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WG-Biogas-06-18

26/09/06

Final Draft Recommendation

Injection of Gases from Non-Conventional Sources into Gas Networks

D497

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Foreword

Under the legal framework of European directive 2003/55/EC the utilisation of gases from renewable energies becomes a preferred option. The composition of such gases varies from one country to another, depending on social, political and economic practices. Because they arise from non-conventional sources, they are generally not suitable for use in gas supply without treatment.

In some European countries, standards or codes of practice are already published on specific issues of injection of gases from non-conventional sources ("NCS gases").

In autumn 2003 MARCOGAZ decided to develop a recommendation of the European gas industry for this issue and installed a working group. Experts from 9 European countries actively participated in this working group.

This recommendation offers guidance to gas network operators that receive requests for delivery of gases other than natural gas, NCS gas supply companies wishing access to gas networks, authorities involved in the process and for developers of standards and codes of practice.

The working group identified several gaps of knowledge related to the accommodation and use of such NCS gases mentioned by the above directive. Consequently, it is not possible at this moment to define a complete set of well-based minimum requirements that should be applied in order to ensure that injection of NCS gases can be carried out with acceptable consequences. Therefore, further investigation activity is recommended[1].

This document is neither exhaustive, categorical nor definitive. No liability can be assumed by MARCOGAZ for any damage or loss by application of this recommendation.

Brussels, September 2006

[1] E.g., a European project (GERG) "Biogas and Others in Natural Gas Operations (BONGO)" started that aims to address and fill identified gaps in knowledge, and will support the preparation of related norms and standards.

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1 Introduction

On the 26th June 2003, the European Parliament adopted the Directive 2003/55/EC, repealing Directive 98/30/EC, concerning common rules for internal market in natural gas. The scope of this new Directive covers not just natural gas and liquefied natural gas, but also biogas, gas from biomass and all other types of gases that can meet necessary quality requirements.

Whereas § 24 of Directive 2003/55/EC calls for admission to the gas network for biogas and gas from biomass for environmental reasons provided this is compatible with the secure and efficient operation of the network on environmental grounds: "*Member States should ensure that, taking into account the necessary quality requirements, biogas and gas from biomass or other types of gas, are granted non-discriminatory access to the gas system, provided such access is permanently compatible with the relevant technical rules and safety standards. These rules and standards should ensure, that these gases can technically and safely be delivered into, and transported, through the natural gas system and should also address the chemical characteristics of these gases".*

Directive 2003/55/EC, Chapter 1, Article 1 defines the scope of the Directive: "*The rules established by this Directive for natural gas, including liquefied natural gas, shall also apply to biogas and gas from biomass or other types of gas in so far such gases can technically and safely be delivered into, and transported through, the natural gas system*."

Currently, gas companies and national authorities adopt different approaches concerning addition of NCS gases to natural gas networks. In the future, with networks becoming increasingly interconnected, a pan-European approach and a common position on the definition of "*technical rules and safety standards*" is required. Delivery of some NCS gases into distribution or transmission networks, without caution, can create not just technical and operational problems (e.g., corrosion, appliance performance and safety) but may also lead to health issues for consumers (e.g., presence of minor volatile organic compounds, carbon monoxide, micro-organisms).

2 Scope

This MARCOGAZ recommendation covers the utilisation of non-conventional sources of piped gases. Such non-conventional sources include:

- Gases from thermal or fermentation processes;
- Coal-bed methane and coal mine methane;
- Hydrogen-rich gases from gasification of e.g., biomass, or other chemical processes;
- Hydrogen produced from electrolysis (generally using renewable energy).

The main aspects covered are the technical and gas quality requirements for delivery of such gases into gas networks. This MARCOGAZ recommendation should be considered in addition to any existing National standards or directives covering installations for manufacture, extraction, treatment and utilisation of these gases at the site of their production.

The interface between gas supply and gas manufacture, treatment and compression is given in figure A.1. It is important to distinguish between:

- Raw gases before treatment (which are not covered by this MARCOGAZ recommendation);
- Gases that, after treatment, are suitable for direct delivery into transmission or distribution networks;
- Gases that, after treatment, are suitable for delivery into gas networks only after blending with other gases.

3 Definitions

For the purpose of this recommendation the following definitions apply:

3.1
Biogas
Generic term used to refer to gases produced by anaerobic fermentation or digestion of organic matter

NOTE: this can take place in a landfill site to give landfill gas or in an anaerobic digester to give biogas. Sewage gas is biogas produced by the digestion of sewage sludge. Biogases comprise mainly methane and carbon dioxide.

3.2
Biomass
Organic matter from renewable sources suitable for decomposition into usable energy sources

NOTE: the decomposition may either be thermal or anaerobic.

3.3
Coal bed methane
Gas emitted from un-worked coal seams. Coal bed methane comprises mainly methane with relatively small amounts of other hydrocarbons, nitrogen and carbon dioxide

3.4
Coal mine methane
Gas emitted from exposed coal in worked coal seams. Because the coal seam has been exposed to air, either through forced ventilation or natural swings in temperature or pressure, coal mine methane comprises methane with significant quantities of nitrogen and carbon dioxide

3.5
Biosyngas

Gas manufactured from biomass using thermal gasification processes

NOTE: the production of biosyngas may be optimized either to yield methane or to yield hydrogen

3.6
Landfill gas
Biogas produced from natural decomposition processes in landfill sites. Landfill gas comprises mainly methane and carbon dioxide

3.7
Sewage gas
Biogas produced by the digestion of sewage sludge

3.8
Raw gas
Any untreated gas that requires further treatment before delivery into a gas network

3.9
Gas treatment
Process or series of processes to convert raw gas into one suitable for use, e.g. for delivery into a gas network

NOTE: the treatment of raw gases can be distinguished between upgrading and purification. Upgrading is the process to remove major constituents in the gas not supporting combustion, e.g. carbon dioxide, in order to increase the heating value of the gas. Purification is the process where minor constituents as e.g. hydrogen sulphide, water vapour with only small influence on the heating value are removed.

3.10
Injection
Action at which a gas is transferred from the pipeline system of one pipeline owner/operator to the system of another pipeline owner/operator

3.11
Digestion
Anaerobic degradation of organic matter under the action of specific bacteria

The digestion can be natural (like in landfill sites) or subject to process intensification in a digester.

3.12
Digester
Reactor in which the digestion process takes place

3.13
Non-conventional source (NCS) gas
Any kind of combustible gas different from natural gas under consideration for pipeline injection

3.14
Point of injection
Zone in a pipeline at which a gas is transferred from the pipeline system of one pipeline owner/operator to the system of another pipeline owner/operator

3.15
Gas network
System of pipelines conveying gas from the point of production or delivery to the point of use

3.16
Gas supply
Gas network supplying the general public with gas, under the regime of directive 2003/55/EC

4 Description of raw gases

The nature of non-conventional source (NCS) gases varies strongly, depending on type and source and this is summarised in table 1.

The **first kind** of NCS gas is biogas, produced either naturally in a landfill site or in a digester, by a controlled process of anaerobic digestion. The composition of biogas depends on the composition of the waste treated (green residue, municipal solid waste, agricultural waste, manure slurry, waste from industrial food production, etc.). Because of the composition of such waste varying from one region to another (depending on social, political and economic factors), the resulting biogas composition may also vary between different countries and regions.

Table 1: Types of non-conventional gas and the scope of this recommendation

<table>
<tr><th>Source</th><th>Production process</th><th>Treatment process</th><th>Injectable product</th></tr>
<tr><td>Landfill (municipal & industrial waste)</td><td rowspan="4">Digestion</td><td rowspan="4">Purification
Upgrading</td><td rowspan="4">Biogas</td></tr>
<tr><td>Sewage</td></tr>
<tr><td>Organic waste/by-product (agricultural, industrial or municipal)</td></tr>
<tr><td>Energy crop</td></tr>
<tr><td>Coal mine methane</td><td rowspan="2">None (except extraction)</td><td rowspan="2">Purification
Upgrading</td><td rowspan="2">Coal-associated gas</td></tr>
<tr><td>Coal bed methane</td></tr>
<tr><td>Hydrogen-rich compounds</td><td>Reforming, chemical processes</td><td>Purification</td><td rowspan="2">Hydrogen-rich gas</td></tr>
<tr><td>Biomass (wood, crop, etc.)</td><td rowspan="4">Gasification</td><td>Purification
Water-gas-shift</td></tr>
<tr><td>Organic waste/by-product (agricultural, industrial or municipal)</td><td rowspan="3">Methanation
Purification</td><td rowspan="3">Substitute natural gas</td></tr>
<tr><td>Oil</td></tr>
<tr><td>Coal</td></tr>
<tr><td>Water</td><td>Electrolysis</td><td>Drying</td><td>Hydrogen</td></tr>
</table>

The **second kind** of NCS gas is represented by coal mine methane (**CMM**) and coal bed methane (**CBM**). The composition of CBM is generally similar to that of conventional high methane natural gas. CMM compositions vary more widely, depending upon the amount of air to which the gas has been exposed and the degree of conversion of oxygen to carbon dioxide.

The **third kind** of NCS gas is a hydrogen-rich gas e.g. produced by thermal processes. This will include town gas, coke gases, refinery gases, but also gases resulting from the gasification of biomass. In methanation and purification processes, these gasses can be transferred into Substitute Natural Gas, the fourth type of NCS-gas mentioned in Table 1.

Although related to (and carrying many of the features of) hydrogen-rich gases pure hydrogen is included in Table 1 as its own kind of NCS gas. In a future "hydrogen economy", hydrogen may become an important energy carrier and can be produced in a relatively pure form by electrolysis, using electricity derived from sustainable sources such as wind-, hydroelectric- and photovoltaic power. Emissions of pollutants from combustion of hydrogen are very low. Studies are in progress in assessing the need for a new gas transportation system dedicated solely to hydrogen, or whether the existing natural gas system can be employed, using hydrogen/natural gas mixtures and hydrogen separation techniques.

Tables 2 and 3 give some examples of compositions and properties (expressed on a dry basis) of NCS gases. Note also that the composition and consequently the physical and chemical properties of different raw and treated natural gasses can differ significantly: The figures included for natural gas concern indicative values of gas supplied to European households.

Table 2: Indicative composition of different raw gases from non-conventional sources and of natural gas

Composition	Units	Natural gas (typical North Sea H)	Biogas		Coal-associated gas		Biomass gasification	
			Anaerobic digester	Landfill	CMM	CBM	O_2-fired	Air-fired
Methane	mol%	88.8 (86.6 - 88.8)	65.0 (50 - 80)	45.0 (30 - 60)	65.0	90.0	15.6 (0 - 18)	2.0 (1 - 10)
C2+ Hydrocarbons		8.3 (8.3 - 8.5)	-	-	1.5	2.2	5.8 (0 - 5.8)	(0 - 2)
Hydrogen		-	(0 - 2)	1.5 (0 - 2)	-	-	22.0 (4 - 46)	20.0 (10 - 25)
Carbon monoxide		-	-	-	-	-	44.4 (13 - 70)	20.0 (9 - 25)
Carbon dioxide		2.3 (1.9 - 2.3)	35.0 (15 - 50)	40.0 (15 - 40)	16.0	3.3	12.2 (2 - 35)	7.0 (7 - 16)
Nitrogen		1.1 (0.9 - 1.1)	0.2 (0 - 5)	15.0 (0 - 50)	18.0	4.5	0 (0 - 7)	approx. 50.0
Oxygen		< 0.01	(0 - 1)	1.0 (0 - 10)	0.5	-	-	-
Hydrogen sulphide	mg/m^3	1.5 (0 - 5)	< 600 (100 - 10000)	< 100 (0 - 1000)	(0 - 5)	(0 - 5)		
Ammonia		-	100 (0 - 100)	5 (0 - 5)	-	-	-	-
Total chlorine		-	(0 - 100)	(0 - 800)				
Total fluorine	mg/m^3	-	0.5 (0 - 100)	10 (0 - 800)	-	-	-	-
Siloxanes	mg/m^3	-	0 - 50	0 - 50	-	-	-	-
Tar	g/m^3	-	-	-	-	-	0 -5	0,01 -100

NOTE: 1: all compositions are purely indicative, derived from different sources. Bracket values indicate ranges which may be encountered.

NOTE 2: For biomass gasification, different methods are available with significant differences in the composition of the product gases.

Table 3: Indicative properties of different raw gases from non-conventional sources and of natural gas

Properties	Units	Natural gas (typical North Sea H)	Biogas		Coal-associated gas		Biomass gasification	
			Anaerobic digester	Landfill	CMM	CBM	O_2-fired	Air-fired
Gross calorific value (1)	MJ/m^3	40	32	17	25	36	14	6
	kWh/m^3	12	7	7	7	10	4	3
Net calorific value(1)	MJ/m^3	35	22	21	23	32	13	9
	kWh/m^3	10	6	6	7	9	4	3
Wobbe Number (1)	MJ/m^3	50	26	27	29	45	29	20
	kWh/m^3	15	8	8	8	13	8	6
Relative Density (1)		0.6	0.9	0.7	0.8	0.6	0.2	0.3
Density (1)	kg/m^3	0.7	0.8	0.8	0.8	0.7	0.3	0.3
Methane Number (2)		76	135	144	109	90	64	77

Sources: (1) GERG-Report PC 1 "Biogas characterization WG 1.49"
(2) calculated in accordance with AVL-List

NOTE: Properties are calculated from the indicative single values given in Table 2, on a dry basis (although the raw gas may in practice be saturated).

5 Potential additional hazards of NCS gases

NCS gases, depending on their production process, may be characterized by a wide range of composition and by a possible presence of a wide variety of components (either chemical or biological components) which could be corrosive or toxic.

The hazard is generally associated with the raw gas and hence depends upon the source and/or production process. In some circumstances the treatment process required to bring the raw gas to general pipeline quality (e.g., calorific value, Wobbe number) may be sufficient to reduce the hazard to acceptable levels. On other circumstances, specific treatment processes may be required. Nevertheless, the effectiveness of countermeasures needs guarantees including checks, and a Quality Assurance system.

The following kinds of hazards have to be taken into account:

hazards on human health of end-users and for employees of e.g. the gas industry;

hazards on gas networks integrity;

hazards to the safe operation of gas appliances.

For human health, the hazards are: direct toxicity in case of leak in a semi-confined environment, indirect toxicity by combustion products, water pollution in case of injection in subterranean storage and air pollution.

For gas networks and gas appliances, the hazards are: corrosion and clogging of pipelines and safety devices, undue change of combustion properties. Furthermore, the safety risks related to the transmission, distribution and end use and the performance of end user appliances may change.

Table 4 below indicates potential hazards arising from each type of NCS gas.

Risk assessment is recommended in order to evaluate specific requirements (see 7.1).

Table 4: Additional* potential hazards associated with NCS gases and countermeasures applied to raw gases or in gas treatment

<table>
<tr><th>Product</th><th>Source</th><th>Hazardous components</th><th>Hazard for health</th><th>Hazard related to transmission, distribution and use</th><th>Countermeasure</th></tr>
<tr><td rowspan="10">Biogas</td><td rowspan="4">Digester gas</td><td>Siloxanes</td><td></td><td>Production of silica under burner conditions</td><td>Sampling and analysis for siloxanes. Exclusion of sources of known high silicon content. Removal of siloxanes from product</td></tr>
<tr><td>Biological agents</td><td>Possible presence of pathogenic agents
(need to be demonstrated)</td><td>Biocorrosion of gas networks</td><td>Hygienization of the substrate
Long digester retention time
Filtration (see note below)</td></tr>
<tr><td>Ammonia</td><td>Toxic gas</td><td>Corrosion</td><td>Removal of ammonia</td></tr>
<tr><td>Halocarbons</td><td>Production of dioxins and furans under burner conditions</td><td>Corrosion</td><td>Sampling and analysis for halocarbons. Exclusion of sources of known halocarbon content</td></tr>
<tr><td rowspan="5">Landfill gas</td><td>Halocarbons</td><td>Production of dioxins and furans under burner conditions</td><td>Corrosion</td><td>Sampling and analysis for halocarbons. Exclusion of sources of known halocarbon content</td></tr>
<tr><td>Biological agents</td><td>Possible presence of pathogenic agents
(need to be demonstrated)</td><td>Biocorrosion of gas networks</td><td>Filtration (see note below)</td></tr>
<tr><td>Siloxanes</td><td></td><td>Production of silica under burner conditions</td><td>Sampling and analysis for siloxanes. Exclusion of sources of known high silicon content. Removal of siloxanes from product.</td></tr>
<tr><td>Ammonia</td><td>Toxic gas</td><td>Corrosion</td><td>Removal of ammonia</td></tr>
<tr><td>Polyaromatic hydrocarbons (PAHs)</td><td>Toxic,
carcinogen</td><td>Affects plastic and elastomere material ; sooting when burnt</td><td>Permanent monitoring and removal</td></tr>
</table>

* in addition to known potential hazards connected with natural gas

Table 4 (continued): Additional* potential hazards associated with NCS gases and countermeasures

Product	Source	Hazardous components	Hazard for health	Hazard related to transmission, distribution and use	Countermeasure
Coal associated gas		Radioactive compounds	Radioactivity		Measurement. Exclusion of high radioactive sources.
		Biological agents	Possible presence of pathogenic agents (need to be demonstrated)	Biocorrosion of gas networks	Filtration (see note below).
Hydrogen rich gas	Syngas (from coal or biomass)	Polyaromatic hydrocarbons (PAHs)	Toxic, carcinogen	Affects plastic and elastomere material ; sooting when burnt	Permanent monitoring and removal
		Carbon monoxide	Toxic gas		Permanent monitoring and removal
		Hydrogen	Hazards associated with changed combustion properties	Corrosion; safety and performance of gas appliances; impact on industrial processes	Gas quality control; removal; increased pipeline integrity management
SNG	Gasification	Carbon monoxide	Toxic		Removed by normal treatment process (Water gas shift, methanation)
		Polyaromatic hydrocarbons (PAHs)	Toxic, carcinogen	Affects plastic and elastomere material ; sooting when burnt	Permanent monitoring and removal
Hydrogen	Electrolysis	Hydrogen	Hazards associated with changed combustion properties	Corrosion; safety and performance of gas appliances; impact on industrial processes	Gas quality control; removal; increased pipeline integrity management

*in addition to known potential hazards connected with natural gas

NOTE: Micro-organisms can be removed by filtration with mesh size <1µm. However the effectiveness of filtration systems has not been fully demonstrated for all NCS sources.

Halocarbons (Organo-halides)

Efficient combustion of landfill gas should result in destruction of most toxic compounds resulting in largely carbon dioxide, water and traces of oxides of sulphur and nitrogen, and hydrogen chloride. However, when materials containing halocarbons are burnt, trace levels of dioxins and furans are produced; the amount dependent upon the type of material burnt and the combustion process.

There is little dioxin and furan release data available for landfill gas combustion (and in particular landfill gas treated for pipeline injection). Data published on the Internet (www.ping.be/ be/~ping5859/eng/ chlorinediinp.html) shows chlorine input and dioxin output from a variety of process. There does not appear to be a correlation between chlorine content of fuel and the amount of dioxin released. Natural gas does not normally contain halocarbons so the risk associated from dioxins and furans posed by landfill gas combustion must be carefully assessed.

Biological agents

A number of NCS gases are produced by biological processes, the transport of micro-organisms as an aerosol has to be considered. The quality of the treated gas is generally guaranteed by quality assurance (QA) of ingoing raw material to the biogas plant, QA of the biogas or bio-syngas production process and QA of upgrading and purification process.

– Human health

Relatively little information is available on the health risks associated with biological agents in NCS gases. Two studies addressing human health have been performed and the main conclusions are summarised below. Whilst neither of these studies found any recorded examples of biological problems associated with injection of biogas or coal-associated gases, there has been very little research performed across the range of NCS gases. Further research into this area is highly recommended.

In the UK, Advantica conducted a preliminary assessment of risks posed by biological agents for National Network Transco in the UK. Further, a study performed in Sweden gave some recent results about the occurrence of micro organisms and their levels in different gases, including biogas from anaerobic digester before and after treatment and of natural gas. The conclusions from this work are summarised below

The atmosphere in coal beds and coal mines and landfill sites in the methane phase are either anaerobic or microaerobic (i.e., containing a trace amount of oxygen). These conditions favour the growth of prokaryotes (bacteria and archeae) such as methanogenes (which produce methane) and sulphate-reducing bacteria (which produce hydrogen sulphide). Both types of organism are fairly commonly found in anaerobic conditions, normal and extreme, and neither is pathogenic to humans. *Clostridium spp* may act as sulphate-reducing bacteria and is potentially pathogenic to humans, causing botulism and gangrene. These species are unlikely to survive outside an anaerobic environment, however.

Micro-organisms that survive in a micro-aerobic environment include *Actinomyces spp* (see below).

A significant biological risk could arise from gas associated with e.g. landfill sites known to contain sewerage waste, animal and abattoir waste or clinical waste, since these wastes could contain pathogenic microorganisms. Generally speaking, waste from sewerage, animals and abattoirs are categorised and are digested at elevated temperatures in specific digesters. Hazardous abattoir waste and clinical waste is usually incinerated.

In Sweden, the Swedish Institute for Veterinary Medicine reported [30] on the content of micro-organisms measured during 2005 in biogas from four different Swedish biogas plants, two sewage treatment plants and two co-digestion plants. Biogas was analysed before and after treatment in three different types of biogas upgrading plants. The results were compared with similar analysis of natural gas and air. The results show a very low level of micro-organisms in biogas, similar to that detected in natural gas, whilst the level of micro-organisms in air is generally much higher than that in either natural gas or biogas. The type of micro-organisms found did not differ significantly between natural gas and biogas. A preliminary risk analysis concluded that the risk for explosion or suffocation is much higher than the risk for infection when being exposed to biogas.

– ***Pipeline integrity***

There is no information available that proves that bacteria-assisted corrosion by NCS gasses initiates other, less or more problems than experienced with natural gas. Therefore, bacteria-assisted corrosion initiated by NCS- gas may be an issue worthwhile further investigation.

Microbiological problems are more likely to be associated in the gas production process and such problems include:

Sour gas production owing to the growth of sulphate - reducing bacteria stimulated by water and elemental sulphur or sulphates associated with coal.

Blockage of filters by microbial sulphide production. If iron-reducing bacteria are present, they metabolize reduced iron, which may result in slimy precipitates of ferric oxide in their secretions.

It could be argued that these problems are largely those of the gas production facility operator, however, and not those of the gas transporter.

Radioactivity

Radon is a radioactive gas that occurs in nature everywhere. It is produced from decay of trace amounts of radioactive uranium present in soils and rocks and is therefore present in both natural gases and in coal-associated gases. European legislation covering the safe handling of radioactive substances and safe disposal of radioactive waste limits also the content of radioactive components in natural gases.

Concentrations of radon in coal-associated gases can vary considerably and can, depending on the respective source, be up to several tens of thousands of Becquerel/m^3. These levels are higher than those seen in natural gas and therefore may lead to denial of access to the natural gas network for a particular gas.

Production of silica

Siloxanes may be frequently encountered in municipal sewage and landfill. During combustion they are converted to SiO_2, which is particularly destructive to combustion engines.

Poly-aromatic hydrocarbons

Poly-aromatic hydrocarbons may be present in NCS-gases including landfill gas. These hydrocarbons may affect PE-pipelines, rubber and other synthetic parts present in the natural gas chain, and some are known carcinogens. In combustion, higher poly-aromatic hydrocarbons may result to the formation of soot.

Carbon monoxide

Carbon monoxide can be present in gases from gasification plants and is very toxic. Unintended gas releases from for instance small leaks in confined rooms can easily lead to fatal accidents.

Ammonia

Ammonia is a toxic gas which can induce a risk in case of a leak. Also, it can induce corrosion in gas networks.

Hydrogen

Hydrogen added to natural gas in the natural gas system may affect

- the integrity of the gas system (e.g., hydrogen induced stress corrosion);
- the safety risks related to the transmission, distribution and use of the gas (e.g., unintended gas release, combustion properties as e.g. explosion limits, radiation of flames, ignition en ergy);

✧ the performance of end user appliances (e.g. flame speed and flash back);

✧ the performance of industrial processes (change of chemical composition).

NOTE: Currently, a European project is undertaken under the name “NaturalHy” to examine the effects of hydrogen addition to the natural gas grid.

6 Minimum gas quality requirements for network delivery

6.1 Minimum requirements for any type of network entry

In order to ensure the safety, integrity and operability of gas networks, all gases (conventional or non-conventional) shall meet certain minimum gas quality requirements. The choice of gas quality parameters and their limiting values are generally specified nationally. The table below - taken from the report on the national situation regarding natural gas quality by the MARCOGAZ Gas Quality working group – illustrates the parameters that are generally constrained by national legislature.

Table 5: Gas quality parameters currently specified in national legislation or within EU directives

		COUNTRY								
		AT	BE	DK	DE	FR	IT	NL[4]	ES	UK
Reference Temperature, °C Volume Energy		 0 25/0	 0 25/0	 0 25/0	 0 25/0	 0 0/0	 15 15/15	 0 25/0	 0 0/0	 15 15/15
GCV		X	X		X	X	X		X	
Wobbe index		X	X	X	X		X			X
Density		X		X	X		X			
Methane number										
Hydrocarbon dew point		X		X	X		X			X
Water dew point		X		X	X	X	X			X
Sulphur	Total	X	X	X	X	X	X			X
	H_2S	X	X	X	X	X	X		X	X
	Odorant[2, 3]		X	X			X			
	Mercaptan	X			X		X			
	COS	X								
Other indices[1]	Comb. Potential									
	Lift Index									
	ICF									X
	Soot index									X
CO									X	
Carbonyl metals										
Impurities (liquids, solids)		X		X	X		X			X
CO_2		X					X			
N_2		X								
O_2		X			X		X			X
H_2		X								X
Aromatics[5]										
NH_3		X							X	

Source: MARCOGAZ report on the national situation of natural gas quality; July 2003, including amendment of December 2005; figures for Austria are not part of the original table, but have been added by the Biogas Working Group.

Note 1: Other indexes relate to indexes use for interchangeability.

Note 2: In every country except the Netherlands there is a national legislation stating that gas shall be odorised. Thus if the table shows an indication for odorant specification it means that an actual concentration of odorant is specified to fulfil this obligation. This specification may be written in a standard. In some countries a specification on mercaptan concentration is made apart from odorisation requirement.

Note 3: Odorants are not always sulphur-based. In some countries, a sulphur free, acrylate based odorant is used. However, all countries ask for gas to arrive sufficiently odorized at consumers' premises.

Note 4: In the Netherlands gas quality parameters are agreed between the gas supplier and its customers.

Remark 1: Directive 76/769/EC set further limits on benzene and mercury. Furthermore, the directives 67/458/EC (concerning classification of compounds in categories), 1999/45/EC (concerning preparations) and 2001/58/EC (Safety data sheets) should be considered

Remark 2: there are relevant developments concerning REACH: it does not concern natural gas (exemption Annex 3) but it may concern NCS-gas, particularly when it concerns land fill gas

Within the European Union there is a proposal to harmonise natural gas quality specification and a specification has been produced by EASEE-Gas, noted by the Madrid Forum. A Common Business Practice has been prepared by EASEE-Gas which suggests an action plan and timescales for its implementation. The harmonised gas quality specification is only applicable for cross-border transportation of gases within gas family H. Gases complying with this specification can not be rejected for gas quality reasons. However, gases outside this specification may be exchanged if the parties involved agree to do so. Further, the EU Commission decided to issue a standardisation mandate of the gas quality to CEN. As a consequence, the standard which will be produces will be applicable on natural gas type H in the entire area of the EU member states. The table below indicates the parameters that form part of the harmonised specification, together with limit values and status.

Table 6: Gas quality parameters currently considered in proposed harmonised EU specification

Parameter	Value	Status
Wobbe Index	13.6 ÷15.81 KWh/m^3 (25^{o}C/0^{o}C)	Recommended. A difficulty has been recognised with the lower WI value and as a result a starting range of 13.76 ÷15.81 has been recommended.
Relative Density	0,555 ÷0,7	
Total sulphur	Maximum 30 mg S/m^3	
(H_2S + COS)	Maximum 5 mg S/m^3	
Mercaptans	Maximum 6 mg S/m^3	
Oxygen	Maximum 100 ppm molar	Under discussion at the time of publication of this report
Carbon dioxide	Maximum 2.5 % molar	
Water dewpoint	Maximum – 8^{o}C at 70 bar a	
Hydrocarbon dewpoint	Maximum – 2^{o}C over 1 ÷70 bar a	
Hydrogen		Currently unspecified, but it is recognised that the above WI and RD limits are only valid for "insignificant" amounts of hydrogen and may need to be changed if hydrogen content is significant.

Non-conventional supplies of gas must comply with prevailing national and European legislation and must be compatible with those gas quality specifications of the gas to which the non-conventional gas is being added.

Where a gas offered to a pipeline owner/operator does not meet the specifications set above, the parties generally examine the possibility of additional treatment of the gas or blending with other gases before it is actually added to the gas system that directly supplies gas to customers.

Increase in magnitude and frequency of gas quality changes may result from the injection - and cessation of injection - of different gases. This may cause operational problems for certain industrial applications of natural gas and safety problems in domestic and industrial applications. Further research in this aspect is required. If the addition of gases leads to a lower content of particularly methane, the commercial value of the gas supplied to industries that use natural gas as a feedstock (for instance producers of H_2, methanol, ammoniac, soot) may decrease.

6.2 Requirements particularly relevant for NCS gases

Some countries define specific requirements for injection of NCS gases (see table below):

Table 7: Specific requirements for the injection of NCS gases into natural gas networks in some European countries

	Austria	France	Germany	Netherlands	Sweden	Switzerland	
Property						Unlimited Injection	Limited injection
CH_4	> 96 %	/	-	85%	>97%	>96%	>50%
CO_2	< 3 %	<2,5%	#6%	/	<3%	<4%	<6%
CO		<2%	/	/	/	/	/
Total S	< 10 mg/m³	< 30mg/m³	#30 mg/m³	<45 mg/m³	< 23 mg/m³	< 30mg/m³	< 30mg/m³
H_2S	< 5 mg/m³	< 5 mg/m³ (H_2S+COS)	# 5 mg/m³	< 5 mg/m³	10 ppm	< 5 mg/m³	< 5 mg/m³
Mercaptans	< 6 mg/m³	<6 mg/m³	15 mg/m³	/	/	/	/
O_2	< 0,5 %	<0,01%	<0,5%	<0,5%	<1%	<0,5%	<0,5%
H_2	< 4 %	<6%	#5 %	/	<0,5%	<5%	<5%
H_2O	Water dew point -8°C/40 bar	Water dew point <-5°C at MOP	Water dew point: Ground temperature	<32 mg/m³	<32 mg/m³	<60%	<60%
Hydrocarbon dew point	0°C at OP	<-2°C (1-70 bar)	Ground temperature	/	/	/	/
Wobbe index	13,3 - 15,7 kWh/m³	13,64-15,7 kWh/m³ for H gas 12,01- 13 kWh/m³ for B gas	10,5 -15,7 kWh/m³	43,6-44,41 MJ/m³	45,5 - 48,5 MJ/m³	13,3-15,7 kWh/m³	/
Pressure			Pressure of pipeline to be injected into				
Gross calorific value	10,7- 12,8 kWh/m³	10,7- 12,8 kWh/m³ for H gas 9,5 -10,5 kWh/m³ for B gas	/	35,1 MJ/m³	/	10,7-13,1 kWh/m³	/
Relative density	0,55 - 0,65	0,555-0,70	/	/	/	0,55-0,70	/

Table 7(continued): Specific requirements for the injection of NCS gases into natural gas networks in some European countries

	Austria	France	Germany	Netherlands	Sweden	Switzerland	
Odorant	Gas to be odorized at consumer	15-40 mg THT/m³	Gas to be odorized at consumer	Gas to be odorized at consumer	/	15-25 mg THT/m³	15-25 mg THT/m³
Impurities	Technically pure	Technically pure				Technically pure	Technically pure
Halo-genated compounds	0 mg/m³	< 1 mg Cl /m³ < 10 mg F /m³	nil	< 25 mg Cl/m³	/	/	
Ammonia	Technically pure	/	/	<3 mg/Nm³	<20 mg/Nm³	/	/
Dust	Technically pure	/	No dust	No dust			
Mercury		< 1 µg/m³	/	/	/	/	/
Benzene							
Siloxanes	< 10 mg/m³						

Sources:

Austria: ÖVGW codes of practice G 31, G 33

France: prescriptions techniques du distributeur Gaz de France prises en application du décret n° 2004-555 du 15 juin 2004 relatif aux prescriptions techniques applicables aux canalisations et raccordements des installations de transport, de distribution et de stockage de gaz.

Note: Depending on the nature of the gas to inject in the French natural gas grid, others maximal concentrations of some compounds must be added according to the risk of damages which can be caused on the grid.

Germany: DVGW codes of practice G 260, G 262

Netherlands: draft proposal for Dutch distribution network companies

Sweden: Swedish Standard SS155438

Switzerland: SVGW codes of practice G 13

NOTE: Depending on the nature of the NCS, specific requirements not mentioned in this table may apply.

6.2.1 Minimum gas quality requirements for grid delivery of gases

With the exception of those based on hydrogen, the main component of NCS gases and of natural gas is methane. Upgraded biogas therefore has many properties similar to those of natural gas. However, NCS gases differ from natural gas in a number of key aspects that must be addressed by appropriate specification of quality.

NOTE: It is important that any item mentioned in a gas quality specification can be determined with standardized and reproducible analytical and measurement methods. Such methods are not developed for some of the risks associated with NCS gases (in particular biological agents). This is an area in which further research and development is recommended. Because biogas is produced by fermentation of organic material it may contain compounds not normally encountered in natural gases.

6.2.1.1 General requirements

Risk assessment prior to injection of any gas, irrespective of source, is recommended in order to assess requirements for measurement, control and safety devices. Such risk assessment should therefore consider the additional risks associated with NCS gases.

Gas Transporters will generally require that treatment plants feeding gases into a natural gas grid should be equipped with continuous determination of calorific value, Wobbe index, relative density and water content or dew point and, depending on the source of gas and requirements in place, also methane, CO, higher hydrocarbons, sulphur and oxygen. Systems to shut down the delivery in case of deviations from minimum requirements may also be required.

Measurement of gas properties from non-conventional sources should where possible be performed with standardized methods defined by international, European or national standards. ISO/TC 193 “Natural gas” has developed a number of relevant standards, however standards relevant to some NCS gases are not available (for example PAHs, micro-organisms).

6.2.1.2 Requirements concerning biological compounds

Gas that is distributed on the natural gas grid shall not contain substances that can cause danger to the health of gas users or other persons that may come into contact with the gas or its products of combustion. Also, any additional hazard to the natural gas transport system and of its components shall be avoided. NCS gases with high risk from biological agents, such as biogas plants feeding gas into the natural gas grid should therefore have a quality assurance system or equivalent proof for handling raw material, gas production and gas treatment in order to eliminate the risk for contamination.

Biogas distributed on the natural gas grid shall be specified in a safety data sheet in accordance with Directives 91/155/EEC and 2001/58/EC.

6.2.1.3 Requirements concerning silicon compounds

Siloxanes may be frequently encountered in municipal sewage and landfill. During combustion they are converted to SiO_2, which is particularly destructive in combustion engines. To avoid damage to engines, silicon compounds in gas that is delivered to the natural gas grid may require limitation. In Austria, e.g., Siloxanes are required to be at a level of < 10 mg/m³ (as Si).

6.2.1.4 Requirements concerning halogenated compounds

Gas conveyed to the general public shall be technically free of halogenated hydrocarbons. Under the conditions of a gas burner in the presence of copper, dioxins and furans may be produced. Halogenated hydrocarbons are often encountered in landfill gases and where this is so, these gases should not be admitted to the natural gas grid unless the grid only supplies a defined number of industrial customers with the capability for fully monitored use of the gas. In the UK, National Grid has indicated in its annual Ten Year Statement, a limit on the maximum content of organo-halides permitted for network entry of 1.5 mg/m^3.

6.2.1.5 *Requirements concerning ammonia*

Ammonia is corrosive in the presence of oxygen for ferrous metals (carbon steel) and non ferrous metals (brass). It induces risks of cracking, especially with high strength steels (> 400 MPa). Above 0,2% of water in the gas, this tendency decreases.

The corrosion with ammonium chloride is known to be fast.

6.2.2 Minimum gas quality requirements particularly relevant for network delivery of gases produced from biomass by thermal process

Gases produced from biomass by thermal process will be of a similar composition to town gas produced from coal or lignite, because the production processes available are based on coal gasification processes. Depending on the process chosen the product gas will contain significant methane, or will be predominantly a mixture of hydrogen and carbon monoxide. Gases produced from biomass gasification in general contain less sulphur components and ash residue than gases from the gasification of coal. After cleaning, (utilising the same methods developed for raw town gases) such gases are suitable as a replacement for town gas. However, as town gas is hardly ever encountered in Europe, its use is limited to augmenting gas in natural gas grids. Such use demands more thorough treatment, including total removal of carbon monoxide, partial removal of carbon dioxide and eventually hydrogen. Drying is required as such gases (like their coal-based counterparts) are generally wet.

Polyaromatic hydrocarbons (PAHs) are formed when thermally gasifying any kind of solid carbon containing fuel. PAHs are generally defined as organic compounds containing two or more condensed aromatic rings. PAHs can condense in gas pipes and cause clogging, and because they decompose only very slowly can accumulate in the human body if exposed.

PAHs are normally formed in the gasifier but removed in subsequent processes to produce a gas suitable for grid injection.

In Germany, DVGW specifies, for towns gases, a maximum content of single ring aromatics of 10 g/m^3 and the maximum content of double ring aromatics (naphthalene) to be 50/P mg/m^3 (where P = max pressure in bar where gas is injected) in order to avoid condensation. DVGW also requires a hydrocarbon dew point to be less than the temperature of the pipe where gas is injected.

Carbon monoxide can be present in gases from gasification plants and is very toxic. Very little town gas production is practiced today, but in Denmark and Sweden, typical towns gas specifications limit carbon monoxide level to 3 mol%.

6.2.3 Minimum gas quality requirements particularly relevant for network delivery of coal-associated gases

Due to their similarity to natural gas, for these gases, after treatment, the same network entry requirements apply as for natural gas. However, for some sources of this type radioactive gases, e.g. radon content, may exclude them from grid entry.

In the UK, the Radioactive Substances Act 1993, as modified by the Radioactive Substances (Natural Gas) Exemption Order 2002 requires registration of all natural gas installations where a content (for each nucleotide) of 5 Becquerel per gram is exceeded. This threshold value is around ten times the typical radon content of UK natural gases.

6.2.4 Minimum gas quality requirements particularly relevant for network delivery of hydrogen

Some NCS-gases may contain a significant percentage of hydrogen, and as a consequence of this, the chemical and physical properties of these gases may differ significantly from natural gas. Hydrogen affects both the combustion properties of the gas and the mechanical properties of pipeline materials and consequently it may have a major impact on both safe utilisation and pipeline integrity. The amount of hydrogen to be delivered depends on materials and on operating conditions of the respective grid and may vary from 0,02% for some high-pressure grids up to 60% in some low-pressure towns gas grids. Investigative research on this issue is ongoing and should be extended.

End user perception and acceptance of gases containing hydrogen are also relevant (and critical) issues. Hydrogen content is currently unspecified in the proposed EASEE-Gas harmonised gas quality specification (see Section 5.1).

7 Requirements at delivery point

7.1 Risk assessment

For entry of any gas into a network, a risk-assessment based approach is recommended to assess technical requirements at the point of entry. Such a risk assessment would identify those parameters that present either: high risk (and hence continuous monitoring at network entry is recommended); medium risk (and hence occasional sampling and analysis at network entry is recommended); or low risk (and hence either no analysis or initial verification is recommended). Such risks might include risks to health, risks to the safety and integrity of the network, as well as regulatory compliance and commercial risks (e.g., adequate measurement of the quantity of energy injected).

Typically, the following properties may need to be continuously monitored: calorific value, Wobbe index, relative density and water content or dew point t. For some NCS gases additional monitoring may be required, such as hydrogen sulphide, radioactivity and halocarbons.

In some cases, risks associated with NCS gases are controlled not only by treatment processes downstream of gas production, but also by quality assurance processes on the raw material itself. For example, anaerobic digesters may rely on control of the quality of the input waste material to ensure the adequate control of biohazards. In such cases the quality assurance system should satisfy the requirements of, e.g., ISO 9000.

7.2 Technical requirements

The gas producer should adjust the temperature in the biogas to a level that will not cause any condensation or changes of the resulting temperature in a way that has any impact on the measurement of gas to consumers.

The gas producer should equip the delivery system with a pressure control system that ensures that the operating pressures in the biogas system and in the natural gas system are within the operating limits agreed. Such system can include safety valves and/or computerised pressure control systems.

The delivery system should be equipped with automatic devices that shut down the delivery if gas qualities outside the agreed limits are detected. The delivery system should be equipped with systems that can deviate

- any gas not meeting the specifications or
- being in surplus to the maximum delivery rate or
- in situations when delivery has to be aborted.

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Annex 1 Schematic example for the injection of gases from non-conventional sources into natural gas networks