

The revision of ISO 6976 and assessment of the impacts of changes in this standard on the natural gas industry

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1. Introduction

The natural gas industry is large; in 2016 worldwide natural gas consumption was some 24 % of total energy consumption and its production amounted to 3542 bcm (BP, 2017). Accurate determination of energy flows of natural gas is therefore very important to all stakeholders in the natural gas industry and ISO 6976 (Natural gas – Calculation of calorific values, density, relative density and Wobbe indices from composition) is an extensively employed standard. It is widely used to determine calorific value of natural gas and hence to compute the amount of energy traded or consumed. It is therefore a reference standard for many natural gas sales contracts and is critical to gas consumer billing in many countries. In addition to calorific value, ISO 6976 is also employed to calculate other important properties of natural gas, such as Wobbe index – a critical property when considering safe operation of natural gas appliances.

The third and latest edition of ISO 6976 was published in 2016 after an extensive period of revision by a working group of international experts in the field. The process of revision commenced in 2006 and so is the result of a ten-year international collaboration, addressing technical issues with the property calculations themselves, the latest and most appropriate pure component properties, and the development of a GUM-compliant approach to estimation of uncertainty. A considerable amount of effort was also spent in addressing issues relating to harmonising this standard with standards in use in the United States.

The aim of this paper is to provide an update to the standard, highlighting the differences between the latest and previous editions. In addition the result of commercial and regulatory impact assessment will be presented using the UK downstream industry as an example. Impact assessment for other countries and other sectors employing this standard is recommended.

It is also worth noting at this point that two other “sister” standards, widely used in conjunction with ISO 6976 for energy determination have undergone, or are undergoing, significant revision:

- ISO 20765 Natural gas – Calculation of thermodynamic properties. Although a relatively new standard it is expected to gain increasing prominence in the future. Part 1, published in 2005, essentially replicates the AGA-8 detail characterization method (AGA, 1994) for calculation of compression factor and density of natural gas. Part 2, published in 2015, extends the range of applicability of Part 1 and also, by utilising the GERG-2008 equation of state, permits calculation of a wide range of thermodynamic properties. Further Parts to this standard are under development.

Publication of an updated AGA-8 that implements the methods of Part 2 of ISO 20765 is anticipated in 2018.

- ISO 6974 Natural gas – Determination of composition and associated uncertainty by gas chromatography. This suite of standards covers provision of compositional data used by both ISO 6976 and ISO 20765.

Adoption of ISO 20765-2 (or the comparable new AGA-8) in particular will have impact in high pressure energy metering applications and impact assessment is also recommended.

2. The ISO working group responsible for revision of ISO 6976

ISO/TC193 SC1 WG18 was the working group formed by ISO for the revision of ISO 6976. As befits a standard of this importance the working group had participation from a large number of experts (56) representing fourteen countries. We would like to acknowledge the contributions of the members of WG18, the wider ISO TC193 community and all those in the worldwide gas industry who commented on the draft versions of the standard. It is not possible to list all of the members, but the authors would like to make special thanks to Andrew Laughton from DNV GL in the UK and Eric Lemmon from NIST in the USA who made significant technical contributions to the draft. Thanks are also due to Roy Meyer, Jeffrey Savidge, Don Sextro, Ken Starling and Ali Quraishi, of the USA, and Warren Peterson of Canada, all of whom have encouraged and assisted with our efforts in technical harmonisation of ISO 6976 with comparable US standards.

3. Principal changes in the third edition of ISO 6976

The changes incorporated in the third edition of ISO 6976 fall into four main types and are set out below. Clearly, the changes with the potential for greatest impact are the first three.

3.1. Changes to pure component and auxiliary data employed to calculate a particular property of natural gas

3.1.1. Molecular Weights

Molecular weights are calculated from the atomic weight of each constituent, which are updated biennially by the IUPAC Commission on Atomic Weights and Isotopic Abundances. The last change in CAWIA atomic weights affecting the natural gas industry was in 1995 and as a result, the second edition of ISO6976 incorporated molecular weights that are not internationally accepted. The 2007 CAWIA values atomic weights are listed in the third edition. Subsequent atomic weights from CAWIA have been published, but there are complications in the adoption of these values due to the decision by CAWIA to publish ranges of values for some atomic weights.

3.1.2. Summation factors

The molar volume of a real gas at a given temperature and pressure differs from that of the ideal gas. The deviation from ideal behaviour is expressed in terms of its compression factor, z . For ideal gases $z=1$, whereas for real gases z tends to unity only at high temperatures or low pressures.

Knowledge of the compression factor is required in order to calculate molar volume (or determine properties on a volume basis e.g. gross calorific value in MJ/m³). ISO 6976 estimates the compression factor from “pure component summation factors”, s_i (called “ $\sqrt{b_i}$ ” in the second edition):

$$z = 1 - \left[\sum_j^N x_j s_j \right]^2$$

Values of s_i in the second edition were based on a compilation in a 1986 GERG technical monograph by Humphreys (A.E.Humphreys, 1986). Values in the third edition are from data provided by Eric Lemmon.

3.1.3. Gross calorific value

The gross calorific value of methane at a reference temperature of 25°C has been updated in the third edition to reflect further determinations made since the 1995 second edition. All others remain unchanged. The pure component values at other reference temperatures have been re-calculated from the 25°C values. The re-calculation also corrects an incorrect value for gross molar calorific value of n-butane at a reference temperature of 0°C that was discovered during the revision process.

3.1.4. Auxiliary data.

The molar gas constant R and properties of dry air (molecular weight, compression factor at reference conditions) have been updated to reflect the latest accepted values.

3.2. Changes to the method of calculation of the property

3.2.1. Non-definitive methods

Non-definitive methods for calculation of calorific value (either gross or net) on a mass or volumetric basis have been removed. For example, the second edition cites the definitive method for calorific value on a volumetric basis to be from the molar calorific value and its molar volume:

$$H_{mass, real} = \frac{H_{molar, real}}{V_{molar, real}}$$

However, it is possible to calculate it from the weighted volume-based calorific value for the pure components since the second edition listed these data. This can result in slightly different property values owing to differences caused by truncation of the tabulated data. Whilst this is not significant for day-to-day application, it has been known to cause confusion, and even dispute, over e.g. whether software implementations of the standard are compliant. Non-definitive methods and pure component data on bases other than molar were therefore removed.

3.3. Additions to and removals from the second issue

3.3.1. Net calorific values

Net calorific values are now calculated directly from gross calorific values and the latent heat of water at the corresponding reference combustion temperature. In the second edition net molar calorific value was calculated as the weighted mean of the pure component net molar calorific values. Providing the latent heat of vaporisation of water at the reference combustion temperatures avoids the need for a large table of in excess of 50 components of pure component net calorific values.

3.3.2. Ideal gas calorific values

Calorific value of the real gas will continue to be assumed to be that of the ideal gas. The molar calorific value of a real gas differs slightly from that of the ideal gas by a very small amount. This difference is very small but because it is relatively constant, results in a very small bias in

the calculated properties. Various means of correcting for this difference were considered by WG18, including that of simply adding a single correction term (the so-called “enthalpic correction”) of +0.01 kJ/mole to the ideal gas molar calorific value. However, the working group decided that the enthalpic correction should continue to be ignored.

3.3.3. Net Wobbe index.

Wobbe index on a net calorific value basis has been included as an additional property in the third edition.

3.3.4. Component list

The component list has been reviewed. The range of hydrocarbons has been extended to those of carbon number 14 from the 10 of the second edition. Other components relevant to the gas industry were considered for removal (e.g. glycols, some common odorant species). Some components might be considered no longer relevant to a post towns-gas gas industry, but (especially with the increasing interests in non-conventional gas sources such as biomass gasification) the working group decided not to remove them.

3.3.5. Pure component compression factors.

Tabulations of pure component compression factors have been removed for the third edition (see summation factors in 3.1.2, above).

3.3.6. Uncertainty

The section on accuracy in the second edition has been removed and replaced with guidance on and equations for estimation of uncertainty in calculated properties in accordance with the Guide to the Expression of Uncertainty in Measurement (JCGM , 2008).

3.3.7. Examples

New examples have been written and example uncertainty calculations included. A spreadsheet implementing the property and uncertainty calculations has been produced and is available for download from ISO. The spreadsheet implements the calculations of the examples and is principally intended for software development purposes.

3.4. Changes to the structure and layout of the current issue

3.4.1. Format

The second edition is now over 20 years old and ISO’s current recommendations regarding formatting and layout have been implemented.

3.4.2. Technical report

All of the support and background material has been removed and placed in a new ISO technical report that the working group drafted in parallel with the main standard. This technical report was published in 2017 (ISO, 2017).

3.4.3. Component names

Component names have been aligned with current IUPAC recommendations.

4. Comparison of values of properties calculated according to the two editions

The changes in the values of properties calculated using the two editions show some, albeit relatively small, composition dependence. It is important therefore that, when evaluating impacts, changes are evaluated using gas compositions that are representative of the application under study.

For the purposes of this paper a composition set of compositions for the UK comprising over 22,000 compositions from a number of gas chromatographs located at exit points from the UK's National Transmission System (NTS).

All calculations were carried out at ISO reference conditions of 15°C (combustion), 15°C and 1.01325 bar (metering) for the real dry gas, unless stated otherwise.

Table 1 shows minimum, maximum and mean values for selected properties calculated according to the Second Edition for the UK dataset, together with minimum, maximum and mean differences when recalculated according to the Third Edition. All property values calculated according to the Third Edition differed only very slightly from that calculated according to the Second Edition. Mean differences for the real gas properties varied from around -0.014% to +0.001% of the mean value of property. With the exception of Wobbe index all differences were negative, i.e. all properties fall in value when recalculated according to the Third Edition. This is the case for all of the UK composition dataset, so the difference - albeit very small - results in a very small overall bias when calculating according to the Third Edition.

Table 1: Change in values of selected properties on adoption of the Third Edition for the UK gas composition dataset

	Gross CV MJ/m ³	Relative density	Wobbe index MJ/m ³	CEF(V) Kg CO ₂ /m ³
Property[1]:				
minimum	37.7634	0.5684	47.2449	1909.4708
mean	39.4790	0.6333	49.6134	2031.1255
maximum	41.3993	0.6794	51.2373	2161.7166
Change[2] in value:				
minimum	-0.0025	-0.0001	0.0001	-0.0366
mean	-0.0024	-0.0001	0.0003	-0.0276
maximum	-0.0023	-0.0001	0.0005	-0.0209
% change in value:				
minimum	-0.0063%	-0.0144%	0.0002%	-0.0018%
mean	-0.0061%	-0.0134%	0.0006%	-0.0014%
maximum	-0.0059%	-0.0120%	0.0009%	-0.0010%

Notes to Table 1:

1. Calculated according to Second Edition.
2. Third Edition minus Second Edition, i.e. a negative change indicates value decreases on adoption of Third Edition.

5. Impact of changes in the standard

The changes arising from the revised standard will impact principally in one of two ways:

- Firstly, the change in the values themselves, which are likely to be small and whose financial impact will vary with the amount of gas involved;
- Secondly, the fact that the standard has changed and any requirement (regulatory or commercial, implied or specific) to employ the latest version of the standard may require changes in hardware or software to be made.

In the latter case, the financial impact is fixed and does not depend on amount of gas involved. The nature of these two types of impact is discussed below.

5.1. Impact of the changes in property value

5.1.1. Data precision

The changes arising from adoption of the Third Edition, although relatively small, are still greater than the precision with which data is held and would be transferred through the “business cycle”:

- Typically, process gas chromatographs store calculated properties as 32-bit double precision IEEE floating point numbers, which typically have an accuracy of about seven digits ($\pm 1.234567E00$).
- Bespoke software employed in the UK stores data as floating point numbers.
- Transfer of data to Remote Telemetry Units is currently handled with floating point precision.

5.1.2. Calorific value

The principal purpose of calculating calorific value is in energy determination, either for gas sales or calculation of transportation revenue. Energy is calculated as the product of calorific value and volume at reference conditions.

The main impact in energy determined is through the change in determined calorific value¹. The change in calorific value for the UK dataset varied from -0.0063% to -0.0059% (mean -0.0061%). The impact of this change for different parties is assessed in Table 2 and summarised below.

¹ In principle the volume determined by orifice plate metering systems could also be affected by changes in the value of gas density at reference conditions if ISO 6976 were employed to calculate this property. Quite often density at reference conditions is calculated using the AGA 8 detail or gross characterisation methods (ISO 5167 does not specify how it should be determined).

Table 2: Illustrative financial impact of adoption of Third Edition of ISO 6976

		NTS Entry	NTS Exit	NTS Shrinkage	Consumers
gas price	p/kWh	1.2	8.5	1.2	8.5
Current situation:					
Energy throughput	Twh pa	1003.60	1000.00	3.60	1000.00
Value	£million pa	12043.20	85000.00	43.20	85000.00
3rd edition adopted at NTS entry					
Energy throughput	Twh pa	1003.54	1000.00	3.54	1000.00
Value	£million pa	12042.47	85000.00	42.47	85000.00
change	£million pa	-0.735	0.000	-0.735	0.000
3rd edition adopted at NTS exit					
Energy throughput	Twh pa	1003.60	999.94	3.66	999.94
Value	£million pa	12043.20	84994.81	43.93	84994.81
change	£million pa	0.000	-5.185	0.732	-5.185
3rd edition adopted at both:					
Energy throughput	Twh pa	1003.54	999.94	3.60	999.94
Value	£million pa	12042.47	84994.81	43.20	84994.81
change	£million pa	-0.735	-5.185	-0.003	-5.185

Assuming annual flows through the UK NTS in 2016 of around 959 TWh (National Grid), and annual NTS shrinkage of 3.6 TWh (National Grid), and wholesale and retail price of gas around 1.2 p/kWh (Ofgem) and 8.5 p/kWh (Ofgem) respectively,

- Gas producers' income would diminish by on average 0.0061%, equivalent to a total loss of around £0.735 million pa.
- Gas shippers' markup (expressed as the difference between retail and wholesale prices) would decrease by on average 0.0061%, collectively equivalent to around £4.45 million.
- Gas consumers' energy bills will decrease by on average 0.0061%, equivalent to a total decrease of around £5.185 million pa. Assuming an average domestic gas bill of around £1,100 (Ofgem) the change represents a decrease of around 6.7 pence pa.
- Assuming adoption at NTS entry and NTS exit, NTS shrinkage would be decreased by on average 0.0061%, Cost of shrinkage gas to the shrinkage provider would decrease by around £2,600 pa assuming a shrinkage gas cost of around 1.2p/kWh.
- Adoption at NTS exit only would cause NTS shrinkage (and hence shrinkage gas requirements) to increase from 3.6 to 3.66 TWh/y (or from around £43.20 million pa to

£43.93 million pa, an increase of £0.73 million pa). Adoption at NTS entry only would cause cost of NTS shrinkage to decrease by around £0.735 million pa.

- Daily Flow Weighted Average Calorific Value and LDZ energies would decrease on average by 0.0061%. For the Gas Distribution Price Control Review for 2008-2013, the volume driver (the adjustment to the allowed income of a Gas Distribution Network according to the amount of gas transported) was removed by Ofgem and hence the change in LDZ energy would have no impact in transportation charges.

5.1.3. Relative density

Relative density is generally not directly used in the UK natural gas industry and indirectly used in calculation of Wobbe index (see below).

5.1.4. Wobbe index

Wobbe index is employed in two main ways: as a means of characterising the energy delivered by a gas burner operating with a constant orifice and constant upstream conditions, and also as an important parameter for assessing the combustion characteristics of natural gas. The Gas Safety (Management) Regulations 1996 require Wobbe index of gas conveyed in networks to be between 51.41 and 47.20 MJ/m³ under normal conditions. In addition the GSMR specify that Incomplete Combustion Factor and Sooting Index must be no more than 0.48 and 0.60 respectively. ICF is calculated from a function in Wobbe index and composition. SI is calculated from a function in composition.

The change in Wobbe index for the 2004 dataset varied from +0.0002% to +0.0009% (mean +0.0006%). In the context of compliance with the requirements of the Gas Safety (Management) Regulations, the magnitude of this change is much smaller than the measurement uncertainty of typical measurement systems based on gas chromatography and can be considered to be not significant. (But see the following section on regulatory changes.)

5.2. Impact of the publication of a new edition

Standards are often referred to in either legislation or in commercial contracts and specifications and when new editions are published the impact may require revision of regulations, specifications or contracts. This leads to the immediate problem of potential requirement for changes in the regulatory or commercial framework.

5.2.1. Impact on the regulatory framework

The legislative areas of consideration in the context of ISO 6976 is that of the Gas Act and Gas (Calculation of Thermal Energy) Regulations (GCOTER), and that of the Health and Safety at Work Etc. Act and the Gas Safety (Management) Regulations (GSMR),

5.2.2. The Gas Act and the Gas (Calculation of Thermal Energy) Regulations

Neither makes specific reference to ISO 6976, but Regulations 6 a), 6b) and 6c) give power for Ofgem to direct gas transporters to determine calorific value. The mechanism for such direction is through a Letter of Direction to the gas transporter, which requires the use of approved instrumentation for such determinations and a Letter of Approval for the particular calorific value determination device is issued by Ofgem. The Letters of Approval for Danalyzers requires that physical constants and data from the Second Edition be used.

If the industry wished to adopt the calculation method of the Third Edition, then the Letters of Approval for existing and any new equipment would require alteration.

The GCOTER and Letters of Direction require that (in effect) daily average calorific values determined are rounded to the nearest 0.1 MJ/m³. As a result, daily average calorific values calculated using either the Second or Third Edition would be identical except when the fractional part of calorific value determined according to the Second Edition were between 0.050 and 0.052 MJ/m³. In such a situation daily average calorific values calculated according to the Third Edition would be rounded up, whereas those calculated according to the Second Edition would have been rounded down.

In the regulatory framework of the UK gas industry therefore, instead of a very small change in all determined calorific values a very small number of more significant changes (of 0.1 MJ/m³) would arise. Rounding to the nearest 0.1 MJ/m³ to data with an offset of 0.002 MJ/m³ would be expected² to give a non-zero (0.1 MJ/m³) difference to 2% of the data. This was verified by applying rounding to the gas composition dataset, which gave a non-zero difference for 463 of the 22636 value (2.05%). (Although in practice it would be the set of end-of day averages for each LDZ that would be rounded, the principle is the same; a non-zero (0.1 MJ/m³) difference to 2% of the data.)

The GCOTER require that consumers are billed on the basis of the average of daily charging area calorific values (i.e. the FWACVs) calculated for the billing period (typically 13 weeks). Regulation 3(2) requires that the average charging area calorific value is truncated to 0.1 MJ/m³, and not rounded, however. Again this would mean³ that a small (around 2%) number of charging period calorific values would be decreased by 0.1 MJ/m³ if the Third Edition were adopted.

Over a period of time the overall impact in energy billing would in practice be no different to that highlighted earlier.

5.2.3. The Health and Safety at Work Act and GSMR.

The GSMR sets limits in Wobbe index and ICF but, whilst it specifies how ICF shall be calculated from Wobbe index, it does not specify how Wobbe index is calculated. The Guide to the GSMR (HSE) suggests that real gross Wobbe index (and the ICF since it is a function of Wobbe index) is calculated by the methods of the Second Edition. Adoption of the methods of the Third Edition would therefore not require change in the GSMR.

In terms of compliance of gases with the requirements of GSMR, the change resulting from adoption of the Third Edition would result in gas currently considered to have Wobbe index too high (albeit by a very small amount) to be deemed acceptable under the current regime, and gas currently considered acceptable to be deemed unacceptable because of low Wobbe index. This could be rectified (almost) completely by application of a single offset of 0.002 to the

² Consider 100 calorific values expressed to 3 dp, ranging from 37.000 to 37.099. Applying an offset of -0.002 would result in an additional two values (37.051 and 37.052) being rounded down to 37.0 instead of being rounded up to 37.1.

³ Consider the same 100 calorific values. Applying the same offset would result in two additional values (37.000 and 37.001) being truncated to 36.9 instead of 37.0.

Wobbe index limits and a revision of the relationship between ICF and Wobbe index. However, in view of the very small magnitude of the offset and the relatively large scatter in the actual experimental data points in the data used by Dutton in defining the original principles upon which the current GSMR limits are based, it could be argued that this would be unnecessarily complicated and unwarranted.

5.2.4. The EU-ETS

The EU ETS is a trading scheme aimed at reducing the European Union's emissions of manmade greenhouse gases. The scheme works by putting a limit on overall emissions from installations covered by the scheme, which is reduced each year. Within this limit, companies can buy and sell emission allowances as needed.

Emitters of greenhouse gases calculate their emissions by use of a various factors and for natural gas combustion systems this is generally the product of an emissions factor and an activity factor. For combustion of gaseous fuels emitters are permitted to calculate their emissions using a volume-based carbon dioxide emissions factor, the CEF(V) and the annual quantity of natural gas combusted. CEF(V) (typical units kg CO₂/m³) for natural gas is calculated from its composition – typically by division of the molar based CEF(M) (typical units kg CO₂/kmol) by the molar volume (typical units m³/kmol). Table 1 shows that adoption of the Third Edition would result in a change in CEF(V) of between -0.0018 % and 0.0010 % (average -0.0014 %). Adoption of the Third Edition in principle would therefore result in a very small under-reporting of carbon dioxide emissions by an individual emitter. However, allocation of allowances by National governments is based on an overall national emissions commitment that were decided on the basis of carbon dioxide emission factors for natural gas based on the Second Edition of ISO 6976. At the EU level, National Agreements were also made on the same basis. The magnitude of the under-reporting very small and could be argued that this would be unnecessarily complicated and unwarranted.

The European framework covering the EU-ETS, Directive 2003/87/EC, and the monitoring and reporting regulations, EU No 601/2012, require that suitable EN or ISO standards are employed when calculating emission factors from composition, but do not specify a particular standard or edition. In the UK, the Guidance Document for Installations issued jointly by the Environment Agency, the Department for Business, Energy and Industrial Strategy, National Resources Wales, the Northern Ireland Environment Agency and The Scottish Environmental Protection Agency (UK, 2017) does suggest by example that net calorific value (also reportable) is calculated according to the Third Edition.

5.3. Impact on equipment and systems

Adoption of the Third Edition by the gas industry would require any software or firmware implementing ISO 6976 to be modified. A list of such software/firmware is provided below:

- **Calorific Value Determination Devices.** In the UK the calorific values employed throughout the regulatory framework for billing are those calculated within the software of process chromatographs that are used for calorific value determination. Revision of such software is likely to be subject to approval by Ofgem at an estimated cost of £10,000. The vendors of process chromatographs would also need to develop appropriate software updates to conform to the Third Edition, which may add additional costs and development time. Implementation of software at all measurement sites

would be required and this is estimated to cost around of £5,000 per Gas Distribution Network. Before software implementation could be carried out generic risk assessment would be required by the Gas Distribution Networks at an estimated cost of £5,000 per Distribution Network.

- Process chromatographs are also located at all NTS entry points for compliance monitoring against the GSMR and Network Entry Agreements. All property calculations are calculated by a single software module for comparison with Network Entry Agreement limit values. Gross calorific value, Wobbe index, Sooting Index and Incomplete Combustion Factor are the properties calculated from composition using ISO 6976 methodology. It may be possible to software implementation during scheduled maintenance in order to limit cost; a non-scheduled site visit to implement the new software or to carry out site specific validation tests may incur charges. Again, generic risk assessment of the changes would need to be assessed at an estimated cost of £5,000.
- Management Information Systems. The Gas Distribution Networks and National Grid employ management information systems that generally receive and store property values calculated elsewhere, but some gas property calculations are performed within the design options of these systems for orifice flow calculations. To be fully compliant, therefore, such systems would require updating. Cost of implementation is estimated to be around £10,000 per Distribution Network.
- Flow computers. At NTS exit/LDZ entry, flow computers determine energy through integration of energy flow, which in turn is determined from volumetric flow and calorific value. The calorific value is provided from the process chromatograph and not calculated by the flow computer. However, flow computers at NTS entry may compute calorific values from gas composition in order to determine energy.

6. Conclusions

- a) The changes in calculated properties arising from revision of ISO 6976 are likely to be relatively very small. For typical UK gases, calorific value will be smaller by around 0.0061%, relative density smaller by around 0.0134%, Wobbe index will be larger by about 0.0006%.
- b) The annual energy determined to have been transported through the UK gas Transportation and Distribution would decrease by around 0.06 TWh, equivalent to around £0.735 million at a gas price of 8.5p/kWh.
- c) NTS shrinkage gas requirements would decrease by around 0.006%, equivalent to £2,600 pa, provided that the Third Edition was adopted uniformly. Adoption solely at NTS exit points would increase shrinkage gas requirements by £0.73 million pa.
- d) The wording of the legal and regulatory framework regarding calculation of thermal energy regarding rounding and truncation of calorific values would lead to a small number of values being changed by 0.1 MJ/m³, rather than all calorific values changing by around 0.002 MJ/m³. Overall (i.e. over time) the impact would be the same, however.
- e) A variety of software or firmware is employed within the gas industry and would have to be modified if the industry were to adopt the standard. The estimated cost of adoption across the NTS and the distribution systems is around £150,000.

- f) Neither the Gas Act nor the Gas (Calculation of Thermal Energy) Regulations makes specific mention of ISO 6976 and would not therefore require modification in order to adopt the Third Edition. A minor change would be required in the wording of Letters of Approval for calorific value determination devices based on calculation from composition.
- g) The Guide to the Gas Safety (Management) Regulations specifies that Wobbe index is calculated according to the Second Edition of ISO 6976. However, the GSMR themselves do not specify how Wobbe index should be calculated. Adoption of the Third Edition by the industry would not require modification of Schedule 3 but formal agreement with the HSE is recommended
- h) In principle, reported emissions of carbon dioxide from combustion of natural gas would fall by around 0.0014% if all emitters adopted the Third Edition.

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