PA Consulting Group

Gas quality report

Quantification of the extent to which gas quality may in future constrain British imported gas supplies

17 December 2009

Executive summary

Centrica Energy commissioned PA Consulting Group (PA) to undertake an assessment quantifying the extent to which gas quality may in future constrain imported supplies to the UK. The particular focus of this report is the upper limit placed on the Wobbe Index number, which is lower in Britain's gas quality specifications (as set out in the Gas Safety (Management) Regulations 1996 (GS(M)R)) than most continental European specifications (known as the EASEE-gas specification).

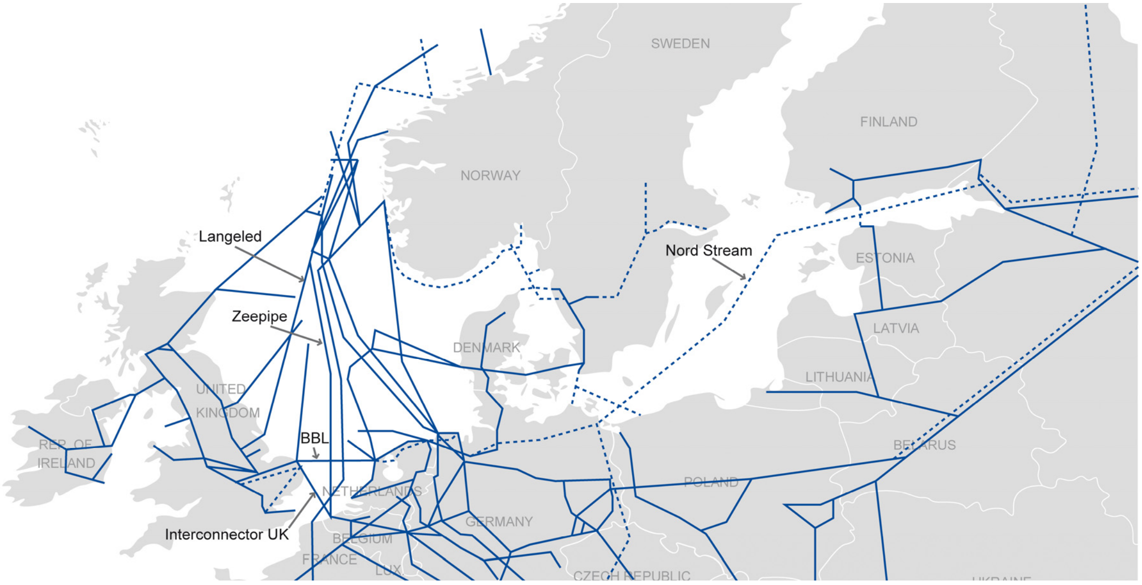
Centrica Energy believes that gas pipeline supplies from Belgium and the Netherlands are potentially most at risk from gas quality issues in the future as not only will the UK become increasingly reliant on these supplies, but also more LNG and other 'richer' gases will be arriving in these source countries within the next few years. While gas destined for the UK can currently be blended with 'leaner' gas of Dutch, Norwegian or Russian origin in order to produce gas which meets British specifications, in future this may not be possible.

This report constitutes PA's assessment of the gas quality issue based on scenario modelling we have undertaken using PA's European Gas Flow Model (EGFM). The model is a nodal flow model which approximates European gas flows for a single day. We believe there are compelling reasons to utilise the EGFM to conduct this analysis:

- It is intuitive, transparent and easy to understand
- It produces an accurate simulation of European gas flows and can easily be adjusted to operate under a range of scenarios and different underlying assumptions
- It has been developed independently by PA.

For this assessment, the EGFM was constructed to reflect 2009 and 2014 (i.e. in five years' time) capacities of the European gas network across all 27 EU member state countries taking into account all current and planned LNG terminals, gas pipelines, gas storage facilities as well as current and projected domestic gas production. It also takes into account current and future gas demand for each EU member state. In addition, the model also includes gas flows into Europe from Norway, Russia, North Africa and LNG flows from a wide range of countries. The model assumes current gas quality policies do not change over the next five years.

The Northern European Natural Gas Grid



Source: Nord Stream

To forecast the volumes and quality of gas likely to flow into the British market from continental Europe and potential limitations on the amount of gas to flow to the UK, we developed the following scenarios:

- **Base** - a scenario based on current gas flows as described in recent transmission system operator (e.g. National Grid) documentation and its base case predicted flows in five years' time. This assumes relatively high LNG imports and commensurately a relatively modest need for pipeline imports from the Continent.
- **Low LNG** - a scenario simulated for 2014 which differs from the 'Base' scenario in that all discretionary LNG for the UK, Belgium and the Netherlands is diverted to alternative markets, under the assumption there is stronger LNG demand resulting in higher prices available outside of continental Europe (e.g. in Asia).
- **Low Langeled** - a scenario, again simulated for 2014, where a high volume of Norwegian gas contracted for the continental European markets is nominated and taken (e.g. due to an exceptionally cold winter), leading to a reduction in the amount of gas available for Britain.

High ZPT scenarios (meaning high Wobbe Index, rather than high volume) were also constructed for each of the above, with the assumption being that Norwegian gas destined for the Zeepipe Terminal (ZPT) in Zeebrugge via the Zeepipe pipeline is above British gas quality specifications.

Key findings

Table 1 summarises the results from our scenario analysis, identifying which scenarios have a potential shortfall of gas to meet the UK's Net Import Requirement.

Table 1: Forecast gas supply constraints, 2014 (Note: ✓ no constraint; X constraint)

	Average Winter's Day	Peak Winter's Day
Base	✓	✓
Low LNG	✓	X
Low Langeled	✓	✓
Base - High ZPT	✓	✓
Low LNG - High ZPT	X	X
Low Langeled - High ZPT	X	X

Source: PA Consulting Group

Our results show that under the 'Low LNG', 'Low LNG - High ZPT' and 'Low Langeled - High ZPT' scenarios, the UK could face gas supply constraints and/or significant wholesale gas price increases on a Peak Winter's Day in 2014. Furthermore, for the 'Low LNG - High ZPT' and 'Low Langeled - High ZPT' scenarios, where gas flows from Norway, through Zeepipe to Belgium are assumed to be above British gas quality specifications, supply constraints and/or significant price increases are also predicted to occur on an Average Winter's Day.

The shortfalls of gas for these scenarios for a Peak Winter's Day and Average Winter's Day are set out in Tables 2 and 3:

Table 2: Potential Peak Winter's Day Gas shortfall, 2014

	mcm(s)/d	As % of total UK demand
Low LNG	3	0.5
Low LNG - High ZPT	44	7.7
Low Langeled - High ZPT	22	3.9

Source: PA Consulting Group

Table 3: Potential Average Winter's Day Gas shortfall, 2014

	mcm(s)/d	As % of total UK demand
Low LNG - High ZPT	22	4.8
Low Langeled - High ZPT	22	4.8

Source: PA Consulting Group

Most worrying are the potential outcomes for the 'Low LNG' scenarios, where LNG is diverted to alternative markets outside of continental Europe. Assuming the Zeepipe pipeline from the Norwegian gas fields to Zeebrugge and also gas arriving at Zelzate and Eynatten is within British gas quality specifications, there is a potential shortfall of 3 million cubic metres of gas, equivalent to 0.5% of total

UK demand. Gas quality constraints on the Zeepipe pipeline are predicted to increase this shortfall dramatically to 22 million cubic metres on an Average Winter's Day, equivalent to 4.8% of total UK demand and 44 million cubic metres for a Peak Winter's Day, equivalent to 7.7% of total UK demand.

The 'Low Langeled' scenarios are better with no shortfall identified for the 'Low Langeled' scenario, although gas quality constraints on the Zeepipe pipeline under the 'High ZPT' scenario are predicted to produce shortfalls of 4.8% and 3.9% of total UK demand on an Average and Peak Winter's Day respectively.

In practice, the result of these constraints is unlikely to be an absolute shortage of gas supplies to the UK. What would most probably happen is a potentially significant rise in wholesale gas prices at the NBP (above continental North-West European levels). Under the 'Low LNG' scenarios this is likely to be sufficient to attract back into the UK 'discretionary' LNG supplies which would otherwise be directed to higher value markets outside Europe, although there is a risk of a lag before LNG shipments arrive.

Under the 'Low Langeled' scenarios, shortfalls could be met from spare capacity from Norwegian gas fields, although this gas may be contracted to other sources on the Continent. In the short term, it is likely there would be more gas taken out of storage - at least on an Average Winter's Day when storage extraction is running below the maximum.

Flows from BBL and the Netherlands

It is unlikely that flows through BBL will be reduced as a result of gas quality - the only likely reductions will be due to maintenance and outages of key Dutch infrastructure for the following reasons:

- GTS has large amounts of flexibility in determining the source of gas to commit to BBL and therefore has a high degree of leverage in terms of managing the gas quality.
- There is sufficient Dutch domestic production (as well as some UK Southern Basin gas) which is landed at Balgzand (adjacent to the BBL entry point) and this gas is generally used first to meet BBL requirements. This gas historically has been within British gas quality specifications and GTS is confident it will remain this way for the future. Forecasts of volume and quality until 2020 show this to be the case.
- If there is a problem with Dutch gas production being unable to flow through BBL due to maintenance and outages, GTS can divert Norwegian gas and also Nord Stream gas (subject to quality) to BBL. It is likely that Norwegian gas would be used before Nord Stream gas to meet BBL requirements, especially if Nord Stream brings in high Wobbe Index gas (falling outside British gas quality specifications).
- Norwegian gas to the Netherlands (delivered via Norpipe to Emden in Germany) so far has remained at a quality that is within British gas quality specifications and has not increased in 'richness' in the same way that Norwegian flows to Zeebrugge have. There does, however, remain some uncertainty as to whether this will continue as it is possible Norway will divert higher Wobbe Index gas to the Netherlands in the future.
- Nord Stream gas entering the Netherlands at Bunde from 2014 is likely to be above British gas quality specifications, although this is likely to be routed south to the Belgian border by GTS. In other words, a quality issue is avoided as regards to flows via the BBL, but would the position at 's Gravenvoeren in Belgium be further exacerbated as a result?
- It is likely that LNG gas from Rotterdam will flow south to Belgium unless there is a problem with Dutch production in the north through maintenance, outages, etc. This gas would only be accepted at Zelzate if the blend there is within British specifications.

Flows via Interconnector IUK from Belgium

Supply from IUK provides the greatest concern for British gas quality. If ZPT gas quality is high (i.e. the Wobbe Index number is above the British limit), there is unlikely to be any flow available through IUK on both an Average Winter's Day and Peak Winter's Day for the following reasons:

- Gas entering the IUK pipeline is currently sourced from three key sources - LNG, ZPT and Eynatten. Zelzate will be added in the fourth quarter of 2010.
- It can be assumed that LNG deliveries will normally be above British specifications.
- The LNG terminal in Zeebrugge does have a nitrogen injection facility. This plant makes it possible to ballast LNG imports with a view to compliance with Britain's gas quality specifications. However this plant only has only limited capacity which can cover limited Wobbe Index peaks, and this is only for a short period of time due to the limited size of the nitrogen storage tanks at the facility. If commercial considerations drive where this gas flows to, it appears likely the Belgian or French gas markets will receive all of the gas from this facility.
- The quality (i.e. the Wobbe Index number) of ZPT flows has been steadily increasing since 2006, although still within existing contractual obligations at this landing point, this is causing significant concern. There have been short, within-day periods where flows into the IUK from ZPT have stopped due to the quality being too high, with Fluxys having to rely exceptionally on linepack to meet shippers' requests to flow gas towards the UK.
- Eynatten flow volumes have a large volatility - they have become highly unpredictable, but the quality is currently always within British gas quality specifications. Eynatten flows are becoming more dependent on the price difference between Zeebrugge hub, Net Connect Germany and Gaspool.
- LNG that will be delivered at the terminal in Rotterdam from 2012 onwards is likely to be routed toward Belgium though Zelzate by GTS if the blend there is within British specification.
- Nord Stream gas (with the first pipeline coming on-stream in 2011; the second in 2012) is likely to be above the Britain's gas quality specifications and is likely to be diverted south to the Belgian network by GTS. This will impact the quality of gas coming through the Netherlands and Belgium and is likely to restrict the volume of gas available for the UK. Nord Stream may also affect the quality, and hence quantity, of gas available through Eynatten in the future.

Implications

The potential shortfalls of gas available via IUK, particularly in the 'High ZPT' quality-constrained scenarios will have to be met from other supply sources and if not, demand side response measures will need to be implemented.

Shortfalls could be met from spare capacity from Norwegian gas fields, although this gas may be contracted to other sources on the Continent. In the short term, it is likely there would be more gas taken out of storage - at least, on an Average Winter's Day when storage extraction is running below the maximum.

These quality related constraints are unlikely to lead to an absolute shortage of gas supplies to the UK. It appears likely that there would potentially be a significant rise in wholesale gas prices at the NBP (above continental North-West European levels), sufficient to attract back into the UK those 'discretionary' LNG supplies which would otherwise be directed to higher value markets outside Europe, although there is a risk of a lag before LNG shipments arrive. Alternatively, traded volumes from Germany need to increase such that quality at Eynatten is acceptable.

Overall, under the scenarios we have developed, which we believe to be realistic, our analysis indicates quality may in future constrain gas supplies from Belgium to the UK.

Whilst a broadening of the British gas quality limits, particularly the upper limit, has been ruled out by the UK Government until at least 2020 due to the prohibitive cost of identifying and converting or replacing all at-risk gas appliances, there appear to be suitable policy responses to address the risks we have identified.

Further research should be conducted to determine the reason why ZPT gas flows to Zeebrugge appear to be on an upwards trend. Such research would investigate whether this is a temporary phenomenon or whether there are real risks British gas quality specifications could be breached permanently at some point in the future. This could also consider Norwegian gas flows to the UK and the Continent to establish whether there are broader gas quality issues associated with such supplies.

However, to ensure security of supply, the development of blending or ballasting facilities at key entry points to the network to enable out of specification imported gas to be treated to bring it within British standards prior to entry to the gas network could be an appropriate solution.

On the basis of our analysis, the key entry point to the UK is Bacton, where the IUK and BBL gas pipelines link the UK with Belgium and The Netherlands. In 2006, a feasibility study undertaken by National Grid looked at different potential plant sizes for a ballasting facility at Bacton with capital expenditure estimated to range between £40 million and £200 million and annual operating expenditure estimated to range between £4.5 million and £22.5 million, assuming a plant size of between 1000 and 5000 tonnes per day. From a policy perspective, these costs could be refined to reflect the construction of a facility of an appropriate size. This raises many issues which are outside of the scope of this study, but given the apparent risks, we believe investigation of the following is warranted:

- Is ballasting at Bacton the only viable solution? Could blending be a more efficient and effective solution? Could the nitrogen injection facility at the LNG terminal in Zeebrugge be expanded?
- If ballasting is the most cost effective solution, what are the options to address the constraints we have identified and the estimated costs of each option?
- How do these estimated costs compare to ballasting facilities built elsewhere?
- What is the most appropriate route to recover these costs i.e. should these costs be fully socialised across the market, recovered directly from the users of the facility or some combination of the two?

Contents

1 Introduction

In this section, we outline why Centrica Energy commissioned PA Consulting Group to undertake an assessment of the extent to which gas quality may in future constrain imported supplies to Britain. We then set out the structure of this report and highlight other considerations.

1.1 Context

Centrica Energy commissioned PA Consulting Group to undertake an independent report quantifying the extent to which gas quality may in future constrain imported supplies to the UK. The particular focus of this report is the upper limit placed on the Wobbe Index number, which is lower in Britain's gas quality specifications than most continental European specifications (known as the EASEE-gas specification).

Centrica Energy believes that gas pipeline supplies from Belgium and the Netherlands are potentially most at risk from gas quality issues in the future as not only will the UK become increasingly reliant on these imported supplies, but also more LNG and other 'richer' gases will be arriving in these source countries within the next few years. While gas destined for the UK can currently be blended with 'leaner' gas of Dutch, Norwegian or Russian origin in order to produce gas which meets UK specification, in future this may not be possible, particularly when gas flows via Nord Stream.

Centrica Energy would also like to understand whether the vulnerability of the UK is due to:

- High volumes of LNG/Norwegian gas, or
- Gas from LNG/Norwegian sources being at the high end of the Wobbe Index range.

1.2 Structure of this report

This report constitutes the Final Report of PA's assessment of the gas quality issue based on modelling we have undertaken using PA's European Gas Flow Model (EGFM). Based on scenario analysis, our assessment quantifies, for 2009 and 2014, the volumes of gas available at the source points for pipelines to the UK from Belgium and the Netherlands together with details of the quality of such gas and the limitations, if any, in volume terms which this puts on the amount of gas which is able to flow to the UK.

Our modelling and analysis incorporates comments from Centrica Energy, Fluxys and Gas Transport Services (GTS).

The Final Report is structured as follows:

- **Section 2** outlines the gas quality standards that apply in Britain and on the Continent, why gas quality has the potential to become a serious risk in the future and provides a high level overview of Britain's gas import infrastructure, focusing on gas networks and pipelines in Belgium, the Netherlands, Norway as well as quality issues associated with LNG sources before concluding which gas import pipelines this assessment will focus on.
- **Section 3** provides an overview of PA's EGFM, highlighting its main characteristics and how the model has been developed for this assessment to consider gas quality issues and flows, particularly in Belgium and the Netherlands, and outlines the various data sources that have been utilised for the analysis.
- **Section 4** outlines and describes the scenarios we have constructed in order to forecast the volumes and quality of gas likely to flow into the British market from continental Europe and the limitations, if any, on the amount of gas able to flow to the UK.
- **Section 5** sets out how to interpret the results from the scenario modelling by considering the UK's Net Import Requirement from continental Europe, introduces the concept of 'GS(M)R compliant gas', and presents the detailed results for each scenario, identifying whether or not there is a shortfall of gas due to gas quality constraints.
- **Section 6** summarises the results from the scenario analysis, identifying which scenarios have identified a potential shortfall of gas to meet the UK's Net Import Requirement before presenting the key findings for the BBL and IUK pipelines.
- **Section 7** briefly outlines the implications of our findings identifying suitable policy responses to address the risks we have identified.

1.3 Other considerations

This report has been prepared for Centrica Energy by PA Consulting Group on the basis of information that is available in the public domain. No representation or warranty is given as to the achievement or reasonableness of future projections or the assumptions underlying them, management targets, valuations, opinions, prospects or returns, if any.

PA expressly disclaims any and all liability for any representation, warranty or undertaking, or omission expressed or implied, which is or will be given in relation to the truth, accuracy or completeness of this report and no representation or liability is or will be accepted by PA. In particular, without limitation, no representation or warranty is given to the achievement or reasonableness of future projections or the assumptions underlying them, management targets, valuation, opinions, prospects or returns, if any. This report does not constitute any form of commitment or recommendation on the part of PA.

In addition, and with specific regard to PA's EGFM:

- We have developed the model with the intent of illustrating how gas quality may in the future constrain imported supplies to the UK and it is based on information that is available in the public domain as of 17 December 2009.
- Although the model has been built using reasonable skill and care, we accept no liability for its outputs except that which is unlawful to exclude.
- Provision of the outputs from the model does not constitute investment advice and we are not recommending the use of the outputs of this model to make any investment decisions without further validation of the outputs.

2 Overview of the gas quality issue

In this section, we outline the gas quality standards that apply in Britain and on the Continent and why gas quality has the potential to become a serious risk in the future. We then provide a high level overview of Britain's gas import infrastructure, focusing on the gas networks and pipelines in Belgium, the Netherlands and Norway as well as quality issues associated with LNG sources before concluding which gas import pipelines this assessment will focus on.

2.1 Context

Natural gas consists of a mixture of hydrocarbon gases (primarily methane but also ethane, propane and butane) with the 'quality' determined by the relative quantities of these gases, which can vary widely between supply sources.

In Great Britain, domestic and industrial appliances are designed to operate within a certain gas quality specification range, with the current specifications based on the quality of indigenous gas supply sources. The specifications are defined in the Gas Safety (Management) Regulations 1996 (GS(M)R), set by the Health and Safety Executive. Under the GS(M)R, the Wobbe Index[1] under normal circumstances is limited to a range of 47.20 to 51.41, with more relaxed limits applying in the event of a supply emergency. This is illustrated in Table 1 (along with the EASEE-gas specifications).

Table 1: Current British and EASEE-gas Gas Quality Specifications

Wobbe Index		British specifications MJ/m3 (s)	EASEE-gas specifications MJ/m3 (s)
Normal	Upper	51.41	54.00
	Lower	47.20	46.99*
Emergency	Upper	52.85	-
	Lower	46.50	-

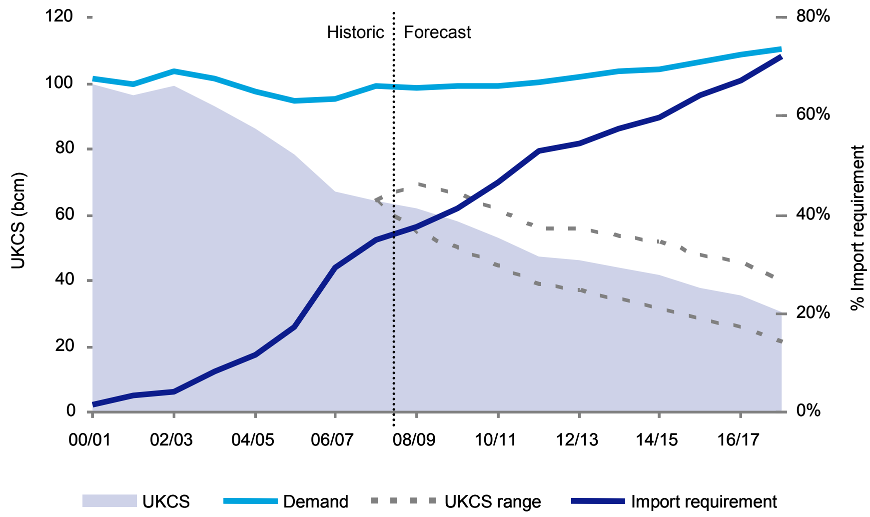
*Source: Schedule 3 of the GS(M)R and EASEE-gas.org Note: * 46.99 initially/46.45 potentially*

Domestic supplies from the UK Continental Shelf (UKCS) have historically conformed to the GS(M)R, however, UKCS production has been declining at a rapid rate, with Britain becoming increasingly reliant on gas sourced from elsewhere i.e. Norway, LNG and continental Europe e.g. the Netherlands and Russia - whose quality may not conform to GS(M)R. Over the next five years, Britain is expected

[1] The Wobbe Index is defined as the Gross Calorific Value (CV) of gas, divided by the square root of its relative density. Generally this report uses numbers relating to Standard cubic metres, however figures 2.4 to 2.7 relate to Normal cubic metres. On the Continent, MJ are expressed at a reference temperature of 25°C (against 15°C in the UK).

to source over half of its gas requirements from non-indigenous sources with Britain's import requirement expected to increase from 37.5% in 2008/09 to 57.5% in 2013/14, as illustrated in Figure 2.1.

Figure 2.1: UKCS Annual Output and Demand



Source: National Grid Ten Year Statement, 2008

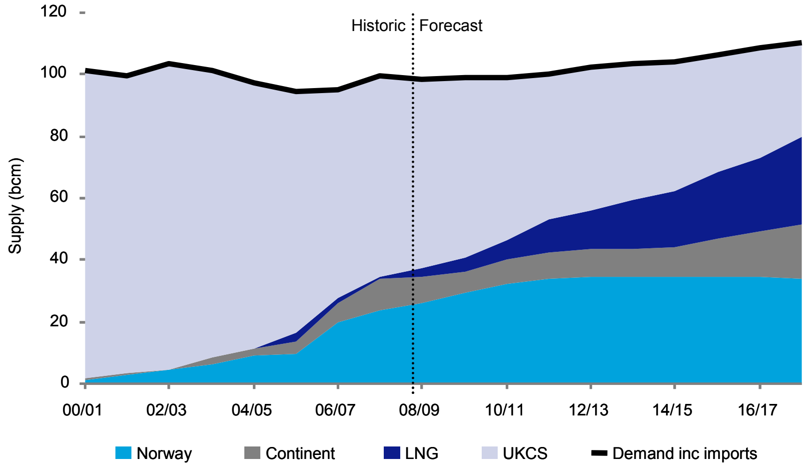
The shift to and increased reliance on non-indigenous supply sources, exposes Britain's gas network to continental Europe's specifications. The European Association for Streamlining of Energy Exchange GAS (EASEE-gas), an industry group, was set up in 2002 to support the development and promotion of common business practices (CBP's) that intend to simplify and streamline business processes. Regarding gas quality specifications, EASEE-gas has proposed a Wobbe Index range of 46.99 to 54.00, that is wider than current British specifications. Although the EASEE-gas specification is non-legally binding, it has been adopted by a large number of continental transmission system operators (TSOs).

Overall, these developments mean that in the future there is a risk gas will not flow to Britain due gas quality considerations.

2.2 Britain's gas import infrastructure

With the Britain's dependence on gas imports now established and becoming the dominant source of gas in the future, the make-up of these imports will determine whether quality issues could constrain flows from the Continent and elsewhere.

Figure 2.2: Source of Britain's increasing reliance on imported gas



Source: National Grid Ten Year Statement, 2008

As illustrated in Figure 2.2, Britain is exposed to gas quality developments in Norway and continental Europe (i.e. Belgium and the Netherlands), not only because the UK will become increasingly reliant on supplies from these sources, with around one third of gas supplies sourced from Norway and around 9% from the Continent by 2013/14, but also because more LNG will be landing on the Continent. Gas is transported to Britain from these sources via the following pipelines:

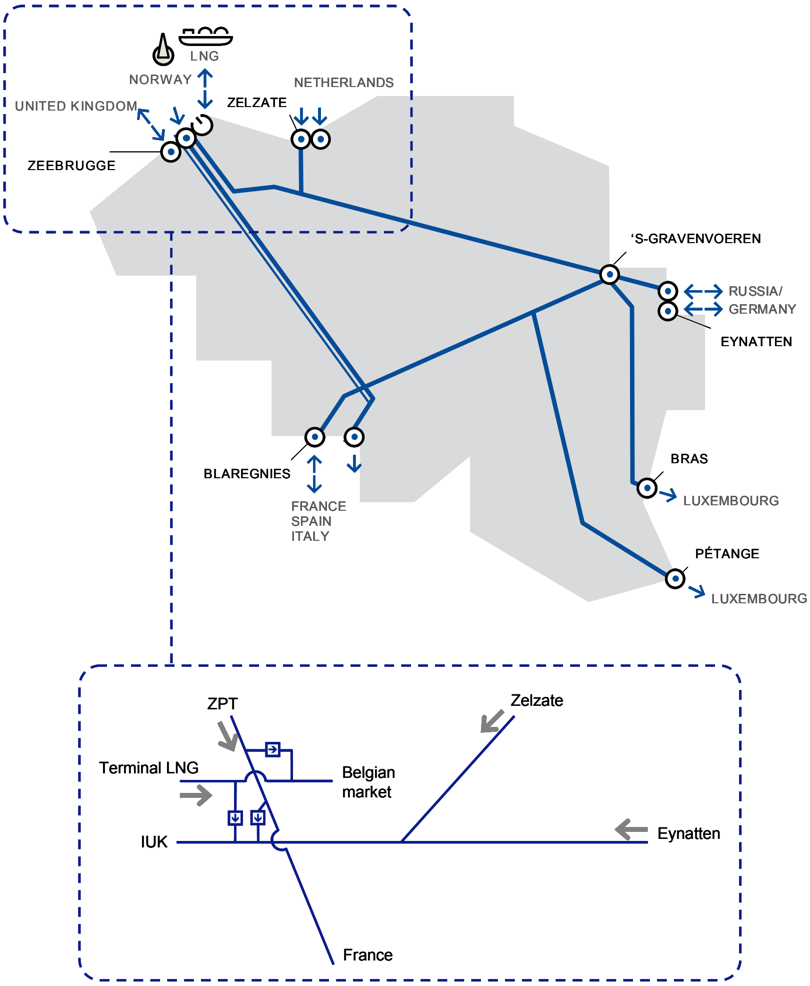
- IUK, which lands at Bacton from Zeebrugge Belgium
- BBL, which also lands at Bacton from Balgzand in the Netherlands
- Langeled, which lands at Easington from the Norwegian gas fields
- Vesterled, which lands at St. Fergus from the Norwegian gas fields.

The following subsections provide a high level overview of the gas transport infrastructure for these source countries, outlining any quality and/or flow issues. We then consider the quality of LNG sources, before concluding which pipelines to Britain this assessment will focus on.

2.2.1 Belgium

Figure 2.3 depicts the Belgian natural high-caloric gas (H-gas) network. For this assessment we have ignored the low-calorific (L-gas) network as only H-gas will flow to the GB gas network.

Figure 2.3: The Belgian Gas Network & Simplified Network Configuration



Source: Fluxys

The main pipeline from the Belgian natural gas network to the UK is IUK, providing a bi-directional link between the Zeebrugge hub and Bacton in the UK . It comprises compression terminals at Bacton and Zeebrugge connected by 235 kilometres of pipeline. Currently, it is capable of annually transporting 25.5 billion cubic metres of gas from Zeebrugge to Bacton and 20 billion cubic metres in the opposite direction.

Natural gas from the Belgian gas network can be shipped to the UK from four main sources:

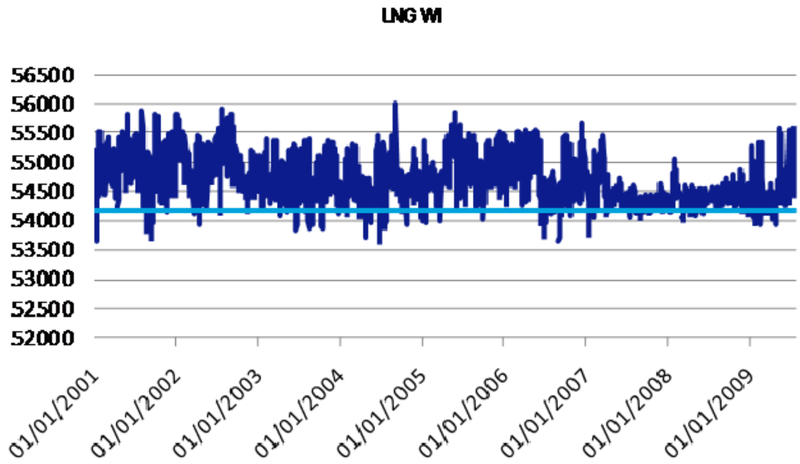
- **LNG terminal** at Zeebrugge
- **Zeepipe,** a 814 kilometre pipeline, which connects the Norwegian Sleipner gas production fields in the North Sea with the Zeepipe Terminal (ZPT) in Zeebrugge
- **Eynatten** pipelines which link the network at Eynatten with Germany and Russia, with entry capacity principally booked for transit through the bi-directional VTN pipeline to Zeebrugge
- **Zelzate**, from 2010 a pipeline from the Netherlands will also be available for entering gas into the VTN and hence this gas will be available for shipping to the UK.

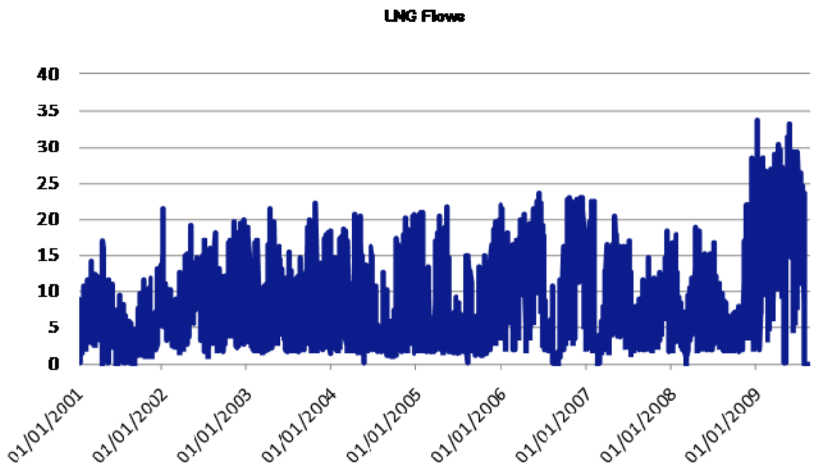
The Zeebrugge LNG terminal and the Belgian gas transit and transport network are owned and operated by Fluxys LNG and Fluxys respectively.

Fluxys has an obligation to ensure that all gas entering the VTN pipeline meets GS(M)R specification and hence has to be able to monitor and shut off supplies from any of the four points which do not meet this gas quality specification.

Figures 2.4, 2.5 and 2.7 presents the quality (on the basis of the 'normal' Wobbe Index[2]) and volumes of gas from the three current principal sources from the beginning of 2001 to mid-2009. For the quality figures, the light blue line represents the upper limit of the GS(M)R.

Figure 2.4: Zeebrugge LNG Quality & Flows





Source: Fluxys

For LNG, the quality of the gas landing in Zeebrugge appears to be generally constant, although above the upper GS(M)R limit.

LNG flows into Zeebrugge have exhibited generally constant quality, although in more than 90% of cases this is above the upper GS(M)R limit with relatively stable volumes although some recent increases in 2009.

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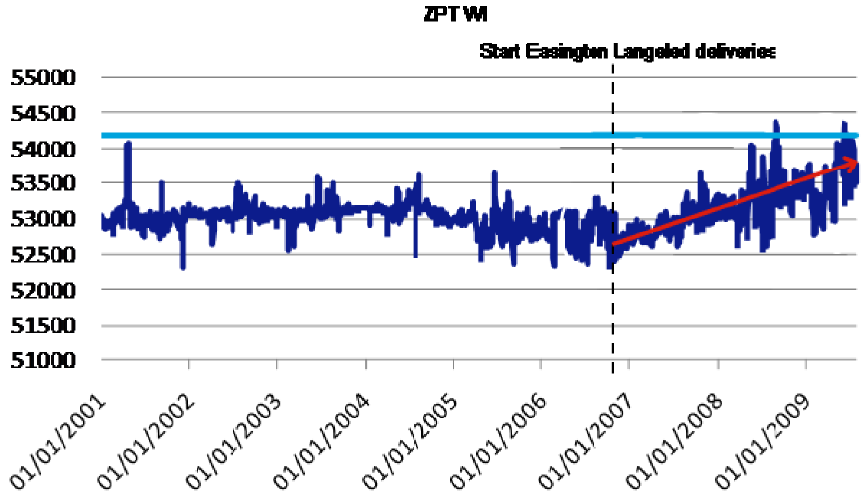
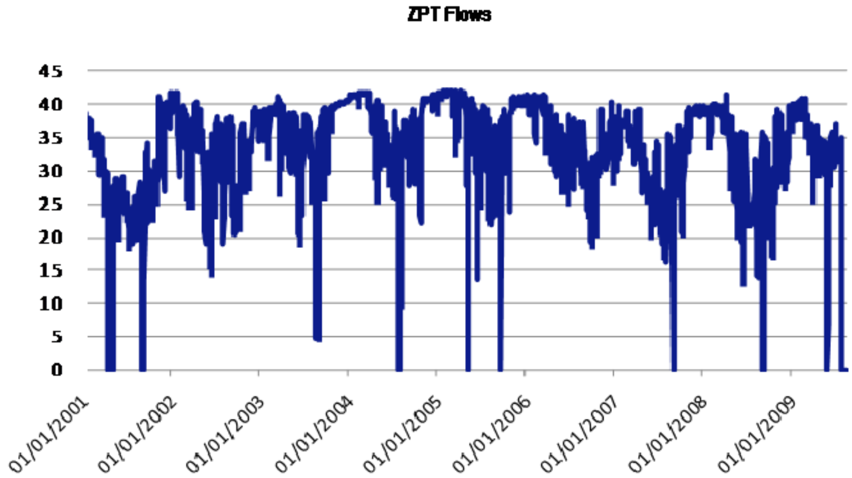
[2] To convert from the 'standard' to the 'normal' Wobbe Index at 15°C a conversion factor 1.053861 is applied (i.e. 1.054915 to convert from standard to normal cubic metres divided by 1.001 to reflect the difference in reference temperature). The 'normal' Wobbe Index under normal circumstances has a range of 49.79 to 54.23.

Figure 2.5: ZPT Quality & Flows

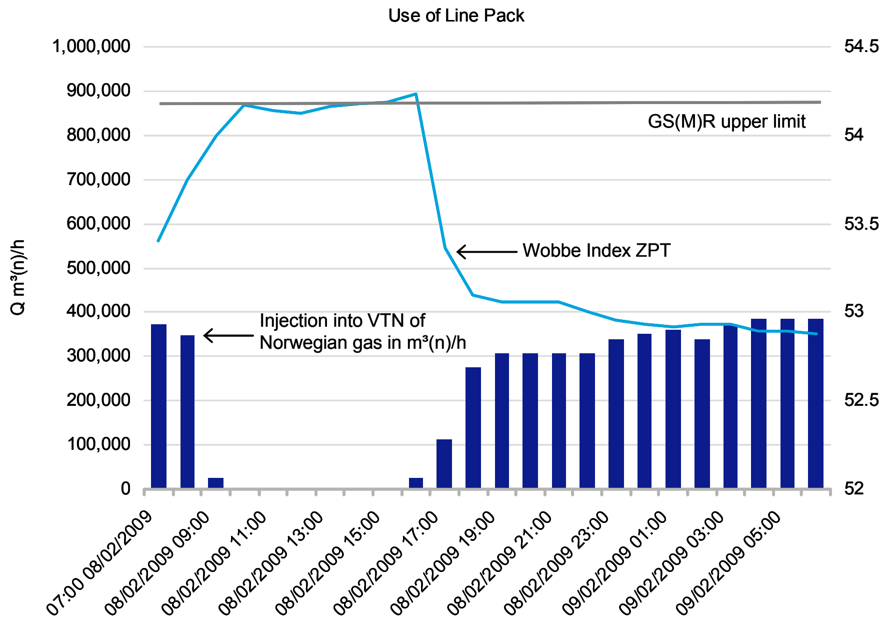




Source: Fluxys

Although Norwegian gas flows into the Belgian gas network are relatively stable, the quality of such flows has become more erratic and been on a noticeable upwards trend since 2006. On at least two recent occasions, flows breached the GS(M)R limit, meaning there was no Norwegian gas flows on to the VTN pipeline, with line pack required to meet Britain's demand requirements. Figure 2.6 illustrates the second episode on 8 February 2009.

Figure 2.6: Impact of ZPT Gas Quality on VTN

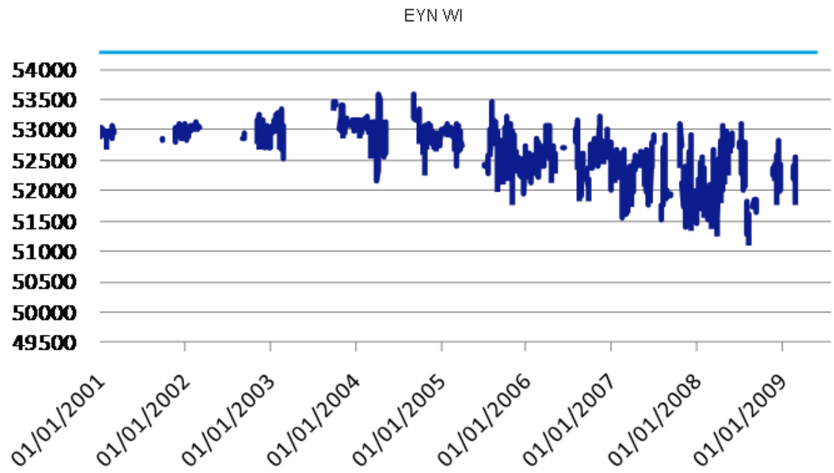


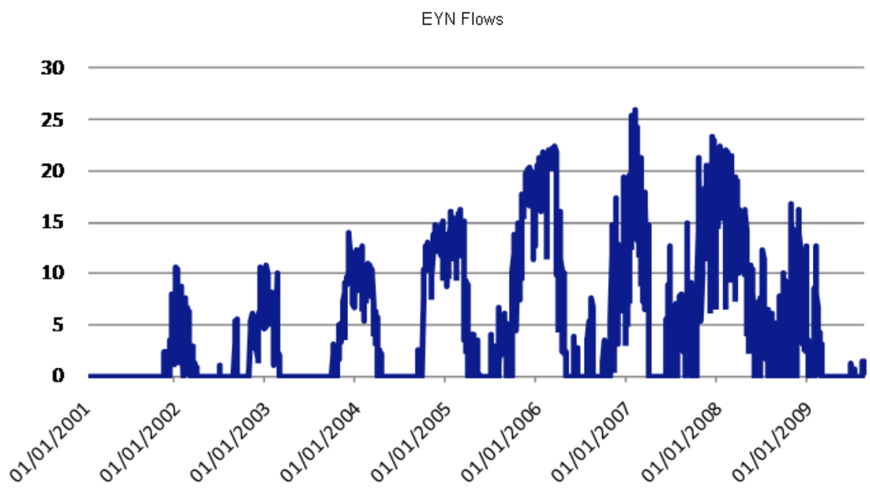
Source: Fluxys

Figure 2.6 highlights the potential pressure that having Norwegian gas above the GS(M)R limit can place on the VTN pipeline, and line pack in particular, as a means of meeting Britain's gas import requirements. On 8 February 2009, the Wobbe Index of the Norwegian gas from the Zeepipe increased sharply, even breaching Britain's upper GS(M)R limit at one point. As a result, there were no Norwegian gas flows into the VTN pipeline for several hours.

When such situations occur, the Belgian TSO is entitled to curtail the flow since the Zeeplatform is operated at British specifications, but Fluxys has so far maximised the use of its installations as well as exceptionally its linepack to meet gas shippers nominations toward the UK. For the above case, gas flows were not curtailed. However, if such situation occurred on a peak day, or Norwegian gas remained above the relevant thresholds for longer, the Belgian TSO might not have been able to meet Britain's gas requirements.

Figure 2.7: Eynatten Quality and Flows





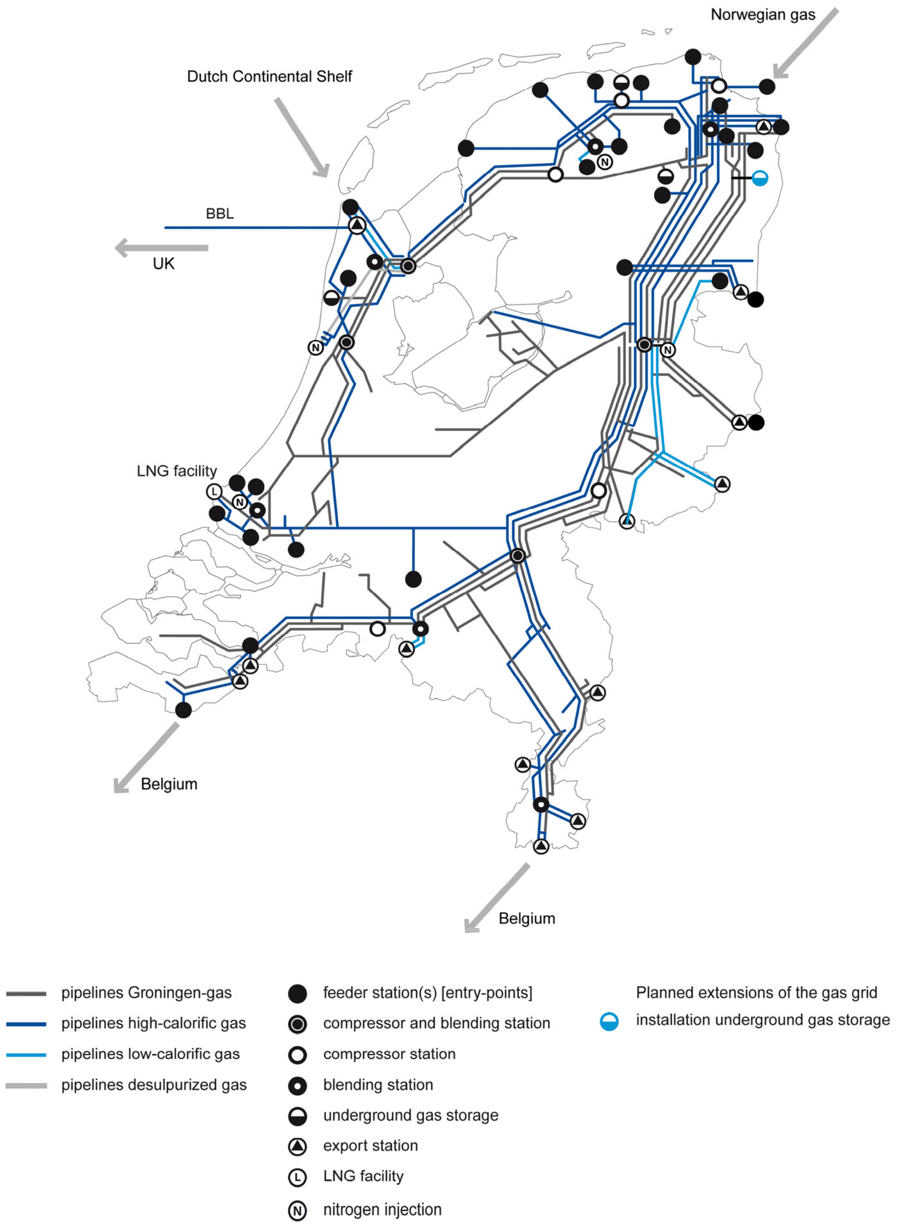
Source: Fluxys

Note: The flows graph represents volumes physically entering the VTN pipeline (i.e. the sum of both Eynatten cross-border points) and available for transit towards the Zeebrugge area. Netted-off flows towards Germany are not displayed.

Eynatten gas flows have become increasingly erratic, both in quality and volume terms, although quality is within the GS(M)R specifications. It is unclear what impact Nord Stream flows through both the Wingas and E.ON Gas Transport systems in Germany will have on this in the future.

2.2.2 The Netherlands

Figure 2.8: The Dutch Gas Network



Source: GTS

The main pipeline from the Dutch H-gas network to the UK is BBL. It comprises a 235 kilometre pipeline between Balgzand in the Netherlands and Bacton in the UK.

Gas from the Dutch network can be shipped to the UK primarily from the Dutch Continental Shelf production and possibly from Norwegian imports via Germany, although we can not be certain of this due to confidentiality of many supply contracts. Currently, gas from the Netherlands meets the GS(M)R specifications but future sourcing arrangements could alter this. GTS has indicated and is confident that Dutch gas production will remain within British specifications until 2020, with the TSO's forecasts showing this to be the case.

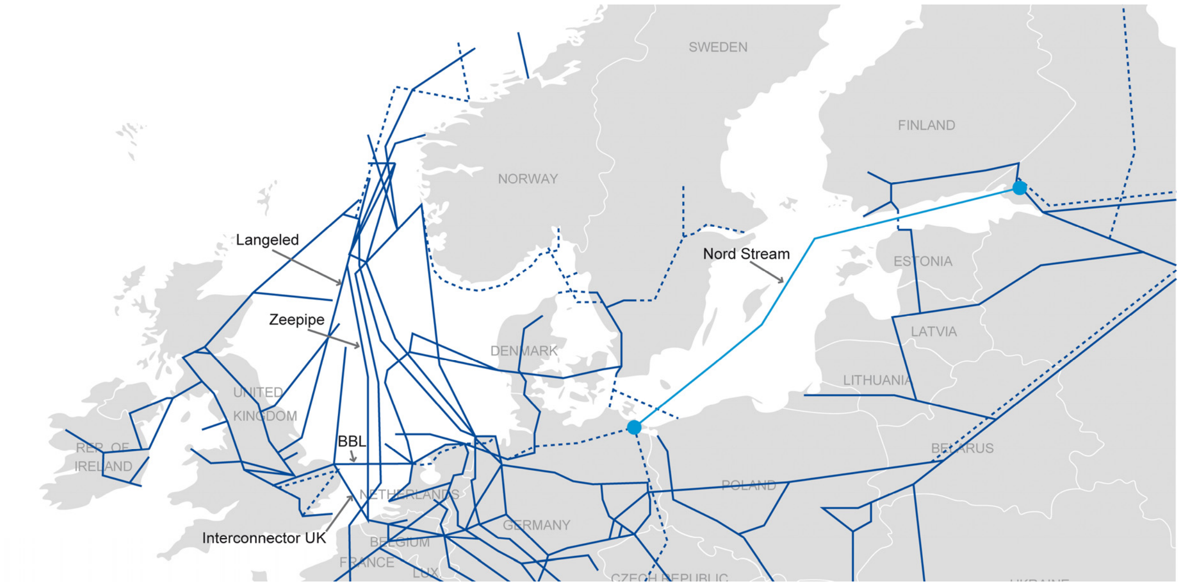
If problems occur with Dutch production, due to a high degree of leverage in terms of managing gas quality going through BBL, GTS can divert Norwegian gas. Norwegian gas has so far remained within British specifications, although there are uncertainties as to whether this will continue in the future.

In terms of future sources, LNG and Russian gas will be delivered from 2012 and 2014 onwards. Indications are LNG delivered at Rotterdam and Russia gas arriving via Nord Stream will be routed south to Belgium provided these meet the quality required by Fluxys unless problems occur with Dutch production.

Nord Stream

Nord Stream is a natural gas pipeline linking Russia with continental Europe via the Baltic Sea. It will be 1,220 kilometres long consisting of two parallel lines. The first pipeline, which is due for completion in 2011, will have transmission capacity of around 27.5 billion cubic metres a year. The second, due for completion a year later in 2012, will double annual capacity to 55 billion cubic metres. The pipelines will deliver gas produced and supplied by Gazprom. Most of the gas to be supplied via Nord Stream will come from the Yuzhno-Russkoye oil and gas field, with additional gas from fields on the Yamal Peninsula, in Ob-Taz Bay and Shtokmanovskoye. Indications are that this gas is likely to have a high Wobbe Index.

Figure 2.9: The Nord Stream pipeline

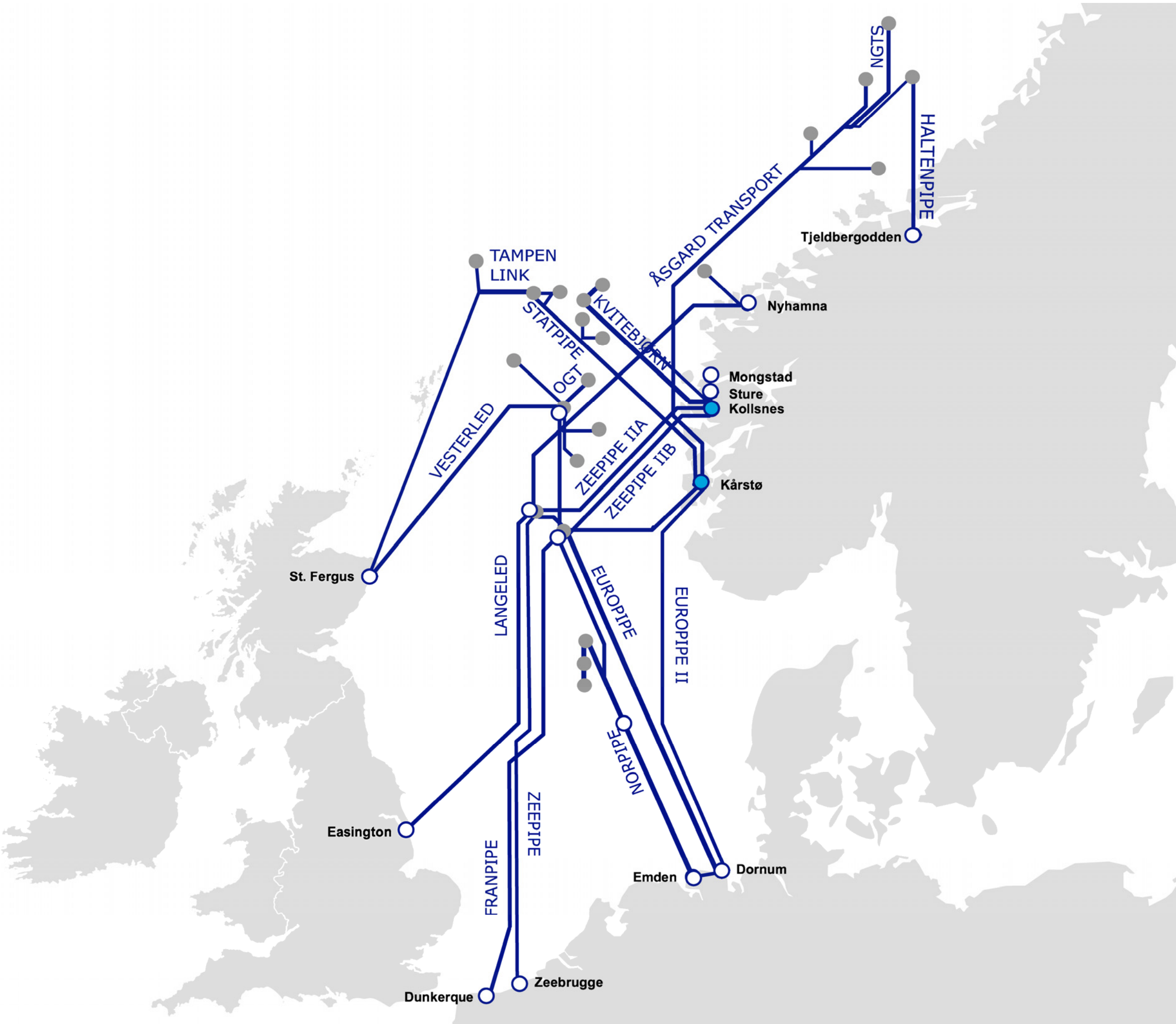


Source: Nord Stream

Gas from Nord Stream will go south via OPAL to Olbernau and west via NEL to Achim. The effects of this are likely to be that at Bunde gas will have been blended with leaner Norwegian gas to give something close to the GS(M)R limit but it is not clear whether at Eynatten the Wobbe could be above the GS(M)R limit.

2.2.3 Norway

Figure 2.10: Norwegian Gas Pipelines



Source: Gassco

The main gas pipelines from the Norwegian gas fields to Britain are:

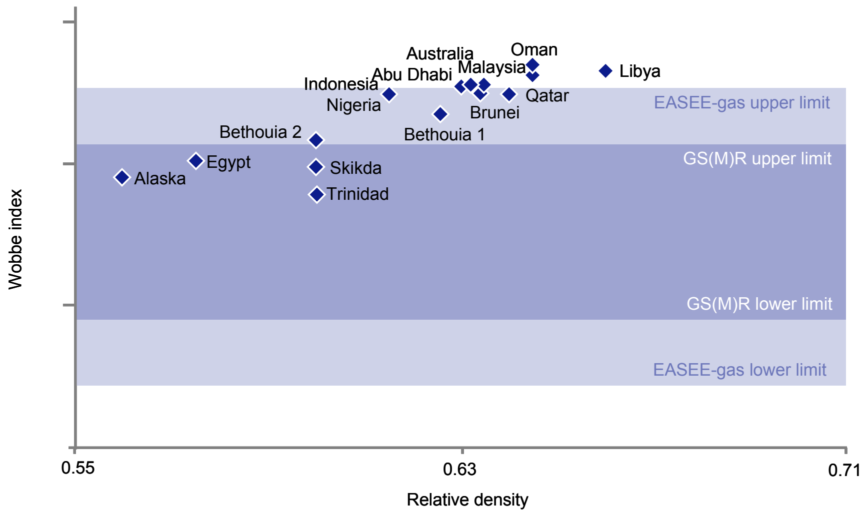
- Vesterled, a 361 kilometre pipeline from the Heimdal Riser platform to St. Fergus in Scotland, and
- Langeled, a 1,166 kilometre pipeline from the Ormen Lange field to Easington on the east coast of England.

Vesterled has historically met GS(M)R specifications although fields in the Heimdal area rely on blending for St. Fergus entry. Gas from Ormen Lange is close to the GS(M)R upper limit, relying on daily blending with Kollsnes and Sleipner production and has back-up ballasting arrangements for nitrogen blending. For the purposes of this assessment, it is assumed Norwegian gas landing in Britain via these pipelines will remain within GS(M)R limits for the foreseeable future.

2.2.4 LNG

Sourced from a wide range of countries, most LNG has a Wobbe Index which is well above the upper GS(M)R limit, as illustrated in Figure 2.11.

Figure 2.11: LNG Gas Quality by Source



Source: Interconnector

LNG therefore requires processing to meet this limit. To address this, LNG import facilities in Britain are built with their own ballasting facilities to ensure the GS(M)R limit is met. However, due to the wider specifications of the Continent, LNG landing in Zeebrugge does not require as rigorous processing, with gas sourced from Qatar, for example, being within the EASEE-gas upper limit, but not Britain's GS(M)R.

2.3 Importance of IUK and BBL

For the purposes of this assessment, we believe it is reasonable to consider the following gas supplies to Britain will be within the GS(M)R limits:

- Supplies from the UKCS (although some new and existing UKCS supplies may have gas quality constraints due to limited terminal blending gas)
- British LNG import facilities, which have nitrogen ballasting capability
- Norwegian imports through Langeled, which also have nitrogen ballasting capability
- Vesterled flows, which have historically always met GS(M)R limits.

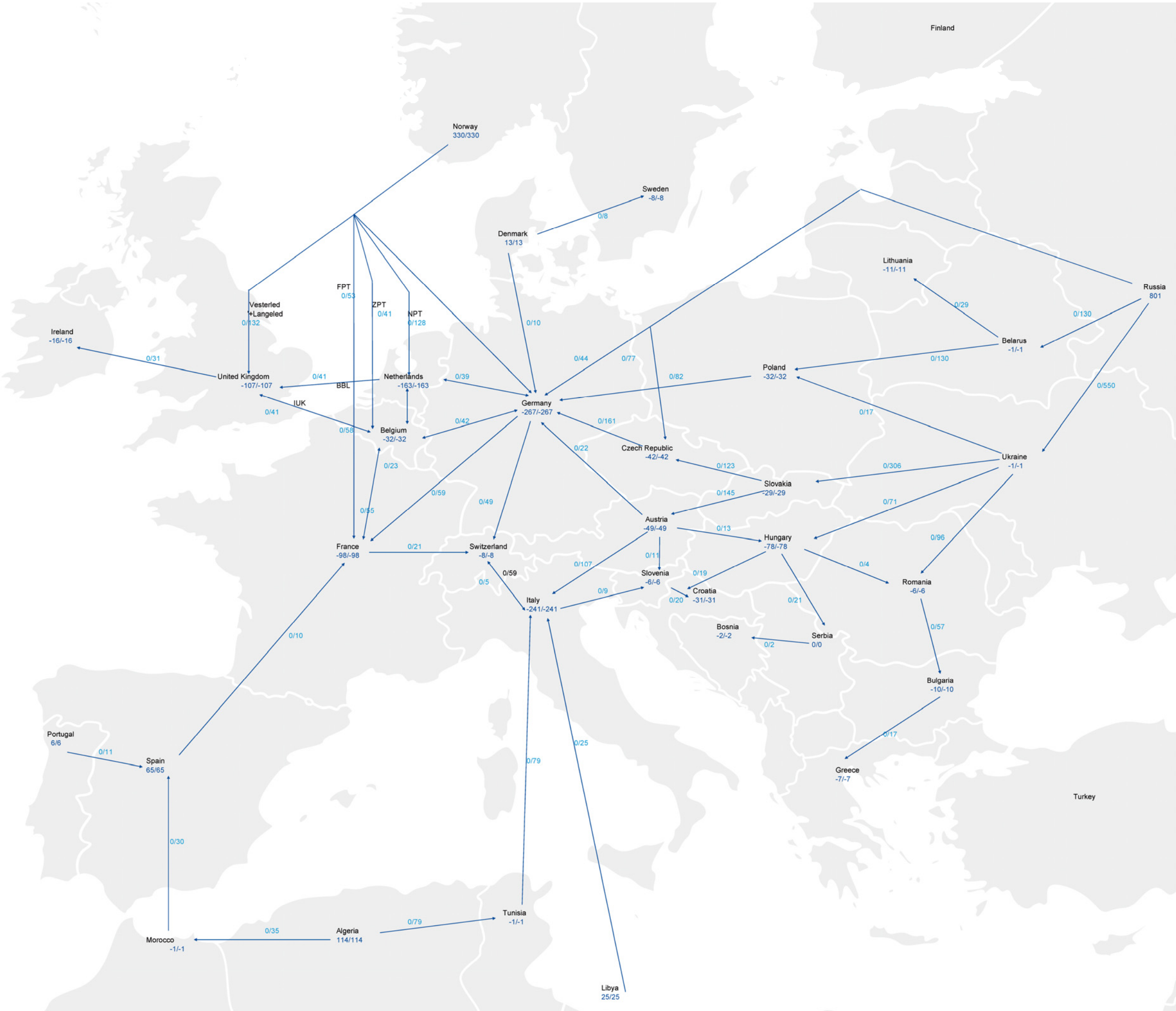
This leaves IUK and BBL as the primary source of concern with regards to gas quality restrictions on gas entering the GB network. IUK is directly connected to the VTN pipeline in Belgium, which in turn connects to the Wingas pipeline across Germany from Mallnow. As all of the IUK, BBL and VTN pipelines operate within GS(M)R limits and would, for both contractual and safety reasons, seek to shut off rather than accept gas outside of GS(M)R limits, changes in the sources of supply for these pipelines could have a detrimental impact on gas quality. The two pipelines delivering gas to the UK will therefore be the focus of this assessment.

3 PA's European Gas Flow Model

In this section we provide an overview of PA's European Gas Flow Model (EGFM), highlighting its main characteristics and how the model has been developed to consider gas quality issues and flows, particularly in Belgium and the Netherlands. We then outline the various data sources we have utilised for this assessment.

3.1 Overview

Figure 3.1: PA's European Gas Flow Model



Source: PA Consulting Group

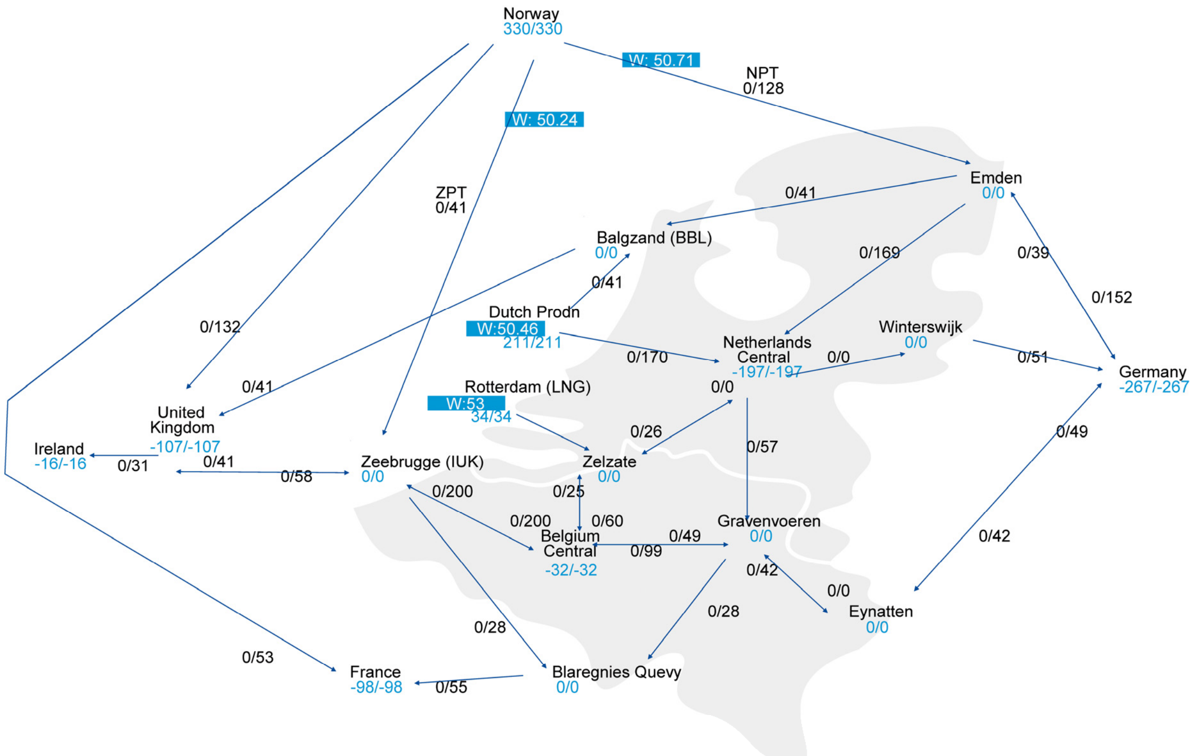
PA's EGFM is a nodal flow model which approximates European gas flows for a simulated day. PA believes there are compelling reasons to utilise the EGFM to conduct this analysis:

- It is intuitive, transparent and easy to understand
- It produces an accurate simulation of gas flows and can easily be adjusted to operate under a range of scenarios and different underlying assumptions
- It has been developed independently by PA.

The model calculates each country's net import requirement allowing for LNG deliverability, storage deliverability, domestic production and demand. The model then flows gas from each country that is net long to the neighbouring country that has received the least amount of gas in proportion to its total gas demand, allowing for interconnector capacity constraints. The model continues to flow gas around the network until the net position of each country is enough to meet its net import requirement. Figure 3.1 provides a simplified representation of the model.

For the purposes of modelling gas quality issues more closely and to consider gas flows to Britain from North-West Europe, the model includes the internal gas flows of Belgium and the Netherlands. This 'micro' component of the model enables the different qualities of different sources of gas flowing to these countries to be combined to produce the quality of gas flowing to Britain across the IUK and BBL pipelines. This smaller component of the model replaces the Belgian and Dutch nodes of the wider 'macro' version of the model, as illustrated in Figure 3.2.

Figure 3.2: The 'micro' component of PA's European Gas Flow Model



Source: PA Consulting Group

For this assessment, the EGFM was constructed to reflect 2009 and 2014 (i.e. in five years' time) capacities of the European gas network across all 27 EU member state countries taking into account all current and planned LNG terminals, gas pipelines, gas storage facilities as well current and projected domestic gas production. It also takes into account current and future gas demand for each member state. In addition, the model also includes gas flows into Europe from Norway, Russia and North Africa.

All current and planned LNG terminals, gas pipelines and gas storage facilities are sourced from the GTE+ Demand Scenarios vs. Capacity Report 2009.

Consistent with standard industry estimates, Average Winter's Day demand is calculated at 80% of peak demand, where Peak Winter's Day demand has been derived by the TSO in each respective country. For the Peak Winter's Day demand, it is assumed only countries in Northern Europe (i.e. Austria, Belarus, Belgium, the Czech Republic, Denmark, France, Germany, Irelands, the Netherlands, Poland, Romania, Slovakia, Switzerland, Ukraine and the United Kingdom) have peak demand. This is to allow for the fact that not all European countries will experience their peak demand at the same time.

Peak demand is sourced from the GTE+ Demand Scenarios vs. Capacity Report 2009 and represents the demand scenarios applied by the TSO (or other relevant body) in each EU member state. For the GTE+ report, TSOs were asked to derive an appropriate peak scenario on the basis of relevant publicly available information and its expertise on the relationship between yearly consumption and peak day consumption in the respective country.

PA's model represents the H-gas network. Dutch gas for conversion to L-gas is added to the Dutch demand for H-gas.

Gas quality at each node is calculated as a volume weighted average of the volumes entering a given node and the associated Wobbe Index of the gas.

3.2 Data sources

The data and sources we have utilised for this exercise are set out in Appendix A.

4 Scenarios

In this section we outline and describe the scenarios we have constructed in order to forecast the volumes and quality of gas likely to flow into the British market from continental Europe and the limitations, if any, on the amount of gas able to flow to the UK.

4.1 Overview

PA developed a number of realistic scenarios to assess the gas quality issue, as illustrated in Table 4.1:

Table 4.1: Scenarios

	Average Winter's Day		Peak Winter's Day	
	2009	2014	2009	2014
Base	●	●	●	●
Low LNG	-	●	-	●
Low Langeled	-	●	-	●
Base - High ZPT	-	●	-	●
Low LNG - High ZPT	-	●	-	●
Low Langeled - High ZPT	-	●	-	●

Source: PA Consulting Group

Overall, the scenarios were developed to understand:

- The volumes of gas likely to flow into the GB market from continental Europe
- The quality of such gas
- The limitations, if any, on the amount if gas which is able to flow to Britain.

4.2 Scenario descriptions and assumptions

4.2.1 Base

The 'Base' Scenario is built on the 2009 and 2014 flows taken from the GTE+ Demand Scenarios versus Capacity Report. 2009 is used to calibrate the model against current flows as described in recent TSO (i.e. National Grid) documentation while 2014 is used to model the most likely outcome over the medium term.

The 'Base' Scenario assumes the following:

- New LNG destined for the terminal in Rotterdam in 2012 will be diverted by the Dutch TSO, GTS, south via Zelzate to the Belgian border
- Norwegian gas destined for the Zeebrugge hub through ZPT is within the GS(M)R upper limit
- Nord Stream gas is above the GS(M)R upper limit
- Flows towards the UK via BBL are met by Dutch Continental Shelf production
- A high level of LNG imports to the UK producing only modest requirements for pipeline imports from continental Europe.

A 'Base - High ZPT' scenario was also constructed with the same assumptions as above, aside from Norwegian gas destined for ZPT in Zeebrugge via the Zeepipe pipeline is assumed to be above the GS(M)R upper limit, not below it. We have not considered the position with regard to this in 2009 although we are aware that in these circumstances there could be a shortage of gas available for IUK.

4.2.2 Low LNG

The 'Low LNG' scenario was simulated for 2014 and differs from the 'Base' scenario in that all 'discretionary' (i.e. not contracted) LNG for the UK, Belgium and the Netherlands is diverted to alternative markets, under the assumption there is stronger LNG demand resulting in higher prices outside of continental Europe. This creates a supply shortfall for Britain which is met through alternative sources from continental Europe and a greater dependence on IUK and BBL.

A 'Low LNG - High ZPT' scenario was also constructed to simulate gas quality above the upper GS(M)R limit for flows via ZPT to Zeebrugge.

4.2.3 Low Langeled

This scenario, again simulated for 2014, represents high nominations of Norwegian gas contracted for the continental European markets leading to a reduction in the amount of gas available for Britain.

A 'Low Langeled - High ZPT' was also constructed on the same basis as the other 'High ZPT' scenarios.

5 Modelling results

In this section we set out how to interpret the results from the scenario modelling by considering the UK's Net Import Requirement from continental Europe and by introducing the concept of 'GS(M)R compliant gas'. We then present the results for each scenario, identifying whether or not there is shortfall of gas due to gas quality constraints.

5.1 'GS(M)R compliant gas' and gas quality considerations

To interpret the results from our scenario modelling, it is important to consider the UK's Net Import Requirement of gas from continental Europe. This figure represents how much gas is required from IUK and BBL to keep the UK in supply demand balance, after supply from Norwegian gas fields, storage, LNG and UKCS production are taken into account.

Once it is established how much gas the UK requires from continental Europe, the next step is to consider where this gas will come from, and the quality of these sources. A useful concept to consider this issue is 'GS(M)R compliant gas' i.e. gas that is available through BBL and IUK for the UK and lies within the GS(M)R limit.

To work out how much 'GS(M)R compliant gas' is available for the UK we must consider the sources of gas supplying BBL and IUK.

BBL is most likely to be supplied by Dutch Continental Shelf production and GTS is confident this gas will be within GS(M)R limits until at least 2020, with the TSO's forecasts supporting this view. Should Dutch domestic production not be available to meet BBL demand, GTS has the flexibility to divert Norwegian gas to meet BBL requirements. Norwegian gas flowing into the Netherlands has historically been within GS(M)R upper limit and its Wobbe Index has remained constant and not increased in the same manner as Norwegian flows through Zeepipe to Zeebrugge. GTS also has the option of diverting Nord Stream gas (subject to quality) through to BBL. Therefore the daily volume of 'GS(M)R compliant gas' available from BBL is most likely to be equivalent to its full capacity of 41 million cubic metres.

Under the 'Base', 'Low LNG' and 'Low Langeled' scenarios we assume that Norwegian gas flowing through Zeepipe to Belgium will be within GS(M)R specifications. Fluxys is able to divert this gas to meet IUK requirements so it is likely that 41 million cubic metres per day of 'GS(M)R compliant gas' will also be available from IUK under these scenarios.

Belgian gas imports from the Netherlands and Germany are unlikely to be available to IUK as these may be restricted due to gas quality constraints. Due to high quality, LNG landing in Rotterdam is likely to be diverted south to the Belgian border. Similarly, Nord Stream gas is also likely to be above GS(M)R specifications and also diverted south to the Belgian border by GTS although this gas may not be accepted by Fluxys. Although existing gas flows from Eynatten are within GS(M)R specifications, these flows are becoming more dependent on the price difference between Zeebrugge hub, Net Connect Germany and Gaspool. In addition, there is the possibility that higher quality Nord Stream gas will make its way through the German system to Eynatten and onto the Belgian network but the impact of this is unclear. Therefore it is possible Fluxys will only have the option of using Norwegian gas from Zeepipe to meet IUK requirements. The models assume that there will be sufficient gas entering Belgium.

A combined total of 82 million cubic metres per day from BBL and IUK of 'GS(M)R compliant gas' is therefore available from the Continent to meet UK demand. It can therefore be assumed that if the UK's Net Import Requirement is less than 82 million cubic metres per day, there will be no gas quality constraints. If the UK's Net Import Requirement is above 82 million cubic metres per day then increased volumes will need to be sourced from Norwegian gas production, storage, LNG and UKCS production leading to an increase in wholesale gas prices to the GB market.

Under the 'High ZPT' scenarios, it is assumed that Norwegian gas through Zeepipe is above GS(M)R upper limit and will not be available to meet IUK flow requirements. Therefore the daily volume of 'GS(M)R compliant gas' from the Continent reduces to only the gas available from BBL, i.e. 41 million cubic metres per day. Under these scenarios, if the UK's Net Import Requirement is less than 41 million cubic metres per day, there will be no gas quality constraints. If the UK's Net Import Requirement is above 41 million cubic metres per day, then increased volumes will need to be sourced from Norwegian gas production, storage, LNG and UKCS production, leading to an increase in wholesale gas prices to the GB market.

Table 5.1 sets out the 'GS(M)R compliant gas' daily volumes under the various scenarios we have constructed.

Table 5.1: 'GS(M)R Compliant Gas' Daily Volumes Summary

Scenarios	TOTAL mcm(s)/d	BBL mcm(s)/d	IUK mcm(s)/d
'Base', 'Low LNG' & 'Low Langeled' scenarios	**82**	**41**	**41**
'High-ZPT' scenarios	**41**	**41**	**0**

Source: PA Consulting Group

5.2 Scenario results

5.2.1 Base

Results from the 'Base' scenario show that for both 2009 and 2014 the UK's Net Import Requirement for both the Peak and Average Winters' Day scenarios is less than the 82 million cubic metres of 'GS(M)R compliant gas' available from continental Europe through IUK and BBL.

Table 5.2: Base Results

		Base Scenario 2009		Base Scenario 2014	
		Average Winter	Peak	Average Winter	Peak
Demand					
GB Demand	mcm(s)/d	414	518	438	548
Exports to Ireland	mcm(s)/d	17	20	16	22
Total Demand UK	mcm(s)/d	431	538	454	570
Supply					
UK - LNG	mcm(s)/d	71	88	141	163
UK - Storage	mcm(s)/d	42	103	42	135
UK - Production	mcm(s)/d	202	202	126	126
Norwegian Imports	mcm(s)/d	85	124	122	127
Total Supply (Less Continent)	mcm(s)/d	400	517	431	551
Net Import Requirement (From Continent)		32	21	23	18
BBL Flows	mcm(s)/d	35	35	41	41
Wobbe Index	MJ/m3 (s)	50.13	50.13	50.13	50.13
IUK Flows	mcm(s)/d	-3	-14	-17	-23
Wobbe Index	MJ/m3 (s)	-	-	-	-
UK Net Position	mcm(s)/d	0	0	0	0
Belgian Wobbe	mcm(s)/d	51.79	51.50	52.20	51.81

Source: PA Consulting Group

Under the 2009 Average Winter's Day scenario, the UK has a Net Import Requirement from the Continent of 32 million cubic metres. With BBL flowing at capacity of 35 million cubic metres, this leads to an excess of 3 million cubic metres which is diverted back to the Continent through IUK. With the Net Import Requirement of 32 million cubic metres being less than the 82 million cubic metres of 'GS(M)R compliant gas' available, there is unlikely to be any gas quality issues on an Average Winter's Day in 2009.

With storage available to flow at peak capacity, the 2009 Peak Winter's Day scenario shows a Net Import Requirement for the UK of 21 million cubic metres. Again this is less than the 82 million cubic metres of 'GS(M)R compliant gas' available and there is unlikely to be any gas quality issues under this scenario. Again BBL flows at capacity of 35 million cubic metres with the excess of 14 million cubic metres being diverted back to the Continent via IUK.

Under an Average Winter's Day in 2014, the Net Import Requirement for the UK is only 23 million cubic million metres and again this demand is met comfortably by BBL. Excess gas of 17 million cubic metres is again diverted to the Continent.

On a Peak Winter's Day in 2014, the UK's Net Import Requirement is 18 million cubic metres. This figure is again less than the 82 million cubic metres of 'GS(M)R compliant gas' available and is easily met from gas supplies from BBL and also this time with flows of 23 million cubic metres from IUK.

Gas quality considerations

For the 'Base' scenario, for both 2009 and 2014, BBL gas quality, sourced directly from Dutch domestic production, has a Wobbe Index value of 50.13. This is based on the annual average Wobbe Index value of Dutch domestic production for 2008 which is assumed to remain at this level for 2009 and 2014. Flows though IUK towards the Belgian market are assumed to be within GS(M)R specifications as these flows originate in the UK.

Flows through IUK towards the UK market are assumed to originate from Zeepipe in Belgium and thus the quality of this gas of 50.13 is in line with Norwegian flows through this pipeline. For gas flowing from the UK towards Belgium via IUK is within GS(M)R limits.

Belgian flows from Zelzate and Eynatten are unable to flow through to the UK due to gas quality constraints on both Average and Peak Winters Days. Gas flows through Zelzate are a mixture of high Wobbe LNG from Rotterdam, possibly high quality Nord Stream gas, within specification Norwegian gas and Dutch local production. Eynatten flows, although possibly small given their erratic pattern, are also mixed with higher specification Nord Stream gas leading to an uncertain availability for flows to the UK.

Overall, under the 'Base' scenario there are unlikely to be any gas quality implications due to an excess availability of 'GS(M)R compliant' gas from continental Europe above the UK's Net Import Requirements.

5.2.2 Low LNG

Under the 'Low LNG' scenario, LNG supplies for the UK, Zeebrugge and Rotterdam are reduced to reflect increased demand resulting in higher prices being paid for LNG gas in other world markets (i.e. Asia and/or North America). On an Average Winter's Day, the UK has a reduction of 45 million cubic metres to 96 million cubic metres, whilst on a Peak Winter's Day, there is a reduction of 67 million cubic metres to 96 million cubic metres. On both Average and Peak Winters Days, Zeebrugge and Rotterdam supplies are reduced from 40 million cubic metres to 20 million cubic metres, and 34 million cubic metres to 17 million cubic metres respectively.

Table 5.3: Low LNG Results

		Base Scenario 2014		Low LNG 2014	
		Average Winter	Peak	Average Winter	Peak
Demand					
GB Demand	mcm(s)/d	438	548	438	548
Exports to Ireland	mcm(s)/d	16	22	16	22
Total Demand UK	mcm(s)/d	454	570	454	570
Supply					
UK - LNG	mcm(s)/d	141	163	96	96
UK - Storage	mcm(s)/d	42	135	42	135
UK - Production	mcm(s)/d	126	126	126	126
Norwegian Imports	mcm(s)/d	122	127	127	127
Total Supply (Less Continent)	mcm(s)/d	431	551	391	484
Net Import Requirement (From Continent)		**23**	**18**	**63**	**85**
BBL Flows	mcm(s)/d	41	41	41	41
Wobbe Index	MJ/m3 (s)	50.13	50.13	50.13	50.13
IUK Flows	mcm(s)/d	-17	-23	22	41
Wobbe Index	MJ/m3 (s)	-	-	50.24	50.24
UK Net Position	mcm(s)/d	**0**	**0**	**0**	**-3**
Belgian Wobbe	MJ/m3 (s)	52.20	51.81	51.81	51.73
LNG to Zeebrugge	mcm(s)/d	40	40	20	20
LNG to Rotterdam	mcm(s)/d	34	34	17	17
Maximum Flows on Langeled	mcm(s)/d	72	72	72	72

Source: PA Consulting Group

Under an Average Winter's Day in 2014, the UK's Net Import Requirement increases to 63 million cubic metres. With this being less than the 82 million cubic metres of 'GS(M)R compliant gas' available, it is again unlikely that gas quality constraints will affect the GB market.

For a Peak Winter's Day in 2014, the UK's Net Import Requirement increases to 85 million cubic metres. With this being above the 82 million cubic metres of 'GS(M)R compliant gas' available through BBL and IUK, this 3 million cubic metres of extra gas will need to be found.

5.2.3 Low Langeled

Under the 'Low Langeled' scenario, flows on Langeled are reduced to maximum of 20 million cubic metres per day. This is to reflect a possible reduction of flows available through Langeled as a result of Norwegian gas which is contracted to continental Europe being nominated at high levels.

Table 5.4: Low Langeled Results

		Base Scenario 2014		Low Langeled 2014	
		Average Winter	Peak	Average Winter	Peak
Demand					
GB Demand	mcm(s)/d	438	548	438	548
Exports to Ireland	mcm(s)/d	16	22	16	22
Total Demand UK	mcm(s)/d	454	570	454	570
Supply					
UK - LNG	mcm(s)/d	141	163	141	163
UK - Storage	mcm(s)/d	42	135	42	135
UK - Production	mcm(s)/d	126	126	126	126
Norwegian Imports	mcm(s)/d	122	127	82	82
Total Supply (Less Continent)	mcm(s)/d	431	551	391	506
Net Import Requirement (From Continent)		**23**	**18**	**63**	**63**
BBL Flows	mcm(s)/d	41	41	41	41
Wobbe Index	MJ/m3 (s)	50.13	50.13	50.13	50.13
IUK Flows	mcm(s)/d	-17	-23	23	22
Wobbe Index	MJ/m3 (s)	-	-	50.24	50.24
UK Net Position	mcm(s)/d	**0**	**0**	**0**	**0**
Belgian Wobbe	MJ/m3 (s)	52.20	51.81	52.98	52.31
LNG to Zeebrugge	mcm(s)/d	40	40	40	40
LNG to Rotterdam	mcm(s)/d	34	34	34	34
Maximum Flows on Langeled	mcm(s)/d	72	72	20	20

Source: PA Consulting Group

On an Average Winter's Day in 2014, the UK's Net Import Requirement from the Continent for the UK is 63 million cubic metres, which can be met from the 82 million cubic metres of 'GS(M)R compliant gas' available through IUK and BBL.

For a Peak Winter's Day in 2014, the model shows a UK's Net Import Requirement from the Continent of 63 million cubic metres. This is again below the 82 million cubic metres of 'GS(M)R compliant gas' available.

5.2.4 Base - High ZPT

Under the 'Base - High ZPT Base' scenario, gas flows from Norway, through Zeepipe to Belgium are assumed to be above the GS(M)R upper limit and therefore unavailable for IUK and the UK gas market. With gas flows from the Netherlands above the GS(M)R upper limit and gas from Eynatten also likely to be above the GS(M)R upper limit, this scenario reflects the possible unavailability of gas for the GB market from Belgium. This reduces the volume of 'GS(M)R compliant gas' available from the Continent from 82 million cubic metres to only the 41 million cubic metres of gas available through BBL.

Table 5.5: Base - High ZPT Results

		Base Scenario 2014		High ZPT 2014	
		Average Winter	Peak	Average Winter	Peak
Demand					
GB Demand	mcm(s)/d	438	548	438	548
Exports to Ireland	mcm(s)/d	16	22	16	22
Total Demand UK	mcm(s)/d	454	570	454	570
Supply					
UK - LNG	mcm(s)/d	141	163	141	163
UK - Storage	mcm(s)/d	42	135	42	135
UK - Production	mcm(s)/d	126	126	126	126
Norwegian Imports	mcm(s)/d	122	127	122	127
Total Supply (Less Continent)	mcm(s)/d	431	551	431	551
Net Import Requirement (From Continent)		**23**	**18**	**23**	**18**
BBL Flows	mcm(s)/d	41	41	41	41
Wobbe Index	MJ/m3 (s)	50.13	50.13	50.13	50.13
IUK Flows	mcm(s)/d	-17	-23	-17	-23
Wobbe Index	MJ/m3 (s)	-	-	-	-
UK Net Position	mcm(s)/d	**0**	**0**	**0**	**0**
Belgian Wobbe	MJ/m3 (s)	52.20	51.81	52.57	52.35
LNG to Zeebrugge	mcm(s)/d	40	40	40	40
LNG to Rotterdam	mcm(s)/d	34	34	34	34
Maximum Flows on Langeled	mcm(s)/d	72	72	72	72

Source: PA Consulting Group

Under an Average Winter's Day for 2014, there is no change between the 'Base' and 'High ZPT' scenarios as no flows are required for the UK market from Belgium. Flows from BBL continue to meet the UK's Net Import Requirement and excess gas is diverted back to the Continent through IUK.

On a Peak Winter's Day in 2014, the UK's Net Import Requirement from the Continent is 18 million cubic metres. Again this is below the volume of 'GS(M)R compliant gas' available from the Continent of 41 million cubic metres.

5.2.5 Low LNG - High ZPT

Decreased availability of LNG for the UK, Zeebrugge and Rotterdam, coupled with a restriction of flows on IUK as a result of high Wobbe Zeepipe gas leads to gas quality constraints on the volume of gas entering the GB market on both an Average and Peak Winters Day.

Table 5.6: Low LNG - High ZPT Results

		Base Scenario 2014		Low LNG 2014		Low LNG - High ZPT 2014	
		Average Winter	Peak	Average Winter	Peak	Average Winter	Peak
Demand							
GB Demand	mcm(s)/d	438	548	438	548	438	548
Exports to Ireland	mcm(s)/d	16	22	16	22	16	22
Total Demand UK	mcm(s)/d	454	570	454	570	454	570
Supply							
UK - LNG	mcm(s)/d	141	163	96	96	96	96
UK - Storage	mcm(s)/d	42	135	42	135	42	135
UK - Production	mcm(s)/d	126	126	126	126	126	126
Norwegian Imports	mcm(s)/d	122	127	127	127	127	127
Total Supply (Less Continent)	mcm(s)/d	431	551	391	484	391	484
Net Import Requirement (From Continent)		**23**	**18**	**63**	**85**	**63**	**85**
BBL Flows	mcm(s)/d	41	41	41	41	41	41
Wobbe Index	MJ/m3 (s)	50.13	50.13	50.13	50.13	50.13	50.13
IUK Flows	mcm(s)/d	-17	-23	22	41	0	0
Wobbe Index	MJ/m3 (s)	-	-	50.24	50.24	-	-
UK Net Position	mcm(s)/d	**1**	**0**	**0**	**-3**	**-22**	**-44**
Belgian Wobbe	MJ/m3 (s)	52.20	51.81	51.81	51.73	52.14	51.98
LNG to Zeebrugge	mcm(s)/d	40	40	20	20	20	20
LNG to Rotterdam	mcm(s)/d	34	34	17	17	17	17
Maximum Flows on Langeled	mcm(s)/d	72	72	72	72	72	72

Source: PA Consulting Group

For an Average Winter's Day in 2014, the UK's Net Import Requirement from the Continent is 63 million cubic metres while for a Peak day, the requirement is 85 million cubic metres. As these values are above the 41 million cubic metres of ' GS(M)R compliant gas' available from BBL, there is a potential shortfall of gas to the UK

5.2.6 Low Langeled - High ZPT

With decreased volumes of gas available though Langeled, and also through IUK, there are significant reductions in gas available for the GB market.

On an Average Winter's Day in 2014, the UK's Net Import Requirement under this scenario is 63 million cubic metres, resulting in a potential shortfall of 22 million cubic metres for the UK gas market.

On a Peak Winter's Day in 2014, with low Langeled flows and no flows available through IUK as a result of a high Wobbe Index on the Zeepipe, there is a potential shortfall of 22 million cubic metres for the UK gas market.

Table 5.7: Low Langeled - High ZPT Results

		Base Scenario 2014		Low Langeled 2014		Low Langeled - High ZPT 2014	
		Average Winter	Peak	Average Winter	Peak	Average Winter	Peak
Demand							
GB Demand	mcm(s)/d	438	548	438	548	438	548
Exports to Ireland	mcm(s)/d	16	22	16	22	16	22
Total Demand UK	mcm(s)/d	454	570	454	570	454	570
Supply							
UK - LNG	mcm(s)/d	141	163	141	163	141	163
UK - Storage	mcm(s)/d	42	135	42	135	42	135
UK - Production	mcm(s)/d	126	126	126	126	126	126
Norwegian Imports	mcm(s)/d	122	127	82	82	82	82
Total Supply (Less Continent)	mcm(s)/d	431	551	391	506	391	506
Net Import Requirement (From Continent)		**23**	**18**	**63**	**63**	**63**	**63**
BBL Flows	mcm(s)/d	41	41	41	41	41	41
Wobbe Index	MJ/m3 (s)	50.13	50.13	50.13	50.13	50.13	50.13
IUK Flows	mcm(s)/d	-17	-23	23	22	0	0
Wobbe Index	MJ/m3 (s)	-	-	50.24	50.24	-	-
UK Net Position	mcm(s)/d	**0**	**0**	**0**	**0**	**-22**	**-22**
Belgian Wobbe	MJ/m3 (s)	52.20	51.81	52.98	52.31	52.77	52.53
LNG to Zeebrugge	mcm(s)/d	40	40	40	40	40	40
LNG to Rotterdam	mcm(s)/d	34	34	34	34	34	34
Maximum Flows on Langeled	mcm(s)/d	72	72	20	20	20	20

Source: PA Consulting Group

6 Key findings

In this section we summarise the results from our scenario analysis, identifying any shortfalls of gas to meet the UK's Net Import Requirements. We then present the key findings for the BBL and IUK pipelines.

6.1 Overview

Table 6.1 summarises the results from our scenario analysis, identifying which scenarios have a potential shortfall of gas to meet the UK's Net Import Requirement.

Table 6.1: Forecast gas supply constraints, 2014 (Note: ✓ no constraint; X constraint)

	Average Winter's Day	Peak Winter's Day
Base	✓	✓
Low LNG	✓	X
Low Langeled	✓	✓
Base - High ZPT	✓	✓
Low LNG - High ZPT	X	X
Low Langeled - High ZPT	X	X

Source: PA Consulting Group

Our results show that under the 'Low LNG', 'Low LNG - High ZPT' and 'Low Langeled - High ZPT', the UK could face gas supply constraints on a Peak Winter's Day in 2014. Furthermore, for the 'Low LNG - High ZPT' and 'Low Langeled - High ZPT' scenarios, where gas flows from Norway, through Zeepipe to Belgium are assumed to be above the GS(M)R upper limit, supply constraints also occur on an Average Winter's Day. The potential shortfalls of gas for these scenarios for a Peak Winter's Day and Average Winter's Day are set out in Tables 6.2 and 6.3:

Table 6.2: Potential Peak Winter's Day Gas shortfall, 2014

	Mcm(s)/d	As % of total UK demand
Low LNG	3	0.5
Low LNG - High ZPT	44	7.7
Low Langeled - High ZPT	22	3.9

Source: PA Consulting Group

Table 6.3: Potential Average Winter's Day Gas shortfall, 2014

	Mcm(s)/d	As % of total UK demand
Low LNG - High ZPT	22	4.8
Low Langeled - High ZPT	22	4.8

Source: PA Consulting Group

Most worrying are the potential outcomes for the 'Low LNG' scenarios, where LNG is diverted to alternative markets outside of continental Europe. Assuming the Zeepipe pipeline from the Norwegian gas fields to the Zeepipe Terminal in Zeebrugge is within British gas quality specifications, there is a potential shortfall of 3 million cubic metres of gas, equivalent to 0.5% of total UK demand. Gas quality constraints on the Zeepipe pipeline are predicted to increase this shortfall dramatically to 22 million cubic metres on an Average Winter's Day, equivalent to 4.8% of total UK demand and 44 million cubic metres for a Peak Winter's Day, equivalent to 7.7% of total UK demand.

The 'Low Langeled' scenarios are better with no shortfall identified for the 'Low Langeled' scenario, although gas quality constraints on the Zeepipe pipeline under the 'High ZPT' scenario are predicted to produce shortfalls of 4.8% and 3.9% of total UK demand on an Average and Peak Winter's Day respectively.

The potential shortfalls of gas available via IUK, particularly in the 'High ZPT' quality-constrained scenarios, will have to be met from other supply sources and if not, demand side response measures will need to be implemented.

Under the 'Low Langeled' scenarios, there would be sufficient spare capacity on the Langeled pipeline for these shortfalls to be met from the Norwegian gas fields, although this gas may be contracted to other sources on the Continent. In the short term, it is likely there would be more gas taken out of storage - at least, on an Average Winter's Day when storage extraction is running below the maximum.

These quality related constraints are unlikely to lead to an absolute shortage of gas supplies to the UK. It appears likely that there would potentially be a significant rise in wholesale gas prices at the NBP (above continental North-West European levels). Under the 'Low LNG' scenarios this likely to be sufficient to attract back into the UK 'discretionary' LNG supplies which would otherwise be directed to higher value markets outside Europe, although there is a risk of a lag of before LNG shipments arrive. Furthermore, there would be sufficient spare UK LNG terminal capacity to accommodate this 'discretionary' gas.

Overall, under the scenarios we have developed, which we believe to be realistic, our analysis indicates quality may in future constrain gas supplies from Belgium to the UK or lead to significant impacts on wholesale prices.

6.2 Key findings by pipeline

6.2.1 Flows from BBL and the Netherlands

It is unlikely that flows through BBL will be reduced as a result of gas quality - the only likely reductions will be due to maintenance and outages of key Dutch infrastructure for the following reasons:

- GTS has large amounts of flexibility in determining the source of gas to commit to BBL and therefore has a high degree of leverage in terms of managing the gas quality. It is probably safe to assume that GTS has sufficient flexibility to ensure that gas delivered to Zelzate meets GS(M)R limits but it is unclear whether this would imply delivering GS(M)R compliant gas at 's Gravenvoeren and Bocholtz or that non-compliant gas would be diverted to those points.
- There is sufficient Dutch domestic production (as well as some UK Southern Basin gas) which is landed at Balgzand (adjacent to the BBL entry point) and this gas is generally used first to meet BBL requirements. This gas historically has been within GS(M)R limits and GTS is confident it will remain this way for the future. Forecasts of volume and quality until 2020 show this to be the case.
- If there is a problem with Dutch gas production being unable to flow through BBL due to maintenance, outages, etc., GTS can divert Norwegian gas and also Nord Stream gas (subject to quality) to BBL. It is likely that Norwegian gas would be used before Nord Stream gas to meet BBL requirements, especially if Nord Stream brings in high Wobbe Index gas (falling outside British gas quality specifications).
- Norwegian gas to the Netherlands (delivered via Norpipe to Emden in Germany) so far has remained at a quality that is within GS(M)R limits and has not increased in quality the same way that Norwegian flows to Zeebrugge have. There does, however, remain some uncertainty as to whether this will continue as it is possible Norway will divert higher Wobbe Index gas to the Netherlands in the future.
- Nord Stream gas entering the Netherlands at Bunde from 2014 is likely to be above British gas quality specifications, although this is likely to be routed south to the Belgian border by GTS. In other words, a quality issue is avoided as regards to flows via the BBL, but would the position at 's Gravenvoeren in Belgium be further exacerbated as a result?
- It is likely that LNG gas from Rotterdam will flow south to Belgium unless there is a problem with Dutch production in the north through maintenance, outages, etc. This gas would only be accepted at Zelzate if the blend there is within British specifications.

Flows via Interconnector IUK from Belgium

Supply from IUK provides the greatest concern for British gas quality. If ZPT gas quality is high (i.e. the Wobbe Index number is above the British limit), there is unlikely to be any flow available through IUK on both an Average Winter's Day and Peak Winter's Day for the following reasons:

- Gas entering the IUK pipeline is currently sourced from three key sources - LNG, ZPT and Eynatten. Zelzate will be added in the fourth quarter of 2010.
- It can be assumed that LNG deliveries will normally be above the GS(M)R.
- The LNG terminal in Zeebrugge does have a nitrogen injection facility. This plant makes it possible to ballast LNG imports with a view to compliance with the quality specifications of the GS(M)R. However this plant only has only limited capacity which can cover limited Wobbe Index peaks, and this is only for a short period of time due to the limited size of the nitrogen storage tanks at the facility. If commercial considerations drives where this gas flows to, it appears likely the Belgian or French gas markets will receive all of the gas from this facility.

- The quality (i.e. the Wobbe Index number) of ZPT flows has been steadily increasing since 2006 although still within existing contractual obligations at this landing point, this is causing significant concern. There have been short, within-day periods where flows into the IUK from ZPT have stopped due to the quality being too high, with Fluxys having to rely exceptionally on linepack to meet shippers requests to flow gas towards the UK.
- Eynatten flow volumes have a large volatility - they have become highly unpredictable, but the quality is currently always within GS(M)R limits. Eynatten flows are becoming more dependent on the price difference between Zeebrugge hub, Net Connect Germany and Gaspool.
- LNG that will be delivered at the terminal in Rotterdam from 2012 onwards is likely to be routed toward Belgium though Zelzate by GTS if the blend there is within British specifications (to avoid massive nitrogen injection aiming at creating pseudo Groningen gas for the local Dutch distribution networks).
- Nord Stream gas (with the first pipeline coming on-stream in 2011; the second in 2012) is likely to be above the Britain's gas quality specifications and is likely to be diverted south to the Belgian network by GTS. This will impact the quality of gas coming through the Netherlands and Belgium and is likely to restrict the volume of gas available for the UK. Nord Stream may also affect the quality, and hence quantity, of gas available through Eynatten in the future.

7 Implications

This section briefly outlines the implications of our findings and sketches out the possible policy responses to address the quality risks identified under certain scenarios.

7.1 Policy implications

Whilst a broadening of British gas quality limits, particularly the upper limit, has been ruled out by the UK Government until 2020 due to the prohibitive cost of identifying and converting or replacing all at - risk gas appliances, there appear to be suitable policy responses to address the risks we have identified.

Further research should be conducted to determine the reason why ZPT gas flows to Zeebrugge appear to be on an upwards trend. Such research would investigate whether this is a temporary phenomenon or whether there are real risks British gas quality specifications could be breached permanently at some point in the future. This could also consider Norwegian gas flows to the UK and the Continent to establish whether there are broader gas quality issues associated with such supplies.

However, to ensure security of supply, the development of blending or ballasting facilities at key entry points to the network to enable out of specification imported gas to be treated to bring it within British standards prior to entry to the gas network could be an appropriate solution.

On the basis of our analysis, the key entry point to the UK is Bacton, where the IUK and BBL gas pipelines link the UK with Belgium and The Netherlands. In 2006, a feasibility study undertaken by National Grid looked at different potential plant sizes for a ballasting plant at Bacton with capital expenditure estimated to range between £40 million and £200 million and annual operating expenditure estimated to range between £4.5 million and £22.5 million, assuming a plant size of between 1000 and 5000 tonnes per day. From a policy perspective, these costs could be refined to reflect the construction of a facility of an appropriate size. This raises many issues which are outside of the scope of this study, but given the apparent risks, we believe further investigation of the following is warranted:

- Is ballasting at Bacton the only viable solution? Could blending be a more efficient and effective solution? Could the nitrogen injection facility at the LNG terminal in Zeebrugge be expanded?
- If ballasting is the most cost effective solution, what are the options available to do address the constraints we have identified and the estimated costs of each option?
- How do these estimated costs compare to similar ballasting facilities built elsewhere?
- What is the most appropriate route to recover these costs i.e. should these costs be fully socialised across the market, recovered directly from the users of the facility or some combination of the two?

Appendix A: Data sources

For each EU member state	2009	2014
Demand	GTE+ Demand Scenarios vs. Capacity Report 2009 IEA Natural Gas Statistics 2009	GTE+ Demand Scenarios vs. Capacity Report 2009
Indigenous production	GTE+ Demand Scenarios vs. Capacity Report 2009	GTE+ Demand Scenarios vs. Capacity Report 2009
Storage (withdrawal rates)	GTE+ Demand Scenarios vs. Capacity Report 2009 National Grid Ten Year Statement 2008 GSE Investment Data	GTE+ Demand Scenarios vs. Capacity Report 2009 National Grid Ten Year Statement 2008 GSE Investment Data
LNG imports	GTE+ Demand Scenarios vs. Capacity Report 2009 National Grid Ten Year Statement 2008 GLE Investment Data	GTE+ Demand Scenarios vs. Capacity Report 2009 National Grid Ten Year Statement 2008 GLE Investment Data
Pipeline capacities	GTE Capacity Data/GTE+ Demand Scenarios vs. Capacity Report 2009	GTE Capacity Data/GTE+ Demand Scenarios vs. Capacity Report 2009
Gas quality	Ofgem Gas Quality presentation, 13 October 2009 Ofgem Gas Quality Development Workstream presentation, 18 December 2006 Fluxys GTS IUK National Grid	Ofgem Fluxys GTS IUK National Grid

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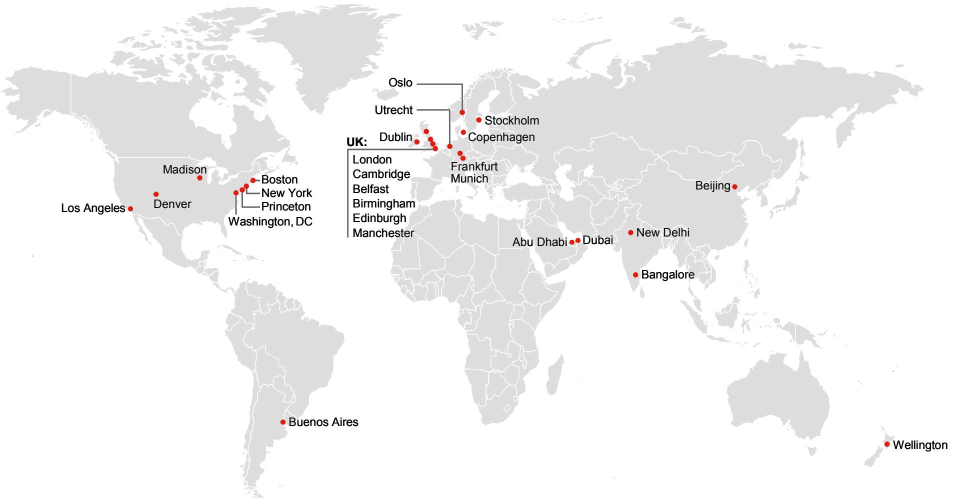

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