Common Arrangements for Gas

Draft Final Report on the Requirements for a Single Natural Gas Quality Standard for Northern Ireland and the Republic of Ireland

CER/08/258

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Executive Summary

As part of the Common Arrangements for Gas (CAG), the Commission for Energy Regulation and the Northern Ireland Authority for Utility Regulation (the Regulatory Authorities) are assessing a single approach to gas quality. Although the two jurisdictions currently operate under different gas quality specifications, physically the natural gas currently brought onshore from both Inch and Moffat is of the same range of Wobbe Index and complies with the Gas Safety (Management) Regulations specification for natural gas. However, future developments may mean that gas of differing quality specifications may enter the RoI network as new gas fields are developed and liquefied natural gas (LNG) importation commences. Although there is likely no potential safety issue in the short term until LNG imports commence, new arrangements will be needed to facilitate cross-border gas flows, which would harmonise arrangements between the two jurisdictions. Facilitating the CAG objectives to establish arrangements whereby all stakeholders can buy, sell, transport, operate, develop and plan the natural gas market in both jurisdictions effectively on an all-island basis. Were the gas quality specifications not to be harmonised this would result in the physical flow of gas between Ireland and Northern Ireland being restricted or even prevented. The Regulatory Authorities have stated their intention to make a decision in relation to gas quality in the near future to ensure that the issue of gas quality does not delay the rest of the CAG project – whether or not gas can physically flow between the jurisdictions is a key factor in the progression of the CAG project. In addition to this the Commission is of the view that due to the apparent inappropriateness of the current Irish specification from a safety perspective it is prudent to change the specification given the body of evidence brought to its attention this year.

With this in mind, a Gas Quality Industry Group (the Group) was established in August 2008, comprising industry participants, with the primary purpose of assessing the appropriate gas quality specification for NI and RoI with regards to the safety of gas appliances. The Group's terms of reference were to:

- Recommend an appropriate Wobbe Index range for NI and RoI;
- Review current reports regarding safety and appropriate Wobbe Indices;
- Review responses to the CAG Consultation Paper *"Single Approach to Gas Quality"*;
- Review RoI regulatory arrangements for gas appliances as regards gas quality;
- Recommend relevant gas quality parameters, other than the Wobbe Index;
- Examine the issues facing gas-fired power generators in relation to gas quality;
- Assess the issue of appropriate measurement of gas quality on an all-island basis in the context of the CAG; and
- Assess the impact on security of supply

A Work Programme for the Group was developed, which involved a series of group meetings/workshops held between August and November 2008 to discuss the various issues associated with gas quality and to develop a report with recommendations which would be issued to the Regulatory Authorities by 28th November and a Decision Paper published by 19th December 2008. The Group's activities during the period involved a detailed consideration of the relevant combustion and non-combustion parameters of gas quality in order to assess the impacts of variations in gas quality on the safe operation of appliances and the integrity and operation of gas transportation infrastructure. This included a comparison of the gas quality specifications and experiences in RoI, NI, GB, mainland Europe and the USA so as to benefit from the studies and learning experiences of other jurisdictions that are facing similar

challenges with respect to varying indigenous gas quality and the impacts of increasing levels of LNG imports.

Considering the significant amount of research and discussion that has been undertaken on gas quality issues in GB over the last five years, the Group reviewed the output of the recent DTI/BERR studies into changing gas quality and the potential impacts on the safe operation of gas appliances in GB and, also, to understand the impacts of gas quality issues for gas-fired generators. A separate study, commissioned by Gaslink and undertaken by Advantica, concluded that the population of gas appliances in RoI and GB were sufficiently similar to allow the GB findings on appliance safety to be extended to the RoI gas appliance population. The key finding from this study was that tests within the range 47.20 to 51.41 MJ/m^3 – i.e. the GS(M)R Wobbe Index range – resulted in acceptable performance, however, exponential increases in carbon monoxide (CO) emissions are seen at values of Wobbe Index beyond 53 MJ/m^3, which is an unacceptable situation from a safety perspective.

Additionally, the CEN Study that is currently underway in Europe was discussed in the context of the Group's work. The CEN (Mandate M/400) Study involves an initial two-year programme of market analysis and domestic gas appliance testing to investigate the tolerance of new and used European appliances to wider gas quality variations although the CEN Study has not yet concluded and reported on its findings. It is anticipated that the timescale for full completion of CEN Study is five years. The output of the CEN Study should be reviewed as and when it becomes available in 2012/13.

The requirements of the Gas Appliance Directive (GAD) were also reviewed and discussed within the Group workshops. The GAD was introduced in the early 1990's to provide a consistent European approach to gas appliance safety and there was a general expectation that post-GAD appliances are therefore more tolerant to gas quality variations than their predecessors but this is not necessarily the case. Modern appliances, for example boilers, are tuned closely to the current expected pipeline gas specification in order to meet efficiency and emissions performance requirements. If gas quality in future varies more than previously seen, then an appliance adjusted to optimal combustion performance at one limit of Calorific Value or Wobbe Index may be maladjusted to tolerate gas at an opposite limit. Therefore, while the population of domestic appliances could be adjusted to accept a wider range of Wobbe Index, it has not been established from any testing programme whether or not appliances could operate safely over a wider range in the longer term.

The Group considered the implications of changing gas quality on the power generating sector. As part of the Group's activities, a questionnaire was developed and issued in order to obtain comments from the power generating sector on the potential impacts of gas quality limits and variations on the safe and efficient operation of gas-fired generation plant. The key issue for generators is variations in gas quality and variations of +/- 2% in Wobbe Index (based on an average of 50 MJ/m^3) require some form of adjustment to plant, with wider variations of +/- 5% requiring major adjustments or hardware changes.

With regard to the importation of LNG and the potential impacts on gas quality, a detailed discussion and presentation on the implications of LNG imports on gas quality was held and the various options for the processing of LNG were explained. As there are limited opportunities for gas co-blending in the RoI transmission system, there would be a need to undertake gas processing of 'high' Wobbe Index gas prior to injection at system entry point. Shannon LNG submitted an overview document on the gas processing options currently under consideration. Based on an inert injection rate of 4% and a target Wobbe Index of 51.41 MJ/m^3 – i.e. the upper limit of GS(M)R – the results of Shannon's modelling show that air ballasting, which is the lowest cost option, would result in an oxygen content of 0.84% molar. A membrane-type nitrogen generation plant, which is a higher cost option, would result in an oxygen content of 0.2% molar, which is compliant with GS(M)R. To achieve an oxygen content of 0.001% molar, a cryogenic air separation plant (or some other high purity system) would be required, which is the most costly option currently under consideration.

Security of supply was also considered both from the perspective of: (i) *security of gas supply*; and (ii) *security of power supply.* The discussions on this issue revealed that, whilst a relatively wide gas quality specification, primarily in terms of Wobbe Index, improved overall security of gas supply, this is not necessarily the case for security of power supply as sudden and unexpected variations in gas quality can have adverse impacts on gas turbine efficiency and reliability. Given that c.60% of power generation in RoI is gas-fired and that unexpected gas quality excursions could cause generators to shut down, it is important that security of gas supply be considered in light of potential adverse consequences for security of power supply.

The Gaslink proposed Gas Entry Quality Specification was reviewed and discussed in detail and whilst it was agreed that alignment with the GS(M)R specification was the preferred approach, there were other, primarily non-combustion parameters that required further study and review. The Group has agreed that: (i) the Entry Specification proposed by Gaslink (as amended in Annex B) also serves as the Exit Specification for the transmission system; and (ii) that the Emergency Gas Specification should be aligned with GS(M)R. However, it was also agreed that further work was required to define an Exit Specification for the distribution network as this issue had not been addressed by the Group.

The current approach to monitoring gas quality in RoI and NI was also reviewed in order to ascertain if appropriate gas quality monitoring arrangements are currently in place and what improvements, if any, need to be made. A number of issues emerged during the Group's discussions on this subject and require further consideration. These included:

- Gaslink's ability to act as an RPO given the current gas quality measurement arrangements;

- The independence of Gaslink in measuring gas quality at entry points; and

- The range of the gas quality parameters that can be physically measured by existing equipment at entry points.

Additionally, the Group identified the requirement to implement a system for monitoring of gas quality in real time to be made available to interested parties so as to make any necessary adjustments to gas-fired generating plant, or other sensitive industrial processes, sufficiently well in advance. It was agreed that further work was required in the area of gas quality measurement and monitoring.

The following broad **conclusions** were reached by the Group:

- Given the substantial body of researched evidence on the adverse effects of wider (than GS(M)R) Wobbe Index gas on domestic appliances, the responses and opinions of power generators in RoI and similar experiences associated with changing gas quality in other gas markets internationally, the Group is led to the conclusion that the current

Code of Operations gas quality specification is too wide and should be aligned with the Gas Safety (Management) Regulations so as to reflect the specification of the gas that is currently being imported into RoI and will continue to be imported in the short term to medium term. This, in itself, would achieve a fundamental CAG objective of harmonising gas quality standards between RoI and NI;

- There are limited opportunities for undertaking co-blending of high Wobbe Index gas, specifically re-gasified LNG, within the RoI transmission system to achieve a range of Wobbe Index that can be safely utilised in RoI domestic gas appliances and some form of gas processing is therefore required prior to injection at system entry point. Increasing the oxygen limit to $\leq$ 0.2% molar appears to provide for more options to achieve a WI in line with GS(M)R and potentially reduce costs. ; and

- Further work is required to determine if the current regime for gas quality measurement and monitoring is appropriate from the perspective of: (i) Gaslink's role as an RPO; (ii) the provision of independent gas quality signals to Gaslink in order to measure gas quality at entry points; (iii) the suitability of current gas quality measuring equipment at system entry point to measure the full range of gas quality parameters as contained in the Entry Specification; and (iv) the need for a system of monitoring gas quality information in real time to be made available to interested parties who are adversely affected by unexpected gas quality excursions.

Given the above, the **recommendations** of the Group are that:

1. The Gaslink proposed Gas Quality Entry Specification, based the GS(M)R and UK-NTS Entry Specification, is adopted in the Code of Operations as a combined Entry and Exit Specification, subject to the following changes:

    - Oxygen Content $\leq$ 0.2% molar (subject to further review)
    - Methanol to be removed

    The Exit Specification for the transportation system will be the same as the Entry Specification. The recommended specification is as outlined in Annex B.

2. Emergency gas specification limits should be adopted based on the GS(M)R limits of:

    a) Wobbe Number

        (i) $\leq$ 52.85 MJ/m^3
        (ii) $\leq$ 46.50 MJ/m^3

    b) Incomplete Combustion Factor $\leq$ 1.49

3. The Gas Quality Industry Group should convene at least twice yearly, in May and November, in order to address those issues identified as requiring further work as listed below.

The decision criteria that will be used to determine when the emergency gas specification limits are to be used in RoI will be developed as part of the Natural Gas Emergency Plan and implemented by the National Gas Emergency Manager.

Annex B of this report shows the full recommended Gas Quality Entry and Exit Specification

Further Work Required:

a) Gaslink are to develop:

- a minimum functional specification and estimate of costs for gas quality measurement at system entry;

- a system for monitoring gas quality excursions of gas being conveyed in the network, in real time, in order to allow power generators to make necessary adjustments to gas-fired plan. This will be based on a due consideration of options and costs; and

- a system of alerts for gas quality excursions

Gaslink's proposals will be considered by the Gas Quality Industry Group and be subject to the approval of the Regulatory Authorities;

b) Oxygen Content – the limit of $\leq$ 0.2% molar has been accepted subject to review and will be considered in conjunction with Water Content/Dewpoint. Gaslink are to develop recommendations;

c) Gaslink to develop a detailed specification for 'Contaminants' in order to address the concerns of power generators of the impacts on gas turbine operation. These include the contents of: (i) Sodium; (ii) Potassium; (iii) Calcium; (iv) Lead; (v) Vanadium; and (vi) Manganese. This will include a review of the total inerts in the gas quality mix.

d) Gaslink to assess the need to develop a separate Exit Specification for the Distribution Network; and

e) To manage the ongoing implementation of CAG and other EU developments including the 'Third Package'

1. Introduction and Background

As part of the European Union, Northern Ireland (NI) and Republic of Ireland (RoI) are committed to the development of a single European Gas Market. The European Commission has put in place an overarching legislative framework within which all member states are working to achieve the Single Gas Market which is designed to bring benefits to all European citizens and to contribute to Europe's competitiveness. Additionally, the EU Commission has mandated CEN, the European standards organisation, to create a European standard for gas quality. The CEN Study has been reviewed by the Group and the outcome(s) will be considered as and when the results are published.

Within this framework, cross border trade is developing and the interconnectivity of gas networks is increasing across the EU member states. Physical interconnection between the NI and RoI gas systems is now in place following the construction and commissioning of the South-North gas transmission pipeline in late 2006, however, differing arrangements are an obstacle to the actual flow of gas between the two jurisdictions. As stated in the recent CAG Consultation Paper *"Single Approach to Gas Quality"* (ref. CER/08/101), RoI presently imports over 90% of its natural gas from GB via the interconnector pipelines and the gas quality specification that applies to this imported gas is that contained in the Gas Safety (Management) Regulations 1996. Other indigenous gas used in RoI conforms to the GS(M)R specifications via Connected Systems Agreements (CSA's) at each entry point to the RoI transmission system. Similarly, natural gas conveyed in the NI transmission system conforms to the Gas Safety (Management) Regulations (Northern Ireland) 1997, which are the same as the UK GS(M)R.

However, the current RoI gas entry specification as contained in the Code of Operations is wider, primarily with respect to Wobbe Index, than the GS(M)R specification although gas entering the RoI system has never actually reached the limits of the Code of Operations entry specification. With the proposed introduction of liquefied natural gas (LNG) to RoI and the development of indigenous gas fields, there is the possibility that gas with wider Wobbe Index limits, than is currently being received, may enter the RoI gas transmission system. The introduction of LNG directly into RoI will not occur for some years and any LNG supply that is received indirectly via the UK interconnectors is required to comply with the applicable UK gas quality specifications in force at that time. Whilst LNG imports and new indigenous gas field production will reduce dependence on imported gas from GB and strengthen security of gas supply for RoI, there are safety concerns, based on researched evidence, over injecting gas with wider Wobbe Index limits into the system due to potential changes in the combustion performance of gas appliances. There are similar operational concerns regarding gas-fired turbines for power generation, which have the potential to adversely impact security of power supply. Additionally, it is considered unlikely that the HSE (NI) will agree to a change in GS(M)R (NI) without compelling evidence to counter concerns over appliance safety.

New arrangements are therefore needed to facilitate cross-border gas flows based on Common Arrangements for Gas (CAG), which would harmonise arrangements between the two jurisdictions. With this in mind, the Utility Regulator and the Commission for Energy Regulation (CER), together with the relevant Government Departments, have scoped the work areas required under the CAG and their timescales, sequencing and priority. A Memorandum of Understanding (MoU) between the Utility Regulator and CER, published in April 2008, sets out the vision of CAG, which is to establish arrangements whereby all stakeholders can buy, sell, transport, operate, develop and plan the natural gas market in both jurisdictions effectively on an all-island basis.

A key part of the CAG vision, is the operation of the gas transmission systems in NI and RoI on a single, all-island network basis. This will be enabled by, amongst other things, a single transmission operational regime which will include a single gas quality standard. Consequently, a Gas Quality Industry Group (the Group) was established in August 2008, comprising industry participants (see Annex A), with the primary purpose of assessing the appropriate gas quality specification for NI and RoI with regards to the safety of gas appliances.

Specifically, the Group's terms of reference are to:

- Recommend an appropriate Wobbe Index range for NI and RoI;
- Review current reports regarding safety and appropriate Wobbe Indices;
- Review responses to the CAG Consultation Paper "Single Approach to Gas Quality";
- Review RoI regulatory arrangements for gas appliances as regards gas quality;
- Recommend relevant gas quality parameters, other than the Wobbe Index;
- Examine the issues facing gas-fired power generators in relation to gas quality; and
- Assess the issue of appropriate measurement of gas quality on an all-island basis in the context of the CAG.

A Work Programme for the Group was developed, which involved a series of meetings to discuss the various issues associated with gas quality, following which, a Final Report with recommendations would be issued to the regulatory authorities by 28th November and a Decision Paper published by 19th December 2008.

2. Current RoI Gas Entry and Exit Specifications

This section describes the origins and current status of the existing Gaslink gas quality specification, the requirements of the RoI Code of Operations and the gas quality specifications as they apply in NI, namely the:

- UK Gas Safety (Management) Regulations 1996; and
- National Grid UK-NTS Gas Entry Specification (as contained in the National Grid Ten Year Statement)

An overview and description of the proposed European gas transportation EASEE-gas specification is also provided.

2.1 Background to the Current Code of Operations Entry Specification

The specification for gas quality was first documented in the Bord Gáis/Marathon Commercial Agreement drawn up in 1976. With the understanding that gas entering the system at Inch was homogeneous since first produced, the specification remained unchanged. However following the construction of the GB interconnectors, it was now possible for gas with different gas quality specification to enter the network. Therefore gas quality became an issue for power station operators as turbines became more sensitive to variations in gas quality (in particular combustion components).

In 1999, Bord Gáis Éireann drew up a 'Quality Specification for Natural Gas' entering the network. This was based on the original Commercial Agreement with Marathon, international standards and UK legislation - i.e. GS(M)R. Specifications contained within the gas entry provisions described in the Code of Operations were introduced in June 1999. Many of the parameters from the BGÉ specification were transposed across into the Code, the remaining originated from the annually published 'Transco Ten Year Transportation Statement'.

The following table shows the sources from which the Code of Operations gas quality specification has been derived.

Natural Gas Characteristic	Reference
Type of Gas	IS/EN 437:1993
Gross Calorific Value	Original Marathon Contract and BS 3156-11.0.2:1998
Wobbe Index	IS/EN 437:1993
Relative Density	BS 3156-11.0.2:1998
Hydrogen Sulphide Content	H&S 1996 No. 551 and GS(M)R 1996
Total Sulphur Content	H&S 1996 No. 551 and GS(M)R 1996
Oxygen Content	GTE Gas Specification 2002
Carbon Dioxide Content	Transco Ten Year Statement
Nitrogen Content	Transco Ten Year Statement
Water Content	Transco Ten Year Statement
Hydrocarbon Dewpoint	Transco Ten Year Statement
Mist, Dust, Liquid	BS 3156-11.0.2:1998

Table 1: Sources of Current Code of Operations Gas Quality Specification

2.2 RoI Code of Operations Requirements for Gas Quality

The main provisions relating to the gas quality specification for gas entering the RoI transmission system are contained in 'Part G – Technical' (Version 2.0) of the Code of Operations. Each entry point has an associated Connected Systems Agreement (CSA), which specifies the limits of the various gas quality parameters that are acceptable at that particular entry point. In cases where there is no CSA, or the CSA does not contain an agreed gas quality specification, the specification as outlined in Appendix 1 of Part G applies. The gas quality specification at system offtake is specified in Appendix 2 of Part G. These are shown below in Table 2.

Gas Quality Parameter	Entry Specification	Offtake Specification
Relative Density	Min 0.55 Max 0.70	
Total Sulphur	$\leq$ 50 mg/m^3	$\leq$ 50 mg/m^3
Oxygen	$\leq$ 0.1 mol%	$\leq$ 0.2 mol%
Carbon Dioxide	$\leq$ 2.0 mol%	
Hydrocarbon Dewpoint	$\leq$ - 2^{0}C up to 85 barg	
Hydrogen Sulphide	$\leq$ 5 mg/m^3	$\leq$ 5 mg/m^3
Nitrogen	$\leq$ 5 mol%	
Water Content	$\leq$ 50 mg/m^3	
Gross Calorific Value	36.5 to 47.2 MJ/m^3	
Wobbe Index	45.7 to 54.7 MJ/m^3	45.7 to 54.7 MJ/m^3

Table 2: Gas Quality Specifications at System Entry and Offtake

The Code of Operations requires Shippers *"to use reasonable endeavours to procure that the appropriate contractual arrangements are in place and to procure implementation of any quality control measures requested by the Transporter to ensure that the quality of all Natural Gas tendered for delivery by a Shipper to the Transportation System when delivered at the Entry Point accords to the Entry Specification….."*

2.3 Gas Safety (Management) Regulations 1996

The key objective of these Regulations is to ensure security of supply to domestic consumers by taking appropriate measures to either avoid a gas supply emergency or to minimise the adverse effects if one occurs. The Regulations also aim to maintain the safety standards achieved by the former British Gas plc prior to liberalisation. The key requirements with respect to gas quality are contained in Schedule 3 Regulation 8 CONTENT AND OTHER CHARACTERISTICS OF GAS. These are:

Part I - REQUIREMENTS UNDER NORMAL CONDITIONS

1. The content and characteristics of the gas shall be in accordance with the values specified in the following Table 3.

Content or Characteristic	Value
Hydrogen Sulphide content	$\leq$ 5 mg/m^3;
Total Sulphur content (including Hydrogen Sulphide)	$\leq$ 50 mg/m^3;
Hydrogen content	$\leq$ 0.1% (molar);
Oxygen content	$\leq$ 0.2% (molar);
Impurities	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 1994 Regulations) which a consumer could reasonably be expected to operate;
Hydrocarbon Dewpoint and Water Dewpoint	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 1994 Regulations) which a consumer could reasonably be expected to operate;
Wobbe Number	(i) $\leq$ 51.41 MJ/m^3, and (ii) $\geq$ 47.20 MJ/m^3;
Incomplete Combustion Factor	$\leq$ 0.48
Soot Index	$\leq$ 0.60

Table 3: GS(M)R Gas Quality Specification

2. The gas shall have been treated with a suitable stenching agent to ensure that it has a distinctive and characteristic odour which shall remain distinctive and characteristic when the gas is mixed with gas which has not been so treated, except that this paragraph shall not apply where the gas is at a pressure of above 7 barg.

3. The gas shall be at a suitable pressure to ensure the safe operation of any gas appliance (within the meaning of regulation 2(1) of the 1994 Regulations) which a consumer could reasonably be expected to operate.

In addition to the specification of gas quality under normal conditions there is also a specification for wider limits of Wobbe under emergency conditions. The Regulations recognise that in some circumstances the introduction of out-of-specification gas into the network is less undesirable in safety terms than the loss of supply (particularly to domestic consumers). These are:

Part II - REQUIREMENTS FOR GAS CONVEYED TO PREVENT A SUPPLY EMERGENCY

The requirements of the gas referred to in regulation 8(2) and (4) are —

(a) Wobbe Number

(i) $\leq$ 52.85 MJ/m^3

(ii) $\geq$ 46.50 MJ/m^3;

(b) Incomplete Combustion Factor $\leq$ 1.49

and in all other respects the gas shall conform to the requirements specified in Part I of this Schedule.

2.4 EASEE-Gas Specification

EASEE-gas was set up in 2002 to develop and promote the simplification and streamlining of both the physical transfer and the trading of gas across Europe. The creation of EASEE-gas is a project that is fully supported by the European Commission and by the European Regulators through the so-called Madrid Forum. EASEE-gas, through its Working Groups, provides a structured platform where industry participants can discuss the harmonisation and simplification of business processes by developing Common Business Practices (CBP's).

The EASEE-gas proposal for the Common Business Practice (CBP) on '*Harmonisation of Natural Gas Quality*' was finalised on the 14th of December 2004. This resulted from some two years development involving 37 companies (mostly gas transporters) and 6 industry trade associations representing 14 European countries.

CBP 2005-01 was approved by the EASEE-gas Executive Committee on 3rd February 2005. The CBP recommends gas quality specifications at cross-border points in Europe. Natural gas arriving at cross-border points in line with these proposed quality specifications should not be refused for quality reasons. However, the CBP does not specify jurisdictional gas quality specifications nor does it attempt to restrict parties at a cross-border point in agreeing other specifications.

The EASEE-gas proposal for gas quality is shown below in Table 4.

Parameter	Unit	Min	Max	Recommended Implementation Date
Gross Wobbe Index (W.I.)	kWh/m^3	[13.60]	15.81	1/10/2010
Relative Density (d)	m^3/m^3	0.555	0.700	1/10/2010
Total Sulphur (S)	mg/m^3	-	30	1/10/2006
Hydrogen Sulphide + Carbonyl Sulphide (H_2S + COS (as S))	mg/m^3	-	5	1/10/2006
Mercaptans (RSH (as S))	mg/m^3	-	6	1/10/2006
Oxygen (O_2)	mol %	-	[0.01]*	1/10/2010
Carbon Dioxide (CO_2)	mol %	-	2.5	1/10/2006
Water Dewpoint (H_2O DP)	^oC at 70 bar (a)	-	- 8	see note **
Hydrocarbon Dewpoint (HC DP)	^oC at 1 - 70 bar (a)	-	- 2	1/10/2006

Table 4: EASEE Gas Quality Specification

* *EASEE gas have organised an oxygen measurement survey, which by end of 2005 will examine the maximum feasible limit equal to or at an alternative specified value below 0.01 mol %*

** *At certain cross border points, less stringent values are used than defined in this CBP. For these cross border points, these values can be maintained and the relevant producers, shippers and transporters should examine how the CBP value can be met in the long run. At all other cross border points, this value can be adopted by 1st October 2006.*

[Note: 1.0 kWh = 3.6MJ = 3412 Btu]

2.5 Wobbe Index Limits

The Wobbe Index of a gas is an indicator of its combustion acceptability for a given population of appliances and is the most significant parameter in terms of gas combustion safety. The Wobbe Index is calculated by dividing the higher heating value (or gross calorific value) by the square root of the relative density of the gas.

$$WobbeIndex = \frac{HHV}{\sqrt{RD}}$$

In all gas appliances, the flow of gas is regulated by making it flow through a hole or orifice of given size at a constant pressure. The higher the Wobbe Index of a gas, the greater the heating value of the quantity of gas that will flow through an orifice of a given size in a given amount of time. The Wobbe Index is therefore an indicator of the rate of heat flow from the burner. Too high a Wobbe Index can result in the over-heating of appliances, or sooting and carbon monoxide (CO) formation due to incomplete combustion. Too low a Wobbe Index can result in flame lift, or extinguishing of flames, resulting in the release of unburned gas. With respect to gas-fired power generating plant, Wobbe Index is a critical factor for generator combustion dynamics.

2.5.1 Variation and Control of Wobbe Index

Ballasting or other similar treatment lowers the Wobbe Index by introducing inert gases into the re-gasified LNG stream. The common forms of ballasting include air injection and nitrogen injection, with the nitrogen produced from either a membrane or cryogenic separation process. There are significant capital and operating costs associated with the installation and operation of ballasting equipment. Based upon typical[1] LNG specifications documented in a 2003 UK study (by ILEX)[2] and the U.S. NGC+ study[3], the existing Wobbe maximum range specification in the Code of Operations would allow for most potential LNG supplies to enter RoI without any treatment (i.e. ballasting) to reduce the Wobbe Index. Under the EASEE-gas Wobbe maximum limit, most LNG supplies could enter RoI without treatment. The UK Emergency Wobbe maximum limit would allow a majority of LNG supplies to enter RoI without treatment. Under the UK Normal Wobbe maximum limit, potentially only LNG from one source could enter RoI without treatment. Taking into account the findings of the same studies, if the U.S. maximum Wobbe limit (52.163 MJ/m^3 = 1400 Btu/scf) was adopted in Ireland, approximately 30% of the LNG supply referred to in the studies could enter the RoI without treatment.

2.6 Impacts of Non-Combustion Parameters

Although Wobbe Index is commonly regarded as the main parameter with regard to combustion safety, natural gas may possess certain physical characteristics and contain non-hydrocarbon constituents that have the potential to adversely affect gas transportation systems infrastructure, power generating plant and customers' installations and appliances downstream of the meter. The potential impacts of each of these commonly specified characteristics and constituents are discussed separately in the following sub-sections.

2.6.1 Total Sulphur

This parameter is the quantity of sulphur contained in the sulphur containing compounds that are present in natural gas (including any sulphur containing odorants). This specification is related to air pollution and indoor air quality control. High levels of sulphur compounds in the gas increase the amount of sulphur dioxide created when gas is burned and may lead to corrosion of appliances. Sulphur compounds in the gas may also lead to the deposition of elemental sulphur in pipelines, which also have a corrosive effect particularly in the presence of water. These sulphur compounds may have a very strong and unpleasant smell and may lead to 'nuisance' leak reports. Additionally, certain industrial processes – e.g. glass manufacturers – may be adversely affected by high sulphur content in the gas stream. The total sulphur content is specified as $\leq$ 50 mg/m^3 in GS(M)R, although short term excursions from the specified limit can be tolerated from a safety perspective provided that the average levels are kept within specification.

[1] LNG continues to 'weather' during shipment and storage in a liquid state, increasing the Wobbe Index and caloric/heating value. An LNG supply contract would have specification ranges exceeding the 'typicals' referred to in this paragraph. 'Typicals' vary to some degree from cargo to cargo.

[2] "Importing Gas into The UK - Gas Quality Issues" Page 58 Table 7', November 2003, ILEX Energy Consulting.

[3] "White Paper on Natural gas Interchangeability and Non-Combustion End Use", US NGC+ Interchangeability Work Group dated February 28, 2005

2.6.2 Oxygen

Oxygen (O_2) in the presence of water can cause corrosion within pipelines and at very high levels there is the potential for the formation of explosive mixtures. Oxygen is generally not present in significant quantities in producing gas fields. Its presence in natural gas is usually attributed either to contamination during transportation, processing, storage and distribution, or to air ballasting as a means of moderating the Wobbe Index. National limits vary widely across the world, reflecting different standards, custom and practice. The EASEE-gas ‘Gas Quality Harmonisation Working Group’ is still debating an appropriate limit to apply to European cross-border gas trade but has specified an interim limit of 0.01 mol% (100ppm). In Great Britain there are two limits pertinent to this review. The first (0.2 mol%) is a safety limit specified in Schedule 3 Part 1 (Regulation 8) of the GS(M)R. The second (0.001 mol%) is a limit imposed by National Grid for network operational reasons. No specific evidence emerged during the DTI Gas Quality Exercise to suggest that a revision of these two specifications was required. The current RoI Offtake Specification is equal to or less than 0.2 mol%. This level is consistent with the current UK GS(M)R specification.

The contribution made by the presence of trace levels of oxygen in the gas supply to the combustion process is negligible. Rather, the air-fuel ratio during combustion, that determines most of the associated emissions behaviour, is governed by primary and secondary air entrainment as the gas leaves an appliance injector nozzle. The contribution made by oxygen in the gas supply to the fuel efficiency of gas appliances in the combustion process is also believed to be negligible. Maximum permissible levels of oxygen for gas engines are typically 0.5% - 1.0% (5,000ppm – 10,000ppm). No issues are therefore expected to arise by either retaining, or by making modest changes to, the current specification.

Gas turbines typically tolerate only trace levels of oxygen in the gas supply.

In the presence of free water oxygen in natural gas can promote metal corrosion within pipelines and associated systems. Managing the prevention of corrosion is achieved by balancing the permissible level of oxygen and the water dewpoint/content. No evidence emerged during the DTI Gas Quality Exercise to suggest that this balance is inappropriate or that the current UK specifications give rise to significant costs. Reducing oxygen concentrations in natural gas below the current National Grid entry requirement of less than 10ppm could place a significant financial burden on gas suppliers, with a requirement to invest in removal facilities, whilst no obvious benefits are apparent for doing so. Similarly, raising oxygen concentrations in natural gas above the current 10ppm limit could also incur significant costs. Potential problems may arise at future gas storage sites and at gas processing facilities where reactions between oxygen and sulphur compounds, exacerbated by the elevated temperature and pressures, can lead to the deposition of solid sulphur. Solid sulphur deposition can block reservoir pore throats, leading to a long term decline in production rates. It can also block surface processing equipment and filters, leading to higher maintenance costs. It is understood that potentially incurring costs to permit a 100ppm oxygen limit would be of little value since a limit of at least 1000 - 2000ppm would be required to make the difference between cryogenic and membrane technologies for nitrogen generation at an LNG import site. Shannon LNG has submitted details of its assessment of the impacts of LNG processing on oxygen levels and this is described in more detail in Section 6.4 of this report. The level of allowable oxygen will therefore have an impact on the capital and operating costs of facilities to reduce the Wobbe Index of re-gasified LNG. The lower the oxygen limit, the higher the capital and operating costs to reduce the Wobbe Index

2.6.3 Carbon Dioxide

Carbon dioxide (CO_2) is classified as an "inert" along with other inert gases, principally Nitrogen (N_2) and to a lesser extent Helium (He) and Argon (Ar), that may be present in the gas stream. Inerts by themselves do not create a safety hazard and the specification limit is a method of controlling the levels of non-methane hydrocarbons (ethane, propane, butane etc.) so as not to exceed the specified Wobbe Index limits. Manufacturing plants that use natural gas as a feedstock may suffer adverse impacts to their processes where there are high carbon dioxide or nitrogen levels. Additionally, the total volume of inerts is an important factor for generators as, typically, they can cope with no more than 6% molar, otherwise breaches in emissions controls can occur, potentially resulting in a breach of the IPCC licence. Typically, the 'total inerts' specification limits for natural gas is c. 7.0 mol% (e.g. c.2 mol% CO_2 plus c.5 mol% N_2).

2.6.4 Nitrogen

See comments in 2.6.3 above.

2.6.5 Hydrogen Sulphide

Hydrogen sulphide (H_2S) is a corrosive, poisonous gas and its corrosion effect on pipelines and copper components in gas installations tends to be cumulative. Hydrogen sulphide is also a stress corrosion cracking agent for pipeline steel and the likelihood of creating stress cracks is dependant on the partial pressure of the hydrogen sulphide inasmuch that at higher gas pressures, a lower level of hydrogen sulphide must be specified. The hydrogen sulphide specification in the Code of Operations and GS(M)R is 5 mg/m^3 although Gaslink has experienced problems with hydrogen sulphide in domestic installations ("black dust") at a content of 2 mg/m^3 and about 100 installations per year require treatment.

2.6.6 Hydrocarbon Dewpoint

The hydrocarbon dewpoint is the temperature at which hydrocarbon liquids begin to condense out of the gas stream. There needs to be a sufficient margin between the ambient temperature of the flowing gas stream (normally c. 5^{0}C) and the hydrocarbon dewpoint. A 'high' hydrocarbon dewpoint may mean that liquid hydrocarbons can collect and form 'slugs' which can travel along pipelines and potentially damage gas flow regulating and measurement equipment. Hydrocarbon liquids also cause odorant removal from the gas phase. The presence of both hydrocarbons and odorant in the liquid phase can cause degradation of the rubber components of pressure regulating installations. Short term, relatively small excursions can be tolerated provided that the average levels are kept within specification. The hydrocarbon dewpoint in the Code of Operations and the UK-NTS Entry Specification is specified as - 2^{0}C up to 85 barg.

2.6.7 Water Content and Water Dewpoint

This parameter is sometimes expressed in terms of water content (e.g. 50 mg/m^3) or as an expression of water dewpoint (e.g. – 10^{0}C up to 85 barg as in the UK-NTS entry specification). ISO 18453:2004 specifies a method to provide users with a reliable mathematical relationship between water content and water dewpoint when one of the two is known. The calculation method, developed by the European Gas Research Group (GERG), is applicable to both the calculation of the water content and the water dewpoint. Using this standard, the water dewpoint parameter of – 10^{0}C up to 85 barg equates to a water content of 24 mg/m^3. The RoI Code of Operations specification for water content is 50 mg/m^3. Excess water in natural gas can condense and absorb carbon dioxide and sulphur compounds creating a corrosive liquid in the pipeline. Additionally, liquid water and high pressure gas can result in the formation of hydrates (snow-like compounds of natural gas and water) that can block gas pressure regulating and metering equipment or the pipeline itself. Therefore, the temperature of the gas stream must be maintained at a level sufficiently above the water dewpoint temperature to avoid liquid water formation in pipelines.

The diagram below illustrates the relationship between temperature and pressure with respect to both hydrocarbon (HC) and water (H_2O) dewpoint.

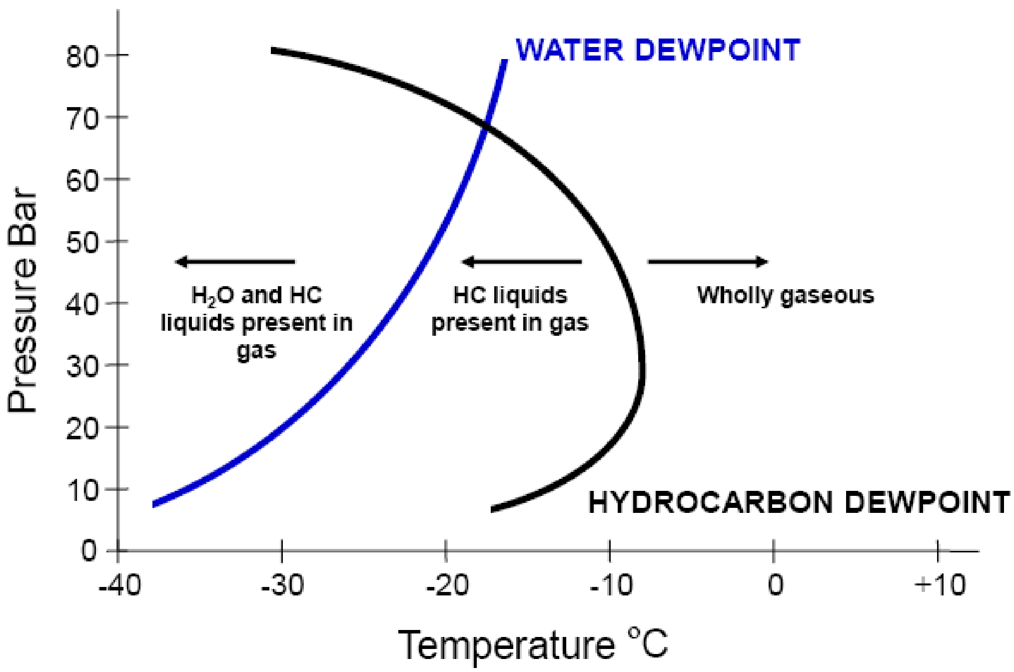

Figure 1: Hydrocarbon and Water Dewpoint - Pressure/Temperature Relationship

2.6.8 Other Gas Quality Parameters

Other gas quality parameters that need to be considered, but are not currently specified include:

- Gas Temperature (maximum and minimum temperatures in ^{o}C) – UK-NTS entry specification is between 1^{o}C and 38^{o}C;

- Gas Odorant NB - typically injected at a rate of 6 to 7 mg/m^3 and expressed in terms of the "Transco Odour Index". The target range is 1.7 to 2.2 equivalent to an odour intensity of 2^{o} on the Sales Scale which equates to a human threshold alert level of 1% gas in air or 20% of the lower explosive limit);

- Impurities and Contaminants – typically defined as *"solid and liquid materials which may interfere with the integrity or operation of pipes or any gas appliance"* as defined in BS 3156 11.02:1998 Analysis of Fuel Gases. Methods for Non-Manufactured Gases. General. Quality Designation for Natural Gas; Impurities and Contaminants are also an important issue for generators. For example, the following are important limits on heavy metals and salts: (i) Lead $\leq$ 2.0ppm; (ii) Calcium $\leq$ 10.0ppm; (iii) Vanadium, Potassium and Sodium $\leq$ 0.5ppm

- Hydrogen (mol%) – specified in GS(M)R as $\leq$ 0.1 mol%.

- Incomplete Combustion Factor (ICF) – specified in GS(M)R as $\leq$ 0.48

- Soot Index (SI) – specified in GS(M)R as $\leq$ 0.60

  [*Note: The ICF and SI are, in part, functions of the Wobbe Index and only occur in the GS(M)R gas quality specification. These parameters were developed during early work by British Gas on gas interchangeability in the 1980's. No other jurisdiction uses ICF and/or SI as part of its gas quality specification*].

- Organo Halides - specified in the UK-NTS Entry Specification as $\leq$ 1.5 mg/m^3.;

- Radioactivity – primarily relates to radon content in natural gas and is limited to 5 becquerels/g in the UK-NTS Entry Specification; and

- Ethane – normally specified in mol%.

As part of the discussion on gas quality parameters, Gaslink has developed a proposed Gas Quality Entry Specification. This is discussed in detail in Sections 4 and 7.

2.7 Arrangements for Gas Quality Monitoring

Natural gas enters the RoI gas transmission system at Moffat and Inch Entry Points and Corrib is scheduled to begin production in Q3-2009. Gas enters the NI gas transmission system at Twynholm Entry Point. Each entry point has an associated Connected Systems Agreement (CSA) that contains the gas quality specification for gas entering the network.

- **At Moffat Entry Point**, there are no gas quality provisions in the CSA but gas leaving the UK-NTS and entering the RoI system at Moffat conforms to the GS(M)R gas quality specification, which is a statutory obligation in the UK. National Grid measures the calorific value of the gas at both Moffat and Beattock using a C6 chromatograph. A more detailed gas analysis is not possible using this equipment thus other gas quality parameters are not measured at these locations. Additionally, Gaslink undertakes calorific value measurement at Beattock using a C6 chromatograph. In reality, there is low risk of non-compliant (with GS(M)R) gas entering the RoI system at Moffat/Beattock but a detailed gas analysis cannot be undertaken due to the nature of the measuring equipment currently installed.

- **At Inch Entry Point**, Marathon Oil Ireland Limited (MOIL) is responsible for the installation, calibration, operation and maintenance to the installed calorimetric equipment and provide repeat signals to Gaslink. The installed equipment consists of two chromatographs and MOIL measure some gas quality constituents at Inch, C1 to C6+, carbon dioxide and nitrogen. Some constituents are measured by manual sampling. Additionally, MOIL provide C1 to C12 measurements offshore and provide these as repeat signals to Gaslink. The Wobbe Index range in the Inch CSA is aligned with GS(M)R and requires MOIL to advise Gaslink as soon as it becomes aware that the gas being made available at Inch Entry Point does not meet the required specification. Additionally, Gaslink has witnessing and audit rights which are detailed in the CSA but not in local operating procedures.

- **At Corrib Entry Point**, the Operator has confirmed that the specification of gas injected conforms to GS(M)R with respect to Wobbe Index.

- **At Twynholm Entry Point**, gas entering the NI gas transmission system conforms with GS(M)R.

Table 5 below shows the various gas quality parameters that are currently measured at the four entry points to the RoI and NI gas transmission systems.

Gas Quality Parameter	**Moffat and Beattock**	**Inch**	**Corrib**	**Twynholm**
hydrocarbon to C6+	✓	✓ onshore		✓
hydrocarbon to C9+			✓	
hydrocarbon to C12+		✓ offshore		
carbon dioxide	✓	✓	✓	✓
nitrogen	✓	✓	✓	✓
calorific value	✓	✓	✓	✓
relative density	✓	✓	✓	✓
wobbe index	✓	✓	✓	✓
hydrocarbon dewpoint		✓ offshore	✓	
moisture content		✓ onshore	✓	
incomplete combustion factor			✓	
soot index			✓	
odorant injection rate		✓	✓	

Table 5: Gas Quality Measurements at Entry Points

In addition to the above, Gaslink undertakes:

- offline analysis based on monthly sampling of key gas quality parameters at Inch, Loughshinny and Gormanston, measuring:
    - hydrocarbon to C12+
    - carbon dioxide
    - nitrogen
    - calorific value
    - relative density
    - wobbe index
    - hydrocarbon dewpoint
    - moisture content
    - odorant concentration

- offline odorant analysis at 25 transmission sites and 25 distribution sites using a mix of Gaslink and independent laboratories;

- exit point analysis using 35+ online chromatographs measuring:
    - hydrocarbon to C6+
    - carbon dioxide
    - nitrogen
    - calorific value
    - relative density
    - Wobbe index

3. Gas Appliance Directive

The debate regarding the safety of gas-fired equipment responding to variations in gas quality has focused on gas turbines for power generation and the population of existing domestic appliances. The Gas Appliance Directive was introduced in the early 1990's to provide a consistent European approach to gas appliance safety. It might be expected that post-GAD appliances are therefore more tolerant to gas quality variations than their predecessors but this is not necessarily the case. The modern gas boiler, for example, is tuned closely to the current expected line gas specification in order to meet efficiency and emissions performance requirements.

The *"Essential Requirements"* for GAD include:

- Appliances must be so designed and built as to operate safely and present no danger to persons, domestic animals or property when normally used as defined in Article 1 (4) of this Directive;

- Appliances must be so constructed that, when used normally, flame stability is assured and combustion products do not contain unacceptable concentrations of substances harmful to health. For the purposes of this Directive, an appliance is said to be 'normally used' when it is:

    - correctly installed and regularly serviced in accordance with the manufacturer's instructions;

    - used with a normal variation in the gas quality and a normal fluctuation in the supply pressure; and

    - used in accordance with its intended purpose or in a way which can be reasonably foreseen.

This raises issues of regular servicing of appliances and the local adjustment of appliance air/fuel ratio as part of installation and maintenance practice. If gas quality in future varies more than previously seen, then an appliance adjusted to optimal combustion performance at one limit of Calorific Value or Wobbe Index may be maladjusted to tolerate gas at an opposite limit.

4. DTI/BERR Gas Quality Programme

During 2005 a major test exercise was performed on behalf of the UK Government Department BERR (formerly DTI) to examine the variation in combustion performance of a range of representative domestic gas appliances working at the extremes of the EASEE-gas Wobbe Index limits and beyond. Some 25 appliances were tested representing circa 70% of the UK gas appliance population. The following data was collected from the appliances operating under different gas qualities:

- CO emissions;
- CO_2 emissions;
- CO/ CO_2 ratio;
- NOx emissions;
- Air Factor from CO_2 and O_2 measurements in flue gas;
- Surface temperature of appliance at three locations (minimum);
- Particulate matter measurements in flue gas;
- Flue gas temperature;
- Derive thermal efficiency of appliance (flue loss method);
- Record any changes in the performance of safety devices;
- Record any changes in ignition characteristics; and
- Fuel leakage measurement from appliance exhaust

A typical graph of test results is shown below for a wall-hung condensing boiler.

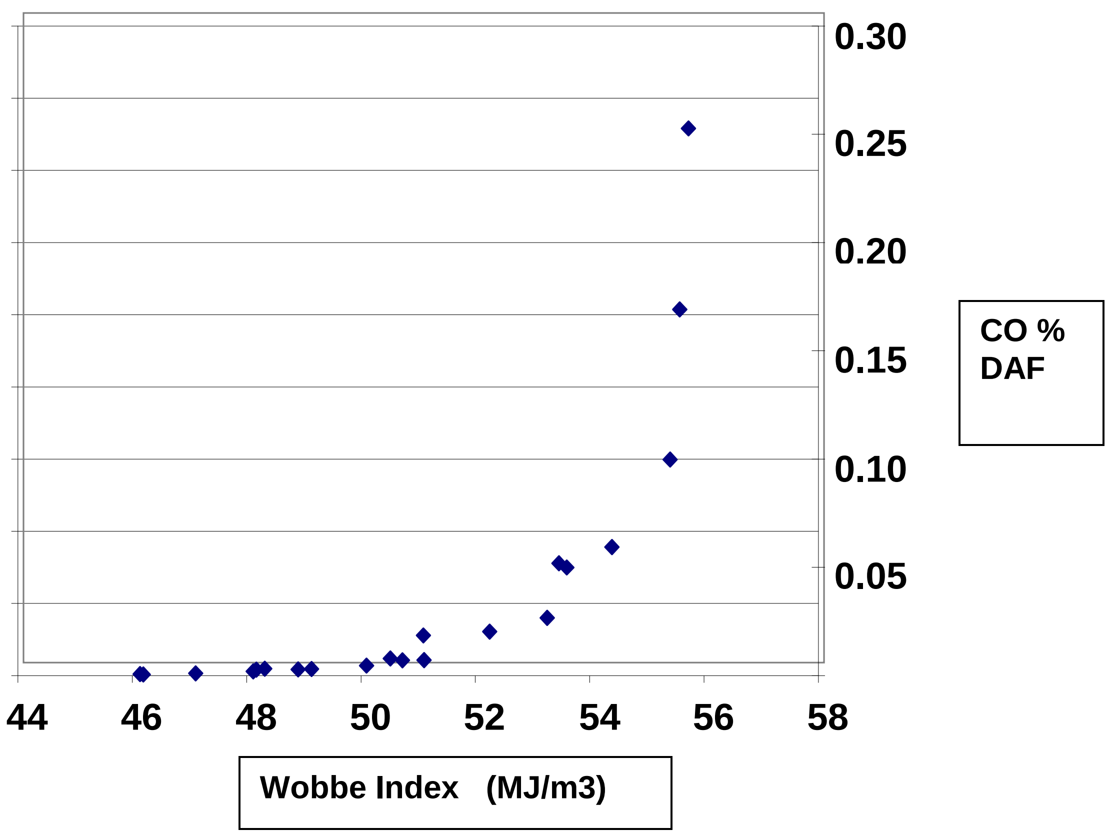

Figure 2: Test Results for a Wall-Hung Condensing Boiler

The conclusions from this work were:

- Tests within W.I. 47.2 – 51.4 MJ/m^3 (GS(M)R) resulted in acceptable performance (the boiler appliance test standard EN 483 requires a maximum of 0.1% CO DAF in the flue gas under normal operating conditions);

- Exponential increase in CO emissions are seen at W.I. beyond 53 MJ/m^3; and

- There is a potential for badly maintained appliances to produce CO levels that may cause risk to consumer safety

Generally the test gases within the range of Wobbe Numbers from 45 to 52 MJ/m^3 resulted in acceptable appliance operability compared with current standards for G20 (pure methane) reference gas.

Increasing the Wobbe Number of the gas used will almost certainly increase the emission level of carbon monoxide. Whilst the levels produced from the appliances tested in this programme were on the whole modest, except for Wobbe Number gases >53 MJ/m^3, there is the potential for badly maintained or installed appliances to produce CO levels that may cause an increasing overall health risk.

Ballasting with nitrogen does not impact on the appliances. High Wobbe Number gas (52 – 56 MJ/m^3) ballasted with nitrogen to produce a gas compliant with the GS(M)R does not appear to have any detrimental effect on emissions or performance. Overall the ballasted gas behaved comparably to G20.

The conclusion from the DTI/BERR study was that an upstream option – i.e. gas ballasting with nitrogen – was a significantly more favourable option than a downstream option of making manual adjustments to consumers gas appliances, not least on the basis of the costs involved.

With this knowledge in mind, an exercise was commissioned by Gaslink and completed during 2008 to compare the issue of consumer safety and risk identified in the UK Gas Quality Programme with that of the gas appliance population in RoI.

The following table compares the UK and Ireland gas boiler populations, which is by far the largest domestic gas load.

Gas Boiler Type	DTI Tests	UK 000's	UK % of total	RoI 000's	RoI % of total
W/Mounted Cast Iron	✓	7971	39	288.7	49.5
W/Mounted Sys Non-Con	✓	1274	6	206.8	35.5
W/Mounted Combi Non-Con	✓	6482	32	43.2	7.4
W/Mounted Htg. Con	✓	901	4	14.4	2.5
Back Boiler Unit	✓	2500	12	13.2	2.3
Floor Standing Non-Con.	✓	78	<1	11.5	2.0
W/Mounted Combi. Con	✓	1159	6	4.9	0.8
TOTALS		**20,365**	**100%**	**582.7**	**100%**

Table 6: Comparison of UK and RoI Gas Boiler Populations

The table shows that the DTI testing covers all the appliances identified in the RoI market and therefore the conclusions to the DTI work are valid for RoI except in terms of scale:

- Irish and UK gas boiler populations are comparable with similar types, models and manufacturer;

- UK Government sponsored appliance test work identified safety concerns, particularly CO emissions, which might occur should existing appliances operate under wider Wobbe Index Limits than current GS(M)R thresholds; and

- Similar safety concerns should be raised regarding the RoI gas appliance population and as such the Code of Operations gas quality specification for Entry and Offtake points should be aligned with the GS(M)R limits of Wobbe Index (47.2 – 51.41 MJ/m^3)

As part of this work, some costing was estimated such that if a wider Wobbe specification was introduced then some appliances would require adjustment, others would require replacement and some may be able to tolerate the wider specification, such that:

- Adjust a proportion of appliances (20%);
- Replace other appliances (60%);
- Assume the remaining 20% of appliances do not require any changes;
- There may be additional other costs and/or the required replacement rate might be higher than estimated; and
- It cannot be assumed that post-1996 (GAD) boilers and more modern high efficiency boilers can meet emissions specifications on Wobbe limits beyond GS(M)R

Even for the appliances targeted for adjustment or replacement there is a risk that a number would not be identified and remain in the system. This mixed scenario option was estimated at approximately €876 million.

Given this scenario, the upstream option of carrying out gas ballasting prior to system entry appears more favourable than a downstream option of converting gas appliances.

5. Experiences of Gas Quality Issues in Europe and USA

5.1 EU Member States

Marcogaz, the European gas technical association has used its membership to gather data on gas quality and the following table summarises the major gas consuming countries and the minimum and maximum values for Wobbe in national regulations. Also shown, and most important, is the indication within these limits of the usual values seen by customers. This indicates, for example, that countries such as Spain and Germany have wider specification limits, but normally they are operating well within these limits and are comparable in range (some 8%) to other countries. These wider specifications do not, however, reflect the narrower operating bands of gas quality within which these countries operate in practice. Also shown on the left of this table is the range of L-gas (low CV gas) specifications which is supplied in some European countries through a completely separate pipeline or network.

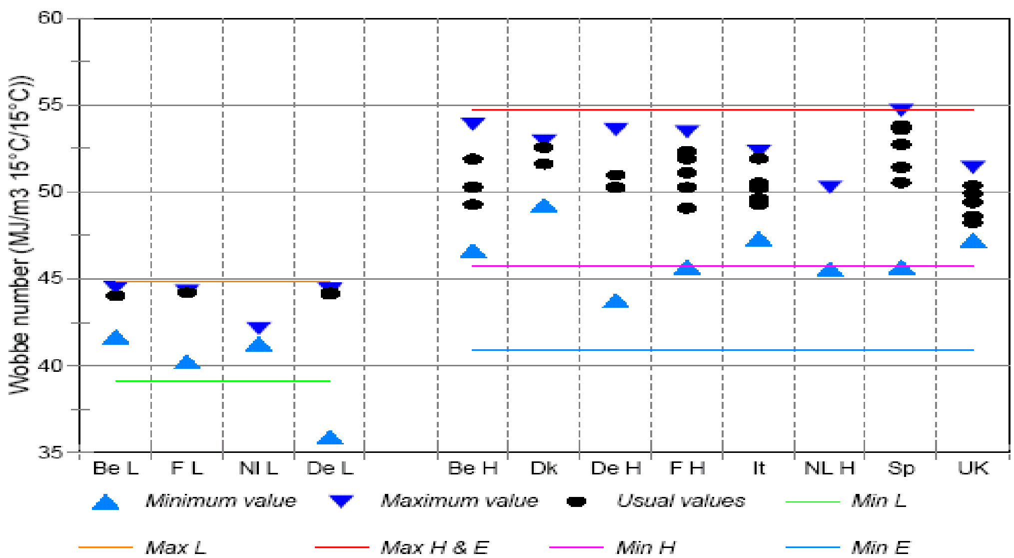

Figure 3: Gas Quality Specification Limits in EU Member States

As a further comparison, the next table shows the gas quality specifications for the major European pipeline operations of Norway, UK (GS(M)R) and National Grid (UK-NTS Entry), Interconnector UK and the EASEE-gas/Marcogaz specifications.

Parameter	Norwegian	GS(M)R	Typical NTS	IUK	Marcogaz	EASEE-gas
Gross CV (MJ/m^3)	38.1 - 43.7		36.9 - 42.3	38.9 - 44.6	35.01- 45.18	
Wobbe Index (MJ/m^3)	48.3 – 52.8	47.2 – 51.41	48.14 – 51.41	48.23 – 51.17	47.0 – 54.0	46.45 – 53.99
Oxygen (% mol)	0.1	0.2	0.001	0.001	0.001 – 1.0	0.01
Carbon Dioxide (% mol)	2.5		2.0	2.0	2.5	2.5
Hydrogen Sulphide (mg/m^3)	$\leq$ 5 mg/m^3	$\leq$ 5 mg/m^3	$\leq$ 3.3 ppm	$\leq$ 3.3 ppm		5.0
Total Sulphur	15 ppm	$\leq$ 50 mg/m^3	15 ppm	15 ppm	$\leq$ 30 mg/m^3	$\leq$ 30mg/m^3
RSH (as S)						$\leq$ 6mg/m^3
Water Dewpoint	-18^{o}C at 69 barg	No impact on integrity or operation	-10^{o}C at delivery pressure	- 10^{o}C at 69 barg	- 8^{o}C at 69 barg	- 8^{0}C at 70 barg
Hydrocarbon Dewpoint	- 10^{o}C at any pressure above 50 barg	No impact on integrity or operation	- 2^{o}C at 75 barg	- 2^{o}C at 69 barg	- 2^{o}C at any pressure above 69 barg	- 2^{o}C at 70 barg
Delivery Temperature (^{o}C)			1^{o}C to 38^{o}C	2^{o}C to 38^{o}C		
Hydrogen (% mol)		0.1	0.1		0.1	
ICF		$\leq$ 0.48	$\leq$ 0.48			
SI		$\leq$ 0.60	$\leq$ 0.60		replace with RD of 0.55 – 0.70	replace with RD of 0.555 – 0.700
Total Inerts (% mol)			$\leq$ 7.0			
Nitrogen (% mol)			$\leq$ 5.0			

Table 7:Gas Quality Specification for Principal Pipeline Operators

[Note: Reference conditions are all at Combustion 15^{o}C: Volume 15^{o}C and Pressure 1.01325 bar]

5.2 CEN Study (CEN Mandate M/400)

CEN is the standards body for European gas and the European Commission has placed a mandate on CEN to develop a harmonised European gas quality standard. This is to be produced over a 5 year period concluding in 2012/13. The initial work is a 2 year programme of market analysis and appliance testing to investigate the tolerance of new and used European appliances to wider gas quality variations. CEN Mandate: *"…for the combustion parameters a testing programme on safety, efficiency and environmental impact is needed in order to define the standards…".* The CEN Mandate (M/400) requirements are:

- Only GAD-compliant appliances are included;
- Only domestic appliances to be tested; and
- All European countries using gas in H Group 2

The work programme will be divided into work packages as shown in Figure 4 below and is generally following the pattern modelled by the DTI/BERR schedule:

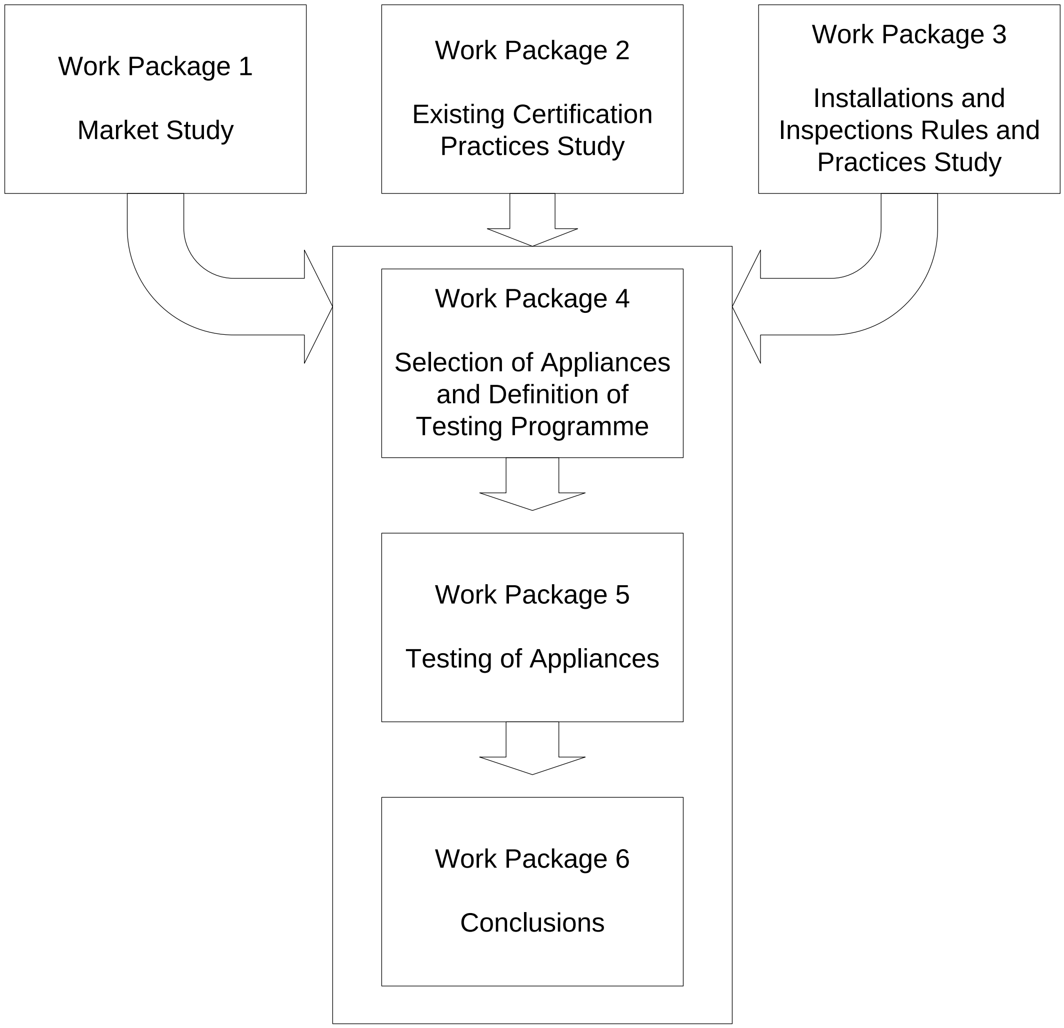

Figure 4: CEN (Mandate M/400) Work Programme

The various work packages that comprise the overall work programme are summarised below in terms of their individual objectives and deliverables.

Work Package 1: Market Study

Objective: To provide a view of the existing market of domestic and non-domestic appliances with respect to typology and trends and within the scope of Directive 90/396/EEC .

Deliverables:

- A list of type of appliances and principle for segmentation;
- The type of user – i.e. domestic or non-domestic, or both, for each segment of appliances;

- An estimation of the size and composition by age of the installed appliance population by segment; and
- The forecast evolution for the number of appliances for each segment

Work Package 2: Existing Certification Practices Study

Objective: To study the certification procedures – i.e. type testing and production assessment – conducted by the Notified Bodies according to Directive 90/396/EEC in order to identify the similarities and discrepancies in the implementation of the directive in the countries considered.

Deliverables:

- The identification of the certification procedures studied;
- The methodology used for assessing the certification practices;
- The results of these assessments; and
- The analysis of these certification practices in terms of similarities and discrepancies

Work Package 3: Installations and Inspections Rules and Practices Study

Objective: To study the installations and inspections practices in order to identify the similarities or discrepancies at a national or regional level.

Deliverables:

- A description of the rules for installations and inspections of appliances with the identification of the main bodies or organisations responsible for the application of the rules;
- For each segment of appliances identified in Work Package 1, a description of the installation and inspection rules applicable to the specific segment of appliances; and
- For each segment of appliances identified in Work Package 1, a description of the accepted practices for installation and during inspection

Work Package 4: Selection of Appliances and Definition of Testing Programme

Objective: To select a sample of domestic appliances for testing and to devise a test programme based on the results of Work Packages 1 to 3. …..The testing programme shall give a good understanding of the impact of changing gas quality on the safe functioning of appliances tested and on the change in efficiency and environmental performance…..

Deliverables:

- A segmentation of the European domestic appliances……and the expected sensitivity of the population of gas appliances to gas quality variations;
- For each segment, the identification of appliances that should be tested;

- For each segment, the intended testing programme; and
- The final budget for the testing programme

Work Package 5: Testing of Appliances

Objective: To execute the testing programme defined for the sample of appliances as defined in Work Package 4 with due attention to reliability.

Deliverables:

- The identification of the laboratories conducting the testing programme;
- The lists of appliances and tests conducted by each of these laboratories;
- Demonstrations of the reliability of the testing results as conducted by the different laboratories;
- Evidences based on the results of inter-comparisons (e.g. round robin tests) demonstrating the repeatability between the laboratories;
- For each appliance tested, a complete test report; and
- For each appliance tested, a synthesis describing the tests that have been conducted and their results in terms of the observed modification in terms of safety, efficiency and environmental performance

Work Package 6: Conclusions

Objective: To conclude about the impact of changing gas quality on the behaviour of appliances in terms of safety, efficiency and environmental performances.

Deliverables:

- Definitions of the parameters for defining gas quality and justifications for this choice;
- For each segment defined in Work Package 4, the range of variations for these parameters that does not compromise the essential requirements as expressed in Directive 90/396/EEC; and
- For non-domestic appliances, the evaluation and the methodology used to achieve this evaluation.

5.3 United States of America

In 2005, the Federal Energy Regulatory Commission (FERC) undertook an initiative to examine and update natural gas interchangeability standards in the light of rising LNG imports and depleting indigenous sources of gas being replaced by new sources of supply from further afield. A group of industry-wide stakeholders, under the leadership of the Natural Gas Council, formed a technical work group (NGC+) to address the gas interchangeability issues associated with high calorific value LNG imports. The output of the Technical Working Group was the *"White Paper on Natural Gas Interchangeability and Non-Combustion End-Use"* dated February 2005.

The objective of the White Paper was to define acceptable ranges of natural gas characteristics that can be consumed by end users while maintaining safety, reliability and environmental performance for both LNG imports and domestic supplies of gas. The White Paper contains numerous findings and recommendations, many of which are specific to the US gas market. However, there are many issues that have common ground with the topics currently under debate within the Gas Quality Industry Group and are highly relevant for the purposes of this report. These are described in the sub-sections below.

5.3.1 Key Findings

The following are the relevant key findings of the NGC+ technical work group in the context of this report:

- *"The Wobbe Number provides the most efficient and robust single index and measure of gas interchangeability. There are limitations to the applicability of the Wobbe Number, and additional specifications are required to address combustion performance, emissions and non-combustion requirements";*

- *"Gas interchangeability guidelines must consider historical regional gas variability as well as future gas supply trends. Interchangeability is an issue for both domestic gas supply and LNG imports";*

- *"Varying natural gas composition beyond acceptable limits can have the following effects in combustion equipment:*

  a. *In appliances, it can result in soot formation, elevated levels of carbon monoxide and pollutant emissions, and yellow tipping. It can also shorten heat exchanger life, and cause nuisance shutdowns from extinguished pilots or tripping of safety switches*.

  b. *In reciprocating engines, it can result in engine knock, negative changes in engine performance, and decreased parts life.*

  c. *In combustion turbines, it can result in increased emissions, reduced reliability/availability and decreased parts life.*

  d. *In industrial boilers, furnaces and heaters, it can result in degraded performance, damage to heat transfer equipment and non-compliance with emission requirements.*

  e. *In all end-use equipment, it can result in flame instability, including lifting and blowout in appliances".*

- *"Varying gas composition beyond acceptable limits can be problematic in non-combustion related applications where natural gas is used as a manufacturing feedstock………because historical gas compositions were used as the basis for process design and optimisation of operating units….."*

- *"Fluctuations in composition beyond the limits equipment is tuned to receive, particularly if it occurs over a short period of time, is likely to reduce the ability of some equipment to perform as intended by the manufacturer".*

- *"Gas system infrastructure impacts must be considered when supply compositions change for extended periods of time……. Additional infrastructure issues include impacts to custody transfer gas measurement techniques (thermal vs. volumetric billing) and related gas accounting issues".*

- *"In the majority of cases, interchangeability is best managed at two key points along the value chain, at the origin of supply or prior to delivery into the existing pipeline infrastructure".*

- *"Overly broad limits in the interchangeability specifications may result in reduced reliability, increased emissions and decreased safety on end use equipment and consequently higher costs to consumers. On the other hand, unduly conservative restrictions on the interchangeability specifications due to lack of data may result in both limited supply options and higher costs to consumers".*

5.3.2 NGC+ Recommendations

The overall recommendation(s) of the NGC+ technical work group was based on the recognition that there is a need to maximise the available supply and at the same time meet the specifications of end use equipment. Additionally, that there are gaps in the data regarding regional characteristics as well as the specific limitations and tolerances for end use equipment. With this in mind, the NGC+ work group recommended the adoption of a transition period to gather and analyse additional data and conduct more testing to provide a basis for establishing more definitive guidelines. However, the work group recommended the adoption of interim guidelines for gas interchangeability based on: (i) extensive data and analysis for traditional gas appliances and combustion behaviour in appliances; and (ii) the lack of data on gas interchangeability for a broad range of other end use applications.

The interim guidelines were developed using conventional interchangeability index calculations based on an 'average gas' characterised by a Wobbe Number of 1345 and gross calorific value of 1035 Btu/scf. The interim guidelines specifications are as shown below.

Interim Guidelines

A. A range of plus and minus 4% Wobbe Number Variation from Local Historical Average or, alternatively, Established Adjustment or Target Gas for the Service Territory

Subject to:

Maximum Wobbe Number Limit: 1,400* (typically 1345)
Maximum Heating Value Limit: 1,100 Btu/ft^3 (typically 1035 Btu/ft^3)

(* this is equivalent to a maximum Wobbe Number of **52.163 MJ/m^3**)

B. Additional Components maximum limits:

Maximum Butanes+: 1.5 % mol
Maximum total inerts: 4.0 % mol

C. EXCEPTION: Service territories with demonstrated experience with supplies exceeding these Wobbe, Heating Value and/or Composition Limits may continue to use supplies conforming to this experience as long as it does not unduly contribute to safety and utilisation problems of end use equipment.

Figure 5: NGC Technical Work Group on Gas Interchangeability and Non-Combustion End Use – Interim Guidelines.

Additionally, a FERC (Federal Energy Regulatory Commission) Policy Statement on Natural Gas Interchangeability (June 2006) emphasized the need to balance safety and reliability concerns with the importance of accommodating the greatest economic mix of gas supply with minimum barriers to new supply sources including pipeline blending when operationally feasible[4].

For the purposes of comparison, the table below summarises the upper Wobbe Index limits for the various jurisdictions discussed.

	MJ/m^3	**Btu/scf**
RoI existing specification	54.70	1468
EASEE – gas	54.00	1449
UK Emergency	52.85	1418.5
US	52.16	1400
UK Normal	51.41	1380

Table 8: Summary of Upper Wobbe Index Limits

[4] June 15, 2006 Press Release (Page 2) 'Commission Adopts Policy Statement on Natural Gas Quality'; 2nd part on blending - Docket PL04-3 dated June 15, 2006 Paragraphs 30 and 39-41.

6. Implications for Maintaining or Changing Gas Quality Specifications

This section reviews the potential implications for maintaining or changing the current RoI gas quality specification.

6.1 Impacts on Customers

6.1.1 Residential Customers

The recent Advantica report, *"The Impact of Gas Quality on Appliances"* – dated 18th February 2008 - documents the potential safety risks associated with domestic gas appliances when allowing gas with Wobbe Index limits of the current RoI gas quality specification (45.7MJ/m^3 to 54.7MJ/m^3) to enter the Gaslink transmission system. These safety risks have been extensively discussed in Section 4 of this report and the Advantica report discusses the impact of CO mitigation activities which are undertaken such as media campaigns and consumer safety literature. The conclusion reached by Advantica with respect to the safe operation of domestic appliances is that the Code of Operations specifications for entry and offtake points should be aligned with the GS(M)R limits for Wobbe Index (47.2 to 51.41MJ/m^3) .

6.1.2 Industrial and Commercial Customers

The main focus of the research and investigations undertaken to date in GB on changing gas quality specifications has been with regard to domestic appliances and gas-fired power generating plant. There is a general lack of data on the potential impacts of changing gas quality on industrial and commercial gas burning processes and non-combustion end use such as chemical feedstock etc. This is not surprising given the potential wide range of applications for natural gas burning processes in the industrial and commercial sector. The Department for Business Enterprise and Regulatory Reform (BERR) Report of November 2007 *"Future Arrangements for Great Britain's Gas Quality Specifications"* documents the general industry responses to questions regarding industrial and commercial appliances. These are:

Question 7: What would be the consequences for industrial and commercial gas appliances (in terms of safety, fuel efficiency and emissions levels) of relaxing the specifications for the combustion parameters of the GS(M)R? At what specification do these impacts become apparent?

"There were 7 specific responses to this question from: AEA Technology plc, E.ON UK plc, Gas Industry Safety Group, Global Energy Associates Ltd, Natural Gas Vehicles Association, PX Limited and SBGI and ICOM Energy Association. Almost all highlighted the adverse impacts of relaxing the GS(M)R specification on safety, fuel efficiency, emissions and reliability. Only one attempted to indicate the specification limits where these impacts become apparent; all others were purely qualitative"

A separate study may be required to better understand the potential impacts of wider Wobbe Index gas (than GS(M)R) being used for industrial and commercial gas burning processes within RoI.

6.1.3 Power Generators

Power generators were provided with a short questionnaire that invited responses to the questions posed by the Working Group. Five respondents provided their comments in response to the questionnaire. There were mixed responses due to the different design, technologies, age, etc. of the various installed gas-fired power generating plant but there is a sufficient consensus of opinion amongst generators to develop a fairly detailed view on generators' requirements. A summarised version of the responses are provided below:

Question 1 - Gas Constituents: Please set out the key gas quality constituents that affect gas generation plant performance and why; If you can, please rank in order of potential impact, and consider in your response possible implications on Security of Supply and Emissions Levels.

All respondents recognised Wobbe Index as the key gas quality parameter with one respondent stating that a Modified Wobbe Index (MWI), which introduces temperature into the calculation, was used for their particular plant. Another respondent stated the importance of specifying the following constituents:

- methane content should be specified in the range 85% to 98% mol;
- inert content (including carbon dioxide and nitrogen) should be limited to 6% mol; and
- hydrocarbon dewpoint/deliver temperature – the lower limit of the delivery temperature of the gas should be 9^{o}C, (not 1^{o}C as currently proposed by Gaslink) so as to maintain an 11^{o}C temperature differential between the hydrocarbon dewpoint (-2^{o}C at 85 barg) and the gas delivery temperature, to avoid hydrocarbon drop-out. Normal gas delivery temperature is in the range 3^{o}C to 5^{o}C, so this proposed increase in gas delivery temperature would require additional heating of the gas stream.

Other suggested limits for gas constituents included:

- ethane limits of 0% to 15%;
- propane limits of 0% to 15%; and
- butane + higher paraffins of 0% to 5%

With respect to security of power supply, there are serious implications with respect to plant reliability, availability and operability due to the need to make manual adjustments to the combustion control settings for fuel gas of varying quality. There is also the potential for an adverse effect on turbine component life and reduced performance.

With respect to emissions levels, the levels of impurities (inert gases) that are present in the gas will affect emissions and impact on compliance with EPA limits and IPPC licence requirements.

Question 2 – Current Specification: Are the gas quality specifications, Code of Operations (RoI) and the GS(M)R (NI), sufficient to meet the demands of modern day power stations, and if not, what changes, additions or subtractions to the specs are needed and why?

There was a broad consensus that the current Code of Operations specification was too wide and that the proposed Gaslink specification, which is aligned with the GS(M)R specification could be adopted as an absolute minimum. One respondent stated that the fuel gas specification for their power generating plant contained limits for trace metals, sodium/potassium and particulates. Other trace metals quoted as requiring specified limits were vanadium, lead, calcium, and magnesium. Another respondent supported the Gaslink proposal for oxygen and hydrogen sulphide limits of 0.001% mol and 5 mg/m^3 respectively.

Question 3 – Gas Quality Variations: To what extent should there be restrictions on gas quality readings/constituents and why?

The key issue for all respondents is unexpected variation in gas quality. Generators have confirmed that excursions outside of the present gas quality ranges that each plant is exposed to will cause issues. Each generating unit will also be tuned to the particular gas environment that it is exposed to. Unannounced significant excursions could cause generators to shut down which has implications for security of power supply. Also, generators have serious concerns with regard to the possible variability of gas quality. Manual tuning can accommodate some, but not all, variations. If variations are significant, it could ultimately shut the plant down until such time as burners can be modified or even replaced. In general, variations of more than +/- 2% in methane and/or Wobbe Index required some form of re-tuning of the generating plant and that operational performance, emissions controls and security of supply cannot be guaranteed outside this range. Other respondents felt that Wobbe Index variations of +/- 5% could be tolerated but outside of this much wider range, manual adjustments and/or change of hardware would be required.

Question 4 – Gas Quality Measurements: Do you believe the present gas quality measuring arrangements and alerts are adequate, if not, please explain why and what would be required going forward?

There was strong support for an improved system of gas quality monitoring, measurement and alert for notifying changes in gas quality to generators. The current system is regarded as inadequate and there should be appropriate controls to contend with:

- active management systems to ensure timely gas quality notifications are provided to generators; and
- reactive management systems to alert generators as quickly as possible to gas quality breaches.

Question 5 – Any other comments you wish to add?

Most of the comments received here were re-iteration and reinforcement of responses made previously under Q's 1 to 4.

6.2 Legislative Impacts

The current RoI gas quality specification is enshrined in the Code of Operations but does not exist in any legislative instrument. Therefore, any change to the current RoI gas quality specification could be undertaken relatively simply via the Code Modification Forum. The current NI gas quality specification, however, is enshrined in the Gas Safety (Management) Regulations (Northern Ireland) 1997 and would require legislative change. In light of the extensive research undertaken and evidence accumulated in GB on gas quality issues over the last several years as part of the DTI/BERR Gas Quality Programme (reference Section 4 of this report), the HSE (NI) have stated that they would not be in favour of changing the GS(M)R (NI).

6.3 Cross Border Flows

Given that legislative change in NI on the gas quality specification is unlikely, there are clear negative implications on cross-border flows as gas that does not conform with GS(M)R from RoI would not be allowed to flow into the NI transmission system. It has been suggested that there is a possibility for gas processing equipment to be installed at the custody transfer point between the RoI and NI transmission systems and moving the 'point of compliance' (with GS(M)R) further downstream. There would also be adverse implications for managing gas supply emergency situations via the Network Emergency Coordinator (NEC) and National Gas Emergency Manager (NGEM) in NI and RoI respectively.

6.4 Security of Gas Supply

Currently, gas supplies to the RoI are primarily imported via the interconnectors with the UK. Indigenous production in the UK is forecast to decline significantly in the coming years. Without any new discoveries of natural gas in Ireland, indigenous production will also reduce in Ireland once the Corrib field enters its decline phase. With over 60% of Ireland's electricity currently being generated by natural gas, security of gas supply is a major concern in the medium to long term. Additional sources of natural gas supply and storage will enhance security and reliability of supply of both the natural gas and electricity grids by reducing dependency on the UK imports through source diversity. An LNG plant in Ireland would contribute significantly to enhanced security and reliability of supply, given the associated LNG storage tank(s) and throughput capacity (re-gasification capability) of an LNG plant. It made sense in the past for Ireland to rely on the UK for the majority of its gas supplies as the UK had a surplus of indigenous gas production. The UK is now moving into a different era - National Grid forecasts that the UK will be importing over 70% of its natural gas by 2016/17, with a significant portion of these imports being LNG. Ireland may well find itself competing with the UK for LNG and consideration needs to be given to this possibility when considering narrowing the Wobbe Index range in Ireland to that of the UK. LNG can be sourced from a variety of countries and LNG liquefaction plants. The LNG producing regions in closest proximity to Europe are located in the Atlantic Basin (Caribbean, Northern Europe, North and West Africa) and the Middle East region. Significant new LNG supplies will be coming on-line within the next few years. Simultaneously, worldwide demand for natural gas and LNG is continuing to grow. Natural gas is widely considered to be the fossil fuel of choice for new electricity generation due to its environmental advantages versus other fossil fuels.

World-wide, there is more LNG import capacity than LNG liquefaction export capability which provides LNG suppliers with increasing choice in markets and destinations and this creates competition for LNG supply between importing countries and facilities. The number of LNG importing countries continues to grow and new import terminals as well as expansions of existing terminals are planned. Different LNG sources have different LNG quality specifications but are generally ‘richer’ (higher energy content with higher Wobbe Index and Caloric Value) than the supply historically received in RoI. A higher energy content can improve the economics of shipment and storage of LNG. Most European and North American markets will accommodate re-gasified LNG supply with a higher Wobbe limit than the proposed UK specifications. As discussed in section 2.5 and 2.6.2, retaining the current RoI gas quality specifications would likely remove the need to construct and operate treatment facilities at an LNG import facility. Conversely, aligning the RoI gas quality specifications with the UK GS(M)R would essentially eliminate LNG as a supply source without some form of ballasting to reduce the Wobbe Index. Treatment facilities are expensive to construct and operate. A low Wobbe maximum limit could limit the potential LNG supply sources, reducing diversity of supply which is a cornerstone of security and reliability. Additionally, a low Wobbe maximum limit coupled with restrictive limits on oxygen will compound this issue and may act as a deterrent to LNG suppliers comparing RoI to other competing markets with broader quality tolerances.

In order to assess the effects of the different ballasting options, Shannon LNG has submitted details of the three basic processes that it is currently considering for the adjustment of Wobbe Index for imported LNG, particularly in respect to the impacts on oxygen levels. In ascending order of cost and complexity, these are:

6.4.1 Air Injection

To use air injection (the injection of atmospheric air, after drying and filtering the air stream and compressing it to pipeline pressure) an oxygen limit of about 0.84% is required. The number of 0.84% is based on an inert injection rate of 4% in the send-out gas flow and would allow treatment of LNG to meet the UK upper Wobbe Index of 51.41MJ/m^3.

6.4.2 Nitrogen Membrane

To allow for the use of membrane-type nitrogen generation systems, the oxygen limit needs to be 0.2% molar. The number of 0.2% is based on an inert injection rate of 4% in the send-out gas flow and would allow treatment of LNG to meet the UK upper Wobbe Index of 51.41MJ/m^3. The 0.2% mol oxygen content complies with the GS(M)R specification limit for oxygen content – i.e. $\leq$ 0.2% mol

6.4.3 Cryogenic Nitrogen

With the potential oxygen limit of 0.001% mol, Shannon LNG would be limited to nitrogen generation by cryogenic air separation (or some other high purity system). An inert injection of 4% in the send-out gas flow would allow treatment to meet the UK upper Wobbe Index of 51.41MJ/m^3, but requires higher capital and operating costs than membrane generation.

7. The Gaslink Proposed Gas Quality Entry Specification

As part of the Working Group discussions and actions, Gaslink has developed a 'Proposed Gas Quality Entry Specification' that is based largely on a combination of: (i) the current GS(M)R gas quality specification; (ii) the UK-NTS Network Entry Quality Specification; and (iii) the current RoI Code of Operations gas quality specification. The specification for relative density has been excluded and there are additional proposed parameters for ethane (max 12 mol%) and methanol (300 ppm v/v). Additionally, there is no nitrogen limit proposed. The full proposed specification is shown below.

Gas Quality Parameter	Entry Specification	Reference
Hydrogen Sulphide	max 5 mg/m^3	GS(M)R 1996
Total Sulphur (including Hydrogen Sulphide)	max 50 mg/m^3	GS(M)R 1996
Hydrogen	max 0.1% mol	GS(M)R 1996
Oxygen	max 0.001% mol	NG Ten Year Statement
Hydrocarbon Dewpoint	-2^{o}C at any pressure up to 85 barg	NG Ten Year Statement
Water Content	50 mg/m^3	RoI Code of Operations
Wobbe Index	47.20 to 51.41 MJ/m^3 (real gross dry)	GS(M)R 1996
Incomplete Combustion Factor	max 0.48	GS(M)R 1996
Soot Index	max 0.60	GS(M)R 1996
Gross Calorific Value	36.9 to 42.3 MJ/m^3 (real gross dry)	NG Ten Year Statement
Carbon Dioxide	max 2.5% mol	NG Ten Year Statement
Contaminants	Note 2	
Methanol	300ppm v/v	
Odour	Note 1	
Delivery Temperature	1^{o}C to 38^{o}C	NG Ten Year Statement
Organo Halides	max 1.5 mg/m^3	NG Ten Year Statement
Radioactivity	max 5 becquerels/g	NG Ten Year Statement
Ethane	max 12% mol	

Table 9: Gaslink Proposed Gas Entry Specification

Notes:

1. Gas delivered shall have no odour that might contravene the obligation of the Transporter to transmit gas which possesses a distinctive and characteristic odour. Where the Transporter requires gas to be odourised, the gas shall be odourised in accordance with the following specification: Odour intensity of 2 Olfactory Degrees on the Sales Scale (Ref – IGEM/SR/16 Edition 2 – Odorant Systems for Gas Transmission and Distribution), or other such specification determined by the Transporter acting as an RPO.

2. Natural gas shall not contain solid, liquid or gaseous material which may interfere with the integrity or operation of pipes or any Natural Gas appliance which a consumer or transporter could reasonably be expected to operate. With respect to Mist, Dust, Liquid gas delivered shall be technically free in accordance with BS 3156 11.0 1998.

3. Standard Reference Conditions: Combustion reference temp = 15^{o}C, Volume unit = m^3 at 15^{o}C and 1.01325 bar

Gaslink's proposed Gas Quality Entry Specification is based largely on the GS(M)R specification, and the Group has agreed that the GS(M)R emergency gas specification limits will form part of the Entry Specification. These are:

a) Wobbe Number

   (i) $\leq$ 52.85 MJ/m^3

   (ii) $\geq$ 46.50 MJ/m^3

b) Incomplete Combustion Factor $\leq$ 1.49

The Group has reviewed the Gaslink proposal in detail and the following concerns have been expressed:

- Oxygen Content – Shannon LNG expressed the view that the 0.001% molar level would limit any gas processing options to a cryogenic nitrogen plant, which is the most expensive option of the three alternatives under consideration;

- Water Content – the Group agreed that the 50mg/m^3 level was acceptable but that this would need to be reviewed in light of any decision on oxygen content;

- Wobbe Index – the proposed limits were agreed as acceptable subject to Commission approval. Shannon LNG expressed the view that they do not consider it necessary to make a decision on the upper Wobbe Index limit at this stage;

- Gross Calorific Value – Gaslink has proposed limits of 36.9 to 42.3 MJ/m^3 in line with the UK-NTS Entry Specification, whereas the current RoI specification is 36.5 to 47.2 MJ/m^3;

- Total Inerts – Gaslink has proposed a carbon dioxide limit of 2.5% molar but no value for nitrogen. Respondents have proposed that the level of 'total inerts' based on CO_2 $\leq$ 2.5% molar plus N_2 $\leq$ 5% molar. Generators have also expressed concerns over the impacts of inerts on emissions levels;

- Contaminants – power generators in particular have concerns with the specification for contaminants and want to see limits imposed on: (i) Sodium; (ii) Potassium; (iii) Calcium; (iv) Lead; (v) Vanadium; and (vi) Manganese.; and

- Methanol – The Group discussed this issue and agreed that the methanol parameter should be removed.

The Group discussed the requirement for a transmission Exit Specification and agreed that the Exit Specification would be the same as the Entry Specification for the transmission system. However, there would be further work required to determine a suitable Exit Specification for the distribution system as there is the possibility that some gas quality parameters may change during conveyance in the distribution network. For example, water content levels are more difficult to control in distribution systems, which may in turn impact on calorific value and ultimately Wobbe Index.

8. Proposed Regime for the Management of Gas Quality

The management of gas quality is an important function for any gas system operator in much the same way as gas pressures and flows must be managed in order to keep the overall system in balance and in a safe operating mode. There are well defined procedures in place for managing gas supply emergencies – i.e. a shortage of gas or a significant, unplanned reduction in pipeline operating pressure – however, there are no equivalent defined procedures for actively managing responses to gas quality variations. It should be noted that the Group did not reach consensus on what would be appropriate gas quality measurement and monitoring arrangements. Consideration of these arrangements and the costs involved will be considered in 2009.

Power generators have commented, both during the course of the Working Group's meetings and via the responses to the issued questionnaire that there needs to be a system in place for notifying variations in the quality of gas being conveyed in the system to power plant operators sufficiently well in advance to allow mitigating actions to be taken. This section, therefore, proposes a regime for the management of gas quality that could be considered as part of the discussion on the gas quality specification for RoI and NI.

A regime for the management of gas quality should comprise the following main components:

a) A defined gas quality specification for gas that is to be transported under 'normal' operating conditions;

b) A defined gas quality specification for gas that may be transported under 'emergency' operating conditions;

c) An agreed system for the monitoring and measurement of identified gas quality parameters utilising specified equipment; and

d) Documented procedures for managing gas quality excursions based on a system of a hierarchy of responses comprising:

    1. CONFIRM: This response level applies to gas that is in specification, but close to the limit – a trigger point to check that the equipment monitoring the gas in question, to confirm that it is measuring correctly.

    2. NOTIFY: This response level applies to gas that has breached specification – a trigger point for relevant parties to be notified and for gas producers/importers to take immediate action to bring the given parameter within specification.

    3. MITIGATE: This response level applies to gas which may adversely impact certain parties – a trigger point for actions to be taken by relevant parties to mitigate any risk from the off-specification gas and indicates possible curtailment of injection.

    4. CURTAIL: This response level applies to gas that may cause significant adverse impacts to one or more parties – a trigger point for the injection of gas to be stopped.

5. REINSTATE: This is the gas quality level that the injecting party must be able to achieve before injection can be re-commenced following curtailment

With respect to a) and b) above, the output of the Working Group will be a recommendation for both a 'normal' and an 'emergency' gas quality specification.

With respect to c) above and arrangements for monitoring and measurement of gas quality at entry point to the RoI transmission system, Gaslink have made the following recommendations with respect to each RoI Entry Point:

- The upstream operator will have two primary chromats, and will provide Gaslink with repeat signals for gas quality parameters;

- Gaslink will install a secondary chromat at each Entry Point, to verify the repeat signals from the upstream operator, and ensure compliance with the gas quality specification;

- At each Entry Point, Local Operating Procedures will be put in place and agreed to include instrument accuracy, measurement range and sampling frequency etc.; and

- Ensure calibration checks on gas quality measurement equipment are witnessed on a regular basis and at the very least occasional audits of the calibration checks

With respect to d) above and in terms of 'Entry Point Arrangements', Gaslink have recommended that:

- Industry Rules/Entry Point Arrangements are developed to ensure as far as possible the consequences of non-compliant gas being delivered at an Entry Point are fully specified; and;

- At each Entry Point, Local Operating Procedures will be put in place and agreed to include:

    - Limits and timings at which gas quality alarms will be triggered;
    - Confirmation and validation of gas quality signals/data;
    - Notifications;
    - Mitigations;
    - Curtailment; and
    - Reinstatement

As an illustrative example of how such a system would work in practice, the confirm, notify, mitigate, curtail and reinstate limits for Wobbe Index as required under the Victorian (Australia) *"VENCorp Gas Quality Guidelines"* (Version 8 October 2007) are shown below in both tabular and graphical format.

Response Action	1. Confirm	2. Notify	3. Mitigate	4. Curtail	5. Reinstate
Wobbe Index Max (MJ/m^3)	51.5	52.0	52.5	53.5	52.0
Excursion Duration (minutes)	10	10	30	30	N/A
Wobbe Index Min (MJ/m^3)	47.0	46.0	45.0	44.0	46.0
Excursion Duration (minutes)	10	10	30	30	N/A

Table 10: VENCorp Response Limits for Wobbe Index

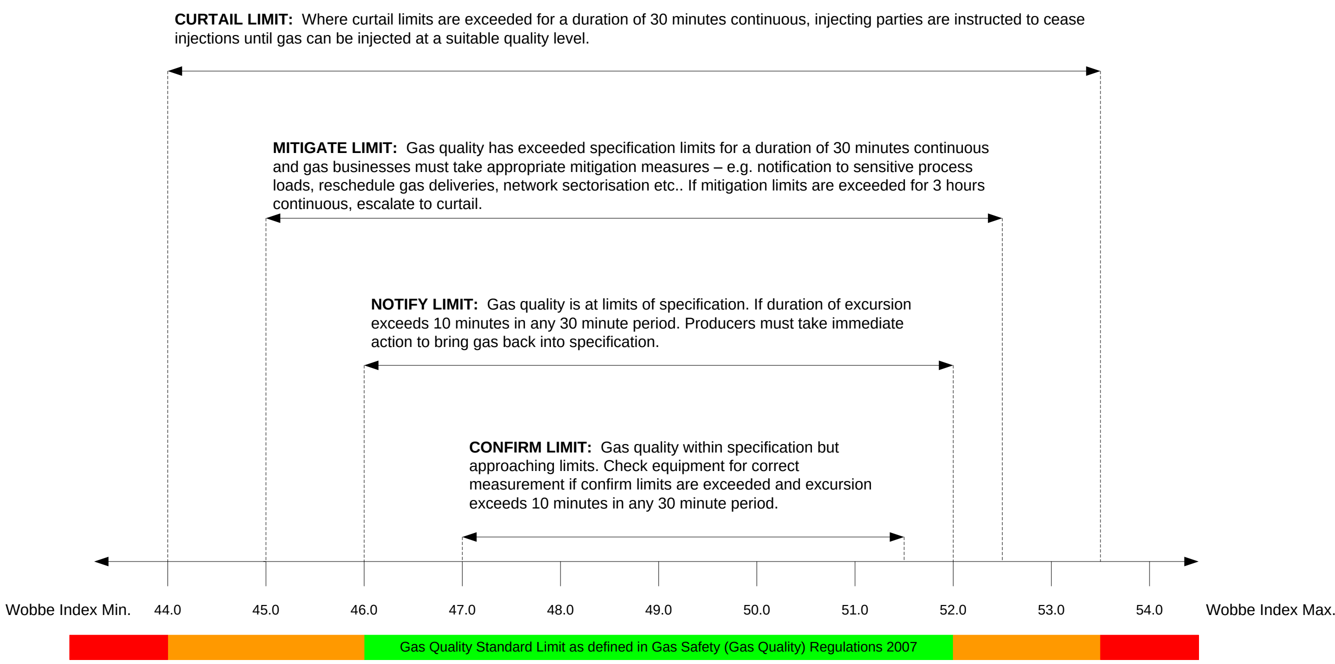

Figure 6: VENCorp Response Limits for Wobbe Index

Other gas quality parameters including oxygen, hydrogen sulphide, total sulphur, water content/dewpoint, hydrocarbon dewpoint, total inerts, odorant and temperature are independently specified in terms of the confirm, notify, mitigate, curtail and reinstate limits within the VENCorp Gas Quality Guidelines.

It is proposed that a similar system for managing responses for off-specification gas be considered as part of an overall gas quality management regime for RoI and NI.

9. Summary and Conclusions

This section provides a summarised analysis of the findings of the Gas Quality Industry Group as part of the workshops held throughout October to November 2008.

Summary of Key Findings:

9.1 Natural gas supplies to RoI over many years have been delivered within the GS(M)R specification despite the fact that the current Code of Operations Entry Specification is much wider than that of GS(M)R, particularly with respect to the range of Wobbe Index. The ‘average’ Wobbe Index experienced in RoI is approx. 50 MJ/m^3 and is within the GS(M)R lower and upper ranges of 47.20 and 51.41 MJ/m^3 respectively. Gas supplies injected at Moffat, Inch and eventually Corrib conform to the GS(M)R specification but the situation may change as other gas fields are exploited and, in particular, is likely to change with the introduction of LNG.

9.2 Although Wobbe Index is regarded as the main parameter with respect to combustion safety, there are other important non-combustion parameters that need to be considered as part of the overall gas quality specification as these can have adverse impacts on gas transportation infrastructure, large scale combustion plant and other gas burning appliances.

9.3 Gaslink has proposed a draft ‘Gas Quality Entry Specification’ which is largely based on GS(M)R and the UK-NTS Entry Specification with some additional limits included.

9.4 Domestic gas appliances imported into RoI undergo short term performance testing using the EN 437 test gas standard and have been shown to operate safely over long periods with no known safety issues related to the limited variations in Wobbe Index that are currently experienced. The Advantica Report *“The Impact of Gas Quality on Appliances”* shows that the population of domestic gas appliances in RoI is comparable to the domestic gas appliance population in GB. Therefore, the results of the combustion performance testing of GB domestic gas appliances over a wider (than GS(M)R) range of Wobbe Index test gases can be directly applied with a high level of confidence to the population of domestic gas appliances in RoI. The results of these tests on GB appliances identified serious safety concerns, particularly with regard to carbon monoxide emissions, which may occur should existing appliances operate under wider Wobbe Index limits than current GS(M)R thresholds.

9.5 The impacts of wider Wobbe Index limit gas on industrial and commercial appliances has not been researched in any great detail in GB or in RoI. Responses to the BERR/DTI consultation undertaken in 2007 highlighted the potentially adverse impacts of relaxing the GS(M)R specification on safety, fuel efficiency, emissions and reliability but not in any quantitative respect. A separate study/consultation may be required to better understand the potential impacts of non-GS(M)R gas on industrial and commercial appliances in RoI.

9.6 Responses from generators to a questionnaire seeking comments on gas quality issues covering: (i) gas constituents; (ii) current specification; (iii) gas quality variations; and (iv) gas quality measurements, demonstrated a consensus of opinion that the current Code of Operation specification is too wide and that the Gaslink proposed specification could be adopted as an absolute minimum with the addition of some new, and the modification of the limits of existing, gas quality parameters. A key issue for generators is variation in gas quality and variations of +/- 2% in Wobbe Index required some form of adjustment to generating plant with variations of +/- 5% requiring major adjustments or hardware changes. There is strong support amongst generators for an improved system of gas quality monitoring and measurements and notifications/alerts of gas quality variations in the gas being conveyed.

9.7 The issues associated with gas interchangeability and differing ranges of Wobbe Index are not confined to RoI and are being experienced in gas markets internationally, as sources of indigenous gas supply change and LNG imports increase. Studies are currently underway in Europe (via the CEN Mandate and EASEE-gas CBP's) and in the US (via the FERC-initiated study undertaken by the Natural Gas Council) to develop appropriate gas quality specifications that promote and support cross border trade in natural gas. The scope, timing and outcomes (where available) of these studies have been reviewed by the Gas Quality Industry Group as part of the Group's terms of reference and the results considered in the context of this draft report.

9.8 The current arrangements for monitoring and measuring gas quality parameters at RoI entry points are, in large part, dependant on the accuracy and reliability of the upstream operators' gas measuring equipment. Gaslink has recommended that the current arrangements are changed to allow Gaslink to perform its own checks and validations of gas quality entering the RoI system at each entry point. Additionally, Gaslink recommend that there should be Local Operating Procedures in place that specify limits for the various stages of confirmation/validation, notification, mitigation, curtailment and reinstatement of gas supplies where non-compliant gas is conveyed in the system.

Conclusions

9.9 Given the substantial body of researched evidence on the adverse effects of wider (than GS(M)R) Wobbe Index gas on domestic appliances, the responses and opinions of power generators in RoI and similar experiences associated with changing gas quality in other gas markets internationally, the Group is led to the conclusion that the current Code of Operations gas quality specification is too wide and should be aligned with the Gas Safety (Management) Regulations so as to reflect the specification of the gas that is currently being imported into RoI and will continue to be imported in the short term to medium term. This, in itself, would achieve a fundamental CAG objective of harmonising gas quality standards between RoI and NI.

9.10 There are limited opportunities for undertaking co-blending of high Wobbe Index gas, specifically LNG, within the RoI transmission system to achieve a range of Wobbe Index that can be safely utilised in RoI domestic gas appliances and some form of gas processing is therefore required prior to injection at system entry point. Increasing the oxygen limit to $\leq$ 0.2% molar appears to provide for more options to achieve a WI in line with GS(M)R and potentially reduce costs.

9.11 Further work is required to determine if the current regime for gas quality measurement and monitoring is appropriate from the perspective of: (i) Gaslink's role as an RPO; (ii) the provision of independent gas quality signals to Gaslink in order to measure gas quality at entry points ; (iii) the suitability of current gas quality measuring equipment at system entry point to measure the full range of gas quality parameters as contained in the Entry Specification; and (iv) the need for a system of monitoring gas quality information in real time to be made available to interested parties who are adversely affected by unexpected gas quality excursions.

10. Proposed Recommendations

The recommendations of the Group are:

1. The Gaslink proposed Gas Quality Entry Specification, based on the GS(M)R and UK-NTS Entry Specification, is adopted in the Code of Operations subject to the following changes:

    - Oxygen Content $\leq$ 0.2% molar (subject to further review)
    - Methanol to be removed

    The Exit Specification for the transportation system will be the same as the Entry Specification. The recommended specification is as outlined in Annex B.

2. Emergency gas specification limits should be adopted based on the GS(M)R limits of:

    c) Wobbe Number

    (i) $\leq$ 52.85 MJ/m^3
    (ii) $\leq$ 46.50 MJ/m^3

    d) Incomplete Combustion Factor $\leq$ 1.49

3. The Gas Quality Industry Group should convene twice yearly, in June and December, in order to address those issues identified as requiring further work as listed below.

The decision criteria that will be used to determine when the emergency gas specification limits are to be used in RoI will be developed as part of the Natural Gas Emergency Plan and implemented by the National Gas Emergency Manager.

Annex B of this report shows the full recommended Gas Quality Entry and Exit Specification

Further Work Required:

a) Gaslink are to develop:

- a minimum functional specification and estimate of costs for gas quality measurement at system entry;
- a system for monitoring gas quality excursions of gas being conveyed in the network, in real time, in order to allow power generators to make necessary adjustments to gas-fired plant. This will be based on a due consideration of options and costs; and
- a system of alerts for gas quality excursions

Gaslink's proposals will be considered by the Gas Quality Industry Group and be subject to the approval of the Regulatory Authorities;

b) Oxygen Content – the limit of ≤ 0.2% molar has been accepted subject to review and will be considered in conjunction with Water Content/Dewpoint. Gaslink are to develop recommendations;

c) Gaslink to develop a detailed specification for ‘Contaminants’ in order to address the concerns of power generators of the impacts on gas turbine operation. These include the contents of: (i) Sodium; (ii) Potassium; (iii) Calcium; (iv) Lead; (v) Vanadium; and (vi) Manganese. This will include a review of the total inerts in the gas quality mix.

d) Gaslink assess the need to develop a separate Exit Specification for the Distribution Network; and

e) To manage the ongoing implementation of CAG and other EU developments including the ‘Third Package’

11. Next Steps

The following steps are planned for the 2009.

- Comments on this Report to be received by 12th January 2009
- The Decision Paper is published in January 2009
- A 2009 work plan for the Gas Quality Industry Group will be proposed in first quarter of 2009
- The next meeting of the Gas Quality Industry Group will be held on 20th May, 2009

Annex A List of Participants

The Commission for Energy Regulation and the Northern Ireland Authority for Utility Regulation would like to express its thanks and appreciation to all participants who contributed their time and effort to this process. Their expertise and insight were valuable and greatly appreciated.

Terry Williams	Advantica
Danny O'Brien	BGN
Denis Cronin	BGN
Donal Kissane	BGN
Liam Nolan	BGN
Keelin O'Brien	CER
Robert O'Rourke (Chair)	CER
Tony Thornton	Energia
Derek Russell	ESB International
Conor Purcell	ESB PG
Tom Canning	ESB PG
Derek Russell	ESBI
Liam Hearne	Gaslink
Steve Roberts	GTL
Damien Geraghty	Huntstown
Kieron Carroll	IOOA (Marathon)
Michael Murray	IOOA (Marathon)
Julian Cetti	IOOA (Shell)
Stuart Basford	IOOA (Shell)

Richard Hume	Utility Regulator
Fergal Finn	NSAI
Liam Doyle	NSAI (Calor Gas)
Bob Millican	Phoenix
Ivan Purvis	Phoenix
Stephen Hemphill	PTL
Martin Regan	Shannon LNG
Michael Petit	Shannon LNG
Conor Murphy	Shell
Christiane Sykes	STUK
Stephen Boldy	IOOA (Ramco)

Annex B Recommended Gas Quality Entry and Exit Specification

Gas Quality Parameter	Entry Specification
Hydrogen Sulphide	max 5 mg/m^3
Total Sulphur (including Hydrogen Sulphide)	max 50 mg/m^3
Hydrogen	max 0.1% mol
Oxygen	max 0.2% mol
Hydrocarbon Dewpoint	-2^{o}C at any pressure up to 85 barg
Water Content	50 mg/m^3
Wobbe Index	47.20 to 51.41 MJ/m^3 (real gross dry)
Incomplete Combustion Factor	max 0.48
Soot Index	max 0.60
Gross Calorific Value	36.9 to 42.3 MJ/m^3 (real gross dry)
Carbon Dioxide	max 2.5% mol
Contaminants	Note 2
Odour	Note 1
Delivery Temperature	1^{o}C to 38^{o}C
Organo Halides	max 1.5 mg/m^3
Radioactivity	max 5 becquerels/g
Ethane	max 12% mol

Notes:

1. Gas delivered shall have no odour that might contravene the obligation of the Transporter to transmit gas which possesses a distinctive and characteristic odour. Where the Transporter requires gas to be odourised, the gas shall be odourised in accordance with the following specification: Odour intensity of 2 Olfactory Degrees on the Sales Scale (Ref – IGEM/SR/16 Edition 2 – Odorant Systems for Gas Transmission and Distribution), or other such specification determined by the Transporter acting as an RPO.

2. Natural gas shall not contain solid, liquid or gaseous material which may interfere with the integrity or operation of pipes or any Natural Gas appliance which a consumer or transporter could reasonably be expected to operate. With respect to Mist, Dust, Liquid gas delivered shall be technically free in accordance with BS 3156 11.0 1998.

3. Standard Reference Conditions: Combustion reference temp = 15^{o}C, Volume unit = m^3 at 15^{o}C and 1.01325 bar

Emergency Gas Quality Parameter	Entry Specification
Wobbe Index	46.50 to 52.85 MJ/m^3
Incomplete Combustion Factor	$\leq$ 1.49

Notes:

1. The decision criteria that will be used to determine when the emergency gas specification limits are to be used in RoI will be developed as part of the Natural Gas Emergency Plan and implemented by the National Gas Emergency Manager.

Annex C Map of RoI and NI Gas Transmission Systems

Source: Gas Capacity Statement 2008