalized mole fractions and their uncertainties recalculated. Guidance on such data processing is provided in BS EN ISO 6974-1 and BS EN ISO 6974-2.

If the compositional data are incomplete, i.e. not all components have been determined, then it is for the user to establish the significance of the error caused by their omission and subsequent normalization.

NOTE One way to establish the significance of any omission is to determine how carbon dioxide emission factor changes when the mole fraction of an undetermined component is estimated to be unity minus the sum of all raw mole fractions.

2 Normative references

The following referenced documents are indispensable for the application of this document. The latest edition of the referenced document applies.

BS EN ISO 6974-1, *Natural gas – Determination of composition and associated uncertainty by gas chromatography – Part 1: General guidelines and calculation of composition*

BS EN ISO 6974-2, *Natural gas – Determination of composition and associated uncertainty by gas chromatography – Part 2: Uncertainty calculations*

BS EN ISO 6976, *Natural Gas – Calculation of calorific values, density, relative density and Wobbe index from composition*

3 Terms, definitions and units

For the purposes of this British Standard, the following terms, definitions and units apply.

3.1 Terms and definitions

3.1.1 carbon dioxide emission factor

mass of carbon dioxide that is produced from complete combustion with oxygen of a specified quantity of gas

3.1.2 coverage factor

numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

NOTE A coverage factor, k, is typically in the range 2 to 3.

3.1.3 gross calorific value
amount of heat that would be released by the complete combustion with oxygen of a specified quantity of gas, in such a way that the pressure p_1 at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature t_1 as that of the reactants, all of these products being in the gaseous state except for water, which is condensed to the liquid state at t_1

NOTE Where the quantity of gas is specified on a molar basis, the calorific value is designated as $(H)_G(t_1,p_1)$; on a mass basis the calorific value is designated as $(Hm)_G(t_1,p_1)$. Where the quantity of gas is specified on a volumetric basis, the calorific value is designated as $(Hv)_G(t_1,p_1;t_2,p_2)$, where t_2 and p_2 are the gas volume (metering) reference conditions.

3.1.4 net calorific value
amount of heat that would be released by the complete combustion with oxygen of a specified quantity of gas, in such a way that the pressure p_1 at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature t_1 as that of the reactants, all of these products being in the gaseous state

NOTE On molar, mass and volumetric bases, the net calorific value is designated respectively as $(H)_N(t_1,p_1)$, $(Hm)_N(t_1,p_1)$ and $(Hv)_N(t_1,p_1;t_2,p_2)$.

3.1.5 molar volume
volume occupied by one mole of a real gas at specified conditions of pressure and temperature

3.1.6 real gas
gas which deviates from volumetric ideality

3.2 Symbols and units

3.2.1 Quantities

A	number of moles of carbon atoms in one mole of mixture, mol^{-1}
a	atomic index for carbon in the generalised component $C_aH_bN_cO_dS_e$
B	number of moles of hydrogen atoms in one mole of mixture, mol^{-1}
b	atomic index for hydrogen in the generalised molecular species $C_aH_bN_cO_dS_e$
C	carbon dioxide emission factor of the mixture on a molar basis, $kg \cdot mol^{-1}$
C_G	carbon dioxide emission factor of the mixture on a gross energy basis, $kg \cdot kJ^{-1}$
C_M	carbon dioxide emission factor of the mixture on a mass basis, $kg \cdot kg^{-1}$
C_N	carbon dioxide emission factor of the mixture on a net energy basis, $kg \cdot kJ^{-1}$
C_V	carbon dioxide emission factor of the mixture on a volume basis, $kg \cdot m^{-3}$
c	atomic index for nitrogen in the generalised component $C_aH_bN_cO_dS_e$

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

d	atomic index for oxygen in the generalised component $C_aH_bN_cO_dS_e$
e	atomic index for sulfur in the generalised component $C_aH_bN_cO_dS_e$
k	coverage factor
H	calorific value of the mixture on a molar basis, $kJ \cdot mol^{-1}$
Hm	calorific value of the mixture on a mass basis, $kJ \cdot kg^{-1}$
Hv	calorific value of the real gas mixture on a volumetric basis, $kJ \cdot m^{-3}$
h_i	gross calorific value of pure component i on a molar basis, $kJ \cdot mol^{-1}$
L	half standard enthalpy of vaporization of water (= ½ $\Delta_{vap}H$), $kJ \cdot mol^{-1}$
M	molar mass of the mixture, $kg \cdot mol^{-1}$
m_C	atomic mass of carbon, $kg \cdot mol^{-1}$
m_{CO2}	molar mass of carbon dioxide, $kg \cdot mol^{-1}$
m_H	atomic mass of hydrogen, $kg \cdot mol^{-1}$
m_i	molar mass of pure component i, $kg \cdot mol^{-1}$
m_N	atomic mass of nitrogen, $kg \cdot mol^{-1}$
m_O	atomic mass of oxygen, $kg \cdot mol^{-1}$
m_S	atomic mass of sulfur, $kg \cdot mol^{-1}$
N	number of components in mixture
p_1	combustion pressure, Pa
p_2	metering pressure, Pa
q_{ij}	element i,j of molar mass correlation coefficient matrix
R	gas constant, $J \cdot mol^{-1}\ K^{-1}$
S	mixture Z summation factor
s_i	Z summation factor for pure component i
t_1	combustion temperature, K
t_2	metering temperature, ° C
U	expanded uncertainty = $k \cdot u$
u	standard uncertainty (1 standard deviation)
V	molar volume of the mixture = $Z \times R \times T_2.P_2$, $m^3 \cdot mol^{-1}$
x_i	mole fraction of component i in the mixture
Y	unspecified property
Z	mixture compression factor = $1 - S^2$
ρ_{ij}	element i,j of mole fraction correlation coefficient matrix

3.2.2 Subscripts

G	gross (calorific value) basis
i,j	component identifiers
N	net (calorific value) basis

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

4 Calculation of the carbon dioxide emission factor

4.1 General

The starting point for the calculation of the carbon dioxide emission factor on any of the commonly used bases is the calculation of carbon dioxide emission factor on the molar basis, *C*. The carbon dioxide emission factor on the desired basis is accomplished by dividing carbon dioxide emission factor on the molar basis by the relevant molar property of the gas mixture. The molar property of the gas mixture shall be calculated according to BS EN ISO 6976.

The calculation of carbon dioxide emission factors and their uncertainties, in accordance with equations 1 to 12, requires values of pure component properties that shall be obtained from BS EN ISO 6976.

The following terms are used for expressing the subsequent equations compactly:

$$A = \sum_{i=1}^{i=N} x_i a_i$$

$$B = \sum_{i=1}^{i=N} x_i b_i$$

$$M = \sum_{i=1}^{i=N} x_i m_i$$

$$S = \sum_{i=1}^{i=N} x_i s_i$$

$$H = \sum_{i=1}^{i=N} x_i h_i$$

where $m_i = a_i \cdot m_C + b_i \cdot m_H + c_i \cdot m_N + d_i \cdot m_O + e_i \cdot m_S$

4.2 Calculation of the carbon dioxide emission factor on the molar basis

The carbon dioxide emission factor on the molar basis shall be calculated from:

$$C = m_{CO2} \times A \qquad (1)$$

4.3 Calculation of the carbon dioxide emission factor on the mass basis

The carbon dioxide emission factor on the mass basis shall be calculated from:

$$C_M = m_{CO2} \times \frac{A}{M} \qquad (2)$$

4.4 Calculation of the carbon dioxide emission factor on the volumetric basis

The carbon dioxide emission factor on the volumetric basis shall be calculated from:

$$C_V = m_{CO2} \times \frac{A}{V} \qquad (3)$$

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

4.5 Calculation of the carbon dioxide emission factor on the gross combustion energy basis

The carbon dioxide emission factor on the gross combustion energy basis shall be calculated from:

$$C_G = m_{CO2} \times \frac{A}{H} \tag{4}$$

4.6 Calculation of the carbon dioxide emission factor on the net combustion energy basis

The carbon dioxide emission factor on the net combustion energy basis shall be calculated from:

$$C_N = m_{CO2} \times \frac{A}{(H - L \cdot B)} \tag{5}$$

5 Uncertainty of calculation

5.1 General

Application of the GUM [1] to equations 1 to 5 results in equations 8 to 12 below for the standard uncertainty in the carbon dioxide emission factors on each basis.

NOTE 1 Depending on the information available, correlation coefficients ρ_{ij} may or may not be known.

In the absence of more specific information, the correlation coefficients ρ_{ij} shall be taken to be the elements of an identity matrix. If uncertainty in the carbon dioxide emission factor on a mass basis is required, then the correlation coefficients q_{ij} shall be calculated from:

$$q_{ij} = \frac{a_i a_j u^2(m_C) + b_i b_j u^2(m_H) + c_i c_j u^2(m_N) + d_i d_j u^2(m_O) + e_i e_j u^2(m_S)}{u(m_i)u(m_j)} \tag{6}$$

where

$$u(m_i) = \sqrt{a_i^2 u^2(m_C) + b_i^2 u^2(m_H) + c_i^2 u^2(m_N) + d_i^2 u^2(m_O) + e_i^2 u^2(m_S)} \tag{7}$$

NOTE 2 q_{ij} is only used for the calculation of the uncertainty in carbon dioxide emission factor on a mass basis; it is not used for other bases.

NOTE 3 For a typical Group H gas, use of the elements of an identity matrix for q_{ij} instead of equation (6) will overestimate the uncertainty in carbon dioxide emission factor on a mass basis by around 1%.

5.2 Calculation of uncertainty in the carbon dioxide emission factor on the molar basis

The uncertainty in the carbon dioxide emission factor on the molar basis shall be calculated from:

$$\left(\frac{u(C)}{C}\right)^2 = \sum_{i=1}^{i=N}\sum_{j=1}^{j=N}\left(\frac{a_i}{A}\right)u(x_i)\rho_{ij}\left(\frac{a_j}{A}\right)u(x_j) + \left(\frac{u(m_{CO2})}{m_{CO2}}\right)^2 \tag{8}$$

5.3 Calculation of uncertainty in the carbon dioxide emission factor on the mass basis

The uncertainty in the carbon dioxide emission factor on the mass basis shall be calculated from:

$$\left(\frac{u(C_M)}{C_M}\right)^2 = \sum_{i=1}^{i=N}\sum_{j=1}^{j=N}\left(\frac{a_i}{A}-\frac{m_i}{M}\right)u(x_i)\rho_{ij}\left(\frac{a_j}{A}-\frac{m_j}{M}\right)u(x_j)$$
$$+\sum_{i=1}^{i=N}\sum_{j=1}^{j=N}x_i\frac{u(m_i)}{M}q_{ij}x_j\frac{u(m_j)}{M}$$
$$-2\frac{u(m_{CO2})}{m_{CO2}}\sum_{i=1}^{i=N}x_i\frac{u(m_i)}{m_i}q_{iCO2}+\left(\frac{u(m_{CO2})}{m_{CO2}}\right)^2 \quad (9)$$

5.4 Calculation of the uncertainty in the carbon dioxide emission factor on the volumetric basis

The uncertainty in the carbon dioxide emission factor on the volumetric basis shall be calculated from:

$$\left(\frac{u(C_V)}{C_V}\right)^2 = \sum_{i=1}^{i=N}\sum_{j=1}^{j=N}\left(\frac{a_i}{A}+\frac{2\cdot S\cdot s_i}{Z}\right)u(x_i)\rho_{ij}\left(\frac{a_j}{A}+\frac{2\cdot S\cdot s_j}{Z}\right)u(x_j)$$
$$+\frac{4\cdot S^2}{Z^2}\sum_{i=1}^{i=N}x_i^2u^2(s_i)+\left(\frac{u(R)}{R}\right)^2+\left(\frac{u(m_{CO2})}{m_{CO2}}\right)^2 \quad (10)$$

5.5 Calculation of uncertainty in the carbon dioxide emission factor on the gross combustion energy basis

The uncertainty in the carbon dioxide emission factor on the gross combustion energy basis shall be calculated from:

$$\left(\frac{u(C_G)}{C_G}\right)^2 = \sum_{i=1}^{i=N}\sum_{j=1}^{j=N}\left(\frac{a_i}{A}-\frac{h_i}{H}\right)u(x_i)\rho_{ij}\left(\frac{a_j}{A}-\frac{h_j}{H}\right)u(x_j)$$
$$+\sum_{i=1}^{i=N}x_i^2\left(\frac{u(h_i)}{H}\right)^2+\left(\frac{u(m_{CO2})}{m_{CO2}}\right)^2 \quad (11)$$

5.6 Calculation of uncertainty in the carbon dioxide emission factor on the net combustion energy basis

The uncertainty in the carbon dioxide emission factor on the net combustion energy basis shall be calculated from:

$$\left(\frac{u(C_N)}{C_N}\right)^2 = \sum_{i=1}^{i=N}\sum_{j=1}^{j=N}\left(\frac{a_i}{A}-\frac{(h_i-L\cdot b_i)}{(H-L\cdot B)}\right)u(x_i)\rho_{ij}\left(\frac{a_j}{A}-\frac{(h_j-L\cdot b_j)}{(H-L\cdot B)}\right)u(x_j)$$
$$+\sum_{i=1}^{i=N}x_i^2\left(\frac{u(h_i)}{(H-L\cdot B)}\right)^2+\left(\frac{B}{(H-L\cdot B)}\right)^2u^2(L)+\left(\frac{u(m_{CO2})}{m_{CO2}}\right)^2 \quad (12)$$

5.7 Compositional uncertainty

In certain circumstances it is appropriate to assume that the uncertainty in the component data and ancillary data is zero. In this case the only source of uncertainty is from composition and equations 8 to 12 above simplify to just the first term.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

5.8 Expanded uncertainty

The expanded uncertainty $U(Y)$ shall be calculated by multiplying the standard uncertainty $u(Y)$ by an appropriate coverage factor, k.

6 Expression of results

a) The expanded uncertainty shall be rounded to two significant figures, using the normal rules of rounding.

b) The numerical value of Y shall be rounded to the least significant Figure in the rounded value of the expanded uncertainty $U(Y)$.

c) The value of the calculated quantity shall be reported in the form $Y \pm U(Y)$ (including units) and the value of coverage factor noted.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013 Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

Annex A (informative) Example of calculation

A.1 General

This Annex gives example calculations for the carbon dioxide emission factor of a natural gas from its compositional analysis. ISO standard reference conditions of 15 °C combustion temperature, 15 °C metering temperature and 101.325 kPa pressure were employed throughout.

NOTE ISO standard reference conditions are taken from BS EN ISO 13443:2005.

In the calculations below, maximum precision is used for all intermediate results, with rounding only done at the final stage for the output.

A.2 Compositional analysis

The analysis report of a natural gas sample provided the following information.

Table A.1 **Example analysis report for natural gas**

Component	x_i	$u(x_i)$
nitrogen	0.025 140	0.000 067
carbon dioxide	0.009 790	0.000 046
methane	0.906 642	0.000 126
ethane	0.039 650	0.000 063
propane	0.010 290	0.000 026
2-methylpropane	0.002 019	0.000 036
n-butane	0.002 063	0.000 014
2,2-dimethylpropane	0.001 101	0.000 020
2-methylbutane	0.001 106	0.000 019
n-pentane	0.001 101	0.000 019
n-hexane	0.001 098	0.000 022

A.3 Component data

Component data are displayed in Table A.2.

NOTE Component data displayed in Table A.2 are illustrative only; for application of this standard the data given in the latest version of BS EN ISO 6976 should be used.

Table A.2 **Component data**

	a_i mol/mol	b_i mol/mol	h_i kJ/mol	$U(h_i)$ kJ/mol	s_i	$u(s_i)$	m_i g/mol	$u(m_i)$ g/mol
nitrogen	0	0	0.00	0.00	0.017 00	0.001 0	28.013 4	0.000 2
carbon dioxide	1	0	0.00	0.00	0.075 20	0.002 0	44.009 5	0.000 5
methane	1	4	896.51	0.19	0.044 52	0.000 5	16.042 46	0.000 424
ethane	2	6	1 562.14	0.51	0.091 90	0.001 1	30.069 04	0.000 827
propane	3	8	2 221.10	0.51	0.134 40	0.001 6	44.095 62	0.001 232
2-methylpropane	4	10	2 870.58	0.72	0.172 20	0.003 1	58.122 20	0.001 638
n-butane	4	10	2 879.76	0.72	0.184 00	0.003 9	58.122 20	0.001 638
2,2-dimethylpropane	5	12	3 517.43	0.25	0.204 00	0.006 0	72.148 78	0.002 044
2-methylbutane	5	12	3 531.68	0.23	0.225 10	0.008 8	72.148 78	0.002 044
n-pentane	5	12	3 538.60	0.23	0.236 10	0.010 7	72.148 78	0.002 044
n-hexane	6	14	4 198.24	0.32	0.300 10	0.027 1	86.175 36	0.002 450

A.4 Ancillary data

Ancillary data taken from BS EN ISO 6976 are displayed in Table A.3.

NOTE 1 Ancillary data displayed in Table A.3 are illustrative only; for application of this standard the data given in the latest version of BS EN ISO 6976 should be used.

NOTE 2 The m_i and $u(m_i)$ data are displayed in Table A.3 for software validation purposes and should be calculated directly from the appropriate atomic masses provided in the latest version of BS EN ISO 6976.

Table A.3 **Ancillary data**

Property	**Units**	Y	$u(Y)$
half standard enthalpy of vaporization of water	$kJ \cdot mol^{-1}$	22.215 500 0	0.002
molar mass of CO_2	$g \cdot mol^{-1}$	44.009 500 0	0.000 5
gas constant	$J \cdot mol^{-1} \cdot K^{-1}$	8.314 462 1	0.000 007 5
metering temperature	K	288.150 000 0	–
metering pressure	kPa	101.325 000 0	–
atomic mass of C	$g \cdot mol^{-1}$	12.010 700 0	0.000 4
atomic mass of H	$g \cdot mol^{-1}$	1.007 940 0	0.000 035
atomic mass of N	$g \cdot mol^{-1}$	14.006 700 0	0.000 1
atomic mass of O	$g \cdot mol^{-1}$	15.999 400 0	0.000 15
atomic mass of S	$g \cdot mol^{-1}$	32.065 000 0	0.002 5

A.5 Correlation matrix of molar mass

As calculated using equation 6, the elements q_{ij} of the molar mass correlation coefficient matrix are given in Table A.4.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

Table A.4 **Correlation matrix of molar mass**

		j									
		N_2	CO_2	CH_4	C_2H_6	C_3H_8	*i*-C_4H_8	*n*-C_4H_8	*neo*-C_5H_{10}	*i*-C_5H_{10}	*n*-C_5H_{10}	*n*-C_6H_{12}
i	N_2	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	CO_2	0.0000	1.0000	0.7551	0.7738	0.7791	0.7815	0.7815	0.7829	0.7829	0.7829	0.7838
	CH_4	0.0000	0.7551	1.0000	0.9968	0.9942	0.9927	0.9927	0.9916	0.9916	0.9916	0.9909
	C_2H_6	0.0000	0.7738	0.9968	1.0000	0.9996	0.9991	0.9991	0.9988	0.9988	0.9988	0.9985
	C_3H_8	0.0000	0.7791	0.9942	0.9996	1.0000	0.9999	0.9999	0.9998	0.9998	0.9998	0.9996
	i-C_4H_8	0.0000	0.7815	0.9927	0.9991	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999
	n-C_4H_8	0.0000	0.7815	0.9927	0.9991	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999
	neo-C_5H_{10}	0.0000	0.7829	0.9916	0.9988	0.9998	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	i-C_5H_{10}	0.0000	0.7829	0.9916	0.9988	0.9998	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	n-C_5H_{10}	0.0000	0.7829	0.9916	0.9988	0.9998	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	n-C_6H_{12}	0.0000	0.7838	0.9909	0.9985	0.9996	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000

A.6 Carbon dioxide emission factors and their uncertainties

The results of applying the equations in Clause **5**, with correlation coefficients ρ_{ij} taken to be the elements of an identity matrix, are reported in Table A.5.

Table A.5 **Carbon dioxide emission factors and their uncertainties, excluding mole fraction correlation**

Property, *Y*	**Units**	*Y*	*u*(*Y*)	*U*(*Y*)
carbon dioxide emission factor on a molar basis	$g \cdot mol^{-1}$	46.917 00	0.015	0.029
carbon dioxide emission factor on a mass basis	$g \cdot g^{-1}$	2.621 57	0.000 35	0.000 70
carbon dioxide emission factor on a volume basis	$g \cdot m^{-3}$	1 988.860 00	0.63	1.25
carbon dioxide emission factor on a gross combustion energy basis	$g \cdot MJ^{-1}$	50.933 00	0.010	0.020
carbon dioxide emission factor on a net combustion energy basis	$g \cdot MJ^{-1}$	56.436 00	0.012	0.025

Expanded uncertainty has been calculated by multiplying the standard uncertainty by a coverage factor of $k = 2$.

A.7 Carbon dioxide emission factors and their uncertainties, including mole fraction correlation

If the composition given in A.2 is raw data, i.e. unnormalized, then the standard uncertainties in mole fractions need to be processed to give uncertainties in normalized mole fractions. This is illustrated in Table A.6.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

Table A.6 **Standard uncertainties of normalized mole fractions and elements of the mole fraction correlation coefficient matrix**

	$u(xi)$	ρij										
N_2	0.000065	1	-0.030	-0.529	-0.062	-0.033	-0.017	-0.014	-0.011	-0.011	-0.011	-0.011
CO_2	0.000046	-0.030	1	-0.363	-0.040	-0.022	-0.010	-0.009	-0.007	-0.006	-0.006	-0.007
CH_4	0.000109	-0.529	-0.363	1	-0.473	-0.175	-0.293	-0.101	-0.160	-0.152	-0.152	-0.178
C_2H_6	0.000061	-0.062	-0.040	-0.473	1	-0.035	-0.026	-0.016	-0.016	-0.015	-0.015	-0.017
C_3H_8	0.000026	-0.033	-0.022	-0.175	-0.035	1	-0.015	-0.008	-0.009	-0.008	-0.008	-0.009
i-C_4H_8	0.000036	-0.017	-0.010	-0.293	-0.026	-0.015	1	-0.006	-0.003	-0.003	-0.003	-0.003
n-C_4H_8	0.000014	-0.014	-0.009	-0.101	-0.016	-0.008	-0.006	1	-0.003	-0.003	-0.003	-0.004
neo-C_5H_{10}	0.000020	-0.011	-0.007	-0.160	-0.016	-0.009	-0.003	-0.003	1	-0.002	-0.002	-0.002
i-C_5H_{10}	0.000019	-0.011	-0.006	-0.152	-0.015	-0.008	-0.003	-0.003	-0.002	1	-0.002	-0.002
n-C_5H_{10}	0.000019	-0.011	-0.006	-0.152	-0.015	-0.008	-0.003	-0.003	-0.002	-0.002	1	-0.002
n-C_6H_{12}	0.000022	-0.011	-0.007	-0.178	-0.017	-0.009	-0.003	-0.004	-0.002	-0.002	-0.002	1

The results of applying the equations in Clause **5**, with correlation coefficients ρ_{ij} taken as given in Table A.6, are reported in Table A.7.

Table A.7 **Carbon dioxide emission factors and their uncertainties, including mole fraction correlation**

Property, *Y*	**Units**	*Y*	*u*(*Y*)	*U*(*Y*)
carbon dioxide emission factor on a molar basis	$g \cdot mol^{-1}$	46.917 00	0.010	0.020
carbon dioxide emission factor on a mass basis	$g \cdot g^{-1}$	2.621 57	0.000 35	0.000 70
carbon dioxide emission factor on a volume basis	$g \cdot m^{-3}$	1 988.860 00	0.44	0.88
carbon dioxide emission factor on a gross combustion energy basis	$g \cdot MJ^{-1}$	50.933 00	0.010	0.020
carbon dioxide emission factor on a net combustion energy basis	$g \cdot MJ^{-1}$	56.436 00	0.012	0.025

A.8 Composition uncertainty only

Where it has been agreed that the uncertainty in the component data and ancillary data can be considered zero, the only source of uncertainty is from the composition (see **5.7**).

The results for no mole fraction correlation and for correlation from normalization are illustrated in Table A.8.

Table A.8 **Standard uncertainties of carbon dioxide emission factors – compositional uncertainty only**

Property, *Y*	**Units**	*u*(*Y*) **no correlation**	*u*(*Y*) **with correlation**
carbon dioxide emission factor on a molar basis	$g \cdot mol^{-1}$	0.015	0.010
carbon dioxide emission factor on a mass basis	$g \cdot g^{-1}$	0.000 35	0.000 35
carbon dioxide emission factor on a volume basis	$g \cdot m^{-3}$	0.62	0.43
carbon dioxide emission factor on a gross combustion energy basis	$g \cdot MJ^{-1}$	0.003 3	0.003 3
carbon dioxide emission factor on a net combustion energy basis	$g \cdot MJ^{-1}$	0.003 4	0.003 4

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN ISO 13443:2005, *Natural gas – Standard reference conditions*

Standards publications/Other publications/Further reading

[1] Joint Committee for Guides in Metrology (JCGM). *Evaluation of measurement data – Guide to the expression of uncertainty in measurement*, JCGM 100:2008. Paris: International Bureau of Weights and Measures (BIPM), 2008.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013 Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013 Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013 Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013 Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013 Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

This page deliberately left blank

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

All the data, software and documentation set out in all British Standards and other BSI publications are the property of and copyrighted by BSI, or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, photocopying, recording or otherwise – without prior written permission from BSI. Details and advice can be obtained from the Copyright & Licensing Department.

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

bsi.

...making excellence a habit.™

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013