TITLE: A key step on the pathway to Net Zero emissions - EVIDENCE REPORT

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COMMENTARY:
This document has to be read in conjunction with:

- IGEM’s Governance of Industry Recognised Standards – Gas Quality

Comments are required by 30th July 2020, and in accordance with the attached Comment Reply Form, forwarded via email to joanne@igem.org.uk
A Proposed New IGEM Gas Quality Standard –
A Key Step on the Pathway to Net Zero
Emissions

UPDATED EVIDENCE REPORT

Report prepared for Institution of Gas Engineers and Managers – Gas
Quality Working Group

April 2020

0. Preamble

The Institution of Gas Engineers and Managers (IGEM) is the professional engineering institution for the
gas industry. The Institution writes and publishes technical standards by working with stakeholders and
experts to inform and influence current and future gas and energy policy.

The Gas Quality Working Group was formed to propose a standard covering the UK gas quality
specification in support of duty holders required to demonstrate compliance with the Gas Safety
(Management) Regulations, GS(M)R. This standard has been produced against a background of
decaying gas supplies from the North Sea, increasing reliance on imported supplies, both via
interconnector and LNG, and the need to decarbonise the gas networks.

This consultation document explains the proposed changes to the gas specification and provides
references to the supporting technical evidence. The proposed IGEM standard will be a dynamic
framework for changes in gas quality but the enduring safety of domestic consumers will be paramount;
the HSE will continue to veto any proposals that could compromise safety. The current proposals are:

- To widen the Wobbe Index range to the existing emergency limits
- To extend the current GS(M)R class exemptions for oxygen in biomethane to a general 1 mol% oxygen limit at ≤38 barg for all gas sources
- To simplify the GS(M)R interchangeability diagram with limits on Wobbe Index and relative
density only
- To move GS(M)R Schedule 3 into a new IGEM standard to create a framework for future changes

Throughout this document, Wobbe Index and relative density are quoted at UK metric standard
conditions of 15 °C and 101.325 kPa.

The Gas Quality Working Group recognises the wide support for incorporation of hydrogen into the new
standard and that hydrogen is likely to have an important role in the decarbonisation of the gas network.
At this time, the new standard will not include changes to hydrogen in the gas quality specification,
rather provide a dynamic means and framework for this addition as the evidence is finalised. Throughout
this consultation document, commentary on how this proposed specification may affect future hydrogen
and hydrogen blended gas supplies is included under separate hydrogen sub-headings.

Comments from all stakeholders on this consultation document are invited using the accompanying IGEM
form.

1 This consultation document was written by DNV GL in full consultation with the IGEM Gas Quality Working Group

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1. About this consultation document

This report presents the evidence for a new gas quality standard for the UK:

- Section 2 describes the work of the Gas Quality Working Group, which has carried out an extensive review over the last three years to develop a new gas quality standard.
- Section 3 sets out why a new gas quality standard is needed to help secure the UK’s gas supplies, decarbonise the gas network and to ensure the continued high standards of safety for gas consumers.
- Section 4 presents a summary of the changes being proposed for the new gas quality standard, and the benefits of each one.
- Section 5 describes the ranges, regional variability and rates if change of gas quality in the networks now.
- Sections 6 to 9 present the detailed safety evidence for each change.
- Section 10 presents the IGEM governance process, the timeline and the next steps for the proposed changes.

This report is being published alongside an evidence pack supplied by IGEM and the proposed GS(M)R standard. The work was jointly supported by SGN (lead network), Cadent, National Grid Gas, Northern Gas Networks and Wales and West Utilities using funding from the Ofgem Network Innovation Allowance scheme. These five gas network operators are collaborating under the Energy Network Association Gas Goes Green programme to tackle climate change by creating the world’s first net-zero emissions gas grid.

1.1 Abbreviations

ATEX ATmosphères EXplosives (EU Directives for equipment in explosive atmospheres)
BEIS Department for Business, Energy and Industrial Strategy
BSI British Standards Institution
CEN Comité Européen de Normalisation
CCS Carbon Capture and Storage
CO Carbon monoxide
DSEAR Dangerous Substances and Explosive Atmospheres Regulations
GS(M)R Gas Safety (Management) Regulations
HSE Health and Safety Executive
ICF Incomplete Combustion Factor
IGEM Institution of Gas Engineers and Managers
LNG Liquified Natural Gas
MER Maximising Economic Recovery
MERGE Modelling and Experimental Research into Gas Explosions
NEA Network Entry Agreement
OFGEM Office for Gas and Electricity Markets
RD Relative density
SI Sooting Index
SIU Statutory (also Scottish) Independent Undertakings
UKCS United Kingdom Continental Shelf

2. About the Gas Quality Working Group

2.1 Aim

The Gas Quality Working Group is led by the Institution of Gas Engineers and Managers (IGEM). Its aim has been to develop a new IGEM gas quality standard to replace Schedule 3 of the (GS(M)R). The proposed new IGEM standard would ensure the gas networks have access to diversified sources of gas to
enhance security of supply, whilst continuing to deliver gas to customers safely and efficiently, to support deep decarbonisation through biogases and hydrogen. It would achieve this by:

- Accessing diverse gas resources from across the North Sea including both UKCS and the Norwegian sector;
- Enabling cost efficient LNG imports;
- Helping to secure UK gas supplies from domestic and imported sources;
- Reducing gas processing emissions;
- Being complemented in the near future by a hydrogen quality standard, to allow hydrogen to be blended, without additional legislation.

It is important to remember that the GS(M)R are primarily intended to ensure the safety of the public and Schedule 3 of the Regulations is the baseline for the changes. Safety will continue to be the primary aim of the proposed new gas quality standard.

This document and the accompanying draft standard incorporate the results of detailed debates and recommendations from the Working Group. The draft IGEM standard has been unanimously approved by the Working Group for issue to industry consultation. The Working Group will consider the consultation responses to enable IGEM to finalise the standard. A UK Government consultation will be led by the HSE prior to a Parliamentary process to effect the legislative change.

2.2 Composition

The IGEM Gas Quality Working Group was formed in June 2016 and meets regularly; the membership includes:

- Ancala Midstream
- Association of Manufacturers and Suppliers of Power Generating Systems, AMPS
- Department for Business, Energy and Industrial Strategy, BEIS
- British Standards Institute, BSI
- Cadent
- Commission for Regulation of Utilities in Ireland, CRU
- Dave Lander Consulting
- DNV GL
- Energy UK
- Gas Networks Ireland, GNI
- Grain LNG representing UK LNG import terminals
- Heating and Hot Water Industry Council, HHIC
- Health and Safety Executive, HSE
- Kiwa Gastec
- The Industrial and Commercial Energy Association, ICOM
- National Grid Gas Transmission
- National Physical Laboratory, NPL
- Neptune Energy
- Northern Gas Networks
- Oil and Gas UK
- Progressive Energy
- SGN
- Wales and West Utilities

2.3 Evidence gathering and stakeholder engagement

The gas quality specified for the UK should be underpinned by relevant, up-to-date, safety evidence. The Working Group has carried out an extensive evidence gathering exercise over three years. The trade bodies represented on the Working Group have also shared output from the Working Group with their members and provided regular feedback.
The evidence gathering and stakeholder engagement has been supported by practical projects to test wider gas quality parameters with domestic and industrial customers, including, but not limited to:

- The Opening up the Gas Market (Oban)\(^4\) and the Statutory Independent Undertakings (SIU) Gas Quality projects\(^5\) which have gained consumer acceptance by testing, demonstrating and rolling out a wider range of gas quality to about 8000 domestic and small commercial customers
- The Industrial and Commercial Gas Quality\(^6\) project which engaged widely with large gas users including power generators, manufacturers of combustion equipment, storage operators and industrials
- Academic journals that published the original interchangeability work by Dutton\(^7\)
- The Gas Safety (Management) Regulations Review carried out by the Energy Networks Association\(^8\)
- The 2019 study on the impact of low Wobbe Index gases on consumer appliances\(^9\)
- The Pathways to Net-Zero\(^10\) report which was academically reviewed by Imperial College London

A more complete (but not exhaustive) list of innovation projects undertaken by the gas transporters is shown in Appendix A.

3. The reasons for a new gas quality standard

The current Schedule 3 of GS(M)R needs to be replaced to reflect current gas quality and the changing needs and sources of gas supply to the UK market. Decarbonising the gas system is essential to meeting net zero, and a new gas quality standard is essential for decarbonising the gas system. The standard will also ensure security of supply from the North Sea, LNG imports and continental Europe via interconnectors and that future gas supplies continue to be as safe as they are now.

3.1 Importance of the gas system

The gas system is central to the UK’s current and future energy supply. The Committee on Climate Change\(^11\) has recognised that gas will be an important part of the energy mix to achieve net zero emissions by 2050. There are over 280,000 km of gas pipelines transporting gas to over 20 million customers across the country, including:

- Heating 84% of homes.\(^12\)

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\(^4\) SGN’s Opening up the Gas Market is a Network Innovation Competition project. Further information: [https://www.sgn.co.uk/about-us/more-than-pipes/investing-in-innovation/oban-project](https://www.sgn.co.uk/about-us/more-than-pipes/investing-in-innovation/oban-project) (last accessed 22 Jan 2020)

\(^5\) SGN SIU Gas Quality report June 2017

\(^6\) DNV GL Report 1166BGP7-07 Applied Research into the Effects of a Wider Gas Wobbe Index Range - Phase Two Report 2018

\(^7\) Dutton, BC A new dimension to gas interchangeability. The Institution of Gas Engineers communication 1246 1984


\(^9\) DNV GL report 10158808 Gas Quality – Low Wobbe Index Study for Neptune Energy. Dec 2019


• Meeting over 40% of the UK’s industrial energy demand

Overall, the gas system supplies 2½ times more energy than the electricity system throughout the year, and around four times more at peak hourly periods, such as cold winter evenings. It is also a key enabler to the necessary growth of variable renewables – gas-fired power plants can ramp up or down quickly depending on the level of wind generation and, if downstream renewable hybrid-heating systems are rolled out, gas boilers will be needed to provide heat on the coldest days or during periods of higher electricity demand.

Fuel poverty and industrial competitiveness are also key considerations:

• A household in England is 50% more likely to be in fuel poverty if it does not have a gas grid connection, and in Scotland, a household is almost twice as likely to be in fuel poverty if it is off the gas grid.

• Including all taxes and levies, the UK currently has the second most expensive electricity prices but amongst the cheapest gas prices in Europe for the largest industrial users. For these larger consumers, the cost of energy is more likely to affect competitiveness.

3.2 Securing gas supplies

Natural gas and the gas network play a critical role in the UK’s energy security. The UK has a commitment to Maximising Economic Recovery (MER) of oil and gas from the UK Continental Shelf (UKCS) and, as UK domestic production declines over time, liquified natural gas (LNG) and interconnector imports are likely to increase. For both domestic and imported gas sources, reducing the need for processing may be reflected in a decrease in wholesale gas prices and help to secure UK supplies. The current Schedule 3 of GS(M)R does not allow some gases to be admitted without additional processing; examples are some LNG cargos which require the addition of nitrogen and some UKCS Wobbe Index gases which require additional removal of nitrogen or carbon dioxide.

3.3 Decarbonising the network

Given the importance of the gas system, it needs to be decarbonised to help meet net zero emissions.

The gas network can be decarbonised by continuing to inject and promote biomethane (and other biogases) in place of natural gas by incorporating current HSE oxygen exemptions into the standard:

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16 Dr Grant Wilson, University of Birmingham, Multi-vector energy diagram Great Britain - daily resolution: Data from: October 2014 to early March 2019 https://www.researchgate.net/project/multi-vector-energy-analytics

17 In England, 10.4% of households with a gas grid connection are fuel poor, compared with 15.5% of households without a gas grid connection. BEIS, Fuel poverty statistics: Detailed tables 2016, Published June 2018, Table 10 https://www.gov.uk/government/statistics/fuel-poverty-detailed-tables-2016 (last accessed 20 Feb 2020)

18 In Scotland, 22% of households on the gas grid are fuel poor, compared with 38% of households off the gas grid. Scottish house condition survey: 2017, Table 36 https://www.gov.scot/publications/scottish-house-condition-survey-2017-key-findings/pages/6/ (last accessed 20 Feb 2020)

19 NB: prices compared for all bands above 20,000 MWh for electricity and 1,000 GJ for gas. Eurostat, Electricity prices for non-household consumers, Gas prices for non-household consumers, latest data for H1 2018 https://ec.europa.eu/eurostat/data/database?node_code=nrg_pc_205# (last accessed 20 Feb 2020)

• Biomethane can be used as a direct replacement for natural gas and is already being blended into the network at 94 locations across the UK, with nearly 10 TWh injected to date.\textsuperscript{21, 22}

Reducing natural gas processing, as highlighted above, and the associated emissions is also an important step.

Decarbonised gas can help to tackle the harder-to-decarbonise sectors. Since 1990, the UK has reduced emissions from electricity by 64%, but it has only reduced emissions from homes by 16%, and emissions from transport are just 2% lower than 30 years ago.\textsuperscript{23} At the same time, some of the UK’s manufacturing has moved to other countries, and so the emissions from these factories are now counted elsewhere; per person, the UK’s net carbon imports are amongst the highest in the world, and the UK imports around 80 million tonnes of carbon dioxide a year from China alone:\textsuperscript{24}

**Hydrogen**

The gas network could also be decarbonised through injecting hydrogen, either to replace natural gas completely or as a blend with natural gas. Natural gas will still be used for some time to come – indeed, it may be a critical feedstock for hydrogen production and flexible low carbon power, if carbon capture and storage (CCS) is developed:

• Subject to the ongoing HyDeploy trials\textsuperscript{25}, the ambition is that hydrogen could be blended up to 20% without changing domestic appliances. The BEIS Hy4Heat\textsuperscript{26}, the H21\textsuperscript{27} and H100\textsuperscript{28} programmes are also assessing the evidence for 100% hydrogen networks and the development of new hydrogen appliances.

• For homes, a combination of biomethane, hydrogen blends, 100% hydrogen, and hybrid systems (where a gas or hydrogen boiler provides heating on the coldest days) offers an effective way to decarbonise without large disruption.

• For transport, biomethane is already being used in trucks and buses, and hydrogen is an attractive zero-emission option for trains, buses, trucks and ships.

• For manufacturing, hydrogen could replace natural gas as a heat source and/or feedstock for some industrial processes.

• For power generation, natural gas with CCS and hydrogen could provide flexible clean power to support the growth of variable renewables. Biomethane with CCS would provide negative emissions, which are critical to meeting net zero in practice.

\textsuperscript{21} SGN’s *Opening up the Gas Market* is a Network Innovation Competition project. Further information: [https://www.sgn.co.uk/Oban/](https://www.sgn.co.uk/Oban/) (last accessed 20 Feb 2020)

\textsuperscript{22} Biomethane is often enriched with propane to standardise the calorific value of the gas and not to meet the GS(M)R gas quality specification. Cadent’s *Future Billing Methodology* project is investigating ways to eliminate the need for propanation by developing a new billing regime. See [https://futurebillingmethodology.com/](https://futurebillingmethodology.com/) (last accessed 20 Feb 2020)


\textsuperscript{25} HyDeploy project, see [https://hydeploy.co.uk/](https://hydeploy.co.uk/) (last accessed 20 Feb 2020)

\textsuperscript{26} Hy4Heat programme, see [https://www.hy4heat.info/](https://www.hy4heat.info/) (last accessed 20 Feb 2020)

\textsuperscript{27} H21 project, see [https://www.h21.green/](https://www.h21.green/) (last accessed 20 Feb 2020)

\textsuperscript{28} H100 project, see [https://sgn.co.uk/about-us/future-of-gas/hydrogen/hydrogen-100](https://sgn.co.uk/about-us/future-of-gas/hydrogen/hydrogen-100) (last accessed 20 Feb 2020)
3.4 The importance of gas quality

Unlike electrons, which are the same whatever the generation source, the molecules that travel through a gas network could impact the pipelines, network equipment and downstream users. Gas quality is therefore kept within a strict range to ensure the safe and efficient operation of the gas network and the appliances and industrial/power generation equipment used by consumers. This should only be changed if there is accompanying safety evidence.

Schedule 3 of GS(M)R – overseen by the Health and Safety Executive – governs the parameters of gases that are permitted in the network and these are summarised in section 4.6. Some of these parameters, for example the Incomplete Combustion Factor and the Sooting Index, are not relevant for the safety of domestic appliances available today. The Sooting Index was never a safety issue as it was intended to limit soot deposition in decorative gas fires. Exemptions from Schedule 3 of GS(M)R for oxygen concentration have been granted in the past to facilitate the injection of biomethane into the gas network, which has been successful, with 94 plants connected to the grid, injecting almost 10 TWh to date. The GS(M)R set out the current limits, in normal and emergency conditions, on sulphur-containing compounds, hydrogen, oxygen, impurities, liquid content and three combustion parameters – Wobbe Index, Incomplete Combustion Factor and Sooting Index.

3.5 A new gas quality standard

The existing gas quality specification is linked to work carried out in the 1970s and 1980s and has not changed since. The proposed transfer of the standard to IGEM will allow the gas quality specification to be kept up to date during the current period of energy transition to net zero emissions.

A broader gas quality change is needed for current gas quality challenges and to facilitate the safe injection of a wider range of gases into the network without costly and emissions-intensive processing. The proposed gas quality standard will help to secure UK gas supplies from:

- UKCS
- Norwegian sectors of the North Sea
- LNG imports
- Interconnector imports

and facilitate deep decarbonisation by:

- Reducing processing emissions
- Promoting biomethane and other biogases by incorporating the HSE oxygen exemption
- Efficiently enabling a quality standard that allows hydrogen to be blended in the near future without additional legislation.

4. Summary of recommended changes

Through its detailed analysis and stakeholder engagement, the Gas Quality Working Group has gathered the safety and other evidence for four key proposed changes:

(i) Widening the Wobbe Index range by decreasing the lower limit and increasing the upper limit:

- Decreasing the lower Wobbe Index limit from ≥47.2 MJ/m$^3$ to ≥46.5 MJ/m$^3$
- Increasing the upper Wobbe Index limit from ≤51.41 MJ/m$^3$ to ≤52.85 MJ/m$^3$

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• Removing the upper and lower emergency limits as these will become the normal limits

(ii) Extending the current GS(M)R class exemptions for oxygen in biomethane to a general 1 mol% oxygen limit at network pressures ≤38 barg for all gas sources

(iii) Simplifying the GS(M)R interchangeability diagram to a Wobbe Index range of 46.5 to 52.85 MJ/m³ and a maximum relative density of 0.700. The current equivalent composition, incomplete combustion, lift index and sooting index limits will be removed.

(iv) Incorporating the above changes and moving GS(M)R Schedule 3 into a new IGEM standard creates a framework for future changes

Throughout this document, Wobbe Index and relative density are quoted at UK metric standard conditions of 15 °C and 101.325 kPa.

4.1 Widening the Wobbe Index Range

Description

Natural gas is a mixture of many different components that can be present in an infinite number of combinations. Wobbe Index is a measure of the interchangeability of different natural gases during combustion. The majority of domestic consumers have appliances with burners that have fixed aeration and the gas supply must suit the burner. Many large industrial consumers have control systems that allow burners and combustion process to suit the gas supply. Therefore, to protect domestic consumers the GS(M)R specify a range of Wobbe Index that is safe to burn in the population of domestic appliances in Great Britain.

The current GS(M)R has a Wobbe Index range for normal and emergency supply conditions. This proposal removes the current emergency supply specification and extends the normal range to the emergency range. A body of evidence is available to demonstrate that the extended range is no less safe for consumers than the current range. A summary of the proposed changes is shown in Figure 1.

![Widening the Wobbe Index](image)

**Figure 1 Summary of proposed changes to the Wobbe Index Range**

Future changes to the upper emergency limit are to be determined by HSE consultation with the Network Emergency Coordinator.

Benefits

Firstly, widening the Wobbe Index at the higher end will allow higher Wobbe Index LNG to be injected into the network with less need to ballast with nitrogen:
• LNG arriving at Grain LNG is associated with emissions from the ballasting process of 0.46 gCO₂e/MJ. ³² The conversion factor is 3.6 MJ per kWh. ³³

• In 2018, net LNG imports to the UK (i.e. those LNG imports that needed ballasting to enter the grid) were just over 76 TWh ³⁴, which equates to 274,590,000,000 MJ. Taking the average emissions from ballasting highlighted above, we estimate UK LNG imports in 2018 required ballasting and just over 126,000 tonnes of CO₂ equivalent were emitted.

• Richer Norwegian gas, which could be delivered to St Fergus gas terminal, would currently require additional nitrogen ballasting with associated increased energy, capital and operating costs, potentially making such developments uneconomic.

These emissions would be substantially reduced if the Wobbe Index were raised³⁵. As LNG becomes more important as a source of UK gas supply, the emissions savings from a higher Wobbe Index will correspondingly increase.

Secondly, reducing the Wobbe Index at the lower end will allow more lower Wobbe Index gas from across the UKCS to be injected into the network without needing to be blended, or without the additional emissions from processing.

By reducing the need for gas processing, widening the Wobbe Index at both ends will reduce the cost of securing current and future North Sea and imported LNG gas supplies, reduce emissions associated with gas processing and promote the injection of hydrogen which lowers Wobbe Index.

Hydrogen

As the addition of hydrogen reduces the Wobbe Index of a natural gas, a new approach will be required for industrial hubs committed to supplying a specific hydrogen blend. A minimum Wobbe Index above the lower limit will need to be quoted in supply contracts. However, this is outside the scope of the new gas quality specification and would be necessary irrespective of whether the proposed gas quality changes are implemented.

4.2 An oxygen limit of 1 mol%

Description

The current oxygen limit of 0.2 mol% is a historical North Sea gas concentration rather than a risk-assessed value. In 2013, the HSE granted a class exemption from GS(M)R³⁶ to allow network conveyance of gas with an oxygen content ≤ 1% (molar) at pressures up to 38 bar. This means that gas conveyors no longer need to request bespoke exemptions to GS(M)R where:

• Pipes used to convey gas with an oxygen content up to and including 1 mol% are operated at pressures below 38 barg; and,
• The gas conveyed complies with all other requirements and prohibitions imposed by regulation 8(1) of the GS(M)R.

³² Energy Technologies Institute, Gas Energy System Well to Motion Modelling for Heavy Duty Vehicles, 2015, Table 5  
https://www.eti.co.uk/search?size=10&from=08_type=all&publicOnly=false&q=Gas+Energy+System+Well+to+Motion+Modelling+For+Heavy+Duty+Vehicles (Last accessed 02 Feb 2020 – download “Final Model Report”)


³⁴ BEIS, DUKES 2019, Table 4.5  

³⁵ It is worth noting that 90% or more of the world’s LNG cargoes would fit within the proposed higher Wobbe limit of 52.85 MJ/m³. Only Australia and Nigeria export even higher Wobbe gas, but these cargoes tend go to the Asian markets. Further information is available from The International Group of Liquefied Natural Gas Importers (GIIGNL)  

Benefits

Biomethane is typically produced with an oxygen content above the 0.2 mol% specified in Schedule 3 of GS(M)R and it is not necessary, from a safety perspective, to reduce the content further. However, it does not necessarily follow that higher oxygen concentrations pose any increased safety risk. Currently, gas networks benefit from GS(M)R class exemptions to permit higher oxygen levels to facilitate biomethane injection. This has been successful, with 94 plants connected to the grid, injecting almost 10 TWh to date.

The class exemption for oxygen has had the same effect as an amendment to GS(M)R by removing a regulatory barrier to the production of low carbon biomethane and it has been in place for a considerable time. To recognise and facilitate the growing role of biomethane, a general oxygen limit of 1 mol% for the lower pressure tiers of the network (≤38 barg) would provide a clear nationwide standard.

Biomethane can also play a vital role in delivering net zero emissions. The recent pathways study for the Energy Networks Association concluded that 57 TWh per annum of biomethane from anaerobic digestion could be injected into the network by 2050, with an even larger potential for biomethane from thermal gasification.

4.3 Relative Density

Description

It is proposed that the maximum relative density for the new gas quality specification should be 0.700. There will be no minimum relative density limit.

The relative density of a gas is calculated from the gas composition and it is quoted at metric standard conditions of 15 °C and 101.325 kPa. The Wobbe Index, calorific value and relative density are all measures of gas quality and they are related by the following simple relationship:

\[
Wobbe\ Index = \frac{Calorific\ value}{\sqrt{Relative\ density}}
\]

The use of relative density has also been suggested by EASEE-Gas, supported by Marcogaz and implemented by CEN as part of a European gas specification that has been adopted as a British Standard. A plot of Wobbe Index versus relative density is shown in Figure 2 for gases distributed in Great Britain in 2019. The plot shows the ranges of gas quality experienced by each of the 13 local distribution zones. All gases had a relative density ≤0.700 which demonstrates that the limit is a practical and useful measure for existing gas qualities across the current allowable range of Wobbe Index.

The greatest range of relative density was found in Wales South and South West which received two distinct supplies of gas. When the LNG terminals at Dragon and South Hook were exporting to the grid, the National Transmission System moved gas through South Wales to the demands in the Midlands and South West England. When the market for LNG was less favourable, natural gas from Bacton, which has a higher relative density, flowed in the opposite direction to fulfil demand in South Wales.

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37 Biomethane – Oxygen Content Assessment Penspen report for Gas Networks Ireland 17985-A1-RPT-001 June 2018
42 EN 16726 Gas infrastructure – Quality of gas – Group H
The range of gas quality delivered to each geographical area varies from year to year and depends on an interplay between gas demand and the local and international commercial market for gas supplied from indigenous sources, LNG and the interconnectors with Europe and Ireland.

Figure 2  A plot of the ranges of Wobbe Index against relative density for gases transported by the National Transmission System in 2019. The results are shown geographically by Local Distribution Zones.
Benefits

The original interchangeability diagram has served the industry well, however, it was based on results from gas appliances that are no longer widely used – this is discussed further in section 6 below. Relative density is proposed to replace the equivalent composition on the horizontal axis of the interchangeability diagram. It is proposed that the sooting index and incomplete combustion factor will also be removed from the gas quality specification. The safety of domestic gas consumers will be maintained by the combined limits on relative density and Wobbe Index.

Relative density is already used in gas quality specifications by many European countries, it is simple to calculate, widely understood and well defined by international standards.

It is proposed that there will be no lower limit on relative density as values \(<0.555\) can only be achieved by the addition of either hydrogen or helium – see Figure 3.

**Figure 3 Summary of relative density of various types of gases**

### Hydrogen and helium

Hydrogen content currently has a limit of \(\leq 0.1\%\) (molar) in schedule 3 of GS(M)R. It is proposed that hydrogen, as a component, will continue to be specified and controlled separately. Should Great Britain receive gases with significant helium content, there would be a strong economic case for producers to separate out the helium as it is a scarce and valuable resource.

#### 4.4 Other GS(M)R Schedule 3 parameters considered for review

Schedule 3 of GS(M)R contains other parameters which were all reviewed - it is proposed that the statements about sulphur content (total sulphur and hydrogen sulphide), hydrocarbon and water dew points, impurities and hydrogen content will remain unchanged.

The inclusion of a requirement for a minimum pressure at consumers’ appliances was discussed. As this pressure is downstream of the emergency control valve and therefore outside the control of the gas transporters, this has not been included in the gas quality standard. However, pressure (and particularly the impact of low pressures) at supply points to appliances is covered by a separate IGEM working group. For completeness, a summary of changes and parameters that remain unchanged is given in Table 1.

### Hydrogen

A hydrogen quality standard is being developed as part of work pack 2 of the BEIS Hy4Heat programme. This study includes recommendations on hydrogen purity (at least 98 mol% for hydrogen

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43 The Marcogaz range of 0.555 to 0.700 is not compatible with hydrogen content greater than zero.

44 Note that natural gas containing up to 20 mol% hydrogen is a second family (2H) gas


46 Hy4Heat work pack 2  [https://www.hy4heat.info/wp2](https://www.hy4heat.info/wp2) (Last accessed 02 Feb 2020)
in a gas network with limits on certain impurities\(^{47}\) and whether a colourant is required to enhance the visibility of hydrogen flames. As part of work pack 2, IGEM is reviewing current gas industry standards and their readiness for hydrogen.

The combination of a relative density maximum limit and the proposed IGEM standard creates a framework for change that will encourage investment in decarbonised solutions such as hydrogen blending and 100% hydrogen without changes to front-end legislation.

### 4.5 Moving GS(M)R Schedule 3 into a new IGEM standard

**Description**

The revocation of Schedule 3 of GS(M)R will be accompanied by other regulatory changes. These will allow the proposed IGEM Standard to be used by a gas conveyor as evidence of compliance with the requirement to convey gas which is safe. Changes to the safe gas specification, ie IGEM Standard, will be able to be made without the need for any change to legislation. The new standard will be beneficial now to support existing, as well as future, supplies of gas. HSE will retain a veto to ensure that consumer and public safety remain the cornerstone of the IGEM Gas Quality Standard\(^{48}\).

**Benefits**

At present, any changes to GS(M)R – including the adoption of this standard – must be done through changes to legislation, which is a lengthy process. A key benefit of moving the safe gas quality specifications contained in GS(M)R Schedule 3 into an IGEM standard will be to create a more agile framework for further change, including blending hydrogen in the future, without the need for changes to legislation. With approval of any changes to the gas quality standard being overseen by HSE, the continuing safety of gas consumers and the public will be maintained.

**Hydrogen**

The standard is likely to be complemented/amended to allow a greater blend of hydrogen into the network soon\(^{49}\) but 100% hydrogen is likely to require a separate standard. The evidence to support the first potential change to hydrogen content is currently being gathered through projects such as HyDeploy, which is testing a blend of up to 20% hydrogen at Keele University. Other work being carried out through the Aberdeen Vision project and the HyNTS project is assessing the impact of hydrogen on the National Transmission System, the local transmission network, LTS Futures (SGN) and existing industrial and power generation equipment. Once the evidence is in place, a hydrogen quality standard can be adopted without additional legislation. Hydrogen will also be a vital part of meeting net zero:

- The recent pathways study for the Energy Networks Association concluded that 236 TWh per annum of hydrogen could be injected into the network by 2050.\(^{50}\)
- The Committee on Climate Change’s net zero scenario envisages 270 TWh per annum of hydrogen by 2050.\(^{51}\)

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\(^{47}\) Hy4Heat WP2 hydrogen purity report [https://www.hy4heat.info/reports](https://www.hy4heat.info/reports) (last accessed 18 March 2020)

\(^{48}\) Note that changes to GS(M)R need to be accompanied by amended Network Entry Agreements (NEA) before the wider range of gases can be admitted to the gas networks. NEAs are considered by the Joint Office of Gas Transporters under the Uniform Network Code modification process. [https://www.gasgovernance.co.uk/mods](https://www.gasgovernance.co.uk/mods)

\(^{49}\) EN 437 includes the G222 test gas which contains 23% hydrogen as a second family gas


4.6 Summary of changes and benefits

Where "no change" is noted for the proposed IGEM standard, this means that there is no change to the principles set out in the superseded Regulations.

**Table 1 Summary of changes proposed to Schedule 3 of GS(M)R in the new IGEM standard**

<table>
<thead>
<tr>
<th>Content or characteristic</th>
<th>Current schedule 3 of GS(M)R</th>
<th>New IGEM standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part I Requirements under normal conditions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen sulphide content</td>
<td>≤5 mg/m³</td>
<td>No change</td>
</tr>
<tr>
<td>Total sulphur content (including hydrogen sulphide)</td>
<td>≤50 mg/m³</td>
<td>No change</td>
</tr>
<tr>
<td>Hydrogen content</td>
<td>≤0.1% (molar)</td>
<td>No change</td>
</tr>
<tr>
<td>Oxygen content</td>
<td>≤0.2% (molar)</td>
<td>≤1% (molar) at pressures below 38 barg</td>
</tr>
<tr>
<td>Impurities</td>
<td>Shall not contain solid or liquid material which may interfere with the integrity or operation of pipes or any gas appliance (within the meaning of Regulation 2(1) of the 1998 Regulations) 52 which a consumer could reasonably be expected to operate</td>
<td>No change</td>
</tr>
<tr>
<td>Hydrocarbon dewpoint and water dewpoint</td>
<td>Shall be at such levels that they do not interfere with the integrity or operation of pipes or any gas appliance (within the meaning of Regulation 2(1) of the 1998 Regulations) which a consumer could reasonably be expected to operate</td>
<td>No change</td>
</tr>
<tr>
<td>Wobbe Index</td>
<td>≤51.41 MJ/m³ and ≥47.20 MJ/m³</td>
<td>≤52.85 MJ/m³ and ≥46.50 MJ/m³</td>
</tr>
<tr>
<td>Incomplete combustion factor</td>
<td>≤0.48</td>
<td>Removed</td>
</tr>
<tr>
<td>Sooting index</td>
<td>≤0.60</td>
<td>Removed</td>
</tr>
<tr>
<td>Relative density Odour</td>
<td>Not present</td>
<td>≤0.700</td>
</tr>
<tr>
<td>Pressure</td>
<td>The gas shall be at a suitable pressure to ensure the safe operation of any gas appliance (within the meaning of Regulation 14(1) of the 1998 Regulations) which a consumer could reasonably be expected to operate.</td>
<td>No change</td>
</tr>
</tbody>
</table>

**Part II Requirements for gas conveyed to prevent a supply emergency**

| Wobbe Index              | ≤52.85 MJ/m³ and ≥46.50 MJ/m³ | Removed |
| Incomplete combustion factor | ≤1.49                         | Removed |

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Table 2 sets out the wider range of gases that each proposed change to Schedule 3 of GS(M)R will facilitate.

**Table 2  Benefits of each proposed change**

<table>
<thead>
<tr>
<th>Proposed Change</th>
<th>UKCS &amp; North Sea</th>
<th>LNG imports</th>
<th>Reducing gas processing emissions</th>
<th>Biomethane</th>
<th>Future hydrogen addition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Wobbe Index</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Wobbe Index</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>1% oxygen</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative density</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Moving GS(M)R Schedule 3 to IGEM standard</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Removal of Incomplete Combustion Factor and Sooting Index</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

5. Existing gas quality variations

The purpose of this section is to illustrate how gas quality varies today in terms of range and rate of change and to estimate future gas quality. All gases that comply with Schedule 3 of GS(M)R can potentially enter the National Transmission System and each gas tends to travel as a slug with a distinctive gas quality; there is a minimum of mixing at the interface.

Figure 4 shows two distinctive gases passing a tee in the pipeline.

![Figure 4 Movement of two different gas supplies through a pipeline. This illustrates why gas users can experience dramatic changes in gas quality over very short time periods.](image-url)
The "red" gas flows past and starts to spill into the tee to replace the "blue" gas. Mixing between the two is shown as the green/yellow area and the flow profile at the interface is well developed by about 25 seconds. Any gas users connected to the tee will see the transition from the initial "blue" supply to the "red supply" over a very short time period. If one of the gases were a low Wobbe Index gas and the other a high Wobbe Index gas, there could be a step change in Wobbe Index of several MJ within less than half a minute. There is currently very little potential for blending different supplies once they are flowing within the National Transmission System.

5.1 Variations across Great Britain

Current variations and rates of change in gas quality are already much greater than is widely recognised by many users. This section illustrates gas quality variations during 2019 using data at gas distribution offtakes from the National Transmission System. The data has been aggregated\(^5\) for the 13 Local Distribution Zones as shown in Figure 5 for Wobbe Index and Figure 6 for calorific value. The key to the diagram is shown in Table 3.

All properties of natural gas depend on the composition - Wobbe Index is just one of many properties that can be derived by calculation, but it is not the only factor that industrial and commercial users need to measure and control. Many different gas compositions may have the same Wobbe Index but the other gas properties are not necessarily the same and can vary considerably. Conversely, any changes to the Wobbe Index also affect other gas properties to a greater or lesser extent but the relationship between different gas properties is complex. Figures 5 and 6 illustrate how Wobbe Index and calorific value vary independently. In Northern England, the range and variability in Wobbe Index was \(<2\) MJ/m\(^3\) and \(<0.25\) MJ/m\(^3\)/min respectively whereas the range and variability of calorific value was considerably greater at \(>3\) MJ/m\(^3\) and up to 0.5 MJ/m\(^3\)/min. The opposite is the case for South West England where the Wobbe Index range and rate of change was greater than the calorific value. The situation shown varies all the time so, for example, although the calorific value in Southern and South Eastern England was quite stable in 2019, that will not necessarily be the case in other years.

Table 3 Key for the ranges and rates of change of Wobbe Index and calorific value shown in Figures 5 and 6.

<table>
<thead>
<tr>
<th>Range of Wobbe Index and calorific value shown as outer circle</th>
<th>Units</th>
<th>Rate of change in Wobbe Index and calorific value shown as inner circle</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(&lt;2)</td>
<td>MJ/m(^3)</td>
<td>(&lt;0.25)</td>
<td>MJ/m(^3)/min</td>
</tr>
<tr>
<td>(2\leq&gt;3)</td>
<td>MJ/m(^3)</td>
<td>(0.25\leq&gt;0.5)</td>
<td>MJ/m(^3)/min</td>
</tr>
<tr>
<td>(\geq3)</td>
<td>MJ/m(^3)</td>
<td>(\geq0.5)</td>
<td>MJ/m(^3)/min</td>
</tr>
</tbody>
</table>

\(^5\) The gas quality data was from the Ofgem directed equipment at the NTS offtakes to the 13 LDZs. Calorific value and Wobbe Index were calculated from each gas composition when there was a gas flow. The measurement frequency from the gas chromatographs was approximately every four minutes. The average calorific value and Wobbe Index for each LDZ was weighted according to the number of readings at each NTS offtake. The rates-of-change were calculated from sequential readings, that is, the difference in the gas property divided by the difference in the timestamp.
Figure 5  Variation of Wobbe Index across the 13 Local Distribution Zones\textsuperscript{54}. The outer circle indicates the range of Wobbe Index and the inner circle shows the maximum rate of change observed in 2019. The key is shown in Table 3.

\textsuperscript{54} Map taken from UK Government Infrastructure 2010 to 2015.  
Figure 6  Variation of calorific value across the 13 Local Distribution zones. The outer circle indicates the range of calorific value and the inner circle shows the maximum rate of change observed in 2019. The key is shown in Table 3.
Figure 7 shows an example of rapid step changes in gas quality in South West England.

Figure 7 An example of gas quality change in the SW LDZ during October 2019

Gas A and gas B are natural gases and gas C is LNG with a distinctive composition comprising no higher hydrocarbons or carbon dioxide. Over a period of half an hour, the Wobbe Index rose from 48 to 50 and then to 51 MJ/m$^3$ as two distinct step changes. Over the same period, the calorific value dropped from 40 to 39.5 and then to 39.2 MJ/m$^3$. The two natural gases had higher calorific values and relative densities than the LNG and this plot reinforces the fact that different sources of gases in the National Transmission System do not mix and that they travel in sequence as illustrated previously in Figure 4.

5.2 Variation of gas quality at two power station offtakes during 2019

Hourly Wobbe Index and calorific value data for 2019 has been obtained from two power stations directly supplied by the National Transmission System. Power station A is in the South East (see Figure 8) and power station B is in the East Midlands (see Figure 9).

The gas quality for power station A is relatively stable - over the year the Wobbe Index and calorific value both varied by 2 MJ/m$^3$. For power station B, the range of Wobbe Index was about 4 MJ/m$^3$ and the calorific value varied by 3 MJ/m$^3$. The range of gas quality received by power station B was greater than that observed from the LDZ offtakes used for Figure 5 indicating that gas quality variations also depend on the exact location of the offtake from the National Transmission System.

Note that the maximum and minimum values in Wobbe Index do not correspond with the maximum and minimum values of calorific value – when the Wobbe Index is relatively stable, the CV is not necessarily also stable. Power station B repeatedly experiences within-day variations of 2 MJ/m$^3$ in calorific value and occasional within-day variations in Wobbe Index of 3 MJ/m$^3$ or more. As the data is hourly, the true ranges and rates of changes are likely to be greater than shown.
The changes noted in 2019 are for a GS(M)R Wobbe Index range of 4.2 MJ/m³. The 2 MJ/m³ variations in Wobbe Index experienced by power station A covers about 50% of the current specification. For power station B, the range is about 95% of the current GS(M)R specification. For the proposed extended Wobbe Index range of 6.35 MJ/m³, (46.5 to 52.85 MJ/m³), variations of about 50 to 100% of the range are similarly likely as there is almost no potential for gas blending within the National Transmission System.
5.3 Impact of gas quality variations on gas users

All categories of gas user can, and do, currently operate satisfactorily. Some users, such as power generators, are already using combustion control systems as they recognise the existing potential for fluctuations in Wobbe Index of up to 4.2 MJ/m$^3$. Certain operators, have, after making assumptions of the potential risk at their locations on the gas network, installed less robust control systems. However, the gas transporters cannot guarantee that historical variations in gas quality will be continued.

If the range of Wobbe Index were extended, the potential variations and rates of change in gas quality are likely to increase accordingly. A stakeholder analysis by DNV GL indicated that sensitive industrial and commercial users would increasingly require more advanced combustion control systems.\(^55\) Gas turbine operators are concerned about extending the range of Wobbe Index beyond ±5%\(^56\) but the operation and performance of gas turbines depends on a variety of factors including machine type, age, control types and manufacturers’ warranties. Additionally, operators of industrial burners and commercial boilers need to optimise combustion systems, but the result would depend on the gas quality at the time of commissioning. If the burners were to be set-up with a mid-range natural gas then the current variability is within typical process fluctuations associated with all input factors, e.g. air pressure, voltage variation, humidity. If the burner were set-up when the gas supply was at the upper or lower range of gas quality, then there could be an impact on the combustion process. This is recognised as an existing, and increasing, challenge.

For domestic consumers, it is recommended that appliances such as boilers are not adjusted and that they are factory set using pure methane.\(^57\)

There is an opportunity to develop a portable means of measuring the local calorific value or Wobbe Index of the line gas to optimise the burner set-up and which could assist in mitigating the impact of gas quality variations that could be varying significantly between the allowable limits. Again, it is fluctuations and the rate of change in gas quality that are the most pressing issues.

6. Update to the Dutton interchangeability diagram

6.1 Origins of the Dutton interchangeability diagram

The GS(M)R\(^58\) interchangeability diagram was based on test results from appliances that were widely available in the 1970s such as instantaneous water heaters, radiant gas fires and cooker hobs. The parameters that were measured were incomplete combustion, sooting index and flame lift. The current GS(M)R limits are based on a simplified version of the GS(M)R interchangeability diagram. Although the original Dutton approach has served the industry well, the parameters are no longer relevant for modern domestic appliances – further information is given by Dave Lander\(^59\) in the knowledge dissemination from SGN’s Oban project.

6.2 Updated interchangeability parameters

As part of the work of the IGEM Gas Quality Working Group, the suitability of the original GS(M)R interchangeability diagram was investigated. Marcogaz\(^60\) has proposed an alternative which is a plot of

55 DNV GL Report 1166BGP7-07 Applied Research into the Effects of a Wider Gas Wobbe Index Range - Phase Two Report 2018
56 Joint Office of Gas Transporters UNC modification 0714  https://www.gasgovernance.co.uk/0714
58 Dutton, BC A new dimension to gas interchangeability. The Institution of Gas Engineers communication 1246 1984
Wobbe Index against relative density (RD). This has been overlaid onto the original diagram in red as shown Figure 10. The current GS(M)R Wobbe Index limits are shown in green – all gases within the green lines and with a relative density between 0.555 and 0.700 (as shown by the vertical red lines) would be compliant. The proposal is that the Wobbe Index and relative density limits should replace the current GS(M)R diagram.

![Wobbe Index diagram](image)

**Figure 10** The current GS(M)R diagram overlaid with the Marcogaz alternative diagram

The area bounded by an upper relative density of 0.700 and the agreed Wobbe Index limits are proposed as the new GS(M)R compliant region. The Incomplete Combustion Factor (ICF) and Sooting Index (SI) limits, which were derived from measurements on typical domestic appliances at the time that Dutton carried out his research, would become redundant.

### 7. Case for change for domestic users

#### 7.1 Increasing the upper Wobbe Index limit

The main risk to domestic consumers from increased Wobbe Index is the potential for increased levels of carbon monoxide (CO). SGN’s *Opening up the Gas Market*[^61] (also known as the Oban project) project was a carefully designed field trial to demonstrate the safe supply of vaporised LNG to Oban’s consumers for a year; the Wobbe Index was greater than the current upper limit of 51.41 MJ/m³. The main finding was that domestic customers were only at risk if their gas appliances were already dangerous.

At the end of the Oban project, SGN’s source of GS(M)R compliant LNG was no longer available and all four of the Scottish Independent Undertakings now receive unballasted LNG with a Wobbe Index greater than the GS(M)R upper limit under an HSE exemption[^62].

[^61]: SGN’s *Opening up the Gas Market* is a Network Innovation Competition project. Further information: [https://www.sgn.co.uk/about-us/more-than-pipes/investing-in-innovation/oban-project](https://www.sgn.co.uk/about-us/more-than-pipes/investing-in-innovation/oban-project) (last accessed 22 Jan 2020)

[^62]: SGN SIU Gas Quality report June 2017
The main outcomes from the Oban project include:

- Domestic and small commercial appliances, correctly installed, serviced and operated, can safely burn gas of Wobbe Index up to 54.7 MJ/m³ (part of the appliance certification testing).
- Consistency with the main findings of the GASQUAL\(^\text{63}\) studies which concluded that the optimum range of Wobbe Index for domestic appliances includes 53 MJ/m³ without significant increases in CO emissions.
- Consistency with earlier testing in support of the UK tripartite\(^\text{64}\) gas quality study. Again, gas with Wobbe Index up to around 53 MJ/m³ operated efficiently and only gave rise to modest increases in CO emissions.
- The best mitigation for the continued safety of domestic consumers is regular appliance servicing to prevent fatalities from CO poisoning.

### 7.2 Decreasing the lower Wobbe Index limit

Since 2004, there have been several laboratory studies on the impact of wider gas quality ranges, including projects for both the UK Government and the EU. The outcome was that the use of gases down to 45.7 MJ/m³ does not lead to significant performance changes. The SGN Oban study had previously shown that lower Wobbe Index gas is acceptable from the point of view of safety and operability. Lower Wobbe Index gas within the 2H band\(^\text{65}\) is used routinely in some parts of Europe (Netherlands, Germany and Poland) using appliances like those used in the UK and certified using EN 437 test gases.

There are substantial reserves of gas in the UKCS with a Wobbe Index between the current lower GS(M)R Wobbe Index (47.2 MJ/m³) and the emergency limit (46.50 MJ/m³). To support supply diversity and UK Government strategy to maximise economic recovery\(^\text{66}\) from the UKCS, a study was carried out for Neptune Energy\(^\text{67}\) to investigate the impact of lower Wobbe Index gas on the safety of domestic appliances. New tests were carried out by BSI on a sample of fires, cookers and boilers and no problems related to emissions, ignition, flame stability or flame lift were observed with gas of 45.7 MJ/m³ Wobbe Index, >1.8% lower than the proposed 46.50 MJ/m³ Wobbe Index gas.

Stakeholder engagement with gas appliance and burner developer experts reinforced the view that lower Wobbe Index gas can be used safely, but there may be usability impacts relating to heat input to certain appliances if the Wobbe Index were too low.

### 7.3 Impact on domestic appliance safety devices

Oxygen depletion sensors (ODS) are safety devices installed on some appliances with pilot lights, including flueless water heaters, back-boiler installations and gas fires. They are designed to respond to changes in the oxygen content in the room or flue gas and safely shut-down appliances if the oxygen concentration drops resulting in vitiation that can give rise to excessive CO emissions.

The ODS are tested during appliance certification as they are classed as a Primary Safety Device. The tests use the G20 reference gas and are undertaken in a vitiation room or chamber so the CO concentration can be monitored as a function of the room oxygen.

Variation in gas quality can result in increased CO emission levels. Tests undertaken as part of the UK tripartite gas quality study, highlighted the variability of the ODS response to gas quality and questioned...

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66 Oil and Gas Authority: The Maximising Economic Recovery Strategy for the UK [https://www.ogauthority.co.uk/media/3229/mer-uk-strategy.pdf](https://www.ogauthority.co.uk/media/3229/mer-uk-strategy.pdf) (last accessed 22 Jan 2020)

67 DNV GL report 10158808 Gas Quality – Low Wobbe Index Study for Neptune Energy. Dec 2019
the overall performance of the devices. Further testing during the SGN SIU project, again showed mixed performance, but some ODS systems did provide the required safety performance. Considering the uncertain performance of these devices, these were not considered as a risk mitigation. SGN is undertaking additional studies to evaluate the performance of a range of ODS devices under strict laboratory-controlled conditions with the aim of characterising the effect of change in gas quality. The results from this study will establish the optimum configuration of these devices and determine what risk reduction can be achieved.

When domestic appliances are installed, the gas quality at the time that the appliance is commissioned is unknown. For this reason, it is recommended that no adjustments are made to the factory setting of the burners as these are corrected to pure methane (also known as test gas G20 in the EN 437 standard) which is approximately midway between the lower and upper GS(M)R limits on Wobbe Index.

8. Case for change for industrial and commercial users

This study, led by SGN, surveyed a range of industrial and commercial consumers using a combination of an industry consultation questionnaire and a workshop, both run by DNV GL facilitated by IGEM. The responses were split into two groups and pure-hydrogen networks were excluded:

- Widening of the Wobbe Index for natural gas mixtures
- The impact of the addition of up to 20% hydrogen to natural gas

Although most of the responses were factual and provided very valuable feedback, some were anecdotal, particularly those around the addition of hydrogen. There is clearly a need for evidence gathering and the dissemination of facts and information as hydrogen has been transported, used and stored by other industries and countries for many years. The responses concerning the change in the GS(M)R for natural gas and those concerned with the addition of hydrogen to natural gas were separated for clarity.

To focus the study for the industrial and commercial market sector, the questionnaire and workshop output was categorised by user type - power generators, industrial users, burners/boilers/control system manufacturers, trade associations and gas storage operators. The spread of the engagement was wide and included face-to-face meetings with representatives from different sectors.

The impact of changes to gas quality on industrial and commercial stakeholders is not directly related to safety. Concerns relate primarily to compliance with emissions regulations, such as the Medium Combustion Plant Directive, and process efficiencies. Emissions and efficiencies are correlated and there is a knock-on commercial impact. For some manufacturers, the quality of product is affected by changes in the combustion properties of the gas. The concerns of individual groups of industrial and commercial users are summarised in the report.

As part of the engagement with industrial and commercial consumers, it was noted that some users were unaware of current gas quality variations. The issue is now better understood, and combustion processes need control system to optimise gas use.

Further debate and discussions have taken place within the Gas Quality Working Group; gas engine users (represented by AMP) and the power generation sector (represented by Energy UK) have provided comments and reflections on the report. As these concerns are mainly commercial, these will be investigated more fully in the formal Government consultation on proposed changes to GS(M)R that will follow.

68 Gas Safe Register Technical Bulletin TB 143 CO and combustion ratio checks using an Electronic Combustion Gas Analyser (ECGA) when commissioning a condensing boiler incorporating air/gas ratio control valve technology. Registered engineers can obtain the most recent copy from https://engineers.gassaferegister.co.uk

69 DNV GL Report 1166BGP7-07 Applied Research into the Effects of a Wider Gas Wobbe Index Range - Phase Two Report 2018
9. Gas network safety

9.1 Explosion Risk

Natural gas that complies with the current GS(M)R specification is mainly methane, but higher hydrocarbons are present in varying concentrations. The increase in the upper Wobbe Index limit to the current emergency limit of 52.85 MJ/m$^3$ may, but not necessarily, lead to an increase in higher hydrocarbon content$^{70}$ and explosion risk$^{71}$.

Higher hydrocarbons do have higher explosion pressures and burning velocities than methane. Test results on methane/propane mixtures from DNV GL’s Spadeadam facility have quantified the increased risks – the results are available in an EU co-funded project MERGE$^{72}$ and in a review of gas explosion modelling carried out by HSE$^{73}$.

The increase in explosion pressures and burning velocities associated with the increase in Wobbe Index from 51.41 to 52.85 MJ/m$^3$ will be negligible. For explosions in buildings and confined spaces the consequences of an explosion are very unlikely to change$^{74}$.

For gas network operations and large industrial consumers, the small increase in Wobbe Index and associated hazardous areas, is already covered under DSEAR$^{75}$ and ATEX$^{76}$ regulations.

SGN has an exemption from GS(M)R to transport gas with a Wobbe Index of up to 53.25 MJ/m$^3$. For the duration of SGN’s Oban project, and the subsequent roll-out of higher Wobbe Index gas to the SIUs, there have been no incidents since 2014 (see Clause 7.1). Note also that a Wobbe Index of 52.85 MJ/m$^3$ is already permitted under current GS(M)R emergency supply conditions.

9.2 Pipeline Fracture Propagation

The mechanism of fracture propagation is related to the condensation of higher hydrocarbons resulting from the sudden drop in pressure caused by a pipeline rupture. Increasing the Wobbe Index may, but not necessarily, increase higher hydrocarbon content. Ballasting of rich LNG with nitrogen lowers the Wobbe Index but does not reduce higher hydrocarbon content nor the risk of fracture propagation. This problem already exists with the current gas quality specification.$^{77}$

$^{70}$ Wobbe Index can be increased by, for example, replacing some of the methane with ethane whilst keeping the higher hydrocarbon content the same. 
$^{71}$ Any increase in explosion risk associated with the higher hydrocarbons should be compared with the existing risk for natural gas and not with the explosion risk for pure methane.

$^{72}$ Modelling and experimental research into gas explosions; overall final report of the MERGE project, Commission of the European Communication. Contract STEP-CT-011 (SSMA) 1993.


$^{74}$ As a guide, if 10% of explosion events in buildings had worse consequences and additional fatalities occurred in 10% of these, then the increase in risk is 1%. The risk is already very small, and a 1% increase would not be measurable.

$^{75}$ The Dangerous Substances and Explosive Atmospheres Regulations. Further information is available at https://www.hse.gov.uk/pubns/priced/i138.pdf. (Last accessed 02 Feb 2020)

$^{76}$ ATEX covers two European Directives 99/92/EC and 94/9/EC. Further information is available at https://www.hse.gov.uk/fireandexplosion/atex.htm. (Last accessed 02 Feb 2020)

$^{77}$ Dave Lander, report DLC/0175 Comparison of pipeline fracture propagation risk for natural gases of differing Wobbe Index Jan 2020
10. Timeline and next steps

Once the proposed standard and evidence pack has completed the IGEM consultation, it will be sent to the Health and Safety Executive. The process lead by the Health and Safety Executive is illustrated in Figure 11 and it is likely to take approximately one year.

Figure 11 Summary of process to be followed by HSE following the IGEM consultation
Appendix A  Key gas network innovation projects (non-exhaustive)

A brief summary of key gas network innovation projects relevant to changing schedule 3 of GS(M)R, demonstrating consumer safety and decarbonisation, is provided below.

Reducing gas processing

- Opening up the Gas Market: Unballasted LNG, with a Wobbe Index above the GS(M)R upper limit, was injected into the Oban network for a year. The project demonstrated that the gas is safe to distribute and safe for consumers.
- As a result of the rollout of the Oban project, unballasted LNG has been injected into the Scottish Independent Undertakings at Oban, Campbeltown, Wick and Thurso since 2015 under a rolling exemption from GS(M)R (the SIU project)
- The DNV GL study which investigated changing the lower Wobbe Index limit to support the production of gas from the UKCS without additional processing.

Biomethane

- Biomethane injected at 94 sites across the country, with almost 10 TWh injected to date.

Flexible gas networks

- Freedom project: Trial of hybrid heat pumps – a heat pump working alongside a gas boiler – in 75 residential properties in Bridgend, South Wales. Demonstrated the ability of the system to switch between gas and electric load.
- Future Billing Methodology: Ongoing project to create more flexible billing arrangements, meaning that biogases and hydrogen in parts of the network would not need pre-processing to meet average calorific value and other requirements.
- Real-Time Networks: An installation of sensors that will enable the measurement of the energy content of different gases within the network, rather than just the traditional flow and volume. This will allow more decarbonised gases to be injected by optimising network operation.

Hydrogen blending

- HyDeploy: Project currently underway and injecting up to 20% hydrogen in part of the Keele University private gas network to test performance and safety of appliances.
- HyDeploy 2: Following the positive results from HyDeploy, the project will blend up to 20% hydrogen in public gas networks, the first of which is 670 homes in North England
- HyNTS: Physical trial of hydrogen blend in the NTS.
- The Industrial and Commercial Gas Quality project investigated the impact of hydrogen on large gas users.

100% hydrogen

- H100: Comprehensive research and development project to underpin construction and operation of a 100% hydrogen network supplying 300 homes.
- H21: Detailed feasibility study which showed how North of England cities (3.7 million meter points) could be converted to 100% hydrogen. Safety testing on existing gas distribution network features to confirm 100% hydrogen suitability and identify any interventions
• Hy4Heat: programme of research, development and testing of 100% hydrogen appliances and associated safety in the home.

• LTS Futures: revalidation and repurposing of the LTS for hydrogen, biomethane and/or carbon dioxide

**Strategic hub developments**

• HyNet: An industrial cluster development in NW England including hydrogen production, carbon capture and storage, fuel switching and network blending

• Project Cavendish: Supply of hydrogen to generate power for Transport for London and low-carbon gas to parts of SE England

• Aberdeen Vision: Studying the potential of blending 2% hydrogen at the St Fergus reception terminal and the viability of building a hydrogen pipeline from St Fergus to Aberdeen to blend 20% into the city and 100% hydrogen for transport