DNV·GL

I&C Stakeholder Workshop – 18 Jan 2018

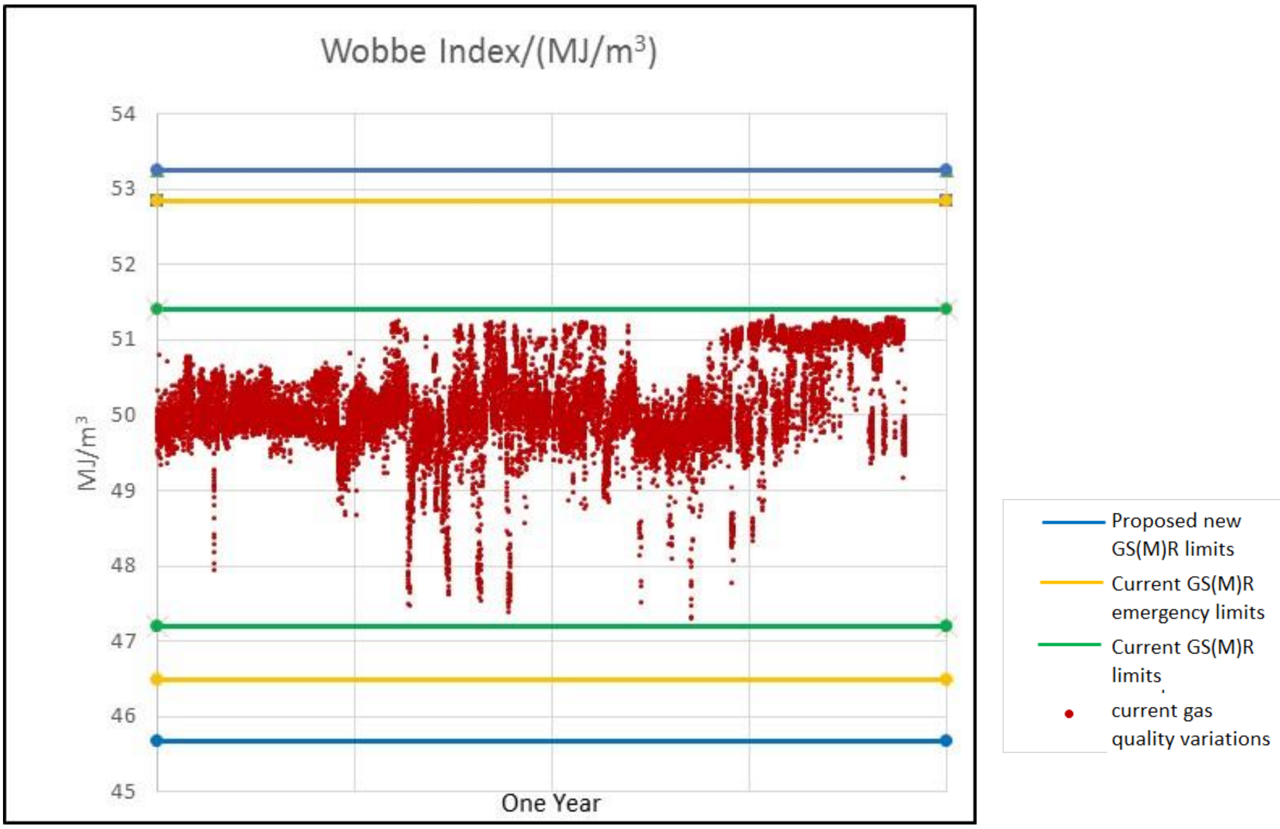
1 INTRODUCTION

The gas network plays a vital role in transporting energy to consumers securely and cost-effectively. The industry is facing its greatest challenge since the introduction of natural gas in the 1960s, with new types and sources of gas and the need to reduce carbon emissions by 2050. Gas quality will play a crucial role in the future of gas in Great Britain as new sources and types of gases become available.

The Institute of Gas Engineers and Managers (IGEM) is working with the gas industry to investigate the impact of making changes to the Gas Safety (Management) Regulations (GS(M)R). This includes increasing the Wobbe Index range and the addition of hydrogen. Gas quality depends on the gas composition and this affects the physical and chemical properties including the way that the gas burns. DNV GL is working with IGEM to study how the proposed gas quality changes would affect industrial and commercial users.

The project will explore the effects of a wider gas Wobbe Index range including blended hydrogen mixtures (containing up to 20 mol% hydrogen) by researching the measures in place around the world to ensure safe and efficient combustion of wider specification gas. The research will also include the effects of rate of change of Wobbe Index. The industrial and commercial equipment examined will be greater than 1 MW in size and the research will also consider any instrumentation which measures, or may be affected by, gas quality.

The range of Wobbe Index for this study is 45.67 to 53.25 MJ/m^3 (compared with the existing GS(M)R range of 47.20 to 51.41 MJ/m^3). This range is not exclusive and information within and outside this range will be considered. The project is collaboratively funded by gas transporters under the Network Innovation Allowance (NIA) – an Ofgem innovation funding mechanism.



On 18 January 2018, a workshop was held at IGEM House to which stakeholders from the Industrial and Commercial gas sector were invited. There were around 40 attendees – the companies and organisations represented are listed in Appendix A and the workshop agenda is shown in Appendix B. The aim of the workshop was to inform stakeholders about the background behind the proposed changes to GS(M)R, provide insight into the quality of the gas currently supplied to the GB network and to act as a forum for gathering information from stakeholders in the gas industry. The attendees were divided into groups to identify:

- The issues and concerns from specific groups of users
- Challenges, impacts and potential solutions
- Industry priorities and timelines

An industry consultation had previously taken place through a widely-distributed questionnaire and a summary of the output is shown in section 2.

This document summarises the output from the industry consultation and the stakeholder workshop.

A glossary of terms is shown in Appendix C.

1.1 Questionnaire

As part of the consultation process, industrial and commercial gas stakeholders were asked to complete a questionnaire which is reproduced in Table 1-1.

#	Category	Question
1	Combustion Plant Details	A brief overview of your combustion equipment/controls and how gas quality impacts your business
2	Current Gas Characteristics	Is your company aware of the gas quality characteristics of your natural gas supply (Composition, Wobbe Index, CV, etc)?
3		Do you experience operational and/or commercial issues with the current variation of gas composition/quality?
4	Current Gas Quality Measurement	Do you measure (or use data provided on) the current variation of gas composition/quality?
4a		Do you take any action when gas quality changes are measured or indicated by a third party?
4b		Can your plant accommodate current variations in gas quality (see illustration in introduction)?
5	Possible Future Gas Characteristics	If the gas quality limits were widened, would this impact on the performance and operability of your equipment for combustion, measurement or control?
5a		If you use gas as a feedstock for a chemical process would the wider range impact on your process?
6		If widening the limits also increased the frequency and magnitude of gas quality changes, would this impact on your combustion equipment, measurement equipment or control equipment?
7		If hydrogen were added to the natural gas supply at amounts of up to 20 mol%, would this impact on your combustion equipment, measurement equipment or control equipment?
8	Remedial actions and research	If the gas quality limits (Wobbe Index and hydrogen content) are amended, can existing systems and equipment be adapted or upgraded to ensure continued operation?
9	Additional information	Any further details which may be relevant

Table 1-1 The I&C Users Consultation Questionnaire

1.2 Questionnaire Responses

The number and spread of responses across industry categories is shown in Figure 1-1

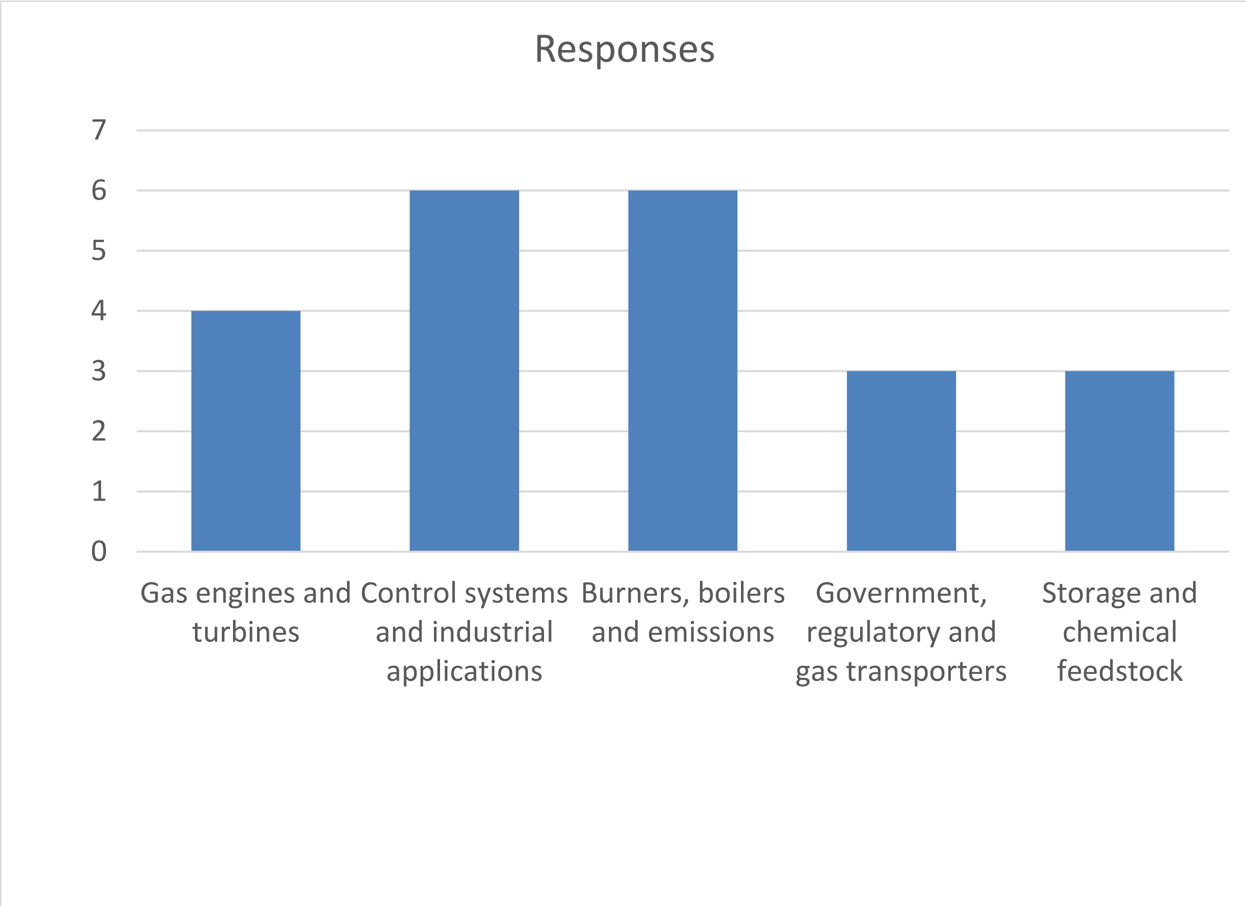


Figure 1-1 Number and categories of responses to the consultation questionnaire

There were no questionnaires returned from the government, regulatory and gas transporters sectors. However, three industry bodies sent their feedback in a free-form format that was not directly aligned to the questionnaire; these three responses have been included in the government, regulatory and gas transporters group (see Table 2-4).

2 IDENTIFICATION OF ISSUES AND CONCERNS

2.1 Gas Engines and Turbines

The responses from the questionnaire for this group are summarised in Table 2-1

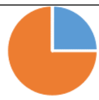
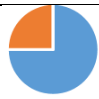
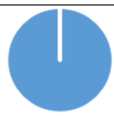
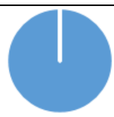
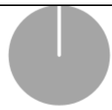
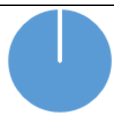
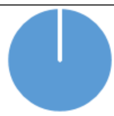
#	Category	Summary of Question	Summary of response	Pie Chart
1	Combustion Plant Details	Overview and gas quality impact	Yes No No response Unknown	
2	Current Gas Characteristics	Awareness of gas quality characteristics (Composition, Wobbe Index, CV, etc)?	All measure gas quality	
3		Impact of current gas quality variations	NOx, CO with low C2+, flame loss, flashback, sulphur. Composition as important as Wobbe Index	
4	Current Gas Quality Measurement	Access to data on current gas quality variations?	Own measurements – gas chromatography	
4a		Any actions taken when gas quality changes?	Control systems used	
4b		Can you accommodate current variations in gas quality?	Generally ok but some older plant is not coping well and some issues occurring already.	
5	Possible Future Gas Characteristics	Impact on the performance and operability of your equipment?	Impact on operations will get worse. Hydrogen is difficult. Concerned about costs	
5a		Impact on processes using gas as chemical feedstock	N/A	
6		Impact of increased frequency and magnitude of gas quality changes	Will be an impact. Current GCs for control may be too slow. Need to contact OEMs	
7		Impact of up to 20 mol% hydrogen	Outside limits of long term contracts. Big impact including on plant start up.	
8	Remedial actions and research	Impact of widening gas quality limits (Wobbe Index and hydrogen content) on existing assets	Research required – impact unknown	
9	Additional information	Any further details	Significant issues – need to contact OEMs	

Table 2-1 Summary of questionnaire responses from the gas engines and turbines sector

2.1.1 Workshop Feedback from Gas Turbines and Engines Group

There are many engine types and they all use different parameters with different responses and characterisation. Any modifications are very expensive and it is important to note that the generation of electricity is coupled with the gas supply. Low NOx engines have a very narrow range of Wobbe Index (WI) – usually about ±2%. The current GS(M)R specification has a WI range of about 8%. The gas composition, and not just the WI, are important for the operation of gas engines and turbines. Operators typically have access to data on current gas quality variation

Gas quality fluctuations impact on:

- Component life
- Electricity output to the grid (efficiency of operation)
- Gas operations (control valve and preheating)
- Tuning of the machines, stability and trips

When gas quality changes, manual control systems are used. Half of the group at the workshop had issues with current gas quality variations. An increase in frequency or magnitude, and especially the rate of change will cause problems. Equipment has a performance specification for a range of gas quality

The addition of 20% hydrogen impacts on:

- Gas turbines – no current specification including the ability to burn hydrogen. The estimated cost for retro-fitting each turbine is estimated to be €10M
- Gas engines – Siemens, for example, have seven different configurations depending on the gas quality
- Start-up – there are limitations on the hydrogen concentration during start-up
- Hazardous area zones will change

Solutions

- Need a study of the installed base of machines as this is diverse
- Need engagement from an OEM
- Treat the gas (but grid operators must take in-specification gas regardless of downstream operations)
- Leave GS(M)R as it is currently

2.2 Control Systems and Industrial Users

The responses from the questionnaire for this group are summarised in Table 2-2.

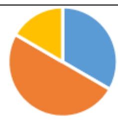
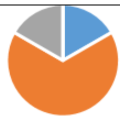
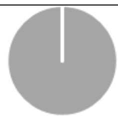
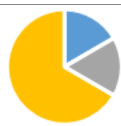
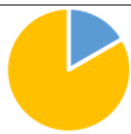
#	Category	Summary of Question	Summary of response	Pie Chart
1	Combustion Plant Details	Overview and gas quality impact	Yes No No response Unknown	
2	Current Gas Characteristics	Awareness of gas quality characteristics (Composition, Wobbe Index, CV, etc)?	Industrials are not aware/do not measure gas quality	
3		Impact of current gas quality variations	Not widely understood	
4	Current Gas Quality Measurement	Access to data on current gas quality variations?	No access. Many clients using old technology.	
4a		Any actions taken when gas quality changes?	No actions –but recommend control systems	
4b		Can you accommodate current variations in gas quality?	Unknown but probably inefficient	
5	Possible Future Gas Characteristics	Impact on the performance and operability of your equipment?	Unknown	
5a		Impact on processes using gas as chemical feedstock	N/A	
6		Impact of increased frequency and magnitude of gas quality changes	Unknown	
7		Impact of up to 20 mol% hydrogen	Unknown	
8	Remedial actions and research	Impact of widening gas quality limits (Wobbe Index and hydrogen content) on existing assets	Unknown	
9	Additional information	Any further details	"Gas is gas"!	

Table 2-2 Summary of questionnaire responses from control systems and industrial users

2.2.1 Workshop Feedback from the Control Systems and Industrial Users Group

The responses to the consultation showed that there was a general lack of awareness of gas quality although large users had more knowledge about their gas supply than small users. Smaller industrial users tend not to be aware of gas quality, have access to any data or have any measurement equipment. The smaller industrial users tend to think "gas is gas"

Current gas quality changes:

- Tolerated by setting burners up with sufficient excess air but when the WI is low, this decreases efficiency
- Gas transporters can provide data about recent gas quality but it is rarely requested
- Within this group, no actions are currently taken when gas quality changes

Future gas quality changes:

- Impact is unknown
- May need to upgrade meters/pressure regulators and other equipment
- A furnace manufacturer with temperature and process control should be okay
- Small/medium users have no control equipment and could be compromised
- Users with mechanical chain-linked controls will struggle to adapt
- Too many unknowns in this group – more research needed.

2.3 Burners, Glass & Ceramics

The responses from the questionnaire for this group are summarised in Table 2-3.

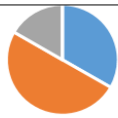
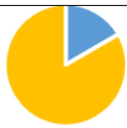
#	Category	Summary of Question	Summary of response	Pie Chart
1	Combustion Plant Details	Overview and gas quality impact		Yes No No response Unknown
2	Current Gas Characteristics	Awareness of gas quality characteristics (Composition, Wobbe Index, CV, etc)?	Burners – not aware Glass – measure but Wobbe meters sensitive to gas temperature Ceramics - no	
3		Impact of current gas quality variations	Glass concerned about reduced temperatures + additional control systems	
4	Current Gas Quality Measurement	Access to data on current gas quality variations?	Glass – yes. Others no	
4a		Any actions taken when gas quality changes?	Mostly no action taken except for glass manufacturers	
4b		Can you accommodate current variations in gas quality?	Occasional manual control for glass manufacturers	
5	Possible Future Gas Characteristics	Impact on the performance and operability of your equipment?	Glass – concern about flame temps and emissivity. GC does not analyse H_2	
5a		Impact on processes using gas as chemical feedstock	N/A	
6		Impact of increased frequency and magnitude of gas quality changes	All expect impact from increased frequency of changes	
7		Impact of up to 20 mol% hydrogen	Research/testing required.	
8	Remedial actions and research	Impact of widening gas quality limits (Wobbe Index and hydrogen content) on existing assets	Unknown impacts – research and testing required.	
9	Additional information	Any further details	Glass/ceramics – increased costs. Burners – some products need testing	

Table 2-3 Summary of questionnaire responses from burners, glass and ceramics sector

2.3.1 Workshop Feedback from Burners, Glass and Ceramics Group

Awareness of gas quality is high within this group. No actions are being taken now as there is no certainty about what is going to happen.

One of the big drivers for this group is control of emissions and combustion systems are highly tuned to achieve both high efficiency and low emissions. To accommodate the requirements of the Medium Combustion Plant Directive (MCPD) part of the Industrial Emissions Directive (IED), combustion chamber sizes may need to be increased to reduce NOx and control temperature. It could be prudent to define NOx limits on a heat input basis to take account of changing gas quality. The focus is on developing equipment for existing gas quality. The long-term issues including appliance reliability are unknown for a wider gas quality range.

Solutions to increased gas quality variability could be:

- In the field, a portable analyser that can measurement gas quality when the burners are set up would be very useful
- Improved and extended flue gas analysers to accommodate a wider fuel gas quality range
- The safety aspects concerned with hydrogen blended natural gas need testing and validating but some work is being carried out by the HyDeploy project. Which “gas family” does hydrogen/natural gas blend fit into?
- Engineer training to understand the impact of the wider gas quality range
- Ballast high WI gas before it gets to the burner – the savings associated with removal of ballasting at LNG terminals could be used for downstream ballasting (possible penalty for smaller users?)
- Use a test facility or Oban/SIUs for some long-term performance testing
- Develop limit gases for equipment and appliance certification

2.4 Gas Transporters, Industry Bodies & Government

There were no direct responses from the questionnaire for this group as shown in Table 2-**4**. Three industry bodies sent their feedback in a free-form format not directly aligned to the questionnaire.

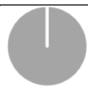
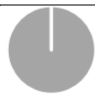
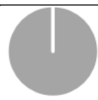
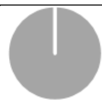
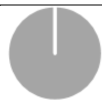
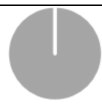
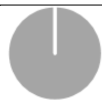
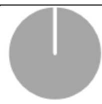
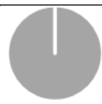
#	Category	Summary of Question	Summary of response	Pie Chart
1	Combustion Plant Details	Overview and gas quality impact	Yes No No response Unknown	
2	Current Gas Characteristics	Awareness of gas quality characteristics (Composition, Wobbe Index, CV, etc)?	None	
3		Impact of current gas quality variations	None	
4	Current Gas Quality Measurement	Access to data on current gas quality variations?	None	
4a		Any actions taken when gas quality changes?	None	
4b		Can you accommodate current variations in gas quality?	None	
5	Possible Future Gas Characteristics	Impact on the performance and operability of your equipment?	None	
5a		Impact on processes using gas as chemical feedstock	None	
6		Impact of increased frequency and magnitude of gas quality changes	None	
7		Impact of up to 20 mol% hydrogen	None	
8	Remedial actions and research	Impact of widening gas quality limits (Wobbe Index and hydrogen content) on existing assets	None	
9	Additional information	Any further details	None	

Table 2-4 Summary of questionnaire responses from gas transporters, industry bodies and government

2.4.1 Workshop Feedback from Gas Transporters, Industry Bodies and Government

Gas transporters have a lot of combustion plant including compressors, gas pre-heating equipment (typically water bath heaters but modular boilers are becoming a significant part of the installed base) and gas-fired LNG vaporisers. Emissions constraints are extremely important for all the above plant as they all come under EU-ETS Industrial Emission Directive (IED) (Large Combustion Plant Directive (LCPD or Medium Combustion Plant Directive MCPD)). Permits are required now for the larger plant and from April 2018 for the smaller gas pre-heaters.

Gas transporters and LNG importers are aware of, and measure, gas quality using chromatography. Emissions permits are based on measurements from the Best Available Technology (BAT) at each of the sites – these emissions measurements show that the plant are currently compliant.

Rates of change of gas quality are not within the gas transporters control; they are caused by interfaces between different gas supplies that are already within the network. There is almost no (axial) mixing of gas within the pipeline apart from at the interface between two supplies. The interfaces and their location are determined by shippers and their nominations. The management of gas quality is negotiated at system entry points. The control of the rates of change at the point of use is very difficult; measurement systems will need to be developed for hydrogen and existing systems reconfigured.

The National Transmission System (NTS) for gas accommodates the current variation as best it can to avoid the FWACV "cap" being imposed on the GDNs (part of the legislated commercial agreements for sale of gas). The gas transporters are mindful that gas quality is influenced by the specification and that measurement and control of gas quality is an issue for users.

Impacts of gas quality changes:

- Gas transporters have looked at the impact on domestic consumers. Is there a possibility that gas quality could be managed within the grid?
- What about the impact on gas being used as a feedstock? More research is required but it is likely that richer gases would be preferable to lean gases. Cadent and SGN have innovation initiatives planned with their industrial base.
- There is an issue of West to East drift of LNG across England when gas is exported from the UK through the Bacton interconnector. This is all influenced by the behaviour of the gas shippers and the variations in gas demand.
- Due to increased variations in the sources of gas, the number of gas interfaces within the network will increase
- There are two longer-term pieces of research currently being undertaken:
    - The Future Billing Methodology NIC project is investigating the current commercial regime and making it fit for the future
    - The Real-Time Networks NIC project is developing energy models of the gas networks from the bottom up which could be used to predict gas quality in the low-pressure tiers
- It is not clear how gas quality would change in response to changes in specification. Most LNG would cease to be ballasted with nitrogen but many gas supplies could remain unchanged. Further work on what the changes would look like is required

- The impact on CNG vehicles needs to be considered.
- Gas containing 20% hydrogen cannot be measured using existing chromatographs – either a retrofit or dedicated new equipment will be required with Ofgem type approval. Regulatory approval would also be needed if significant investment in new equipment were required.

It should be noted that the gas composition does change significantly within the existing GS(M)R specification and problems will be encountered whether GS(M)R is changed or not. For example, an increase in higher hydrocarbons can increase the risk pipeline fracture propagation but the WI could still be within the existing GS(M)R limits.

There may be scope for gas transporters to blend gases either at terminal entry or through reconfiguration of the pipeline system – greater interaction between transporters and consumers is required. Agreement needs to be reached about funding of this extra service.

2.5 Gas Storage and Gas as a Feedstock

The responses from the questionnaire for this group are summarised in Table 2-5.

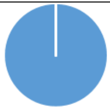
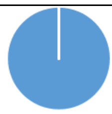
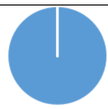
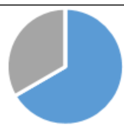
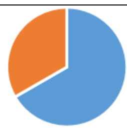
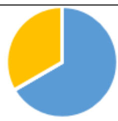
#	Category	Summary of Question	Summary of response	Pie Chart
1	Combustion Plant Details	Overview and gas quality impact	Yes No No response Unknown	
2	Current Gas Characteristics	Awareness of gas quality characteristics (Composition, Wobbe Index, CV, etc)?	Storage operators measure gas quality for GS(M)R compliance and billing	
3		Impact of current gas quality variations	Fixed volume storage – prefer high energy content gas	
4	Current Gas Quality Measurement	Access to data on current gas quality variations?	Yes – contractual requirement	
4a		Any actions taken when gas quality changes?	De-rate capacity. Complain to supplier!	
4b		Can you accommodate current variations in gas quality?	Yes, but cost impact	
5	Possible Future Gas Characteristics	Impact on the performance and operability of your equipment?	Hydrogen – promotes H_2S production Low CV = lower revenues High CV = more hydrates	
5a		Impact on processes using gas as chemical feedstock	As above	
6		Impact of increased frequency and magnitude of gas quality changes	Gas chromatographs may be too slow to track changes	
7		Impact of up to 20 mol% hydrogen	Needs research	
8	Remedial actions and research	Impact of widening gas quality limits (Wobbe Index and hydrogen content) on existing assets	Needs assessment. Not commercially viable	
9	Additional information	Any further details	Too costly, needs research. Storage sites need protection	

Table 2-5 Summary of questionnaire responses from gas storage and gas as a feedstock

2.5.1 Workshop Feedback from Gas Storage and Gas as a Feedstock

Natural gas is a complex mixture and changes in the component impact on storage, LNG and chemical processing operations. Users who burn gas do take note of the current GS(M)R and emissions specifications.

This group is very aware of gas quality issues but it was noted that there was no representation from chemical industries. In the Hull area, there are intensive gas users producing urea. Overall the concept of hydrogen addition to the gas supply was not welcomed.

Storage operators were concerned about changing gas quality that would enhance the production of gas hydrates which could impact on surface and well-head processing requirements. Where depleted gas fields are used for storage, hydrogen sulphide produced from microbiological activity could be an issue but this is mainly for off-shore storage sites. The addition of hydrogen to natural gas could be a problem and changes to carbon dioxide limits could increase corrosion significantly especially in the presence of water (salt cavity gas stores are wet).

There are benefits in increasing the upper WI limit – higher energy densities are good for storage sites and less nitrogen ballasting for LNG terminals would be commercially beneficial.

Issues that may be prevalent with changing gas quality are:

- Layering and separation of gases during storage
- Hazardous area classification is mandatory and impacts on equipment supplies
- Inclusion of hydrogen will be significant on hazardous area classification and hydrogen embrittlement
- Operators of compressors are very sensitive to gas quality. Widening of the limits could lead to increased vibration and associated damage
- Increased emissions especially NOx
- COMAH classification
- How are all these changes going to be paid for?

3 CHALLENGES, IMPACTS AND SOLUTIONS

During the second half of the workshop, the participants were divided into five mixed-interest groups. The overall output is summarised below in Table 3-1. The responses are divided into the five categories which have been colour-coded as shown below:

Industry Engagement	Equipment	Gas Quality	Costs	Hydrogen

Figure 3-1 Colour coding for challenges, impacts and solutions

	Barrier or Challenge	Impact	Solution
Industry Engagement	General awareness of gas quality on each class of equipment needs to be improved - knowledge of gas quality is patchy	Lack of understanding of impact of changing hydrocarbon dew point, pipeline integrity issues, reliability, safety, commercial issues and the consequences	There may be a role for Regulators to provide education Create technical standards A wide and coordinated engagement is required
	Engaging and consulting with the whole industry	Unintended consequences for some sectors of the industry	Disseminate information as widely as possible – role for government, regulators and industry bodies
	Who owns this problem and who pays for the solution? Should it be industry or should the costs be socialised?	Lack of progress in dealing with the challenge of gas quality Awareness needs to cut across the whole gas chain from suppliers (TSO/DSO) to end users and industry regulators	There should be cross-sector cooperation and implementation A high level of commitment from industry/government is required together with timescales and early engagement
	The speed of implementation needs to be synchronised with the solutions. Will this be a "big bang" change or incremental?	The uncertainty is hampering planning, investment and implementation of solutions	Ensure industry-wide engagement
	No understanding of chemical processes	Unknown	Further engagement with chemical industry

	Barrier or Challenge	Impact	Solution
Equipment	Lack of engineers/technicians to undertake modifications to equipment	Limit on progress in making changes /adaptations in the required timeframe	The training of people and the recruitment/provision of resources to undertake changes to equipment
	There is a lack of knowledge about existing gas equipment infrastructure and its operability	Unable to develop solutions to facilitate changing gas quality. This is a pan-European issue	Research to understand the population of equipment with whole industry involvement. What can be adapted and what needs to be replaced?
	Increased WI range could push power plant outside the OEM gas quality specification	Invalidate warranties and insurance	Further development/research by the OEM would be required
	Changing gas composition is important even if the WI range does not change. For power plant, the ethane /propane /butane content is important too.	Varies from efficiency reductions/increased emissions to catastrophic failure of equipment	Further R&D is required on control systems for burners with a high level of "buy-in" from OEMs
	Lack of equipment for measuring and controlling wider ranges of gas qualities and flue gases	Constrain the progress for widening the gas quality range	Develop equipment for measuring and controlling gas quality Adaptive controls are available for domestic consumers so research on knowledge transfer to the I&C sector required
Gas Quality	Proposed increase in WI range is too high	Adverse effect on low CV "green" gases	A WI range of 4 MJ/m^3 is workable but to enable richer gases and increase WI, the lower limit could be raised as well. Consider incremental increases to the upper WI.
	Some users will not be able to adapt to a wide range of gas quality	Malfunction or damage to equipment, output and processes. Stop using gas. Business is no longer viable.	Categorise gas users into those who are gas quality critical. Develop separate nodes on the network for different users

	Barrier or Challenge	Impact	Solution
Gas Quality	Increased rate of change in gas quality may be too rapid for an effective control/response measures	Varies from efficiency reductions/increased emissions to catastrophic failure of equipment	Gas quality tracking equipment and extra measurements will be required. Use buffer volumes?
	Changing gas quality will change emissions and local air quality from combustion processes	Potential for non-compliance with existing legislation. NOx levels are likely to increase.	Emissions legislation may need to be modified Investigate post-combustion removal of NOx and associated costs Better ways of reporting NOx -maybe this could be related to heat input mg/kWh
	One of the biggest issues is the gas specification set by OEMs for the operation of their equipment.	If users operate equipment that is outside the OEM specification, then the insurance/warranty on the equipment is invalidated which is very costly.	More R&D is needed to investigate pre-processing of gas to ensure that it is compliant at the point of use
Costs	The cost implications are unknown. Proper funding, flexibility and innovation is required to be fit for the future.	Uncertainty about gas as a fuel but the attractiveness of gas still likely to be high	Carry out a full cost-benefit analysis quantified with timescales and investigation into possible subsidies to carry out any remedial work. Investment planning should be studied over a 5, 10 and 20-year proposal for specification changes
	Compliance with the Medium Combustion Plant Directive	Industry will need to invest to comply with the new directive	Ensure that investment in equipment/assets is also compatible with widening of GS(M)R

	Barrier or Challenge	Impact	Solution
Hydrogen	The HyDeploy project will not be completed until 2020 and then the concept will need to be trialled on an integrated network over the following five years	Injection of significant levels of hydrogen (> 1 mol%) is unlikely to be possible before 2025.	Hydrogen needs a staged introduction and customers on high-pressure connections need to be segregated from the rest of the network as these are more impacted. Investigate keeping hydrogen in the lower pressure tiers and out of the NTS. The introduction of hydrogen should be deferred.
	Hydrogen	If included it will hold up changes to GS(M)R	Hydrogen should be separated out completely from the proposed GS(M)R change
	Potential changes to ATEX ratings if hydrogen is included in GS(M)R specification	Equipment may need to be changed out	Consideration of hydrogen needs to be deferred.

Table 3-1 Summary of the challenges, impact and solutions from workshop attendees

4 PRIORITIES AND TIMELINE

The final stage of the workshop identified the industry priorities. These have been grouped into six categories which could be phased as shown in Figure 4-1:

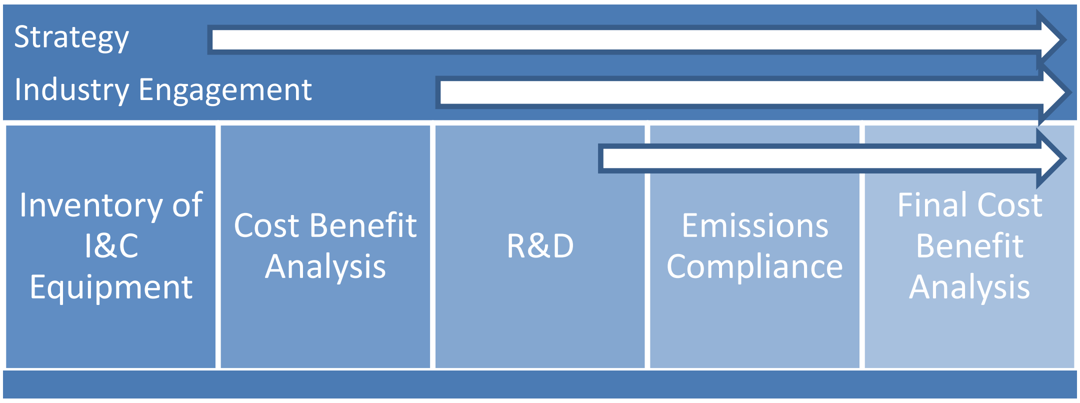


Figure 4-1 Priorities and phasing of activities

A summary of the priorities of the workshop attendees is shown in Table 4-1

	Priorities	**Timeline**
Strategy	The UK needs to take a closer look at how gas quality challenges are being implemented in Europe.	12 months
	Develop a clearer government-led vision for the decarbonisation of the gas network including the staging of the changes	Political lobbying and stakeholder management needs to start now
	Link any future gas quality developments with a clean growth industrial strategy	Start now
Cost Benefit Analysis	Carry out a high-level and refined cost-benefit analysis across all sectors to compare the implementation costs of: • No change to GS(M)R • GB-wide gas quality change • Local gas quality changes	A high-level CBA within one year A refined CBA within three years
Inventory	Create an inventory of gas users' equipment to inform the R&D and buy-in that is required from the OEMs Government support would be useful to drive this forward	
	Develop an understanding about which equipment can be retrofitted or adapted	
	Identify those users with critical gas quality requirements	

	Priorities	Timeline
Research and Development	Identify where R&D can have the greatest impact and establish how this will be funded – lobby industry and government. Include both technical and non-technical investigations. Consider incremental increases in the upper WI and evidence/mitigation required. The inclusion of hydrogen in the revised GS(M)R should be deferred New hardware needs to be developed and demonstrated before it is sold.	90% complete within two years. Remaining R&D could be carried out in five years.
	R&D to get a better understanding of the impact and likelihood of changes to the C2+ components in the gas. This could affect, for example, hydrate formation, flashback, NOx, risk of pipeline fracture and vibrations	
	R&D to understand the impact of molecular mass changes on compressor equipment. How much variation is possible without damaging rotating machinery?	
	Some fundamental R&D needs to be carried out on the impact of 20% hydrogen blend and on combustion and control systems. Research into retrofitting to existing equipment is also required.	Seek sources of funding now
	More equipment needs to be developed and approved for measuring and controlling wider rages of gas qualities and flue gases	
	Investigate network segregation – horizontal segregation by isolating parts of the NTS and LTS or vertical segregation by, for example, hydrogen addition below 7 bar.	12 months
Emissions	Combustion research into the production of pollutants as a result of the proposed changes to gas quality. Greater understanding of the NOx production as a function of the higher hydrocarbon distribution within gas.	Start now
	Management/reporting of local air quality NOx linked to combustion plant operation and the fluctuations in gas quality	
	Investment on post-combustion clean up technology. New systems developed to operate over a wider range of gas quality (and include hydrogen)	
Industry Engagement	Industry engagement to increase awareness amongst institutions, manufacturers, gas transporters, industry and gas suppliers	Start now
	Involve the Chemical Industries Association further to understand the impact on gas used as a chemical feedstock, and as a process energy source.	Now

Table 4-1 Summary of priorities and timelines from the workshop attendees

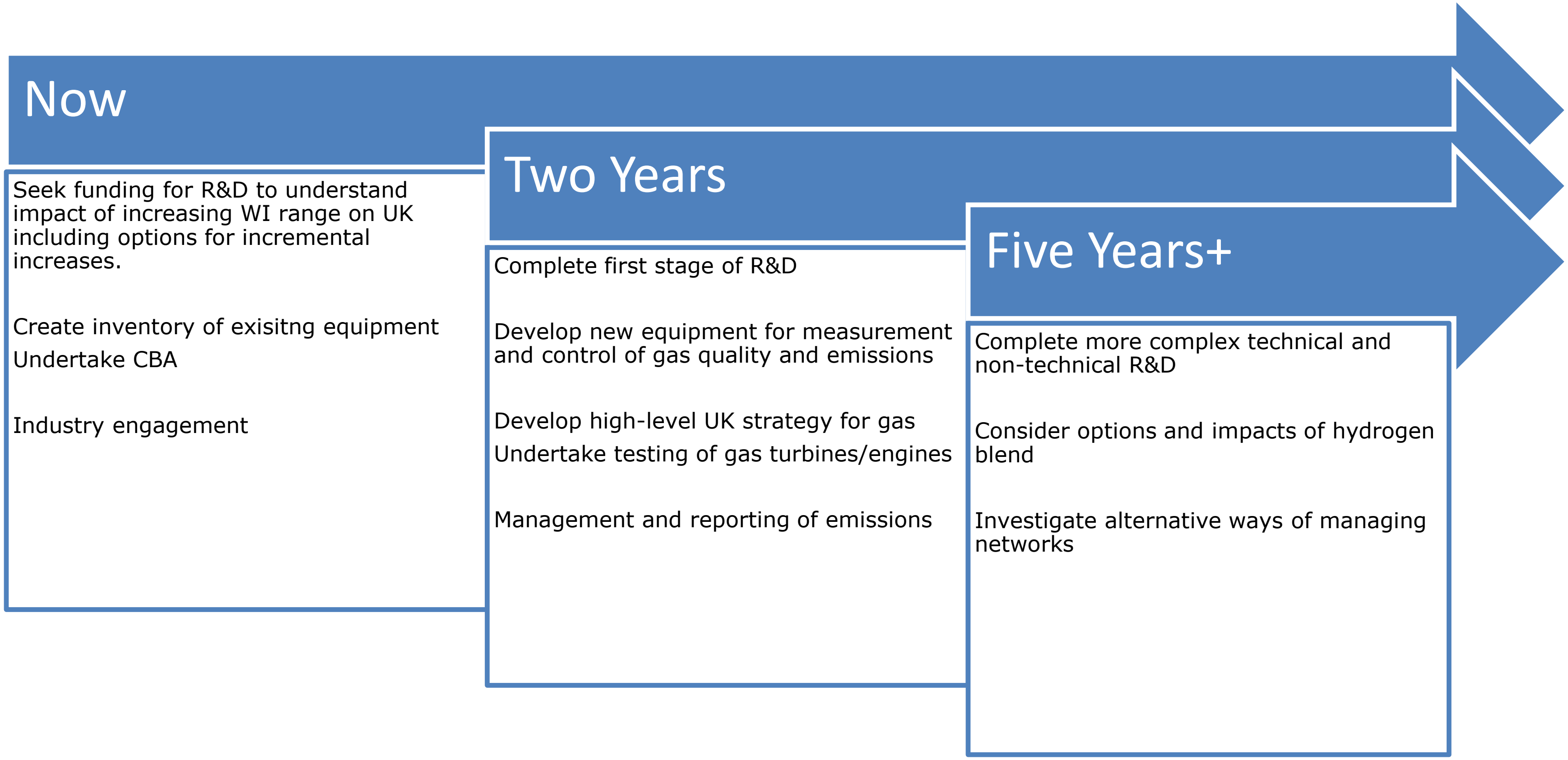


Figure 4-2 Approximate timeline for preparation for changing GS(M)R (excluding hydrogen)

5 APPENDIX A

5.1 List of Organisations and Companies Represented at the Workshop

Bosch

British Ceramic Confederation

British Standards Institute

Cadent

Cranfield University

Crowcon

Dave Lander Consulting

DNV GL

Energy UK

Electricity Supply Board (Eire)

Grain LNG

Holford Gas Storage

Honeywell

Health and Safety Executive

Health and Safety Laboratory

Industrial and Commercial Energy Association (ICOM)

International Flame Research Foundation

IGEM

National Grid

Northern Gas Networks

Riello Burners

Scottish Power

SGN

Siemens

Terry Williams Consulting

Uniper

Wales and West Utilities

6 APPENDIX B

6.1 Workshop Agenda

Topic	Time	Who
Welcome and introduction	10:00	IGEM Ian McCluskey
Background to previous work	10:15	SGN Gus McIntosh
Technical introduction – challenges of changing gas quality	10:30	DNV GL Sarah Kimpton
I&C stakeholder groups – summary of potential issues and feedback from the questionnaire: *Gas engines/turbines* *Control systems/Industrial applications* *Burners/boilers/glass/ceramics/emissions* *Government, regulatory/Gas transporters* *Storage/chemical feedstock*	10:45	DNV GL Martin Brown
Tea/coffee	11:00	All
Purpose of the workshop Forum to discuss challenges and solutions Develop roadmap for changing GS(M)R	11:20	DNV GL
Break attendees into groups - assignment will be on name badge (lead in brackets): *Gas engines/turbines (Howard Levinsky)* *Control systems/Industrial applications (Terry Williams)* *Burners /boilers/glass/ceramics/emissions (Martin Brown)* *Government, regulatory/Gas transporters (Dave Lander)* *Storage/chemical feedstock (Richard Whitehead)*	11:30	DNV GL/IGEM to coordinate
Reconvene – each group to share stakeholder feedback and endorse/support/ enhance/reject. 5 to 10 minutes each.	12:10	Group leaders

Lunch	12:45	All
Break into groups to understand/learn/share the potential barriers and solutions required to change GS(M)R. *Barriers: costs/commercial/technical/legislation (emissions and efficiencies)/trained engineers/fluctuations in gas quality/7.5 MJ/m^3 range in Wobbe Index* *Solutions: focus on what would make the new range of GS(M)R possible such as equipment/control systems (feed forward/feedback), investment* *Prioritise three items that should be on the roadmap for gas quality change. Include timeline*	13:15	DNV GL/IGEM to coordinate Group leads
Tea/coffee	14:00	
Reconvene. Each group leader to report back on roadmap priorities and timeline.	14:20	DNV GL/IGEM to coordinate Group leads
Develop and agree an outline roadmap: GS(M)R limits Timeline Challenges and solutions	15:00	DNV GL/IGEM to coordinate
Round-up to highlight next steps	15:15	SGN Gus McIntosh
Workshop close	15:30	IGEM Ian McCluskey

7 APPENDIX C

7.1 Glossary of Terms

Term	Meaning
ATEX	*Appareils destinés à être utilisés en ATmosphères EXplosibles*. EU directive describing what equipment and work space is allowed in an explosive atmosphere
BAT	Best Available Technology
C2+	A short-hand designation for higher hydrocarbon chemical species meaning ethane, propane and other alkanes
CBA	Cost Benefit Analysis
CNG	Compressed Natural Gas
CO	Carbon monoxide
COMAH	Control of Major Accident Hazards
CV	Calorific value
DSO	Distribution System Operator (electricity)
ETS	EU Emissions Trading Scheme
FWACV	Flow Weighted Average Calorific Value – a method for assigning a CV to consumers for billing
GB	Great Britain
GC	Gas chromatograph – device for determining gas composition
GDN	Gas distribution network
GS(M)R	Gas Safety (Management) Regulations
H_2S	Hydrogen sulphide
HyDeploy	NIC project being conducted by Cadent to investigate the impact of hydrogen/natural gas blend using Keele University
I&C	Industrial and Commercial
IED	Industrial Emissions Directive
LCPD	Large Combustion Plant Directive (part of the IED)
LNG	Liquefied Natural Gas

Term	**Meaning**
MCPD	Medium Combustion Plant Directive (part of the IED)
NIA	Network Innovation Allowance (Ofgem innovation funding mechanism)
NIC	Network Innovation Competition (Ofgem innovation funding mechanism)
NOx	Nitrogen oxides
NTS	National Transmission System – the high-pressure gas network
OEM	Original Equipment Manufacturer
Ofgem	Office of Gas and Electricity Markets
R&D	Research and Development
SIU	Scottish Independent Undertakings (Oban, Wick, Thurso and Campbeltown)
SOx	Sulphur oxides
TSO	Transmission System Operator (electricity)
WI	Wobbe Index (also called Wobbe Number (WN))