



CONFIDENTIAL

Rapportage Projectbureau Nieuw Aardgas April 2012

Datum 13 april 2012
Status Definitive 16-5-2012

Imprint

Project name	Nieuw Aardgas
Project number	
Version number	0.9
Publication number	
Location	
Project leaders	Frank Denys
Contact person	Willem de Vries
Number of appendices	8
Authors	Projectbureau, Willem de Vries
This report has been created in collaboration with:	

Even though this report has been compiled with the utmost care, NL Agency cannot be held liable for any errors.

Table of Contents

Summary	4
1 Introduction	7
2 High calorific gas: market, users and composition	9
3 Activities Projectbureau: reporting and information provision	14
4 Transition H-gas: the Mix of Measures	16
5 Conclusions	25

Appendices

Appendix 1: Summary of Dutch H-gas market, connections and applications

Appendix 2: Current gas composition per region and expected LNG composition

Appendix 3: Distributing LNG in the H-gas network

Appendix 4: Memo – Quality variations in transport

Appendix 5: **Fout! Onbekende naam voor documenteigenschap.**

Appendix 6: Survey of H-gas users dated February 2012

Appendix 7: Responses from businesses - comprehensive summary survey

Appendix 8: Memo – Burner installation H-gas systems

Reader's guide:

This report initially discusses H-gas, the variants and the use thereof. It then describes the activities of the Projectbureau and the contacts that have been made with the market players. There is then a section on the measures taken by the various stakeholders; for measures taken by end-users, this report is based on the survey from February 2012. Finally, the report moves to the conclusions that can so far be drawn. The subsequent appendices provide a great deal of background information.

Summary

This report focuses on the experiences of Dutch industrial companies with the use of high-calorific gas (H-gas) after the LNG Gate terminal came online as one of the supply points for this system. The companies reported on this in a survey that was carried out by Projectbureau Nieuw Aardgas in February 2012.

The transitional period for feeding LNG into the system for high-calorific gas began in September 2011. During this period and until the end of 2012, several further agreements have been made regarding the processing and properties of H-gas. During this period, users can take the appropriate measures in order to ensure they are ready to use the full bandwidth of the composition of H-gas in the future.

During the test phase for feeding-in LNG at Gate terminal in Europoort and the GTS mixing station in Botlek (summer 2011), several fluctuations were experienced in the local network as a result of the commissioning of the GTS nitrogen mixing installation. This was also observed by several companies that lie downstream and close-by the mixing station. Two companies made a specific report of this.

Since the beginning of commercial operations (September 2011), around ten shiploads of LNG have been fed in via the Gate terminal. The composition of this gas was of limited variation in relation to the usual bandwidth of H-gas and did not lead to serious problems for consumers.

The number of reported incidents is limited to the two previously mentioned during the testing phase in the summer of 2011. It should also be noted that LNG has thus far been limited in terms of penetration into the network and, in future, it is expected that LNG will have a more different composition.

There have been no incidents that have led to dangerous situations. Several economic disadvantages have been reported by the users of natural gas as a raw material in particular.

Survey results

The survey of 56 companies led to a very good response rate of over 95 percent. The main results are:

- A quarter of the companies have made a few adjustments.
- About half of the companies expect amendments in order to receive LNG from a source of H-gas to be ready by the end of 2012.
- More than twenty companies indicate that they will not be ready by the end of 2012.
- GTS' signalling system seems to be an important instrument. There appears to be a need for more intensive use thereof; some companies have experienced connection problems. A number of companies find that the signal via the web service cannot be adopted into process control.
- A few companies need further information about H-gas and supplementary meetings with Projectbureau Nieuw Aardgas.
- Various companies are concerned about the willingness of suppliers to adapt the guarantees for their equipment and accept the amended composition of H-gas.

The Projectbureau will get to work on the feedback provided by the survey.

Recommendation: extend the H-gas transitional period until the end of 2013

On the basis of the survey results, the reports and meetings with various companies, we can conclude that the companies are well on the way to adjusting to a changing gas composition.

Around half of the companies are conducting further studies or are unable to implement the necessary modifications in the short term for commercial or (planning) technical reasons.

On this basis, the Projectbureau Nieuw Aardgas recommends that the minister extends the transitional period by one year, to the end of 2013. Projectbureau also recommends carrying out an investigation into which measures can be kept operational even after the transitional period.

1. Introduction

The Dutch energy supply sector is largely dependent on natural gas. A great deal of investment has taken place since the discovery of the large gas reserves in Slochteren (low calorific, G-gas) and other fields both onshore and offshore (high-calorific, H-gas). In the near future, the production capacity of our natural gas resources will reduce. In order to guarantee the supply of gas, it is vital to start importing natural gas (from Russia and Norway, for example) and liquified natural gas (LNG). Since mid June 2011, vaporised LNG has been fed into the GTS network for the purpose of commissioning the Gate terminal on the Maasvlakte. Subsequently, in September 2011, this feed of LNG became a commercial supply.

The Ministry of Economy, Agriculture and Innovation's policy

The ministry of EA&I endeavours to ensure that there is an effective natural gas supply system. This means that supply reliability, a good price and safety for the consumer and employees are prioritised. On this basis, a decision was made to take measures within all elements of the gas chain in order to be able to handle various import streams.

In order to gain an improved insight into the challenges for end users of H-gas, which vary per company, the minister of EA&I set up the Projectbureau Nieuw Aardgas (hereinafter to be referred to as: Projectbureau) in January 2011. The Projectbureau was tasked with investigating the consequences for the individual H-gas users of using changed gas composition in detail. The findings are reported to the H-gas users and the ministry. The Projectbureau is staffed by employees from NL Agency and the national network manager GTS.

The Projectbureau assessed the expected impact of changed composition on the end users of H-gas in the spring of 2011. This showed that a number of measures would have to be taken in order to handle the new composition. On the basis of this assessment, the minister set out the following basic policy principles on 14 June (Lower House, session 2010-2011, 29023, nr. 91):

- A reasonable transitional period is vital for a safe and cost-effective adjustment of processes and equipment.
- During the transitional period, several measures will apply in order to reduce large variations in combustion value (Wobbe Index).

- Clarity regarding gas composition: no comprehensive specifications but a bandwidth of the gas composition expected in North-west Europe.
- All users must eventually adjust to the new gas composition which will vary within the given bandwidth.

Monitoring transition H-gas

The Projectbureau has the task of monitoring the progress of the transition and advising the minister thereupon. Companies can consult the Projectbureau regarding questions about gas composition or the consequences for the gas consuming installations. In February 2012, the Projectbureau sent a survey to all of the companies that are connected to the H-gas network with the aim of charting the progress of the necessary modifications. This report presents the results of this survey.

Several appendices have been added to the report in order to provide more in-depth information on a number of topics that are covered in the report. These appendices are often separate memos that have been published on the Projectbureau website:
www.projectbureaunieuwaardgas.nl

2. High calorific gas: market, users and composition

2.1 The Dutch H-gas market

In The Netherlands, each year, around fifteen billion Nm³ of H-gas is consumed by 56 different companies. These companies have a total of 88 connections to the network of the national network operator GTS. The companies are spread out across the country but there is a significant concentration in the region of Rijnmond. Otherwise, the H-gas end users can be found in IJmond, the region of Delfzijl/Eemshaven, Limburg and Zeeland.

There are also several dozen companies that are provided with H-gas via two regional transport networks. These are managed by Westland and ZEBRA (the latter via a connection in Belgium). Some companies supply the H-gas onto neighbouring companies on the industrial sites where they are located.

2.2 Diversity of H-gas companies

The applications of H-gas among end users can largely be divided into the following types:

- power generation;
- industrial heat applications;
- industrial raw material applications.

Appendix 1 provides a very brief overview of the H-gas network. A division is also made in terms of connections to company activities. These are primarily refineries and chemical companies, electricity power stations, storage and transshipment companies and a few companies from other sectors. The companies vary widely in terms of scope, quantities of gas consumed and the complexity of the installations.

2.3 The expected H-gas composition and implicit variations

In 2010, GTS presented an overview of the properties of classic H-gas in the period 2005-2010 (see appendix 2).

LNG and imported gas

Imported LNG will penetrate the Dutch transport network to a varying extent. This depends on issues such as the output from Gate terminal and actual consumption by end users in the region of Rotterdam.

Since September 2011, the majority of the LNG (95 percent) has been consumed by H-gas users in the region of Rotterdam. As well

as coming from the LNG terminal, the gas in the region of Rotterdam also comes from a number of small fields in the region; these have delivered around 40 percent of the gas supplied over the past few months.

Appendix 3 shows the distribution of LNG in the H-gas network over the period September 2011 to February 2012 in some detail.

In the future, in addition to the imports of LNG, gas from Russia will also be imported via the Nordstream pipeline. Until now, the majority of Russian gas that has been exported to Western-Europe comes from fields that provide more or less pure methane. It is expected that gas from richer fields will also be delivered in the future. GTS has regular contact with Gazprom on this topic. Gazprom has so far been unable to provide definitive insight into expectations regarding the composition of the gas that will be supplied via Nordstream.

The physical penetration of Russian gas in The Netherlands has been very limited so far. In reality, Russian gas rarely reaches the Dutch border. This will, however, occur more frequently in the event of an increase in Russian gas flows to Western Europe.

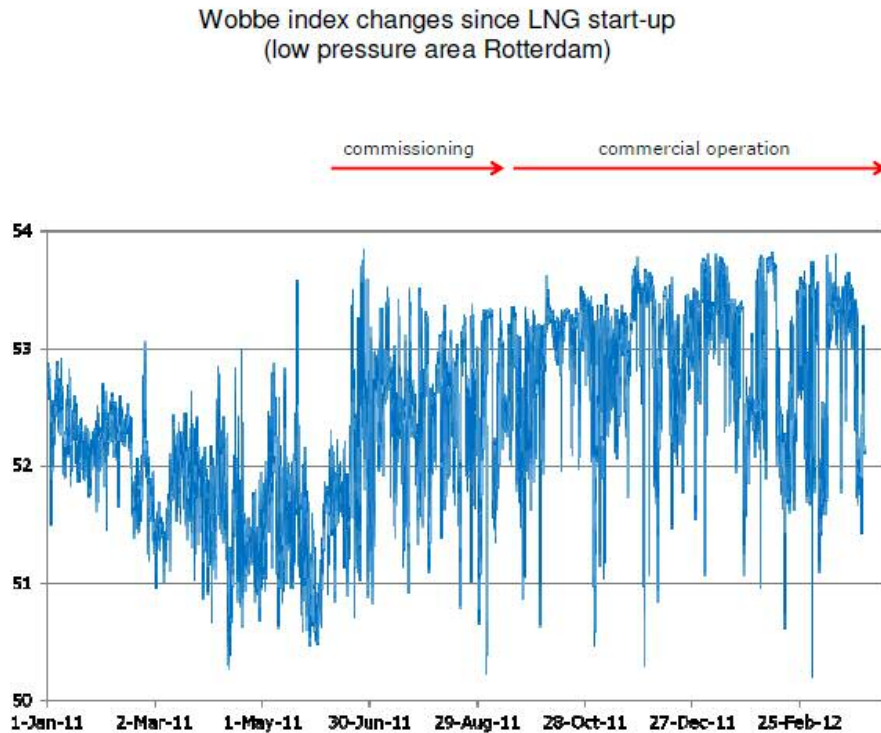
The properties of classic H-gas vary per region and have a diverse bandwidth. It goes without saying, however, that these values all lie within the boundaries set by the Gas Act and the Gas Codes. The most important of these is the Wobbe Index. There are several sources of LNG with compositions that lie outside the current bandwidth of classic H-gas but which do fall within the boundaries set by the Gas Codes. The extent to which these will actually be imported is a market choice.

Composition fluctuations and quality fronts

Depending on the actual production volume of the Gate terminal, LNG will replace the current H-gas in the transport system. On the edges of the penetration area, companies may experience fluctuations in composition such as a quality front between the LNG, imported gas and the classic H-gas. The location of these fronts will depend on too many factors to enable a realistic prediction. Given the, thus far, limited output by the Gate terminal, these quality fronts have undoubtedly occurred already within the Rotterdam area.

Such variations are inherent in the system and have also occurred in the past. If composition fluctuates widely, this type of quality front may have significant consequences for the companies connected to the location concerned.

The diagram below shows that, since the start of the introduction of LNG from 15 June 2011, the variations in the Wobbe Index have increased in intensity and frequency but have remained within acceptable limits.

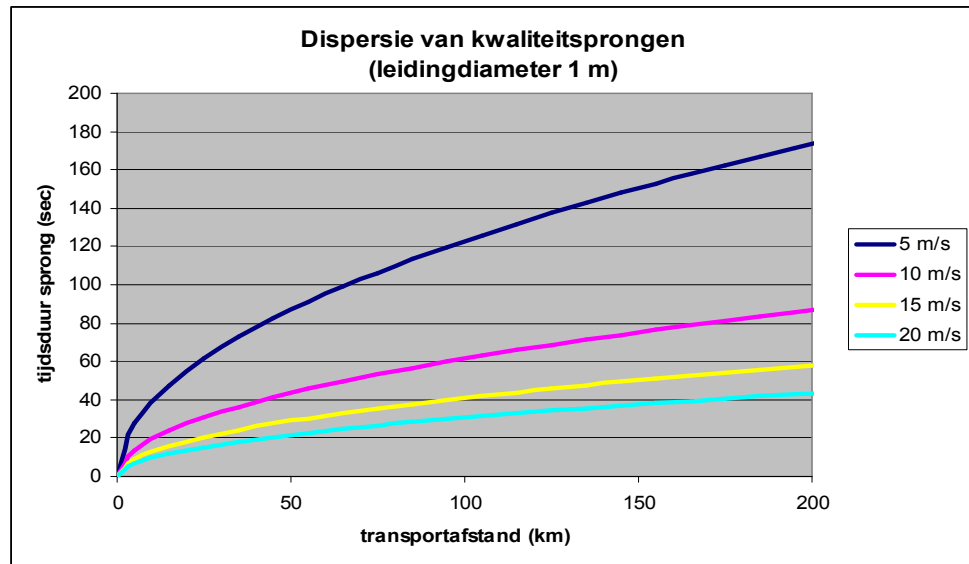


If there is a momentary step-change in the composition of the gas, e.g. due to a switch from classic H-gas to LNG from the terminal, this will affect consumers situated near to the source in a very short time. This step-change will be tempered further downstream in the gas network by various flow phenomena that occur underway. Depending on the gas speed, a momentary step-change could be spread out to over a minute at a distance of one hundred kilometres.

The migration through the system of these abrupt compositional changes for end users can be caused by variations on the supply side but also on the demand side. This leads to a dynamic in the gas composition on which a network manager can have little or no influence. The compositional variations will also be tempered by dispersion in the transport pipeline. On the basis of a dispersion calculation for a range of gas speeds in a specific route, an estimation can be made of the extent to which

variations in gas composition can be spread out during transport. This is indicated in the diagram below.

Dispersion of quality step-changes (pipeline diameter 1m)



Duration of step-change (sec)
Transport distance (km)

Under normal circumstances, speeds of over 10 m/s will not occur. This model calculation has been checked in practice on a number of occasions. These tests have shown that actual dispersion is usually higher than the model predicts by a factor of 2 to 4. This is probably due to the fact that the model assumes a straight, smooth pipeline in which bends, branches, manifolds, diameter changes, etc. are not taken into consideration. Appendix 4 goes into this topic in more detail.

2.4 The effect of H-gas on the emissions of NOx and CO₂

As a result of a request by a number of parties, the Projectbureau investigated the consequences of new natural gas on emissions of NOx and CO₂. This showed that the increase of NOx emissions as a consequence of the higher Wobbe Index (due to LNG or high calorific gas) amounted to just 0.2 percent of current national NOx emissions of around 260.000 tons. If half of the high-calorific gas is replaced by LNG, CO₂ emissions shall reduce by about 0.5 percent. This corresponds with around 0.13 Mton CO₂ (0.5%*56.8*460). Such a reduction is practically negligible. This falls within the margin of error for determining the national emission.

It is also very difficult to establish this at installation level as a result of the relatively significant uncertainty of the measurement. The effect of the increase in NOx emissions could, however, lead to exceedance of the emission requirements at individual installations.

Applying a greater measurement uncertainty would prevent individual emission requirements being exceeded. A prerequisite would be that the measured emission concentration is lower than the emission requirement plus the total measurement uncertainty. Appendix 5 looks at the expected impact of new natural gas on the emissions of CO₂ and NO_x in more detail.

3. Projectbureau Activities: reporting and the dissemination of information

In June 2011, companies that use H-gas were asked to report disruptions within processes that may be a consequence of a changing gas composition to the Projectbureau.

In October 2011, the Projectbureau held their first monitoring round, primarily covering the commissioning period between June and August 2011. In February 2012, a survey was sent to all H-gas users in order to monitor experiences with H-gas and the status of transition.

It is not possible to describe every notification in detail in this report due to the commercially sensitive information involved. Variations in gas composition have been a phenomenon in the H-gas network, which is supplied from a range of sources, for many years. In future, the import of LNG and other gas imports will increase occurrences of variations and these will occur across a broader spectrum. This is already evident.

Commissioning period (June – August 2011)

A few companies experienced disruptions during the commissioning period of the Gate terminal and the GTS mixing station and reported these to the Projectbureau. These disruptions involved a number of significant fluctuations in gas quality. The companies which encountered these issues were primarily producers of industrial gases. The corresponding variations in the Wobbe Index also negatively impacted the operations of several gas turbines. These disruptions were due to the commissioning of the GTS mixing station in the Botlek area.

Commercial operation LNG feed-in (after August 2011)

Since 1 September 2011, three disruptions have been reported. These involved companies suspecting that an unexpected situation in processes had been caused by a variation in the composition of natural gas. Analyses, however, indicated that the gas composition supplied to the relevant companies had been stable at the time.

Since then, no new reports have been submitted to the Projectbureau. Many H-gas users also expected a more stable gas supply after the commissioning period of the Gate terminal and the testing phase of the GTS mixing station. This has, indeed, been the case. The limited variation in the composition of the supplied cargos and the effective tank management by Gate LNG Terminal may have contributed towards this.

The companies seem to principally struggle with rapid variations in gas composition; the variation in LNG quality has not caused quick variations so far.

This underscores the importance of good tank management ('mixing' the various LNG loads) by Gate LNG Terminal that focuses on cancelling out rapid compositional fluctuations.

Information day for companies affiliated to ZEBRA (November 2011)

At the end of November 2011, the Projectbureau organised an information day for companies in South West Netherlands that are connected to the ZEBRA network. For some time, this network has regularly received gas from The Netherlands via the Fluxys network in Belgium and has been fed with LNG from the terminal in Zeebrugge for a while. The companies that are connected to ZEBRA were keen to attend this information day by the Projectbureau. Companies find it extremely difficult to obtain satisfactory responses to specific questions regarding gas composition and the fluctuations therein. The Projectbureau has endeavoured to work with ZEBRA, Fluxys and GTS to provide adequate information to companies located in The Netherlands.

Website Projectbureau New Natural Gas

On the Projectbureau website: www.projectbureaunieuw aardgas.nl new developments relating to gas composition are regularly published. Alongside information about the policy of the Dutch government, a range of relevant publications is also available. An example of one of these is the memo in appendix 8 regarding the set-up of burners using H-gas.

4. Transition H-gas: the Mix of Measures

The minister of EA&I has made a number of agreements with Gate LNG Terminal and GTS (the so-called mix of measures) enabling a transition phase to be created in order to accommodate the new gases and give companies sufficient time to modify their operations in a safe and economically viable manner to receive other natural gas. This transitional period began in September 2011 and runs until the end of 2012. Each year the minister will decide whether to extend the transitional period by one year, ultimately to the end of 2014. The Projectbureau is tasked with making a recommendation to the minister in this regard.

The 'mix of measures' comprises the following elements:

1. National network manager GTS has set up a signalling system for consumers: customers are provided with data about the expected composition of the natural gas and can then extrapolate the relevant characteristics.
2. During the transitional period, the Wobbe index is maximised to 54.0 MJ/Nm³. GTS will also maintain this maximum thereafter by diluting the H-gas with nitrogen gas. (NB: unrelated to the feed-in of LNG, the Wobbe index will be maximised to 55.7 MJ/Nm³ as from 1 October 2014.)
3. For the duration of the transitional period, Gate LNG Terminal will limit the propane equivalent (PE) to a maximum of 8.7. After the transitional period, there will be no further limitation.
4. Gate LNG Terminal will do its best, through the use of 'tank management', to prevent rapid variations in composition occurring in the supplied gas.
5. During the transitional period, companies that are connected to H-gas will modify their processes to the varying gas composition that can be expected in future.

If certain measures function effectively, an investigation may take place into whether they can be maintained after the transitional period.

This chapter presents experiences in relation to the mix of measures. An overview of the measures taken by end users, such as those that were reported in the survey, is also provided.

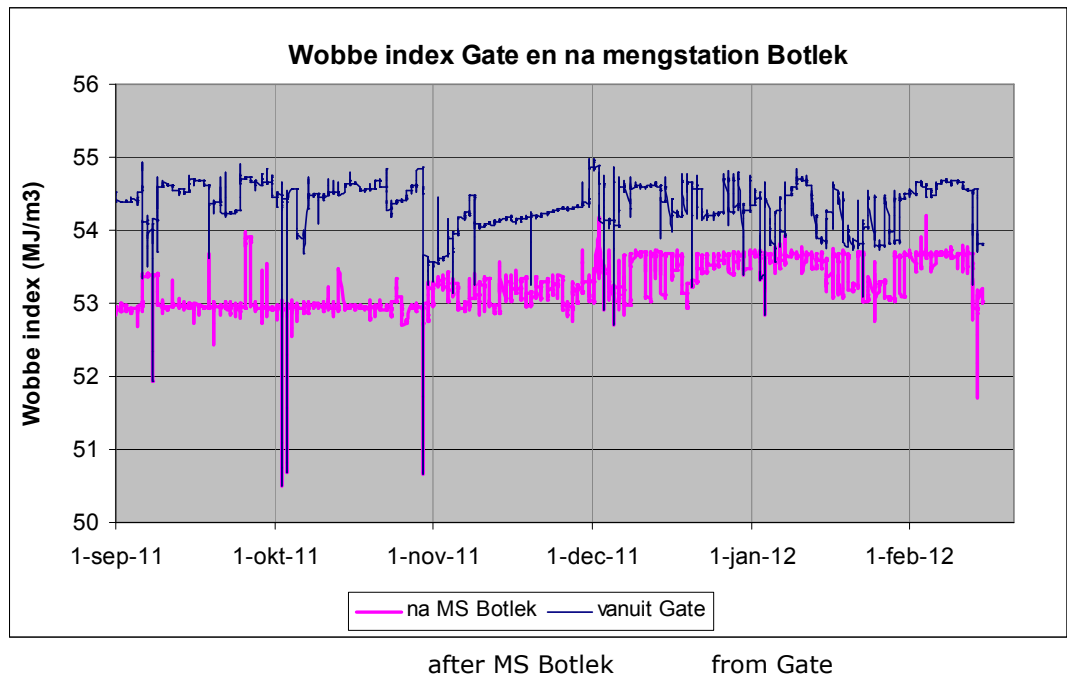
4.1 GTS: mix of measures and experiences

The maximum Wobbe Index

GTS ensures that the LNG is mixed with sufficient nitrogen in order to maximise the Wobbe Index at 54.0 MJ/Nm³. As of October 2014, this limit will shift to 55.7 MJ/Nm³. For the incoming LNG flows, this mixing will be carried out at the new mixing station in the Botlek area.

The diagram below illustrates the course of the Wobbe Index before (upper blue line) and after (lower purple line) the mixing station.

Wobbe index Gate and after Botlek mixing station



This shows that the Wobbe Index after the Botlek mixing station has remained under 54 almost permanently. At two moments (10 December 2011 and 4 February 2012) and for a total of five hours, there were small excursions up to 54.4 MJ/m³. These excursions have not reached the end users because of a mixing with other natural gas after leaving the Botlek mixing station. The highest measured value at end users is 53.8 MJ/m³.

The signalling system

The data for the quality signalling system comes from the many gas chromatographs that GTS has installed in the network for the purpose of accountable measurements. This data is updated every quarter of an hour.

The signalling system comprises a public section and another section that is only accessible for each specific customer, i.e. the 'customised' section.

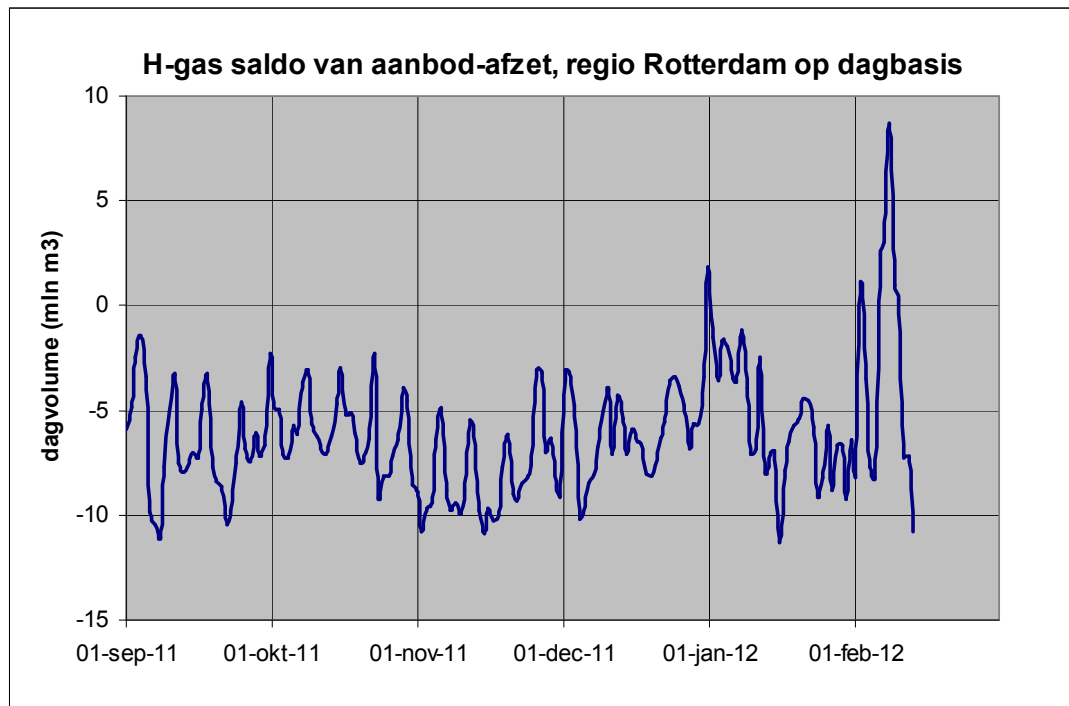
Since 1 October 2011, the public section has provided H-gas maps for The Netherlands which show the Wobbe Index, methane figures and PE values per region. On 12 January 2012, a map of calorific values was also added. These maps are updated each quarter of an hour on the basis of measured compositions and flow directions in the network.

Since 11 July 2011, the 'customised' section has been available for each specific customer as a GTS web service. Every H-gas user can download the values per quarter of an hour of the gas composition from the upstream gas chromatographs relevant to him. Since 1 October 2011, information has been added about the arrival times of this gas composition at the specific end user locations. GTS has provided a full technical and functional definition of this service on its website. This can be found via:

<http://www.gastransportservices.nl/en/balancing/documents/connectedparty>. GTS contact persons (account managers) are also available for further support with setting up the service.

The distribution of the LNG gas coming from the Gate terminal
The volume of LNG from the Gate terminal was limited between September 2011 and February 2012. It was exceptional to have a feed-in level of over 20 percent of capacity.

H-gas balance from supply-consumption, Rotterdam region on daily basis



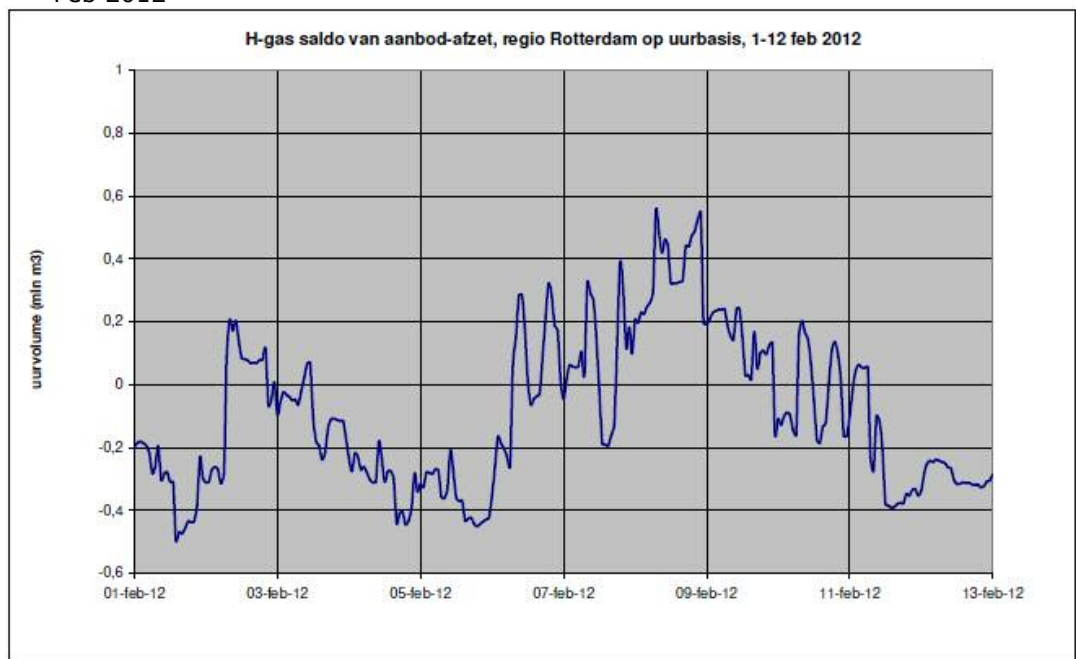
Daily volume

As a result, the distribution of LNG in the gas network was also limited. The diagram above shows the H-gas balance (supply minus consumption) on a daily basis for the Rotterdam region as continuously negative, with the exception of the end of December 2011 and the beginning of February 2012. This means that companies outside the Rotterdam region only have received LNG occasionally.

The balance of the total supply (LNG + small fields) and the market demand, however, was not constant over the day.

The diagram below illustrates the variation in the balance over several days on an hourly basis in the Rotterdam region. It shows that on 7 February 2012 a flow of gas left the region, on average, over the whole day, while there were also a few hours on this day during which classic H-gas was required in order to serve the needs of the region.

H-gas balance from supply-consumption, Rotterdam region on hourly basis, 1-12 Feb 2012



Hourly volume

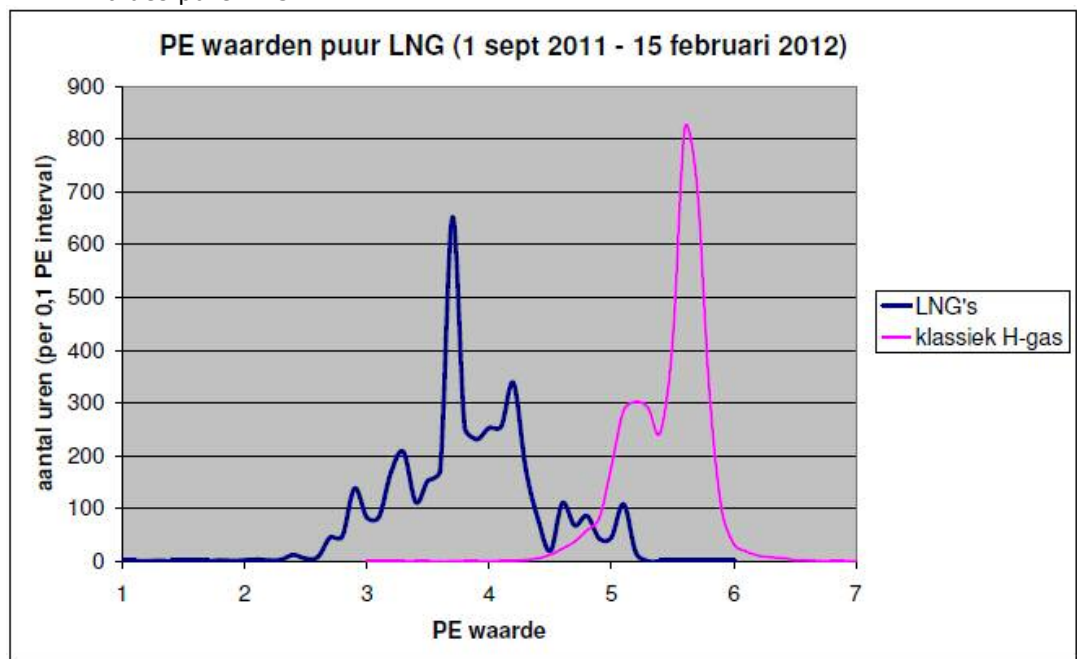
This also means that quality fronts and zero flow points will have occurred continuously somewhere in the Rotterdam region. There have only been a few reports of this. This could possibly be explained by the limited differences between classic H-gas and the shiploads of LNG that were fed-in.

4.2 Gate terminal mix of measures and experiences

The maximum propane equivalent

The diagram below indicates the PE value for the fed-in LNG alongside the PE value of the classic H-gas in the period 2005-2010 in Rotterdam. The LNG supplied thus far has a lower PE value than the classic H-gas in the Rotterdam region.

PE values pure LNG



number of hours (per 0.1 PE interval)
PE value

LNGs
classic H-gas

Tank management

For the purposes of the testing period in the summer, the first cargo of LNG with a favourable composition was unloaded at the Gate terminal as foreseen on 13 June 2011. This was a type of LNG with a Wobbe index of around 54 and a low PE value, below 2 (PE of 1.4). This LNG was fed into the network from 18 June 2011.

The Gate terminal received eleven shiploads between June 2011 and April 2012, three of which were for commissioning and eight were received during commercial operation. The table below indicates the source of the commercial shiploads up to the beginning of March 2012.

Unloaded on	Name of the ship	LNG from
01 09 2011	Bu Samra	Qatar
05 09 2011	LNG Sokoto	Nigeria
02 10 2011	Arctic Princess	Norway
23 10 2011	Murad Didouche	Algeria
02 12 2011	British Trader	Trinidad and Tobago
01 01 2012	Gemmata	Norway
12 01 2012	LNG Jupiter	Trinidad and Tobago
02 03 2012	Arctic Voyager	Norway

The Wobbe Index of the H-gas has so far averaged at around 54.5 MJ/m³ (lower limit is 53.4 MJ/m³; upper limit is 54.8 MJ/m³). This was reasonably constant for a long period. Every day, the expected compositions (Wobbe Index, combustion value and PE) are publicised via the GTS website. The development of these values is indicated in the diagram on the previous page. This concerns values from the Gate terminal, i.e. before the GTS mixing station.

4.3 H-gas end users: Measures and experiences

In February 2012, a second survey was conducted among end users of H-gas with the aim of gaining an insight into the number of companies that experience operational inconvenience as a result of changes in H-gas. The survey also looked into the progress of modifications and updates being made to installations in order to facilitate the use of new natural gas. Questions were also asked about experiences with the signalling system and the need for further information and/or meetings with the Projectbureau. Appendix 6 provides an example of the survey form.

Of the 56 companies that were approached, 54 responded; this is a response rate of over 95 percent. A summary of the responses is provided in appendix 7.

Irregularities in gas supply

The majority of the companies (41) experienced no irregularities. The companies that did experience disruptions were largely able to accommodate this within existing process control and by extra vigilance by the operators.

It appeared that producers of industrial gases had to slightly reduce production rate in the installations in response to the variations that have been evident so far in order to continue to produce safely. Several gas turbines owned by electricity producers

suffered from capacity reduction at certain moments but, thereafter, these turbines could be fully deployed once again. Higher NOx emissions were reported for some gas turbines.

Measures that companies have taken or are still to take

Fourteen of the 54 companies have now modified some process settings and are ready for changing natural gas compositions. These measures sometimes come at the expense of efficiency and production capacity. Several of these companies have also installed extra controls in order to keep combustion efficiency sustained.

Six companies have worked out and planned additional measures for the near future. This involves the installation of extra devices or control systems. Forty-eight companies have no further measures planned; 23 of these do not expect that these will be necessary. Thirty-one companies expect to be ready with their modifications by the end of 2012. This means that 23 companies will not have finished implementing the modifications that may be necessary by the end of 2012.

Fifteen companies cannot yet design their modifications; for eight of these, this is related to having insufficient guarantees on the specifications of the natural gas. In addition, there are still eight companies who will probably have to implement modifications but have to wait on a turnaround that will only take place after 2012. The implementation of measures by several of these companies has also been postponed for economical reasons.

Use of the GTS signalling system

The GTS signalling system serves a need. It is regarded by 25 companies as an important facility and they want to use it or continue to do so. Sixteen companies have a technical or other issue that prevents them from using it for the moment. Eighteen companies indicate that they will not use it. Eleven companies did not respond to this question.

Information from GTS, however, shows a different user picture. At the beginning of 2012, four end users were actively obtaining up-to-date gas compositions from the 'customised system'. Three of these also indicated this in the survey. The public element, the freely accessible GTS website with the 'quality radar', has had a maximum of two users per day, measured over the peak period at the beginning of February 2012.

One can thus conclude from the survey that end users regard the signalling system as an important measure within the package but that they are not yet making full use of this facility.

Need for further information

Sixteen companies indicated a need for additional information. Six companies have specifically asked for stricter information about the bandwidth of the gas composition. Thirty-eight companies do not require further information.

Need for supplementary meetings with Projectbureau

Forty-two companies indicated that they needed no additional meetings with the Projectbureau. Twelve companies would like additional meetings and, for around one third of these, the meeting should cover specific topics.

Company concerns

Several companies have expressed concerns via the survey. This involved the following issues:

- Modifications to a number of installations must be outsourced to suppliers which have to provide guarantees regarding operational reliability. The suppliers will only do so on the basis of concrete specification limits. On the basis of the, so far, communicated expectations about the composition of the LNG, the companies have not been able to provide these suppliers with sufficient robustness to obtain these guarantees. This topic has also been raised via other channels.
- Several companies have connection problems with the GTS signalling system. Assistance provided by GTS may resolve these issues. For more complex installations, it is preferred to include a signal in process control systems. The current message via the GTS website is unuseable for this purpose.
- At several locations, the signalling gas chromatograph is located so close to the site itself that the gas arrives before it is possible to respond to the signal.
- Several companies still have little insight into the necessary modifications to comfort heating systems.

5. Conclusions

The number of reports of disruptions due to variations in the gas composition is lower than expected. An obvious explanation is that the volume of LNG imports has been limited and this had led to little or no LNG ending up at H-gas companies outside the Rotterdam region. It is hard to establish whether the number of disruptions is higher than before as this type of registration was not in place before the Gate terminal came online.

The composition of the imported LNG also closely resembled the historically familiar composition of H-gas. Shiploads with more extreme gas compositions have not been unloaded.

Zero flow points have occurred constantly in the Rotterdam region. A less constant quality of natural gas has also been experienced; this could have been caused by variations in composition but it has not led to significant problems.

There were two disruptions during the commissioning period that were due to specific testing activities related to the Botlek mixing station. After that, two reports were submitted of incidents at companies that were ascribed to gas composition. Further analysis, however, demonstrated that the gas composition had no dominant role as the companies were receiving conventional H-gas at the time of the issue rather than LNG. The composition thereof varied within the usual bandwidth and the deviant phenomena could therefore not be ascribed to changes in composition as a result of LNG.

Rapid, large fluctuations in the composition of the natural gas supply may cause problems for various companies and applications. The existing process control is not equipped to cope with it and is not always easy to modify.

So far, experiences with rapid changes in the composition of natural gas as a result of LNG feed-in is limited:

- The composition of imported shiploads of LNG has varied little and deviates only slightly from usual H-gas.
- The quantity of LNG has been limited and the penetration area has been mainly restricted to the Rotterdam region.
Nevertheless, around fifty H-gas connections have had to deal with an LNG intake.

Natural gas as raw material

The different composition of natural gas (a lower methane content) has led to a small capacity reduction among producers of industrial gases. The rapid changes in the composition of natural gas cause

safety risks that must be accommodated by operating more cautiously. This, however, leads to reductions in capacity and lower production efficiency. Operators must also be particularly vigilant. In the long term, this could be resolved as a result of modifications to process controls.

Several companies are apprehensive about future, possibly higher levels of sulphur in the natural gas. This will not be an issue with LNG but there is uncertainty as to whether it may be an issue with other gas imports.

Natural gas for gas turbines

A high level of heavier hydrocarbons, expressed in the PE number, means a different combustion characteristic. Existing controls for gas turbines cannot always handle these, and, often, the ability to reduce NO_x diminishes simultaneously (modern machines). Suppliers are cautious about extending and providing guarantees now that there will be changes in the composition of natural gas and are providing limited cooperation in terms of finding solutions for their customers. They can and will only provide new guarantees for equipment on the basis of guaranteed gas specifications.

Natural gas in burner systems

Burners can be adjusted to handle imported gases. Problems related to the efficiency of the heating systems can, in principle, be tackled via the installation of a modern oxygen trim regulator. Process furnaces with multiple burners are, however, not easily fitted out and controlled in this way.

For comfort heating systems, fulfilment of the installation requirements that are currently applied in other countries are sufficient for the use of LNG. Older installations that no longer fulfil these requirements must be modified. Several companies are still developing these solutions.

Safety

There have been no incidents that have led to unsafe situations. The companies' systems seem capable of preventing such safety incidents. Extra vigilance by operators has, however, been vital in order to prevent incidents.

Economy

There is an impact on the economic performance of companies. Suppliers of industrial gases have seen production capacity reduce somewhat and have struggled to guarantee the specification of their product. In a number of cases, electricity producers have noticed reductions in their electricity generation capacity as a result

of abrupt variations in gas composition. This production loss has been absorbed by other installations.

Recommendation regarding transitional period

On the basis of the survey results, reports and meetings with various companies, we can conclude that the companies are well on the way to adjusting to a changing gas composition.

Several companies are ready, some companies are working on modifications and around half are still working on additional studies or will not be implementing the necessary modifications for the moment for commercial or technical reasons.

On this basis, the Projectbureau Nieuw Aardgas recommends that the minister extends the transitional period by one year to the end of 2013.

Other recommendations

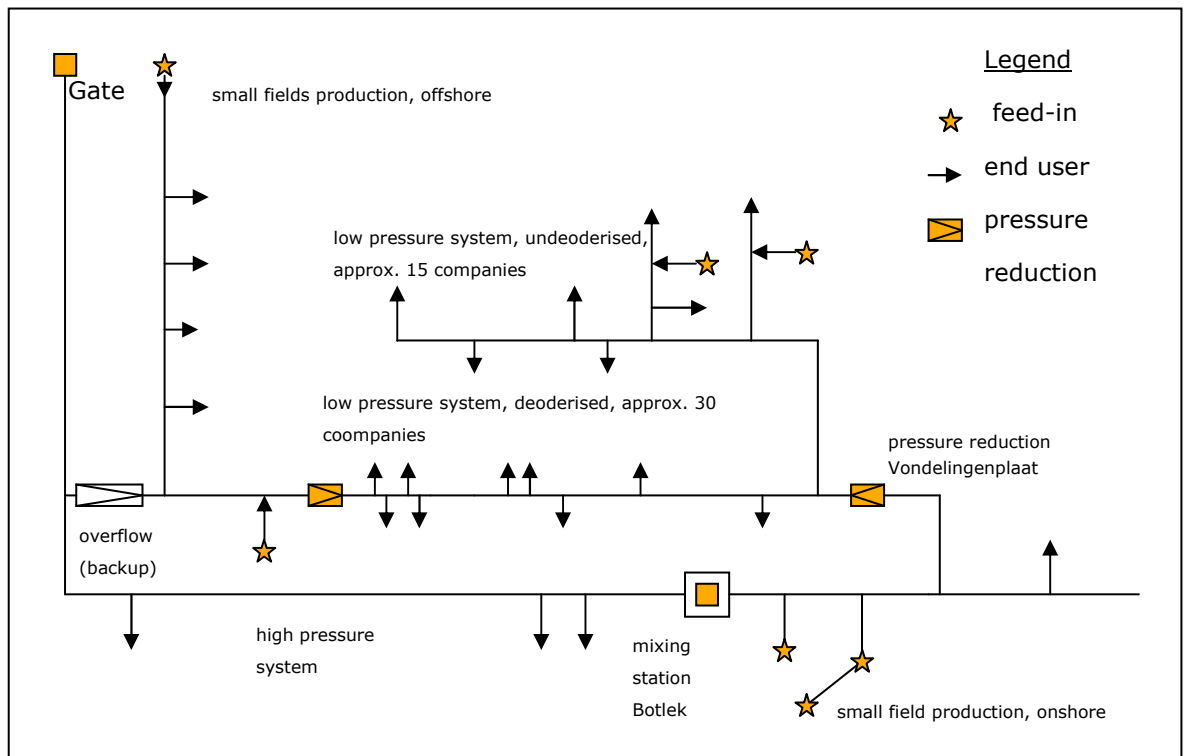
The analyses of and responses from the companies clearly show that the transitional measures fulfil a useful role and serve a definite need. On this basis, the Projectbureau recommends a study into whether certain measures should stay operational after the transitional period.

Appendix 1: Summary of Dutch H-gas market, connections and applications

The H-gas network

The group of H-gas consumers comprises 58 users with a total of 88 connections to the network of network manager GTS. A number of companies also function as private network managers. This means that they supply gas to other companies on the industrial zone. The role of network manager also encompasses the obligation to inform connected companies about any upcoming changes. This involves around ten H-gas locations.

Furthermore, a dozen or so Dutch locations are connected to the ZEBRA pipeline. This is an H-gas pipeline that runs from Zelzate via Bergen op Zoom to Moerdijk and is managed by a Delta/Enexis cooperation. Alongside gas from Belgium, these connections could also receive LNG from The Netherlands, via Belgium, that flows into this pipeline from the border. The relevant network companies have been updated by GTS regarding the changes as a result of issues such as the introduction of LNG in The Netherlands.



The above diagram shows the complex configuration of the H-gas infrastructure in the Rotterdam region.

Characteristics of H-gas companies

Annual consumption by the group of end users is around fifteen billion Nm³. The table below ranks the group connections according to activity to provide an overview of user-diversity.

Company category	Connections
Electric power station	22
Chemical	28
Storage and transshipment	13
Utilities	8
Refineries	5
Metal industry	3
Other	9

The term 'Utilities' is used for the situation where energy and other supplies are specifically delivered to a group of companies in the vicinity of the connected company. This group is comparable with the electric power stations but is smaller and has a range of processes. Over the course of time, many companies have been split up and sold. As a result, there are often numerous companies at one location and the supplies, such as electricity, steam and water, are provided by one of these. The companies vary widely in terms of scope, quantities of natural gas consumed and complexity.

The various applications of H-gas

The end users can largely be divided into the following types:

- Electricity generation. These are companies with large-scale gas-fired electric power stations. Alongside the role of end user, these parties are often also involved in the trade of gas and also import gas, including LNG, via the Gate terminal.
- Industrial fuel applications. This involves a group of companies that vary widely in both scale and application. Gas is used in boilers, burner, comfort systems, furnaces, etc.
- Industrial raw material applications. A limited number of companies uses gas as a raw material for producing industrial gases and ammonia (for fertiliser production), among other things.

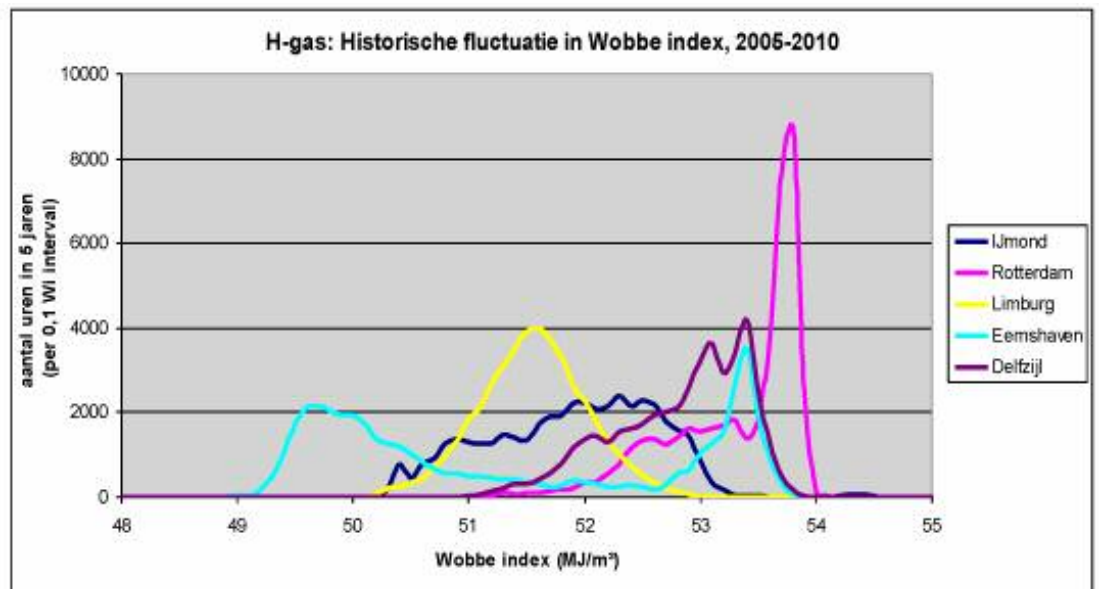
Appendix 2: Current gas composition per region and expected LNG composition

Wobbe Index and Propane equivalent

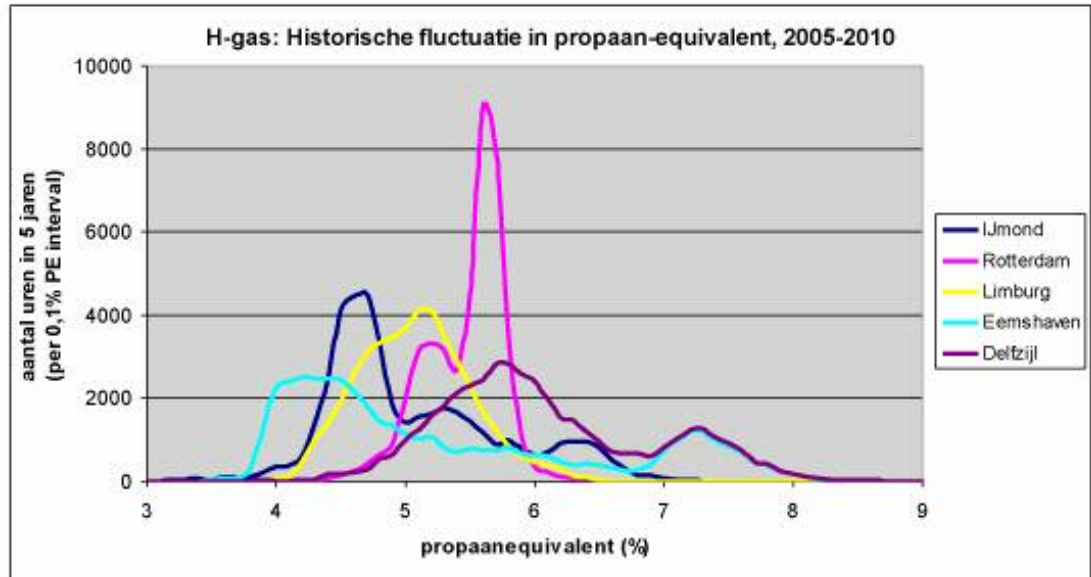
In 2010, GTS published an overview of the properties of H-gas in the period 2005-2010.

There was a spread in the Wobbe Index (WI) per region. The variations herein were generally within 3 MJ/m³ (circa 6%) with the exception of one region with a 5 MJ/m³ bandwidth. The values of the propane equivalent (PE) varied between 4 and 8 percent.

H-gas: Historical fluctuation in Wobbe index, 2005-2010
number of hours in 6 years



H-gas: Historical fluctuation in propane-equivalent, 2005-2010



number of hours in 5 years

propane equivalent (%)

In terms of the expected properties of H-gas, GTS has drawn up a summary of the types of LNG that could be imported into The Netherlands on the basis of the imports in West-Europe over the past few years (source: GIIGNL report 2009).

Composition of known LNGs Wobbe'd to H-gas with a maximum Wobbe index of 54MJ/m³

Samenstelling bekende LNG's afgewobd tot H-gas met een maximum Wobbe index van 54 MJ/m³

	CH4 %-V	C2H6 %-V	C3H8 %-V	C4H10 %-V	C5H12 %-V	N2 %-V	CO2 %-V	methaan getal	Ws MJ/mn3	Hs MJ/mn3	rd -	propaan equivalent (%)
Arzew	85,6	9,2	2,0	0,5	0,0	2,8	0,0	72,2	54	43,11	0,637	7,3
Bethioua 1	86,3	8,3	2,1	0,7	0,0	2,7	0,0	72,0	54	43,09	0,637	7,2
Bethioua 2	90,1	7,6	0,8	0,0	0,0	1,4	0,0	79,7	54	42,03	0,606	4,6
Skikda	91,2	6,9	0,6	0,1	0,0	1,2	0,0	80,8	54	41,85	0,601	4,2
Damietta	97,7	1,8	0,2	0,2	0,0	0,1	0,0	91,5	53,87	40,63	0,569	1,4
Ikdu	95,3	3,1	0,8	0,3	0,0	0,6	0,0	84,5	54	41,28	0,584	2,8
Eq. Guinea	92,8	6,4	0,0	0,0	0,0	0,8	0,0	84,4	54	41,47	0,590	3,2
Lybia	78,2	12,9	3,6	0,7	0,0	4,7	0,0	65,1	54	44,58	0,682	11,0
Nigeria	89,1	4,5	2,5	1,4	0,0	2,5	0,0	70,7	54	42,93	0,632	6,8
Norway	91,8	5,3	1,2	0,4	0,0	1,3	0,0	79,1	54	41,96	0,604	4,4
Abu Dhabi	82,3	12,8	1,6	0,1	0,0	3,2	0,0	71,6	54	43,45	0,647	8,1
Oman	85,1	7,1	2,8	1,6	0,0	3,4	0,0	67,2	54	43,67	0,654	8,7
Qatar	88,2	6,1	2,3	1,0	0,0	2,5	0,0	71,9	54	42,89	0,631	6,8
Trinidad	96,8	2,7	0,3	0,1	0,0	0,1	0,0	89,9	54	40,88	0,573	1,8
Alaska	99,7	0,1	0,0	0,0	0,0	0,2	0,0	>95	53,34	39,78	0,556	0,1
Australia	84,6	8,0	3,3	0,8	0,0	3,3	0,0	68,8	54	43,59	0,652	8,5
Brunei	88,1	4,9	2,8	1,5	0,0	2,8	0,0	69,3	54	43,17	0,639	7,4
Arun	88,7	6,1	2,0	1,0	0,0	2,3	0,0	72,6	54	42,78	0,628	6,5
Badak	89,1	5,4	2,3	0,9	0,0	2,3	0,0	72,8	54	42,74	0,626	6,4
Malaysia	88,0	5,2	3,0	1,1	0,0	2,7	0,0	70,5	54	43,09	0,637	7,2

The last six locations have only shipped to West-Europe in exceptional circumstances.

The actual composition:

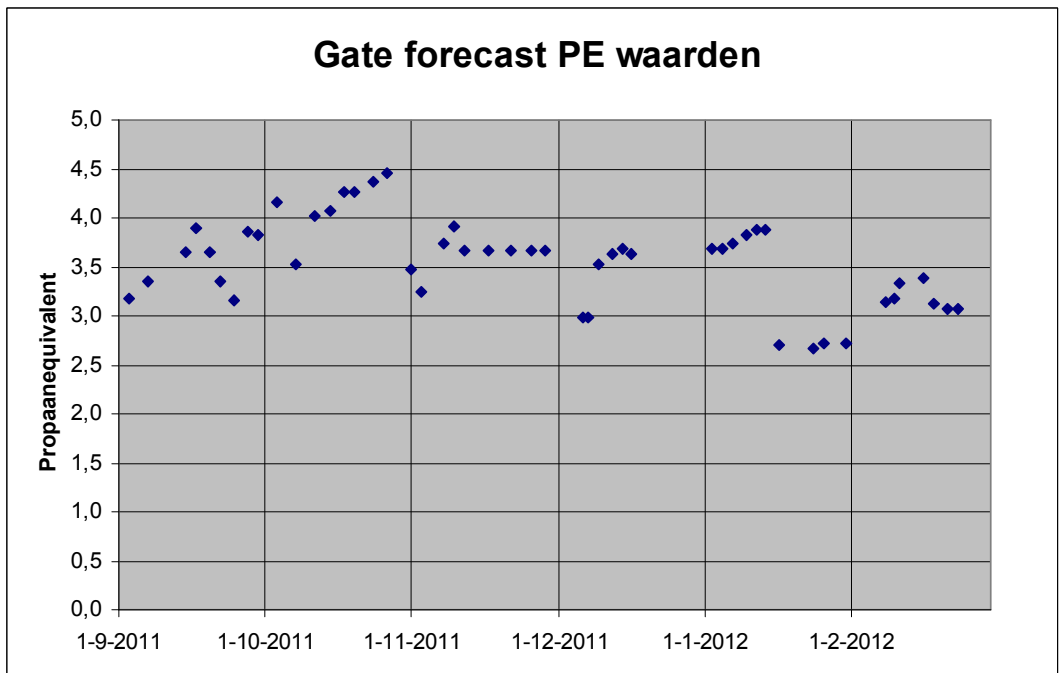
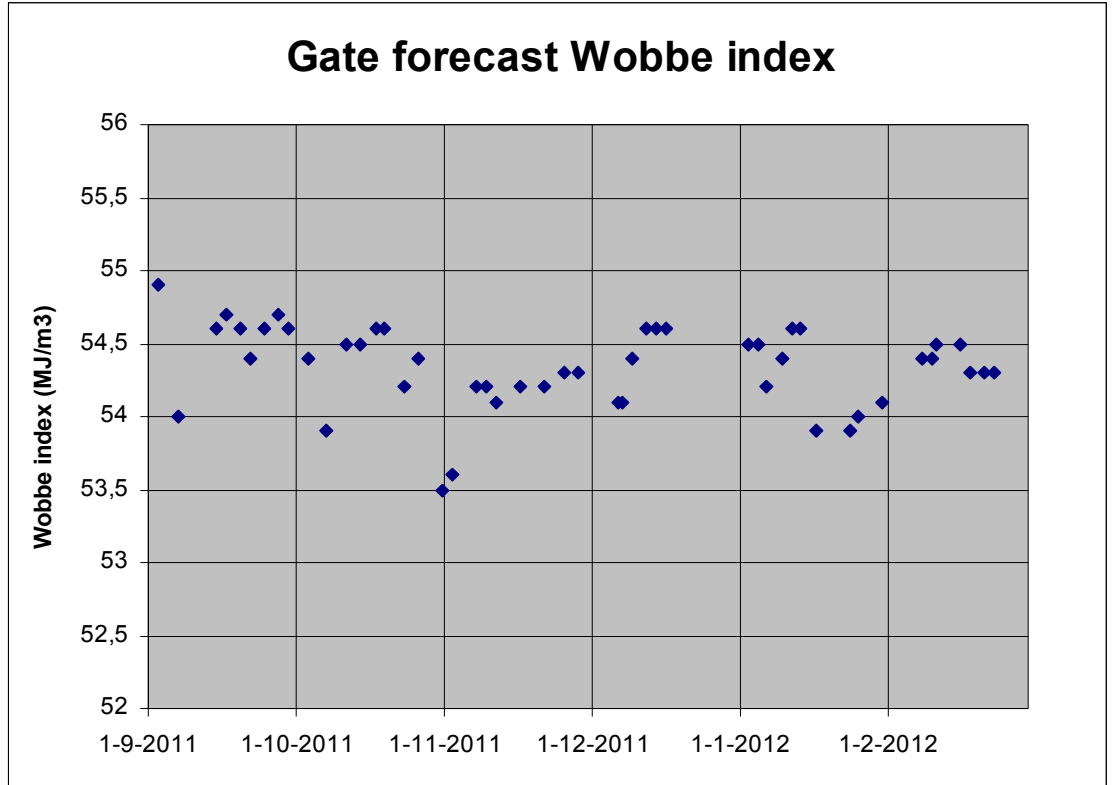
The Gate terminal received eleven shiploads between June 2011 and April 2012, three of which were for commissioning and eight of which were received during commercial operation. The table below indicates the source of the commercial shiploads up to the beginning of March 2012.

Unloaded on	Name of the ship	LNG from
01 09 2011	Bu Samra	Qatar
05 09 2011	LNG Sokoto	Nigeria
02 10 2011	Arctic Princess	Norway
23 10 2011	Murad Didouche	Algeria
02 12 2011	British Trader	Trinidad and Tobago
01 01 2012	Gemmata	Norway
12 01 2012	LNG Jupiter	Trinidad and Tobago
02 03 2012	Arctic Voyager	Norway

One can thus conclude that, during the six month period, gas types with a substantial variation in terms of specification were imported. After reducing the Wobbe Index to a maximum 54 MJ/Nm³ and, on the basis of the information on the origin, the variation in Propane equivalent should be between 1.8 and 7.2 percent and the methane level between 96.8 and 85.6 percent; this corresponds to a methane number (AVL) between 94 and 76.

Not every delivery from a location will be exactly the same; Gate LNG Terminal has also limited variations via tank management.

Every day, the expected compositions (Wobbe Index, combustion value and PE) is publicised via the GTS website. The course of these values is indicated in the diagram below. This concerns values from the Gate terminal, i.e. before the GTS mixing station.



Propane equivalent

The diagrams show that the variations have been limited; the PE values actually lay between 2.6 and 4.5 percent.

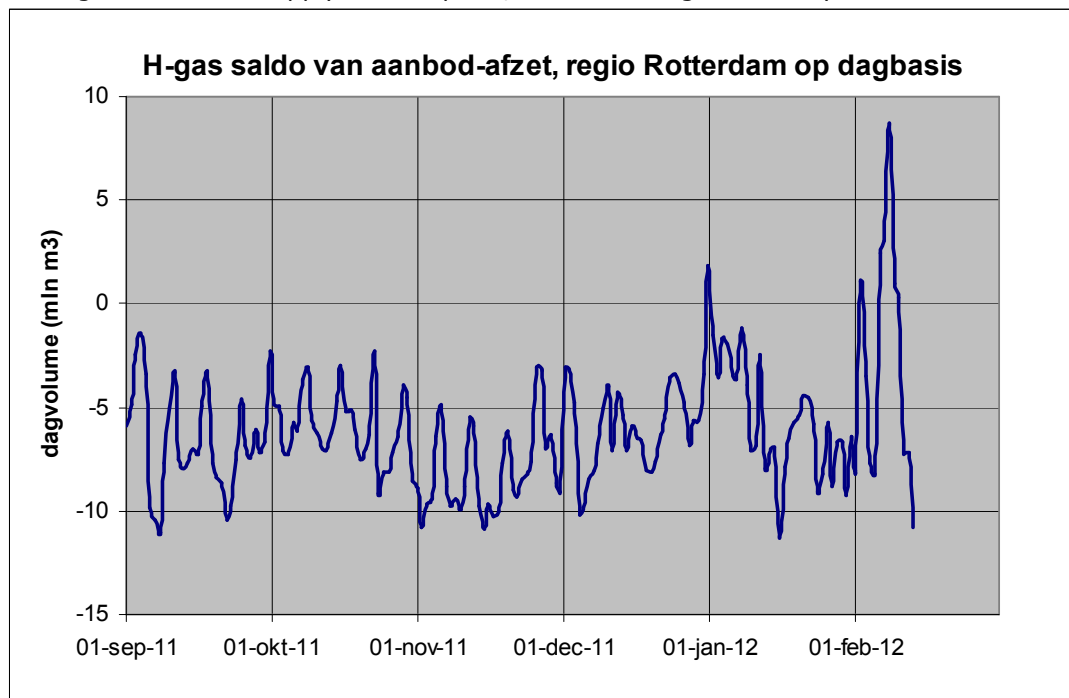
Appendix 3: LNG penetration in the H-gas network

An investigation has been conducted onto the extent to which LNG produced by Gate was distributed via the GTS transport network from September 2011 into The Netherlands.

It would seem that the majority (>95 percent) was supplied to H-gas users in the region of Rotterdam. The gas provision in the Rotterdam region comes from a number of small fields as well as the LNG terminal. This involves both onshore and offshore production that, in the period concerned, accounted for about 40 percent of the total regional supply.

The diagram below indicates the balance of the H-gas supply and consumption in the Rotterdam region. If this is negative, this means that gas has been supplied, on a daily basis, from the remainder of the transport network.

H-gas balance of supply-consumption, Rotterdam region on daily basis



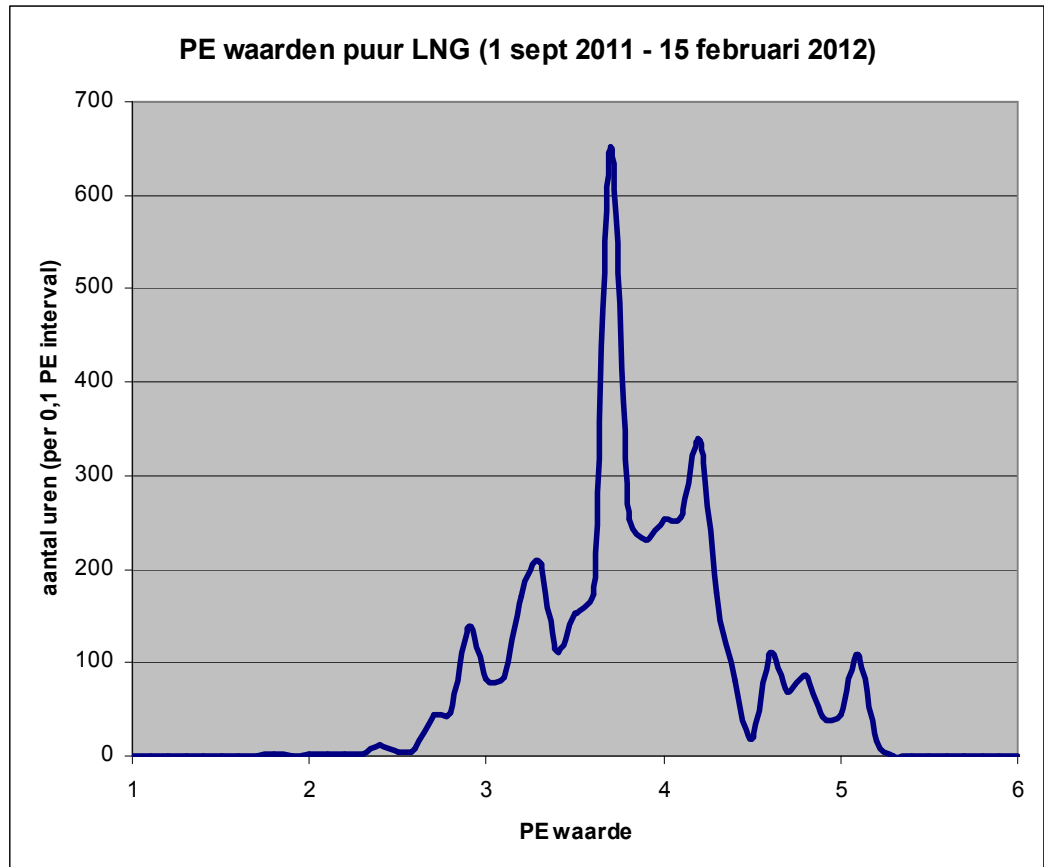
daily volume (mln m3)

It is, however, possible that the momentary net production is positive for several hours even though it is negative on a daily basis in relation to a daily production. In the period reviewed, supplies were taken from the Rotterdam region for just 170 hours on balance. Two thirds of these hours and around 85 percent of the

volume supplied from the Rotterdam region occurred during the very cold period at the beginning of February 2012.

The ultimate destination of the gas transported out of the Rotterdam region was not further analysed, not only because it involved relatively small quantities but also because the composition did not deviate substantially from the other H-gas in the network. The PE values of the produced LNGs lay just above five, as shown in the diagram below. This refers to the PE values of the pure (not yet diluted with nitrogen) LNG.

PE value pure LNG (1 Sept 2011 – 15 February 2012)



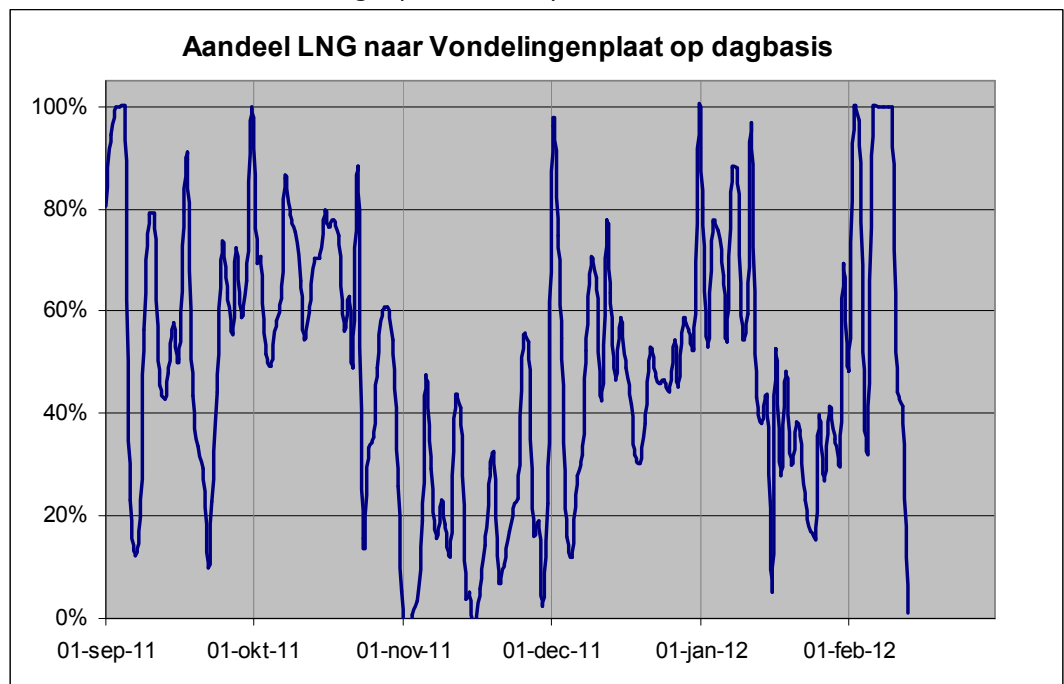
number of hours (per 0.1 PE interval) PE value

For a significant section of the H-gas market in the Rotterdam region, i.e. the low pressure system with around fifty end users, an analysis was carried out on which part of this gas involved LNG. This area is supplied via the GTS reducing station in Vondelingenplaat. This section receives LNG during high production from the Gate terminal and 'classic' H-gas from the rest of the GTS

network or a combination thereof. It is, therefore, a typical example of an area that is supplied from both sides and has to deal with flow zero points as set out in the 'Quality variations in transport' memo (see appendix 4).

On a daily basis, the following image was observed:

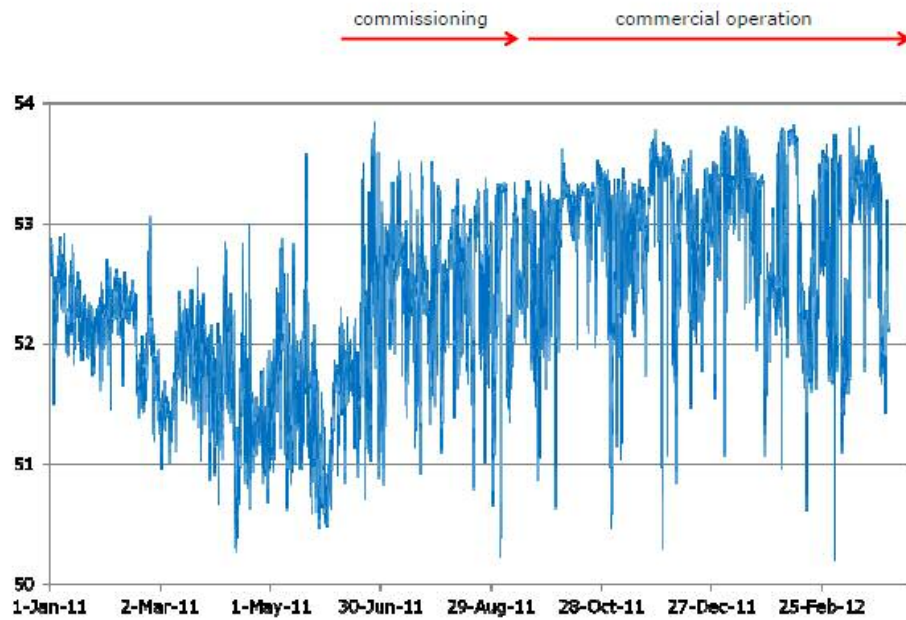
Share of LNG to Vondelingenplaat on daily basis



It was clear that the source of the gas for this area varied greatly. Variations were also pretty significant on an hourly basis (not shown). In one hour, the source could vary up to 50 percent. The extent to which the composition also changes depends on the differences between the produced LNG and the other H-gas.

The variations in actual composition of the H-gas from various sources are shown in the diagram below. The diagram shows that since the feed-in of LNG, variations in the Wobbe Index have increased in spread and frequency and the extent of changes from hour to hour has increased by one and half times.

Wobbe index changes since LNG start-up
(low pressure area Rotterdam)



Appendix 4: Memo – Quality variations in transport

This memo sets out the effects of the dynamics of gas transport on quality variations for end users. It looks at variations in supply and consumption, flow zero points and dispersion in the gas transport network.

Introduction

In gas transport networks, gas is supplied at various entry points. In terms of national gas transport, this involves around fifty different locations spread out across The Netherlands where producers of natural gas can introduce gas into the national transport network. This includes inland and offshore gas sources and, in many cases, multiple gas fields are combined at one, collective entry point. In addition, there are around ten locations on the border with Germany and Belgium, where gas can enter The Netherlands from neighbouring networks. Further entry points include underground storages, the LNG terminal and Green Gas entry points.

Bandwidths for the range of compositional parameters apply to all of these points. These vary for H-gas and G-gas. There is no mutual correlation between momentary entry compositions. The gas from the various supply sources in the transport network is not mixed before it is supplied to end users, other than via the regular mixing that takes place if another production flow is added to an ongoing transport pipeline.

Dynamic gas transport

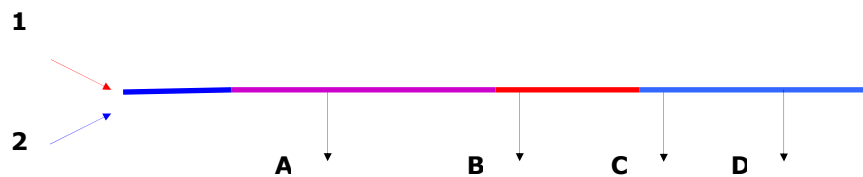
The situation set out above is not steady. The dynamics in gas transport are determined by:

1. Variations in supply as a result of technical issues such as maintenance and interruptions.
2. Variations in supply as a result of adjustments by trading parties (shippers); it is the shippers themselves which determine the extent to which the feed-in points contribute to this variation.
3. Variations as a result of the changing demand at the exit points (those connected, regional and foreign networks, underground stores). Some entry points can change direction and become exit points, such as underground stores and some border stations.

The dynamics of gas transport can change on an hourly basis (but also more quickly) due to these factors.

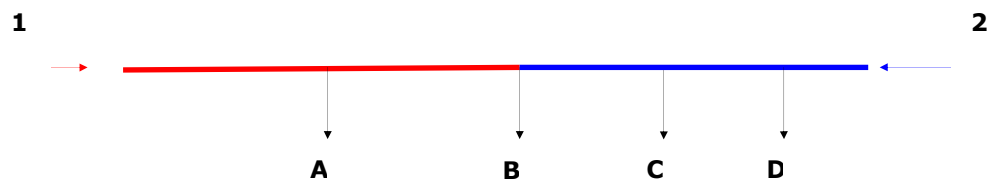
In principle, there are two ways in which these dynamics can lead to quality variations for the end user. In the first case, the flow direction in the transport network always goes in the same direction. In the second case, this can also change.

One flow direction



In this diagram the gas is always brought in from the left. Sources 1 and 2 have different compositions. Variation in the ratios results in compositional variations that move forward in the pipeline and subsequently end up at end users A to D. The maximum variation is the difference between both sources. The ratio between the sources can be the result of a technical issue (maintenance or interruptions) but can also be deliberately dispatched by a shipper. Aside from a little dispersion (see later in the document), these variations end up with the end users in the same way as if they had been created upstream.

Two flow directions



Supply points 1 and 2 are located here on both sides of the continuing pipeline. This diagram can otherwise be summarised as a component of a larger network where two distribution areas a different supply meet one another. This occurs in the situation given at end user B, who receives a certain combination from sources 1 and 2. There is a zero flow point at end user B.

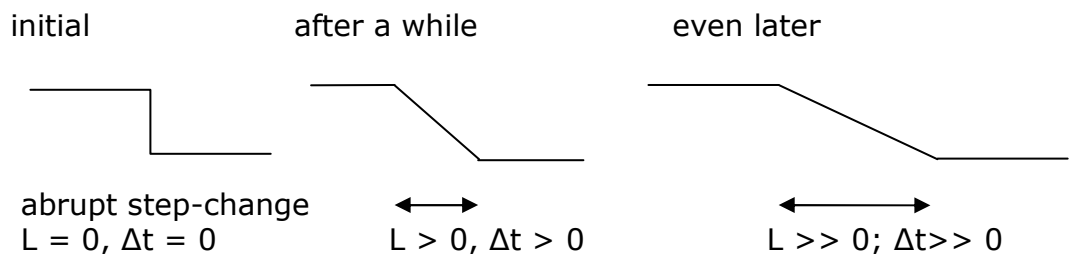
The consequence of changes in supply or demand is now that this zero flow point can move within the network, resulting in the distribution areas of the gas from points 1 and 2 reducing or increasing in size. Once source 2, for example, supplies less and the end users continue to use their gas, the distribution area of source 1 will enlarge with the result that the flow zero point will

shift to the right. If source 2 comes to a halt, all four end users will receive gas from source 1. The 'switch' will take place abruptly for end users C and D.

End user A may also demand less gas. If source 1 does not change its production, this distribution area will expand and the flow zero points will also shift to the right, resulting in compositional variations for end users B, C and possibly also D.

Dispersion

The above text shows that the gas composition can change locally very quickly. There is, however, a slight effect of damping because the severity of the quality step-change in the network gradually reduces. This is caused by turbulent gas movements but also as a result of the gas coming into contact with irregularities such as bends and installations. Furthermore, the imperfectly smooth interior of the pipeline leads to axial speed differences. All of these aspects cause dispersion on the edge of compositional variations during transport. The scope of this effect depends, among other things, on the distance covered, the pipeline diameter and the gas speed. The further 'downstream' the gas travels, the more the quality step-change is levelled off. This can be shown schematically as follows:



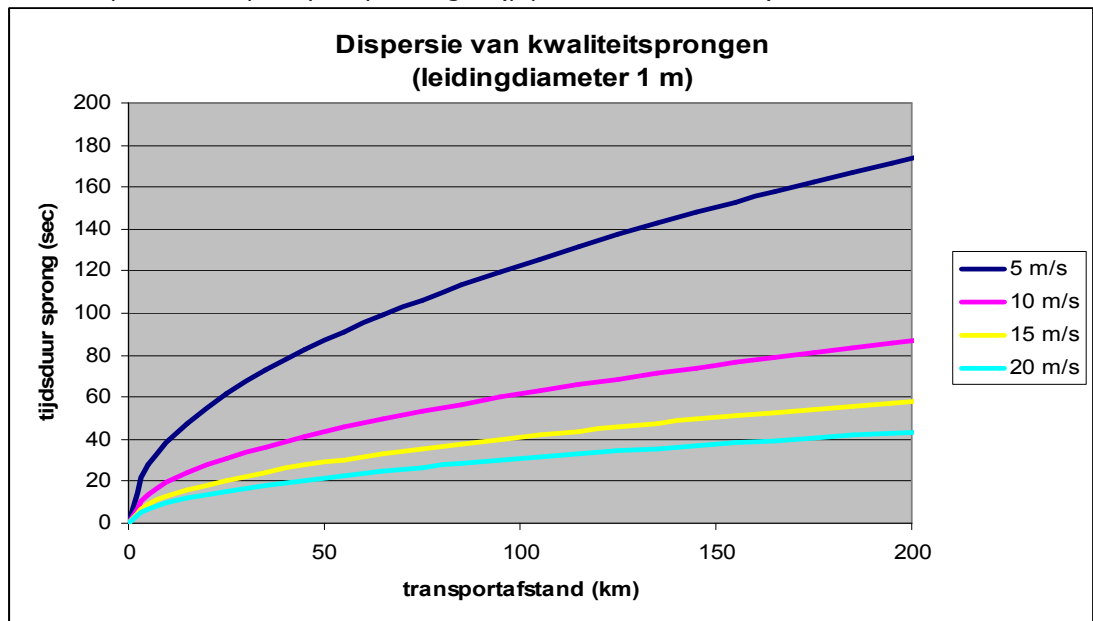
In this, L is the length of the step-change along the pipeline and Δt is the time the quality step-change takes to pass one point in the pipeline. This Δt is of primary importance for the end user. Of the previously defined transported compositional variations, those that move in one direction will spread out more than the zero flow points that move to and fro because the reinforcing impact of pipeline unevenness then plays a less significant role.

There are two conflicting effects of the speed of the gas that influence the scope of the dispersion: lower speed leads to less turbulence but also to a longer stay in the transport network. The longer length of stay, however, seems to have a greater impact and, as a result, quality step-changes spread out more if they are underway for longer.

Calculations show that a quality front that has moved across 100 km through the GTS high pressure network will have spread out over around 600 meters as a result of this dispersion. With normally occurring gas speeds of 10 m/s at most, this step-change would run through in less than 1 minute. This period reduces closer to the source.

The diagram below indicates the effect of dispersion. It gives the duration of an originally abrupt quality jump. The diameter and gas speeds chosen are typical of the normal gas transport for GTS; speeds of over 10 m/s only occur during periods of extremely high gas demand. It goes without saying that further dispersion will occur in the downstream networks. This extra dispersion is, however, less significant in smaller diameters. In the regional transport networks, further dispersion will also be less significant.

Dispersion of quality step-changes (pipeline diameter 1m)



duration of step-change (sec)

transport distance (km)

This model calculation has been tested in practice on a number of occasions. These test have shown that actual dispersion is usually higher than the model predicts by a factor of 2 to 4. This is probably due to the fact that the model assumes a straight, smooth pipeline in which bends, branches, manifolds, diameter changes, etc. are not taken into consideration. The results of the model calculations can therefore be regarded as a *worst case scenario* for a 'normal' transport network. If the extent of fluctuations (e.g. the

delta Wobbe Index in one hour) is known, the maximum speed of change ($\Delta W/\text{sec}$) can be estimated.

Conclusion

Abrupt compositional changes for end users can be caused by variations on the supply side but also on the demand side. This leads to a dynamic in the gas composition on which a network manager can exercise little or no influence. Compositional changes during transport can however be tempered during transport as a result of dispersion. On the basis of a dispersion calculation, an estimation can be made of the extent to which variations in gas composition can spread out during transport.

Appendix 5: Fout! Onbekende naam voor documenteigenschap.

Introduction

Heating installations (boilers, furnaces, gas turbines and gas engines) that are located within one installation with over 20 MWth installed capacity fall under the Dutch system of NOx emissions trading. The emission and fuel data for all installations that fall under NOx emissions trading are stored in the database of the Dutch Emissions Authority (NEa). On the basis of the database details and user details from high calorific natural gas, an estimation is made of the installations that make use of high calorific natural gas. This only looks at combustion emissions. Installations that are appointed as process emissions, such as the glass industry, are not included. Table 1 includes data from installations that are heated using exclusively high calorific gas and in which no other fuels are used for heating. The data is based on emission data from 2010.

Output category	Number of installations	Thermal output	Energy consumption	NOx emission	
Vermogensklasse	Aantal installaties	Thermisch vermogen (GWth)	Energie-verbruik (PJ)	NOx-emissie (kton)	Monitoring
>100 MWth	44	22	318	8,3	continu
50-100 MWth	16	1,1	12	0,5	2x/jaar
20-50 MWth	13	0,4	5	0,2	1x/4 jaar
1-20 MWth	98	0,6	9	0,7	1x/8 jaar
totaal	171	24,1	344	9,7	

Table 1: output and emissions from installations within NOx emissions trading that are heated using High calorific gas

Gasunie has indicated that, in 2010, around 12 billion cubic meters of high calorific gas was used. The energy consumption of 344 PJ (this is around 9 billion cubic meters) means that 75 percent of the high calorific gas was used for heating as a solo fuel in NOx emissions trading installations. Aside from the installations in the above table, there are another 52 installation which use high calorific natural gas as well as other fuels. The total energy consumption of these installations amounted to around 100 PJ in 2010. The database does not clearly show which share of this originates from heating with high calorific natural gas. That is why the installations in which solo high calorific gas is used for heating were chosen as a representative sample of the installation totality. The emissions from all of the installations that fall under NOx emissions trading was 60 ktons in 2010. Total NOx emissions as a result of heating 12 billion cubic meters of high calorific natural gas are estimated to be 13 kton NOx (12/9*9.7).

Consequences for NOx emissions

Table 2 ranks the installations in which high calorific gas is used for heating, per type of installation and monitoring, on the basis of the NEa database.

Type of installation	Number of Installations	Energy Consumption	NOx emission	Monitoring
Type installatie	Aantal installaties	Energieverbruik (%)	NOx-emissie (%)	Monitoring
gasturbine >100 MWth	35	76,3%	74,2%	continu
ketel >100 MWth	7	13,3%	8,2%	continu
fornuis >100 MWth	2	2,6%	3,1%	continu
gasturbine <100 MWth	9	1,7%	3,1%	periodiek
ketel <100 MWth	43	2,0%	4,1%	periodiek
fornuis <100 MWth	21	1,2%	1,0%	periodiek
gasmotor <100 MWth	18	0,3%	1,0%	periodiek
overig <100 MWth	36	2,6%	5,2%	periodiek

gas turbine boiler furnace gas turbine boiler furnace gas engine other

Table 2: installations and monitoring within NOx emissions trading that are heated on high calorific gas

Boiler burners 1-4 NOx vs Wobbe Index gas

Ketelbranders 1-4 NOx vs Wobbe Index gas

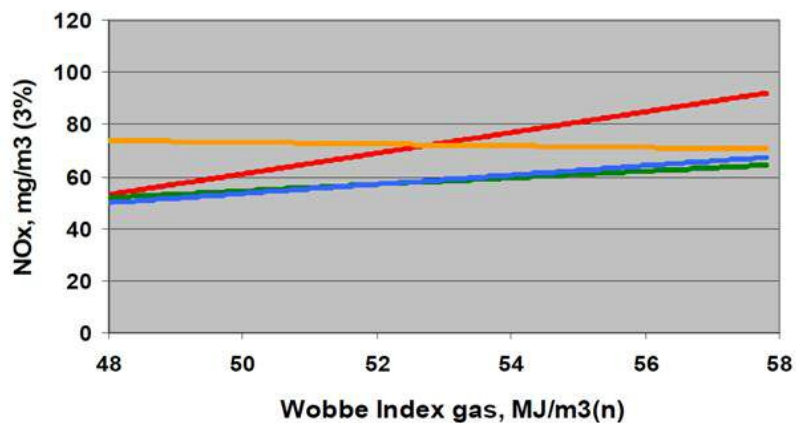


Figure 1: Impact of the Wobbe Index on the NOx emission concentration of four burner types

Research has been carried out into the impact of the Wobbe Index on the NO_x emissions of various burners. As is clear from figure 1, NO_x emissions increase in the event of a higher Wobbe Index with three of the four burners. Across the range of 48.3 – 57.2 MJ/Nm³, the influence varies from -1 to +6% NO_x per MJ/Nm³. This increase is primarily caused by lower excess air and the resulting and corresponding higher flame temperature.

If the Wobbe Index on the gas network increases from 49-53 to 49-55.7 MJ/Nm³ and, as a result, the average Wobbe Index increases by around 1.4 MJ/Nm³, the NO_x emissions from boilers and furnaces would increase by an average of 3.5 percent (1.4 MJ/Nm³ * 2.5% NO_x per MJ/Nm³). This increase will be significantly smaller if an oxygen regulator is installed. For installations larger than 100 MW_{th}, where continuous measurement of O₂ and NO_x is mandatory, an oxygen regulator will already be installed.

Variations in excess air also impact upon the installations' efficiency. Improved management of excess air via an oxygen regulator therefore has a beneficial effect on the installation's profitability. The KEMA investigation showed that the costs for an oxygen regulator on a 3 MW_{th} boiler can be recouped within about a year. Subsequently, it is expected that all boilers and furnaces will be fitted with oxygen regulators and that increases in NO_x emissions will be limited as a result.

In gas turbines, the load is controlled on the basis of combustion temperature or a temperature derived from that. An increase in the combustion temperature as a result of an increased Wobbe Index shall therefore be corrected by lowering the gas supply to the gas turbine. As a result, the increase in NO_x emissions will remain limited. Given that burner technology for boilers and DLN gas turbines is very similar, the increase in this domain will also be lower than 3.5 percent.

Gas engines usually have already been equipped with a deNO_x. Urea dosing is controlled via the outlet concentration. As a result, the emission concentration depends on the inlet NO_x concentration. An increased NO_x emission as a result of a higher Wobbe Index will therefore not result in higher NO_x emissions.

In summary, the expected increase in NO_x emissions as a result of the increased Wobbe Index will be significantly lower than 3.5 percent. On the basis of the 'worst case scenario', national NO_x emissions will increase by 0.45 kton (3.5% of 13 kton). That is just

0.2 percent of national NOx emission of around 260 kton and falls entirely within the uncertainty of the national emission inventory.

Periodical testing of individual heating installations could demonstrate a transgression of the requirement as a result of the Wobbe Index of the natural gas that is being burned during the measurement period. Consideration must be made, however, of the fact that a measurement always has a significant measurement uncertainty of 10 to 20 percent. The measured emission concentration may be corrected for this measurement uncertainty. The increased bandwidth of the Wobbe Index from 49-53 to 49-55.7 MJ/Nm³ means additional independent uncertainty. This extra uncertainty amounts to around 7 percent, as is clear from formula 1.

$$U = \sqrt{\frac{(55,7 - 49)^2 - (53 - 49)^2}{2}} \times 2,5 \% \approx 7\%$$

Formula 1: extra uncertainty as a result of the increase in the bandwidth of the Wobbe Index

Additionally, there is an average increase as a result of the increase of the average Wobbe Index of 3.5 percent. It is for this reason, therefore, that there is a recommendation not to interfere, when heating with high calorific gas if:

Measured emission concentration < emission requirement
 $(100 + (\text{measurement uncertainty}^2 + 7^2)^{0.5} + 3.5/100$

In which the measurement uncertainty is the measurement uncertainty demonstrated by the measurement institution in percentage form.

When establishing an index number in the context of the NOx emissions trade, it can be at a maximum of 10 percent higher than for the new specifications for high calorific gas.

Consequences for CO₂ emissions

If half of the 12 billion m³ of high calorific natural gas is replaced by LNG then CO₂ emissions will reduce by around 0.5 percent. This corresponds to around 0.13 Mton CO₂ (0.5%*56.8*460). This level of reduction is practically negligible. It is also hardly noticeable at installation level.

Conclusions

On a national level, the increase of NOx emissions (0.5 kton NOx) and the reduction of CO2 emissions (0.13 Mton CO2) as a result of the Wobbe Index of the new natural gas will be barely noticeable. The effect of the increase in NOx emissions at heating installations could lead to breaching emission requirements. It is for this reason, therefore, that there is a recommendation not to interfere, when heating with high calorific gas if:

Measured emission concentration < emission requirement(100+(measurement uncertainty²+7²)^{0.5} + 3.5/100*

In which the measurement uncertainty is the measurement uncertainty demonstrated by the measurement institution in percentage form.

Appendix 6: Survey of H-gas users February 2012

The survey below was sent out at the beginning of February 2012:

Survey H-gas

- Progress of modifications within companies -

Dear

As announced in our newsletter a few days ago, we hereby send you a short survey.

Survey notes:

During the current transitional period, there are extra limits on the LNG imports. The propane equivalent has been maximised to 8.7. This measure gives companies time to carry out any modification required in order to work with the ultimate gas composition.

The minister of the Economy, Agriculture and Innovation has indicated that this transitional period will terminate at the end of 2012. He expects your company to utilise this period to take any measures that are necessary in order to process the broader composition once this period has passed. After the transitional period, no limitations will be placed on the propane equivalent. The minister has made additional agreements with GTS that the upper limit for the Wobbe index will remain limited to 55.7 MJ/m³ (n) once the period has come to an end.

The Projectbureau has been asked to monitor the progress of modifications made by end users. **On the basis of the results of this survey, the Projectbureau will advise the minister on a possible extension of the transitional period.**

We would very much appreciate it if you would complete the survey (5 questions). You may respond via e-mail, marking the relevant options in the text field that apply to you and then providing an explanation. It will only take about five minutes of your time. We hope that you are able to respond before **10 February**.

1. Since 1 September 2011, have you noticed irregularities in your processes

that are demonstrably related to the new gas composition supplied and that have not yet been reported to the Projectbureau Nieuw Aardgas?

0 No

0 If yes, what is the nature of these irregularities and how did you resolve them?

- explanation:

2. Has your company implemented technical modifications in relation to the gas composition of natural gas so far supplied?

0 If yes, could you indicate which modifications have been implemented?

- explanation:

0 If no, are you expecting your company to have to make technical modifications in order to be able to process the expected variations in the natural gas composition?

- explanation:

3. Have you planned and elaborated any measures?

0 If yes, what is the nature of these measures and when will they be implemented?

- explanation:

0 If no, why not?

- explanation:

4. Will the measures planned be operational by the end of 2012?

0 Yes

0 If no, what is the reason for the later realisation and when will the necessary measures become operational?

- explanation:

5a. Via their GC-Link, GTS provides gas quality data from transported natural gas for end users. This data provides an insight into the gas composition and, if requested, upstream information so that the arrival time at your location can be calculated. Does your company make use of this signalling system?

0 If yes, is the information supplied useful?

- explanation:

0 If no, do you have any intention of making use of the signalling system?

- explanation:

5b. Do you need further information?

0 No

0 If yes, what information do you need?

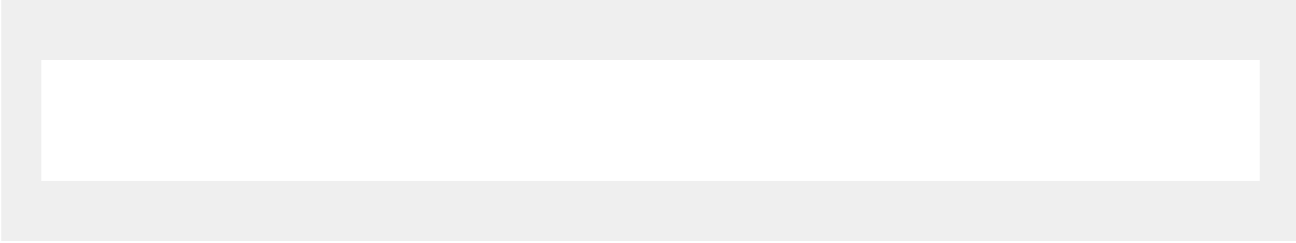
- explanation:

5c. Do you need to have a supplementary meeting with the Projectbureau?

0 Yes

0 No

Many thanks for your responses,
On behalf of the Projectbureau Nieuw Aardgas,



Appendix 7: Responses from companies - comprehensive summary survey

This report is based on 54 responses from 56 companies which encompass 88 receiving stations.

Irregularities in gas supply

Companies were asked whether, in the period between 1 September 2011 and 1 February 2012, they had observed irregularities that could be ascribed to gas composition.

- 41 companies had not experienced any irregularities in gas supply in the sense that the installations functioned less effectively. This, of course, includes companies that are used to processing different types of gas.
- 11 companies indicated that they had experienced disruptions. These companies can be divided into several groups:
 - A few companies noted variations but were able to accommodate these with control devices and/or increased operator vigilance; one report from Noord Nederland regarding disruptions cannot have been caused by LNG from a practical perspective.
 - Several companies which operate gas turbines experienced disruptions:
 - several trips from gas turbines were ascribed to variations in gas composition; further investigations have been carried out or are still underway: in a few cases, it appeared that the trips were not caused by the varying gas composition;
 - the performance of NOx suppression measures deteriorated.
 - Several companies, particularly those that produce industrial gases, struggled with variations to such an extent that production capacity of the factories had to be reduced in order to continue to operate safely.
 - One customer also reported that the demand for extra product could not be fulfilled as a result of this capacity reduction.
 - Finally, one company suspected that disruptions with radiation burners (space heating) and disruptions in a galvanising process were caused by variations in gas composition

Measures that companies have taken or are still to take

- Fourteen of the 54 companies have installed equipment and/or amended process settings in order to be able to accommodate the effects of quality variations in the gas; these measures will affect efficiency and production capacity. Several of these companies have also installed regulators in order to keep combustion efficiency up to the required level.
- Six companies have planned and elaborated further measures; 48 companies have no plans for further measures and 23 of these predict that none will be necessary.
- Thirty-one companies expect to be ready with their modifications by the end of 2012. Twenty-three companies are not yet ready.
 - Fifteen companies have insufficient knowledge of the modifications to be made; eight of these regard the lack of certainty regarding the limits of the gas composition to be the problem; the suppliers of gas turbines will not provide the information required for the amendments without access to this data.
 - Eight companies cannot plan the necessary modifications for this year; for most of these, this corresponds to the timing of a periodic factory closure during which modifications can be implemented/installed.
 - Several companies have given a lower priority to these modifications as a result of economic considerations.

Use of the GTS signalling system

- Twenty-five companies consider it an important facility and would like to use it; for 16 companies, there is a technical or other barrier to using it. The data from the GTS website cannot be used directly in control applications; an interface is required, if it is at all possible. A number of companies have struggled to gain access.
- Eighteen companies have indicated that they do not use it because they have their own measurements, because their own applications will not accept external signals (policy), or because the signal is not relevant for them.
- Eleven companies did not respond to this question.

Need for further information

- Sixteen companies indicated a need for additional information.

- Six companies have specifically asked for more robust information about the bandwidth of the gas composition.
- Thirty-eight companies do not require further information.

Need for supplementary meetings with PNA

- Forty-two companies indicated that they do not need additional meetings with the Projectbureau.
- Twelve companies would like supplementary meetings and around half of these would like the meeting to cover specific topics.

Appendix 8: Memo – Burner installation H-gas systems

This memo provides a guide to dealing with settings for a forced-draught burner, taking into account the variations in the Wobbe Index for H-gas between 48.0 and 55.7 MJ/nm³.

If an industrial burner is set up without a regulator for variations in gas quality, for a specific residual oxygen percentage with a specific Wobbe Index for the natural gas supply, this residual oxygen percentage will vary according to the Wobbe Index. Given that H-gas can also contain CO₂, it is incorrect to set a burner installation on the basis of a CO₂ measurement; it must be set to O₂.

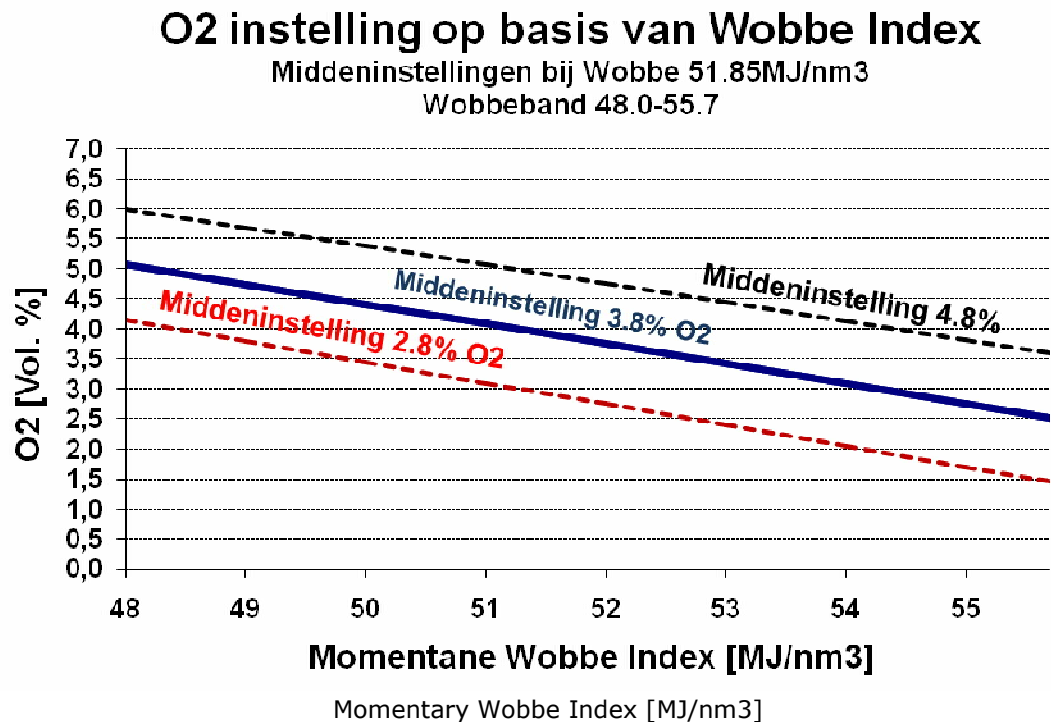
The basic principle is that a choice has to be made regarding the most suitable settings for the relevant burner.

To give an example, we have chosen to set the burner to a residual oxygen percentage of 3.8% with a Wobbe Index of 51.8. Graph 1 shows the residual oxygen percentage across the whole Wobbe band, i.e. between 2.5 and 5.1%. This is safe for most forced-draught burners.

Graph 1 - O₂ mid setting on basis of Wobbe Index.

If another setting line is required, this can be established by choosing the residual oxygen percentage for the mid setting. The link between the Wobbe Index and residual oxygen percentage follows this setting line. The manufacturer/supplier can even fix the desired setting on the basis of knowledge about the behaviour of their burner.

O₂ setting on basis of Wobbe Index
Mid-setting for Wobbe 51.85 MJ/nm³
Wobbe band 48.0-55.7



Setting instructions

- Establish the Wobbe Index for the H-gas at the moment of setting. If this is not possible with your own equipment, an indication of the Wobbe Index can be obtained via GC-link. This is a real-time signalling system that is intended for users that have a connection to the GTS H-gas system. It informs them of the Wobbe Index among other things. End users that are not connected to the GTS system can obtain a less accurate indication via <http://www.gastransportservices.nl/transportinformatie/h-gas-kaart-van-nederland>. This information is accessible to the public and also shows the Wobbe Index per region.
- Depending on the most suitable setting for the burner according to (example) Table 1 below, read off the Wobbe Index indicated with the corresponding residual oxygen percentage to which the burner must be set.
- If another setting is preferred, this can then be determined, as a result of the linear relation, by adding up (or deducting) a

constant residual oxygen percentage for all of the values mentioned in the table.

- This residual setting depends on the load (so no higher residual percentages for low loading).
- The setting margin must be set carefully with the smallest possible deviation.
- The load at 55.7 amounts to 107.5% compared to the mid setting (51.85). The burner supplier must assess whether this is acceptable, taking safety margins and settings into account. If this is considered to be necessary, full loading can be reduced.

Advice and information for EBI workers and the installation manager

- Check the CO-concentration in the flue gases under full and low loading. If this value, in the opinion of the burner supplier is too high, action must be taken to lower the CO-concentration.
- Low loading does not need to be adjusted.
- Across the whole Wobbe band that can be offered, the maximum spread on loading is +/- 7.5% in relation to the mid value on which the setting is based.
- The burner loading for natural gas – with a given setting for the burner – is practically proportional to the Wobbe Index (and not with the calorific value).

Periodic checks of settings

- During a periodic check the installation can be reset (or not) depending on the deviation from the measured value compared to the desired value. It is up to the burner supplier to determine if new settings must be entered for the relevant installation.

Settings of residual oxygen percentage for different Wobbe Indexes (mid setting 3.8% O₂ for 51.85 MJ/nm³)			
Wobbe Index	Corresponding O₂ setting	Wobbe Index	Corresponding O₂ setting
48.0	5.07	51.9	3.78
48.1	5.04	52.0	3.75
48.2	5.01	52.1	3.72
48.3	4.97	52.2	3.68
48.4	4.94	52.3	3.65
48.5	4.91	52.4	3.62
48.6	4.87	52.5	3.59
48.7	4.84	52.6	3.55
48.8	4.81	52.7	3.52
48.9	4.78	52.8	3.49
49.0	4.74	52.9	3.45
49.1	4.71	53.0	3.42
49.2	4.68	53.1	3.39
49.3	4.64	53.2	3.35
49.4	4.61	53.3	3.32
49.5	4.58	53.4	3.29
49.6	4.54	53.5	3.25
49.7	4.51	53.6	3.22
49.8	4.48	53.7	3.19
49.9	4.44	53.8	3.16
50.0	4.41	53.9	3.12
50.1	4.38	54.0	3.09
50.2	4.35	54.1	3.06
50.3	4.31	54.2	3.02
50.4	4.28	54.3	2.99
50.5	4.25	54.4	2.96
50.6	4.21	54.5	2.92
50.7	4.18	54.6	2.89
50.8	4.15	54.7	2.86
50.9	4.11	54.8	2.82
51.0	4.08	54.9	2.79

51.1	4.05	55.0	2.76
51.2	4.01	55.1	2.73
51.3	3.98	55.2	2.69
51.4	3.95	55.3	2.66
51.5	3.92	55.4	2.63
51.6	3.88	55.5	2.59
51.7	3.85	55.6	2.56
51.8	3.82	55.7	2.53

Table 2 - Settings of residual oxygen percentage for different Wobbe Indexes