The European Association of Internal
Combustion Engine Manufacturers

EUROMOT

EUROMOT POSITION

Requirements on the quality of natural gas

09 Nov 2017

1. Introduction

EUROMOT fully supports the efforts of the European Commission and the gas sector to ensure a secure and affordable supply of natural gas in Europe. Natural gas is an excellent fuel for high-efficiency and low-emission cogeneration (CHP) installations and for gas-fuelled back-up generators. These gas applications are most suitable to compensate for the inevitable volatility of the output of renewable electricity sources. It is generally recognised that gas-engine driven generators do, and increasingly will, play an important role in creating a reliable and environmental friendly electricity and heat supply. Germany, as a country showing leadership in implementing a sustainable energy supply, is expected to increase its gas-engine based cogeneration capacity to 30 GW by the year 2020 already [1]. Also the possibility of using natural gas as a clean alternative for on-highway/automotive transport is the result of a stable and quality controlled pipeline gas supply system.
The presence of a wide range of different suppliers of natural gas as well as gas exchange by neighbouring suppliers can improve the security of supply. However, special caution is needed to ensure a good quality of the gas. The general performance, efficiency, emissions and safety of most gas applications are affected by the quality of the gas and therefore a proper and stable gas quality must be guaranteed. Within CEN 234, it has been tried for many years to reach a European standard that should define the quality ranges for cross-border gas of the H category. A first result is CEN EN 16726:2015, which includes limits for e.g. the sulphur contents and the methane number of natural gas. However, manufacturers of gas-using applications and gas user groups disagreed with the initially wide Wobbe Index range as proposed by EASEEgas, a

consortium of the gas sector. Further, many stake holders prefer a much lower total sulphur content than that in CEN EN 16726:2015 and EUROMOT aims for a higher methane number than the current value of 65 in the standard. Instead of the relative density, the calorific value variation range should be given in the new H-gas standard. With respect to the reference conditions for the Wobbe Index and the calorific value, this paper uses a temperature of 15 °C and an absolute pressure of 101.3 kPa.

2. Gas quality indicators

Gas companies generally define gas quality as the chemical composition of the gas, with all its different species such as the various hydrocarbons, inert gases such as nitrogen and carbon dioxide as well as generally undesirable species such as sulphur, water and mercury. For some major gas users, such as the chemical industry which uses gas as a feedstock, the process has to be properly tuned to a given gas composition. For most gas users, adjustment for the typical combustion characterising quantities such as the Wobbe Index, the calorific value and the Methane Number is needed to ensure a clean, safe, energy efficient and reproducible performance. It is therefore important in all discussions about gas quality to have certainty about what is meant by quality. In addition, in all information about quantities such as the Wobbe Index and the calorific value, the reference conditions for pressure and temperature have to be given. Preferably, the ISO 13443:1996 Natural Gas – Standard reference conditions of 15 °C (288,15 K) and 1013,25 mbar (101,325 kPa) should apply in order to create uniformity. Unless otherwise stated, all pressures given should be as absolute pressures.

3. The Wobbe Index

The Wobbe Index (*WI*) is an important gas quality indicator for most gas-burning equipment. If the *WI* of a fuel gas is constant, the fuel energy supply to the gas application is constant for a given supply pressure and temperature, notwithstanding composition variations of the gas. Variability in the *WI* will however result in power output variations of the gas application and also result in air-to-fuel ratio variations. The air-to-fuel ratio λ of most equipment fuelled by natural gas is inversely proportional with the *WI* in case no control action is taken:

$$\lambda' = \frac{WI}{WI'}\,\lambda$$

This effect is called the λ shift factor. Maintaining a close to constant air-to-fuel ratio helps to create maximum energy efficiency and safety and minimum emissions. Feedback control systems can basically compensate the λ and the power output for variability in *WI*, but only to a certain extent and never immediately. Every feedback control system has a proportional band leading to offsets from the original desired setting. The larger the range in *WI* variations, the larger the final deviation from the original process settings will be. Feedback control systems can only act retrospectively. Therefore, very fast fluctuations in *WI*, caused e.g. by the so-called plug flow in case of largely deviating gas compositions, cannot be compensated quickly enough by feedback control systems. Consequently, large fast variations in *WI* have to be avoided for most applications, especially to prevent gas-fuelled generators to cause unacceptable output variations to the electricity grid. Fast variations in *WI* will also induce safety problems in many gas applications due to e.g. possible flame extinguishment, overheating and excessive

emissions of undesirable species.
Many gas applications are not intrinsically suitable to operate in a wide gas quality range. Maintaining a narrow *WI* range for gas users has therefore been a standard goal for most gas suppliers in Europe in the past. That is the reason that most gas applications are not equipped with control systems that at least partly compensate for *WI* variations.

4. The volumetric calorific value

The volumetric calorific value of a gas is a measure of the amount of energy available in a standard cubic meter of gas. Gas meters at the gas customer's site measure the gas volume that is delivered to that customer. This delivered volume is used for billing purposes. In many commercial and industrial installations, the gas volume flow is also used as a diagnostic tool for the energy input to the gas application and hence for the fuel efficiency of the gas consuming process. Legally, larger deviations from a close to constant calorific value will require corrections in order to create a fair billing process. Large deviations in calorific value will also inhibit the possibility of using the gas flow for efficiency determination purposes. Installing a fast reacting calorimeter next to the gas meter might offer a solution, but this requires an unwelcome high additional investment for the users. Moreover, such a meter is not able to compensate quickly enough for the effects of plug flow.
Large deviations in calorific value also mean that the available power of an installation can change and that a gas admission system can have insufficient flow area to accommodate the required gas flow.

5. The methane number

The methane number (*MN*) of a gas is a gas quality indicator typical for reciprocating gas engines. The *MN* gives the knock resistance of a gas, comparable with the octane number for petrol. Pure methane has a high knock resistance and is therefore given a *MN* of 100 [2]. Hydrogen in contrast has a very low knock resistance and therefore has been given a *MN* of 0. The *MN* number of mixtures of different gases can be determined by using the method described in [3], which is recognised by the engine industry as the proper methodology.
Most engines have the best fuel efficiency for a *MN* higher than 80. Engines can also be tuned to run on a lower *MN*, but that has negative consequences for the fuel efficiency and for the response speed to required changes in power output. The *MN* of the bulk of natural gases exceeds 70, which is still acceptable if precautions are taken. Only a very limited number of natural gases have a *MN* lower than 70 [4].
Exposure of engines to gases with a wide range in MN generally means that the engine has to be tuned to the lowest MN value, which results in a lower fuel efficiency than optimum and in a restricted load-step response.

6. The sulphur content

The sulphur in a gaseous fuel will be converted to SO_2 during the combustion process and as such emitted to the atmosphere. Legislation generally restricts the emission of polluting gases such as SO_2. Sulphur-related emissions add to the PM 2.5 problems as present in many European countries [5]. Oxidation catalysts that are often applied to control the emissions of

carbon monoxide, aldehydes and hydrocarbons, get rapidly poisoned when exposed to sulphur components. Further, sulphur compounds lead to an accelerated corrosion of exhaust systems, especially when the energy-efficient condensation of the exhaust gas is applied. Gas producers often tend to remove the sulphur levels from well-head gas to an acceptable level, but gas storage in caverns as well as sulphur containing odorants increase the sulphur level of the gas supplied to the customers.
Reference [6] states that most of the natural gases in Europe today have a natural total sulphur content of less than 5 mg/m^3. For usual sulphur-based odorisation levels, the additional quantity is approx. + 3 mg/m^3 when mercaptans are used and + 10 mg/m^3 when THT is used [6]. The German standard DIN 51624 calls for a maximum total sulphur level of 10 mg/kg, i.e. approx. 8.0 mg/m^3 at a compressed natural gas filling station for CNG-fuelled vehicles, including the odorisation [6]. This low level is needed to protect the vehicle catalysts from a rapid ageing.

7. Hydrocarbon and water dew points

Condensation in the gas supply pipes to engines and to many other gas applications is destructive since puddles of liquids can then occur in low lying parts of the fuel supply. It results in swallows of liquid entering one or more engine cylinders. Especially in colder areas, the dew point of the delivered gas should be low enough to avoid condensation. The dew points of the gas delivered should be such that gas supply companies as well as the users will not be exposed to liquids in the gas. The actually allowed dew point might depend on the climatic conditions in the region of gas application.

8. Positions of EUROMOT

The members of EUROMOT have agreed on a number of positions regarding the quality of natural gas of the family of high-calorific gases (H-gases) and the possible standardisation of this group of natural gas. These positions will be presented and defended when discussing gas quality and its standardisation. As in any trade, the end customer should in principle determine which quality he wants. EUROMOT supports the definition made by the USA NGC+ group [7] about the interchangeability of natural gas: "*The ability to substitute one gaseous fuel for another in a combustion application without materially changing operational safety, efficiency, performance or materially increasing pollutant emissions*."
The Wobbe Index (*WI*) of H-gas as supplied in most regions in Europe has a variation range (= peak to peak value) lower than 3 MJ/m^3. The prominent reference [8] expects that this range will remain so in the mid-term future. Gas engines have in general no difficulty with respect to performance, safety and emissions when tuned to the average value in the 3 MW variation range. The average *WI* can differ largely from region to region, but the engines can be adjusted to that (see Figure 1), al-be-it that the knock resistance in the higher *WI* range is relatively low.

a) The maximum value for the *WI* in Europe should be 53 MJ/m^3. That generally ensures a Methane Number (*MN*) higher than 70, as desired by EUROMOT. Pipeline gases never exceed the 53 MJ/m^3 value in practice. Only minor suppliers of LNG offer gases with a higher *WI* than 53 MJ/m^3. EUROMOT sees no reasons why gases with a *WI* higher than 53 MJ/m^3 cannot be refused for import in Europe.

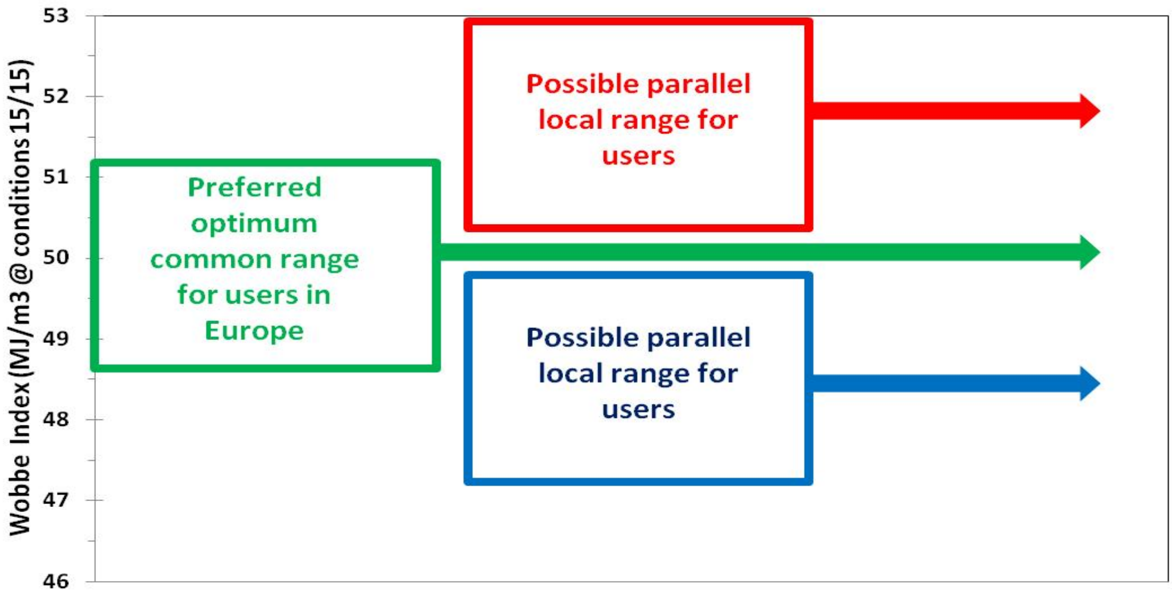

Figure 1: Illustration of the desired maximum regional operating range in *WI:* the EUROMOT scenario

b) The speed of change in the *WI* value should be limited to 0.1 MJ/min in order to ensure that the feedback-control systems have the time to adjust the engine to the new value. This applies only in case the *WI* range does not exceed 3 MJ/m^3. In case a gas supplier plans to shift the quality of the gas to a *WI* outside the initial 3 MJ/m^3 range, the users should be notified in advance in order to be able to take timely measures for the transition.

c) Legislation in Europe should be such that the gas supply sector (producers, shippers, transporters and distributors) is not restricted in technically available and economically acceptable efforts to maintain a limited *WI* range. Gas transmission companies do have proven technical options to modify gases to the desired *WI* range by blending, ballasting and/or stripping. Current EU legislation apparently prohibits them of using those options because this action will affect the composition of the gas and it might require the sales of components such as propane and butane stripped from the gas with an excessive *WI*. Excellent markets exist for products such as propane, e.g. at islands for easy and clean energy supply and storage.

d) The sulphur level of natural gas in Europe should be restricted to a minimum not exceeding 10 mg total sulphur per normal m^3 of gas. Sulphur-free odorants should be used in general.

e) The gas sector should be held responsible for providing a fair and thorough insight into the possibilities to maintain a close to stable gas quality, thereby taking into account the general effect on the economy. The cheapest, safest and most effective solution for ensuring security of supply of quality gas should be preferred.

f) The engine sector, which is represented by EUROMOT, considers itself to have all the required expertise on the sensitivity of its products to gas quality. The test laboratories of the EUROMOT members are more than qualified to generate the necessary knowledge. The gas sector should consult the manufacturers of gas engines in case of questions, especially before stating their opinions on which gas quality engines can accept. This principle of expertise and responsibilities should also apply in case of industrial gas users and power plants.

g) Gas quality specifications for cross-border situations between transporters should not by definition determine the specifications for end users of natural gas since it is often possible to create narrow gas quality solutions for the end users.

h) Caution should be taken when adding species to natural gas that deviate from the standard components in natural gas. Siloxanes as present in some biogases have a detrimental effect on the durability of gas engines. Further, siloxanes cause clogging of exhaust catalysts. Adding hydrogen lowers the calorific value and the methane number of natural gas. Hydrogen addition also increases the explosion limits and increases the flame temperature resulting in higher NOx emissions. Any sensitivities of gas using equipment to a certain fraction of hydrogen added also depend on the initial composition of the gas. Especially the cost effectiveness of adding hydrogen from power to gas to natural gas has to be questioned (see Appendix 3 and ref [9]).

i) The calorific value of the gas supplied to a customer should be within a narrow range in order to create a fair billing process and avoid power capacity limitations. Such a limited range also helps to use the gas meter as a means to determine the energy inflow into the gas application.

9. References

[1] "A showcase for cogeneration", *Decentralized Energy Magazine*, Issue 1, Jan/Febr 2016, pp. 10 -13.

[2] Leiker M., Christoph K., Rankl M., Cartelliery W. and Pfeifer U., "The evaluation of the antiknocking property of gaseous fuels by means of the Methane Number and its practical application to gas engines, CIMAC, Stockholm, Sweden, 1971.

[3] Gas quality standard CEN-EN 16725:2015.

[4] European Commission/DG-move, "LNG Blue corridors – gas quali**ty",** report GC.SST.2012.2-3 GA No. 321592 for the 7th Framework, March 17, 2014.

[5] http://sdg.iisd.org/news/eleven-eu-countries-exceed-air-quality-standards/

[6] Report INGAS_DR_EON RUHR GDF SUEZ_DB01_20110314.doc, http://www.ingas-eu.org/docs/DB0.1.pdf, 2011

[7] White paper on Natural Gas Interchangeability and Non-Combustion End Use, USA NGC+ Interchangeability Work Group, February 28, 2005.

[8] Ten-year network development plan 2017, ENTSOG, Brussels, 2017

[9] http://www.powerengineeringint.com/articles/print/volume-21/issue-5/features/a-waste-of-time-and-money?html

Appendix 1

Closer explanation of the detrimental effect of large Wobbe Index variations on the air-to-fuel ratio *λ*

Modern gas engines use a fuel-lean mixture of gas and air for the combustion process. This means that much more than the minimum fraction of air required for complete combustion is mixed with the natural gas flow to the engines. This has many advantages, such as a lower thermal load on the engine parts, substantially less NO_x emissions and a much higher knock resistance resulting in a higher energy efficiency and power capacity.
Most modern gas engines run at an air-to-fuel ratio λ between 1.8 and 2.1, meaning 80 to 110% extra air compared to a stoichiometric mixture (= $\lambda = 1.0$). In many gas applications, combustible mixtures of gas and air are prepared in a venturi-type mixer which ensures that the λ remains constant in a wide load range, provided the Wobbe Index (*WI*) remains constant. Deviations in *WI* result in λ shifts inversely proportional with the *WI*:

$$\lambda' = \frac{WI}{WI'}\,\lambda$$

EASEEgas has proposed a WI range between 46.44 and 54.0 MJ/m3. If a venturi-based engine tuned at a WI of say 48 MJ/m3 and a λ of 2.0 will suddenly receive gas with a WI of 54 MJ/m3, the initially new λ will be 1.78 resulting in much hotter combustion, excessive NOx production and knocking. Fuel-air mixtures have already a lower knock resistance at a lower λ value, but this effect is surpassed by the sharply lowering methane number when the WI increases. The drop in MN might be from 95 to close to 60. The resulting heavy knocking of the engine can result in an immediate stop at full load. The connection between the WI and the MN for a number of H-gas qualities is illustrated in Figure A1.1. The higher WI values apply for LNGs. A WI lower than 51 MJ/m3 is only reached if inert components (N2, CO2) are present in the gas. Especially biomethane has a WI lower than 51 MJ/m3, while also nationally produced gases can have inert components. It is important to notice that ballasting natural gas with nitrogen in order to lower the WI will not improve the MN.[1]
If the Wobbe Index decreases stepwise from 53 MJ/m^3 to the lower limit of the EASEEgas proposal of 46.4 MJ/m^3, an initial setting for $\lambda = 2.0$ will increase to $\lambda = 2.28$. This will result in immediate misfiring of the engine cylinders and possibly a complete stop of the engine. Such circumstances will give rise to dangerous situations, considering the presence of ignitable mixtures in the exhaust system when tripping, especially at full load. Moreover, the instantaneous loss in power will disturb the electricity grid. Such tripping can be life threatening in case the engine-driven generator is part of an emergency power supply system of e.g. a hospital.

[1] Available for download from: http://www.euromot.eu/download/5438360cde278fdcb4d09364

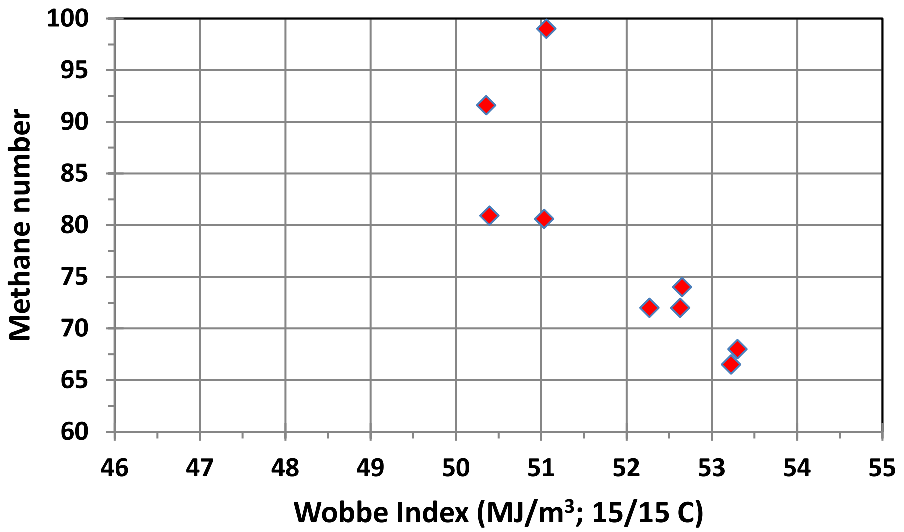

Figure A1: The methane number decreases when the Wobbe Index increases, witness the data for a random selection of commercially available H-gas qualities including LNGs. [see also ref. 4]

Appendix 2

On the need for a limited range in calorific value

The calorific value of a fuel gas is used for the billing process and for a check on the fuel efficiency of a gas application. Large deviations in calorific value can result in insufficient flow area and therefore in power output restrictions of the gas application. There is also a relationship between the speed of combustion and the calorific value, meaning that higher calorific gases in general have a higher combustion velocity. Changes in combustion velocity can induce pulsations in combustion chambers and flash-back in burners and will require changes in the ignition timing of gas engines. One can distinguish between the upper or superior calorific value Hs and the lower or inferior calorific value Hi. The combustion end products are back at the temperature of the process start for both the Hs and Hi, but for the Hs the condensation energy of the water vapour has been included. It will be clear that in the thermodynamic cycle of a gas engine or a gas turbine no condensation can take place. For such applications, the Hi applies. For gases in the upper WI range of the H-Group of gases, the Hi/Hs ratio is about 0.906, while in the lower range it is 0.901.
Figure A2.1 shows that the calorific value Hs can vary between 44 MJ/m3 and 36 MJ/m3, i.e. a range of 8 MJ/m3, for the Wobbe Index range as proposed by EASEEgas, which is unacceptable for most users.

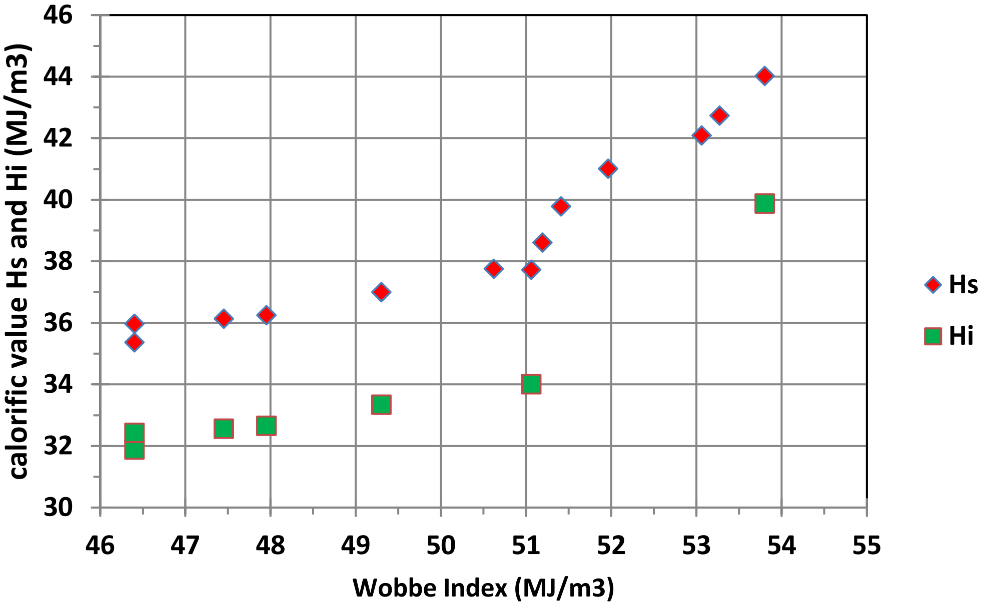

Figure A2: The calorific value can have the wide range from 36 MJ/m3 to 44 MJ/m3 for the WI range as proposed by EASEEgas (conditions 15/15 °C)
Appendix 3

Appendix 3

On the consequences of adding hydrogen to natural gas

Hydrogen is normally not present in natural gas and therefore industrial gas installations and products such as gas engines and gas turbines have not been certified to run on gases containing hydrogen. The fast combustion velocity of hydrogen and its wide explosion range compared with those of natural gas make that the addition of hydrogen to natural gas has also consequences for the tuning and for safety measures for gas-fuelled equipment. The scavenging of exhaust systems has to be more thorough in case hydrogen is present in natural gas, which deteriorates the fast starting process. Hydrogen itself has a very low knock resistance and therefore adding hydrogen to natural gas will lower the quality of gas for engines. The faster combustion velocity of hydrogen compared with that of hydrocarbons also increases the NOx production. Nevertheless, hydrogen is considered by policy makers and gas companies as a possible additive or alternative to natural gas, because the combustion of hydrogen does not directly release any CO2. Moreover, it offers an option for gas transporters to ensure the future use of their capital investment in pipelines.
Gas engines and gas turbines can be designed to run on hydrogen. Problems will however arise with large variations in the hydrogen fraction in case of blends of natural gas and hydrogen, in analogy to the problems associated with a wide Wobbe Index range. Many processes, such as fertiliser production and the chemical industry, need pure hydrogen. EUROMOT therefore prefers a supply of hydrogen separate from that of natural gas in case hydrogen becomes available in adequate quantities.

One problem with hydrogen is its low volumetric energy density. Its superior calorific value is only 12.1 MJ/m^3 where methane, the lowest alkane in natural gas, has already a H_s of 37.7 MJ/m^3 (conditions 15/15 °C). In case of volumetric fraction of 10% of hydrogen in natural gas, the hydrogen represents only about 3% of the energy content of the gas. These 10% of hydrogen also lower the calorific value of the gas by 7%, which negative consequences have already been explained in Appendix 2. For gas engines, 10% of hydrogen in natural gas can lower the methane number by an unwelcome 5 points, depending on the initial composition of the gas.

Another problem with hydrogen is the lower energy density (MJ/m^3) for a given air-to- fuel ratio compared with that of natural gas and air. This will disturb the control methodology of a range of air-to-fuel ratio controllers which are based on the close to constant energy density of natural-gas and air mixtures for a given air-to-fuel ratio λ.

The issue is also to what extent the costs of gas will increase if hydrogen is added to natural gas. Supplying an affordable gas to the customers is also a major goal of the EU. Compression and transportation of hydrogen requires more energy than that of natural gas because of the low volumetric energy density of hydrogen. If the hydrogen is produced from electricity from renewable energy sources (power to gas) via electrolysis, the main goal is energy storage. Currently, the costs of a 1 kW_{peak} solar panel including its installation and converters is about € 1500. For a capacity factor of 0.15, this results in an annual electricity production of $1 \cdot 0.15 \cdot 8760 \approx 1300$ kWh. For a depreciation time of 20 years, when excluding capital costs and profit rates, each kWh produced by a solar panel will costs almost 6 €cts. Converting electricity to hydrogen via electrolysis has in practice an efficiency of about 60%, meaning that producing one kWh of hydrogen-based energy from solar-panel based energy will cost at least 10 €cts, excluding any profits and costs for the electrolysis equipment and compression. One m^3 of natural gas contains at least 36 MJ equalling 10 kWh. Consequently, the basic production costs of hydrogen per unit of energy can be estimated to easily exceed a factor 10 of those of natural gas. A much cheaper way of producing hydrogen can be reforming of natural gas via the water-gas shift reaction, where the CO_2 can be captured and stored.[2]

In proposals for completely fossil-free gaseous fuels, it is suggested that biomethane can accept between 20 and 25 % by volume of hydrogen before user systems will be negatively affected. Although the methane number will not be excessively low, the calorific value drops considerably with an increasing concentration of hydrogen. Also the Wobbe Index decreases to below the minimum proposed by EASEEgas for the higher concentrations of hydrogen.

EUROMOT therefore recommends a thorough independent analysis of the economics of ideas such as power to hydrogen gas before any excessively expensive actions are taken that might not give the optimum results for Europe. Hydrogen might certainly offer opportunities in the supply of energy, but the big question is if it has to be admixed to natural gas pipeline streams, especially in case of high and variable fractions

[2] https://www.statoil.com/en/news/evaluating-conversion-natural-gas-hydrogen.html

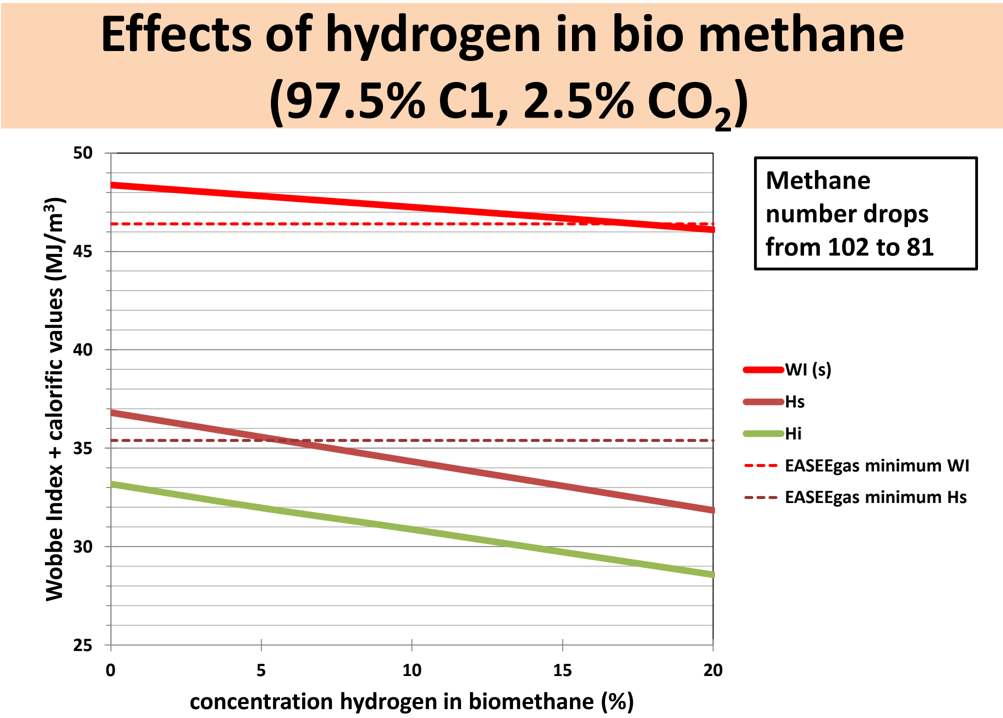

Figure A3: Lowering of the Wobbe Index and the upper and lower calorific value of biomethane via the addition of hydrogen.

Appendix 4

Summary of the proposals by EUROMOT

a) In a new H-gas standard, the Wobbe Index range should be limited to 3 MJ/m^3 for gas applications in a given region.

b) Changes in the average Wobbe Index as desired by the gas supplier should be announced timely so that the gas application can be adjusted to the new situation. The frequency of such changes should as much as possible be limited in time.

c) The maximum value in Wobbe Index should be 53 MJ/m^3, thus enabling a minimum methane number of 70.

d) A new standard for H-gas quality should also contain limits for the range of the calorific value of the gas supplied to a customer. EUROMOT prefers a maximum range in H_s of 2 MJ/m^3.

e) Transmission system operators should be allowed to condition the gas flow by blending, ballasting and stripping. Especially stripping, which is common practice when treating gas from gas production wells, should be used to create an acceptable range in Wobbe Index.

f) The total sulphur contents of natural gas should be limited to a maximum of 10 mg/m^3 and preferably lower if technically possible. Sulphur free odorants are preferred, as common practice already in some areas in Germany.[3]

g) The issue of hydrogen and biomethane addition to natural gas should be properly studied before any attempt to standardisation is made. The effect of hydrogen added to natural gas depends on the initial composition of the natural gas. It is therefore not appropriate to give fixed fractions of hydrogen which might be allowed to adding to natural gas without negative consequences for the user.

h) Siloxanes and any other contaminating species should be removed from gas before the gas is injected into the pipeline system.

For more information please contact:

European Association of Internal Combustion Engine Manufacturers – EUROMOT aisbl
Dr Peter Scherm – General Manager
Phone: +32 (0) 28932141, peter.scherm@euromot.eu

[3] http://pubs.acs.org/doi/abs/10.1021/ef700406x

EUROMOT is the European Association of Internal Combustion Engine Manufacturers. It is committed to promoting the central role of the IC engine in modern society, reflects the importance of advanced technologies to sustain economic growth without endangering the global environment and communicates the assets of IC engine power to regulators worldwide. For more than 20 years we have been supporting our members - the leading manufacturers of internal combustion engines in Europe, USA and Japan - by providing expertise and up-to-date information and by campaigning on their behalf for internationally aligned legislation. The EUROMOT member companies employ all over the world about 200,000 highly skilled and motivated men and women. The European market turnover for the business represented exceeds 25 bn euros. Our **EU Transparency Register** identification number is **6284937371-73.**

http://www.euromot.eu – your bookmark for IC engine power worldwide

Our members are:

DIESEL AND GAS ENGINE MANUFACTURERS

AGCO POWER
CATERPILLAR GROUP
CNH INDUSTRIAL GROUP
CUMMINS
DAIMLER
DEUTZ
DOOSAN
GE POWER & TRANSPORTATION GROUP
HATZ
ISUZU MOTORS GERMANY
JCB POWER SYSTEMS
JOHN DEERE
KAWASAKI EUROPE
KOMATSU ENGINES
KUBOTA
LIEBHERR
LOMBARDINI-KOHLER GLOBAL POWER GROUP
MAN GROUP
MITSUBISHI TURBO & ENGINE EUROPE
MOTEURS BAUDOUIN
ROLLS-ROYCE POWER SYSTEMS
SAME DEUTZ-FAHR
SCANIA
STEYR MOTORS
VOLVO CONSTRUCTION EQUIPMENT
VOLVO PENTA
WÄRTSILÄ
WINTHERTHUR GAS AND DIESEL
YANMAR GROUP
ZETOR

SMALL SI ENGINE MANUFACTURERS

BRIGGS & STRATTON
DOLMAR
EMAK
HONDA EUROPE
HUSQVARNA GROUP
KAWASAKI EUROPE
KOHLER GLOBAL POWER GROUP
SOLO
STIHL
TOHATSU
TORO EUROPE
WACKER NEUSON
YAMABIKO GROUP