GAS QUALITY HARMONISATION COST BENEFIT ANALYSIS

Final Report

A report prepared for the European Commission
by GL Noble Denton and Pöyry Management Consulting

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Contact details

Name	Email	Telephone
Nigel Bryant	Nigel.Bryant@gl-group.com	+44 1509 282133
Angus Paxton	angus.paxton@poyry.com	+44 1865 812263

The GL team comprised Terry Williams, Nigel Bryant, Martin Brown, Len Eastell, Adam Jones and Antony Kane. The Pöyry team comprised: Angus Paxton, Gareth Davies, Andrew Morris, (David) James Cox, James Wyatt, Michael da Costa, Seda Fidanboy, Natasha Austin and Sergej Daut.

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1. SUMMARY

1.1 Introduction

1. At present, the specification of acceptable gas quality varies between Transmission System Operators (TSOs). This presents costs to consumers through inefficient sourcing decisions, deleterious effects of gas market and appliance competition, and potential security of supply concerns. The European Commission (EC) Directorate-General for Energy (DG-ENER) has commissioned GL Noble Denton (GL) and Pöyry Management Consulting (Pöyry) to undertake a cost-benefit analysis of the harmonisation of Europe's gas quality specifications. This report presents the results of the analysis undertaken.

2. This study was intended to produce '*a recommendation to CEN for a definition of gas quality standards that are the broadest possible within reasonable costs.*' We have taken this to mean that we should seek to investigate the costs and benefits of moving to a single gas quality specification that would not hinder trade and transmission of gas within the EU. The stakeholder engagement we have undertaken has also allowed us to identify alternative approaches that help to mitigate the potential issues with current practices.

1.2 The current situation

1.2.1 Background

3. The EU is heavily reliant on supplies of natural gas for a variety of purposes – domestic and commercial, industrial production, chemical processing and production, and power generation. The natural gas markets of Europe were originally developed to meet local demand, exploiting local resources where available. Successive legislative packages, culminating in the 3rd Energy Package (3EP), are creating an internal market where (subject to physical capacity) it should be possible for gas to be bought, transported and sold anywhere within the EU.

4. Natural gas is a mixture of different constituents, predominantly methane. Europe produces and imports a wide variety of different natural gases from a range of locations. These gases are not identical; they have different characteristics that affect use by appliances or system integrity and security.

5. A natural gas quality specification sets out physical, chemical and/or compositional limits that are acceptable within any given system. Specifications usually contain one or more parameters that describe how gas will burn and may contain an array of other parameters.

1.2.2 The current gas market

6. There is a variety of different sources of gas flowing into Europe, with a corresponding variety of gas qualities[1]. Member States (MSs) have developed their own practices with regard to the control of gas qualities within their national systems and with respect to the

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[1] Notably, there is a clear delineation between the low-calorific gases ('L-gas') produced in and around the Netherlands, and the high-calorific gases ('H-gas') produced elsewhere, which are transported through separate systems and in most appliances are not interchangeable. This is a situation peculiar to this particular region so has not been included in the scope of this study, however some of the resulting administrative and commercial practices have informed this study.

control of the safety of natural gas appliances. This has resulted in the establishment of a range of disparate gas quality specifications throughout Europe.

7. Gas quality specifications are applied for a variety of reasons. Most importantly, gas quality specifications ensure the safe operation of household appliances, by ensuring compatibility of gases and appliances. They prevent appliances emitting carbon monoxide, ensure continuity in pilot flame and reliable burner flames, and minimise emissions and particulates (soot). In addition, gas quality and variations in gas quality can have a significant impact on a wide variety of applications including chemical processes, fuel efficiencies, nitrogen oxide (NOx) emissions, household pipework systems, gas transportation maintenance costs, and turbine maintenance costs.

8. There is a range of different approaches to setting gas quality specifications across the EU. Some elements of gas quality (and hence the specifications) relate to the safety and protection of the general public, and have become enshrined in national safety legislation; others arise from the definition of standards and trading standards at both national and European level, by direction from national regulatory authorities (NRAs), or by unilateral declaration by TSOs (sometimes reflecting regulatory settlements).

9. There are a wide variety of different parameters that can potentially be included in a gas quality specification, with no common agreement on which parameters should be included. There is no currently universally acknowledged exhaustive set of parameters, and there are diverse opinions as to whether specifications should be

- thorough (capturing most eventualities, and providing security to all market participants as to the acceptability of the gases); or
- scant (merely capturing safety concerns, but lower the requirements for compliance).

10. There is a range of different approaches to ensuring the on-going safety of installed appliances across the EU. Only a few Member States have regulations that require installations to be regularly maintained or inspected.

11. Some of the existing gas input into the EU is treated either prior to entering the network or during transportation. Input facilities where gas is treated prior to entering the network have received investment by the relevant trading entity (either the upstream producer/importer, or the local supplier), to ensure that the gas entering meets the local gas quality specification. Treatment during transportation can arise as an accident of the mix of flows on the network or through specific TSO endeavours – either reasonable endeavours to configure the network to receive, provide or maintain particular gas qualities, or through specific activity (investment or commercial management).

12. The established flow patterns and gas qualities that exist in Europe today are compatible with the prevailing disparate gas quality specifications that exist. Evidence provided by the European Network of Transmission System Operators for Gas (ENTSOG) covering 20 Transmission System Operators (TSOs) from 16 MSs[2] indicates that historically, over the last 5 to 10 years[3], gas has only actually been prevented from flowing at three EU cross-border points and only for a very limited duration. This is shown in Table 4 on page 25.

[2] From a total maximum potential of 25 (EU27 less the island states of Malta and Cyprus)

[3] Depending on the TSO

1.2.3 Current regulation

13. The current gas market is undergoing significant change as a result of the 3EP. Legislation has already established vertical separation – where the activities of trading gas are split from the transport of gas – and will require the establishment of entry-exit systems. The focus of 3EP, the Internal Energy Market (IEM), is targeted for completion in 2014.

14. The 3EP may place an obligation on TSOs with regards to gas quality issues via a specific Network Code. The 3EP also requires TSOs to publish actual gas qualities at cross-border points.

15. The Gas Appliance Directive (2009/142/EC, the codification of 90/396/EEC) (GAD) establishes a requirement for 'harmonised standards at Community level in particular as to the construction, operation and installation of appliances burning gaseous fuels'. A 'harmonised standard' is defined as 'a technical specification (European standard or harmonisation document) adopted by CEN'. As a consequence of this, EN437, drawn up by CEN, sets out a series of gas quality specifications.

16. The specifications contained within EN437 cover various natural gas families. GAD, which is intended to facilitate the internal market in gas appliances, essentially requires that the design of an appliance must be tested against EN437 specification(s).

17. There is no EU requirement for gas trading or gas transportation activities to comply with EN437.

18. EASEE-gas (the European Association for the Streamlining of Energy Exchange in gas) has proposed an H-gas specification designed to apply at cross-border and EU entry points via a 'Common Business Practice' (CBP). The CBP is intended to apply to facilitate the trading of gas across cross-border points, although the precise detail of how this should be achieved is left to the relevant parties.

19. None of these specifications are obliged, via EU regulation, to apply to the trade or transport of gas.

20. Another regulation of relevance is the security of gas supply regulation (EU/994/2010), which requires MSs to take measures to ensure the supply of gas to protected customers, to ensure a minimum standard of infrastructure resilience, to ensure adequate preparations for a gas supply emergency, to improve coordination between MSs and to ensure the internal market for gas functions for as long as possible. This regulation could encourage MSs to relax any gas quality specifications where doing so might improve their security of supply. Article 9 of the regulation specifies that safety and gas quality considerations should be included in a biennial risk assessment.

1.3 Stakeholders

21. Stakeholders have a variety of interests. The overarching interest is one of economic effectiveness of the market.

22. Most consumers are effectively oblivious to gas quality issues because of action upstream and limited appliance sensitivities, however many large consumers have particular concerns with regards to the stability and rates of change of gas quality. TSOs are interested insofar as they have or may have specific obligations in respect of gas quality, however often they are neutral to it as they are not contractually exposed. Trading entities are exposed to gas quality issues in two main ways: producers and importers are exposed to needing to ensure (i.e. invest) compliance with a prevailing specification; whereas

cross-border traders (shippers) are exposed to unforeseeable interruption and the consequential commercial implications of this. Infrastructure operators might be concerned with absolute levels of particular parameters (e.g. CO2 and O2).

23. Throughout this project we have sought the input and commentary of stakeholders. The results of the consultation exercise are included in Annex O.

1.4 The potential issue

24. The current situation of a disparate set of gas quality specifications means that:

- it can be difficult for a shipper to buy or import gas at one location in the EU and then sell it at another location within the EU;
- there is a restriction to the free movement and trade of gas appliances within the EU;
- there could be security of supply problems in unusual circumstances.

25. Whilst the current flow patterns are compliant with the existing disparate gas quality specifications, there is the potential that some gas is prevented from directly entering a local market or potentially from entering the EU market at all, therefore increasing costs to EU consumers. There is therefore both:

- a potentially inefficient arrangement of the gas transportation network where the particular gas enters a non-local market and displaces gas towards the local market; and
- a potentially inefficient set of supplies to the EU.

26. Many TSOs currently blend different gases to ensure compliant gas is delivered to consumers. We understand this is established practice in at least the Belgian, Dutch and German markets where it is primarily used to accommodate flows between L-gas and H-gas but also allows the accommodation of different H-gas specifications. However, as the TSO often has no certainty that there will be sufficient volumes of any particular gas for mixing, this service is provided on a reasonable endeavours basis. Changes to future flow patterns might make it increasingly difficult for TSOs to meet these endeavours, requiring them to curtail the non-compliant gas.

27. Although probably short-term in nature, this might cause a possible security of supply issue.

28. Furthermore, as indigenous supplies in the EU decline, the flows of gas into Europe are expected to change significantly over the coming decades, with a more diverse set of importation routes and a more diverse set of sources of supply. This may increase exposure to a wider variety of gas qualities. In addition, the completion of the IEM might be expected to impact the physical pattern of flows within the EU.

29. There are a number of implications of these changes to future gas flows:

- TSOs might find it increasingly difficult to meet reasonable endeavours obligations, thereby precipitating greater levels of curtailment;
- competition in the wholesale market might be impacted because of a need to cover the risk of curtailment or the costs thereof; and
- appliance performance might be impacted.

Wholesale market and competition

30. The completion of the Internal Energy Market (IEM) should result in clear price signals to transport gas across a border where there are currently no price signals because of structural deficiencies and the predominance of long-term contracts. Differences in the gas quality specifications across any border create a risk that gas would be prevented from being transported despite these clear price signals. Trade across that border would therefore need to accommodate the risk of curtailment, which would increase the premiums sought by traders, and increase the differential across the border.

31. It may also affect the development of competition across the border as cross-border trade would require a more diverse portfolio to be able to mitigate the risk.

Appliance performance and safety

32. Changes to the future gas quality mix in the EU might have implications for the safe, clean and efficient operation of currently installed appliances.

33. Appliance installation practices differ throughout the EU. The GASQUAL project[4] has examined the variety of installation practices with regard to the on-going operation of appliances. It has concluded that whilst many of the practices are safe based on the current gases presented to the appliance (i.e. the current flows of gas within the network), the practices do modify the behaviour of the appliances significantly, to the extent that future gases might be incompatible with the appliance. It might be that future gases, which remain within the existing applicable specifications used in the trade and transportation of gas, are unsuitable for safe operation of the installed appliance.

1.5 Our analysis

34. The original scope of work for this project was to provide a series of inventories, costs and measures to examine the potential for gas quality harmonisation. It was envisaged that a pilot study would be undertaken prior to the main study, however this proved impossible because of the interdependence of Europe's gas supplies and because of the lack of suitable data.

35. An alternative approach was adopted where analysis was conducted on an EU wide basis, using a set of assumptions which were tested through sensitivity analysis. The options considered to achieve harmonisation were based on mitigating all possible risks, and represented an extreme perspective of the impact that harmonisation might have. The initial analysis culminated in the publication of a preliminary report, which was published alongside a consultation.

36. A public consultation was held between 29th July 2011 and 16th September 2011. This generated a series of responses which are summarised in Annex O. A workshop was held for interested parties on the 5th December 2011, where various stakeholders were invited to speak. The consultation responses and the workshop have highlighted the vast array of issues and interests in the field of gas quality specifications (for example, issues such as minimum methane content, appliance safety, barriers to trade, cost recovery have all been cited), and it is obvious that there is no consensus opinion on how harmonisation should be achieved, or even if it should.

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4 Phase 1 of the CEN Mandate M/400. Final Report N310 dated March 2012 'Standardisation in the field of gas qualities'

37. In addition, the results of Phase I of the GASQUAL study have been made available and have enabled the refinement of the household appliance replacement costs.

38. This paper presents both the possible, likely outcomes of applying a number of individual gas quality specifications throughout the EU, but also includes consideration of the risks and unintended consequences that this might entail.

1.6 Benefits of mitigation

39. The benefits of removing gas quality constraints are expected to be realised in lower costs of supplying gas across the EU. The potential benefits will come from:

- enhanced security of supply, where more supplies would be able to enter a local market;
- better functioning of the gas appliance market, lowering the costs of procuring appliances through increased competition and the costs of installation;
- better competition in the gas supply market, the development of which may be hampered by different specifications; and
- both the more efficient sourcing of gas, because of access to a potentially more diverse set of supplies, and the more efficient transportation of gas, as gas would no longer be required to be displaced to an alternative market and transported along an indirect route.

40. This section details our analysis on the potential impact on prices from removing gas quality constraints. Whilst the existing specifications have driven investments in the local market to ensure compatibility (noting the widespread use of derichment equipment to treat LNG, and the appliance adjustment activity in the Danish market), we have assumed that the costs of these investments are sunk and therefore most of the costs are unavoidable.

41. Our modelling has been focussed on 2020 and 2030, and was based on the Pöyry central scenario prevailing at the time of the analysis (during Q3 2011). This scenario is similar to the PRIMES baseline scenario. Further details on the modelling are provided in Annex J. The results of this analysis are discussed in detail in Annex I.

1.6.1 Efficient sourcing & transportation

42. Our modelling has found that the existing specifications do not impact on the provision of efficient sources of gas to the EU on the basis of potential flow changes into the future: whilst the marginal source of supply may not be directly available to the relevant local market, it is able to enter the EU and displaces other gas towards the relevant local market. This is because LNG is inherently flexible and can be readily diverted to alternative EU destinations if it cannot be made to comply with the prevailing local gas quality specification.

43. Our modelling shows that the majority of the benefits accrue from more efficient routing of gas within the EU. Our modelling suggests that, after consideration of a variety of different scenarios for gas quality specifications and sensitivities on upstream gas qualities, the expected benefit of reducing gas quality problems would predominately manifest themselves as lowered transportation costs.

44. The extent of the benefit from more efficient transportation depends on assumptions but is **in the range €120m to €370m per annum, with a central consensus view of €200m**

per annum. Given that this assessment is the result of modelling perfect competition this is a conservative figure.

45. The inefficiency in internal transportation has not been transparent in the market because of the absence of clear price signals. The completion of the IEM should clarify prices, provide market signals for transportation (as well as supply) and therefore expose any inefficiency.

46. Our conclusion (in respect of the benefits that might be realised because of more efficient transportation) does not appear to be sensitive to variance in our input assumptions, although we acknowledge our assumptions are particularly weak on predicting future upstream gas qualities. However the observation that a large volume of LNG already arrives in the EU from a wide variety of origins means that significant change is unlikely to materialise. The fact that alternative (non-EU) countries also currently receive gas that can be received by the EU indicates that significant volumes of compliant LNG are available in the wider global LNG market.

47. It is interesting to note that, as of today, the EU already receives significant volumes of non-compliant LNG which is processed at several different entry points to meet the local specification. Some of these local specifications are significantly more stringent than other EU specifications.

48. Many of the existing LNG liquefaction facilities have been constructed in the last decade with asset lives of 20 or 30 years or more. These facilities are therefore assumed to continue to operate over the timescales of the analysis. As many of these liquefaction facilities accommodate infrastructure to process LNG to be able to meet some of the more stringent EU specifications, it is not expected that these sources will go into material decline over the study period.

49. One stakeholder considers that future gas qualities through some of the existing pipeline routes to Europe will change materially into the future (specifically, we assume the development of Barents' Sea gas which could be routed through Nordstream). We have been unable to replicate this in our modelling (which assumes that Barents' Sea gas can be diverted within the Russian gas network). Understanding the potential cost implications of this is difficult under the current contractual structures employed to import gas from Russia.

1.6.2 Enhanced gas market competition

50. We note that the benefits that might be realised from the facilitation of trade should, according to economic theory, result in more competition and more effective prices. This may represent the biggest potential benefit from mitigation, potentially more promising than the efficient transportation benefits.

51. Because of the risk that gas is prevented from flowing where cross-border specifications are different, and because shippers bear the ultimate contractual responsibility for gas quality, the development of a competitive gas supply market is potentially hampered.

52. Evidence from stakeholders has not enabled us to quantify the existing or potential future costs trading entities face because of potential interruption of their trading routes. We would expect that the current gas quality risks currently materialise as a premium on prices (i.e. higher transaction costs).

53. In addition, it has not been possible to isolate gas quality problems from other market competition problems.

1.6.3 Enhanced appliance competition

54. Existing appliances are often designed to operate only within a restricted range of gas qualities which limits the economies of scale that might be available, or the appliances are required to be tuned during installation thereby increasing installation and maintenance costs. Harmonisation of specifications therefore might provide additional benefits of lowered overall installation and maintenance costs, and increased competition in appliance manufacturing.

55. However, as tuning costs are small in relation to overall installation and maintenance costs, and GAD has already established a competitive appliance market, the benefits would be limited both in terms of overall installation and maintenance costs, and in providing marginal economies of scale. **We therefore consider that the benefits would be relatively small.**

1.6.4 Security of supply

56. Should gas be prevented from flowing because of gas quality specifications, this could result in a supply security problem. Harmonisation would mean that more supplies would be able to enter a local market. We have been unable to quantify the impact of this but, as it is the subject of specific directive and potential action by MSs, **consider that it might represent a significant benefit.**

1.6.5 Efficiency and emissions

57. Replacing a wide specification and variable gas qualities with a narrower specification and/or less variance in gas quality might provide benefits in terms of increased operational efficiencies being achieved by various gas appliances (from domestic appliances to CCGTs), and may also lower costs of installation by removing the need to tune appliances. This only delivers a benefit where the chosen specification has a narrower Wobbe index; a wider specification would not deliver benefits. Whilst harmonisation might therefore deliver small benefits in some MSs, at an EU level (assuming a wide specification), we therefore **consider that the benefits would be insignificant**.

1.6.6 Conclusions

58. From the five potential issues from which future costs can arise and potentially be avoided, we have been able to quantify only one. **The benefit of mitigating it is in the range €120m to €370m per annum, with a central view of €200m per annum, in addition to the unquantified benefits.** In net present terms (assuming 5% discount rate over 20 years), this translates to between €1.6bn and €4.8bn with a central view of €2.6bn. Given that this assessment is the result of modelling perfect competition this is a conservative figure.

1.7 Costs of harmonisation

59. During the course of the project we have considered a large variety of different approaches to assessing the impacts of harmonisation, and different ways that the benefits explained above might be achieved. These approaches fall into three broad categories:

- considering what the likely impact of adopting a variety of specifications in a variety of situations might be, and identifying associated risks and possible mitigations;
- information provision approaches that deliver some of the benefits without altering gas quality specifications; and

- extreme approaches that fully mitigate all potential risks and all eventualities.

60. An understanding of the scale and form of investment that may be required under alternative situations helps map the likely costs in individual networks of any new standard. We anticipate an uneven distribution because disparate existing specifications influence the ease of complying with changed specifications.

61. There are potentially four realistic situations for any change to specification. These are that the new specification describes gas that:
    - is completely within limits of the baseline specification (‘fully inside’);
    - can be both above and below the maximum and minimum limits of the baseline specification (‘fully overlaps’);
    - can be above the maximum of the baseline specification but whose minimum is above the minimum of the baseline specification (‘overlapping upper’);
    - can be below the minimum of the baseline specification but whose maximum is below the maximum of the baseline specification (‘overlapping lower’).

62. There may be a requirement to invest:
    - to ensure that the TSO can accept all gas;
    - to ensure that appliances are compatible and safe; or
    - for both of these.

63. The impacts of the four situations described above are summarised in Table 1 below.

Table 1 – Impacts of the four situations

Situation	Possible investment *required* for existing gases	*Potential* investment for new gases
Fully inside	Enrichment + derichment	None
Fully overlaps	None	Enrichment + derichment
Overlapping upper	Enrichment	Derichment or appliance modification/replacement
Overlapping lower	Derichment	Enrichment or appliance modification/replacement

64. The costs of derichment (which is typically achieved by the injection of air and/or nitrogen where blending is not available) are generally less expensive than the costs of enrichment (which is typically achieved through the use of LPG injection where blending is not available). **The lowest impact from harmonisation might therefore be expected where the requirement to enrich gas is minimised at the expense of requiring derichment.**

65. We have selected a sample of potential harmonised specifications and estimated the impact on a selection of MSs. We have chosen to apply:
    - the EN437 ‘Second Family H-gas’ specification, with a Wobbe index range of 45.65 - 54.7 , which we have chosen to represent a wide specification;

- the Ireland/UK specification, with a Wobbe index range of 47.20 - 51.41 MJ/m^3, which we have chosen to represent a narrow specification; and
- the EASEE-gas specification, with a Wobbe index range of 46.45 – 53.99 , MJ/m^3 which we have chosen to represent a specification in the middle.

(Reference conditions are 15 °C for combustion, 15 °C and 101.325 kPa for volume).

66. These specifications have been compared against the existing specifications for:

   - Austria
   - Belgium
   - Czech Republic
   - Denmark
   - Estonia
   - France
   - Germany
   - Greece
   - Hungary
   - Ireland
   - Italy
   - Latvia
   - Luxembourg
   - Poland
   - Portugal
   - Spain
   - Sweden
   - United Kingdom

67. **This analysis shows that the lowest immediate impact is expected when a new specification is wide.** The analysis demonstrates that where a new specification is wider than the existing specification, then there is no immediate cost because existing gases are already compliant. It also shows that MSs with low lower Wobbe index limits may face larger immediate impacts than average because of the possible need to enrich existing gas: costs of enrichment are significantly greater than costs of derichment.

68. There are risks associated with the implementation of a new Wobbe index specification. These are:

   - that the existing appliance fleet is incompatible with gases supplied that are compatible with the new specification; and
   - that there are costs associated with other, non-Wobbe index based, parameters.

   It should however be noted that the indications from the sample test appliances used in the GASQUAL study show that there appears to be little impact on safety when operated on a gas with a low Wobbe index. This indicates that there may be no requirement for enrichment to ensure the safe operation of appliances, so a new specification could be set to accommodate existing low-Wobbe index gases.

69. Our modelling suggests that under normal circumstances there are no new gases that are expected to be presented to the EU that would trigger costs associated with harmonising gas qualities.

70. However the extent of this risk and the need for insurance investment is something that we would expect to be determined by Member States/NRAs in discussion with the TSOs. There is a potential outcome that MSs decide to mitigate the safety risks using more extreme solutions.

71. These costs fall into a broad range because of the number of variables involved in determining them, including:

   - which MSs choose to apply the approach;
   - the differences between the existing specifications/gases and the new specifications;

- whether MSs seek efficient trade-offs between upstream and downstream investment;
- the extent to which appliance adjustment or retrofitting is employed instead of appliance replacement; and
- the extent to which appliance replacement can be phased to take advantage of some natural replacement.

1.8 Distributional impacts

72. In the current situation, the potential for the any of the gas flowing into the EU to impact on any particular MS's network is limited by that MS's legal and contractual implementation and enforcement of their own gas quality specification. This is a key feature of the proper functioning of gas quality specifications in maintaining the integrity of gas networks[5]. The options presented above would not impact on this, so do not introduce any safety-related distributional concerns.

73. In the current situation, there is potential for costs to be incurred in one MS because an upstream MS prevents flows of gas that would be acceptable by the downstream MS, on the basis that they are incompatible with the upstream MS's gas quality specification. This impact is implicit in our modelling work which has, at its core, the objective of minimising costs to European consumers regardless of their distribution. The precise impact on any particular MS is difficult to observe because of the convergence of pricing that is assumed in our modelling.

74. The inverse situation is also true: a downstream MS's specifications could prevent an upstream MS from agreeing to receiving gas which it could reasonably (i.e. safely) distribute internally, because of the existing contractual requirements to provide compliant gas to the downstream MS. This would only the case where there the TSO is obligated under an established contractual obligation.

75. The biggest impacts will be felt where there are the biggest differences in gas quality specifications, or, should a single specification be mandated, in MS that have either a wide specification (in the case that a narrow specification is implemented), or a narrow specification (in the case that a wide specification is implemented). **It is therefore the case that the costs identified in this paper would mostly occur only in a small group of countries.**

1.9 Conclusions

1.9.1 Problem

76. The current situation of a disparate set of gas quality specifications means that:

- it can be difficult for a shipper to buy or import gas at one location in the EU and then sell it at another location within the EU;
- there is a restriction to the free movement and trade of gas appliances within the EU;
- there could be security of supply problems in unusual circumstances.

77. The current flow patterns are compliant with the existing disparate local gas quality specifications. Evidence provided by ENTSOG suggests there have historically been only

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5 E.g. it forms an integral part of 'system integrity' in 1(9) Art. 2 EC/715/2009.

been five incidences of rejection of gas due to incompatibility with the local gas quality specification.

78. However the current level of compliance has been accomplished via a variety of different types of investment at a local level, and there remains a residual possibility that some gas is prevented from directly entering a local market or potentially from entering the EU market at all.

79. As indigenous supplies in the EU decline, the flows of gas into Europe are expected to change significantly over the coming decades, with a more diverse set of importation routes and a more diverse set of sources of supply. This may increase exposure to a wide variety of gas qualities. In addition, the completion of the IEM might be expected to impact the physical pattern of flows within the EU.

1.9.2 Benefits

80. There are therefore some benefits that might arise from adopting a single pan-EU gas quality specification. These are as follows.

- Enhanced security of supply:
  - more supplies would be able to enter a local market. Quantification of impact has not been possible, as it is the subject of specific directive and action by MSs, **consider that it represents a significant benefit**.
- More efficient fuel utilisation/fewer emissions:
  - this only delivers a benefit where the chosen specification has a narrower Wobbe index; a wider specification would not deliver benefits. Whilst harmonisation might therefore deliver small benefits in some MSs, at an EU level (assuming a wide specification), the results show **that the benefits would be insignificant**.
- Better functioning of the gas appliance market:
  - existing appliances are often designed to operate only within a restricted range of gas qualities which limits the economies of scale that might be available, or are required to be tuned during installation thereby increasing installation and maintenance costs. Quantification has not been possible, however it is **considered that the benefits would be relatively small**: tuning costs are small in relation to overall installation and maintenance costs, and GAD has already established a competitive appliance market.
- Better competition in the gas supply market:
  - because of the risk that gas is prevented from flowing where cross-border specifications are different, and as shippers bear the ultimate contractual responsibility for gas quality, the development of a competitive gas supply market is potentially hampered. Quantification of this impact has not been possible because it is not possible to isolate gas quality problems from other market competition problems. As the 3rd Energy Package will deliver the internal energy market in 2014, we consider **the incremental benefit of standardising specifications would be potentially significant**.
- More efficient sourcing of gas:
  - if a wide gas quality specification was introduced, the EU would have access to a more diverse set of supplies. This benefit in isolation cannot be quantified, and observe that the potential benefits are limited because of the fungible nature of LNG. The modelling integrates both sourcing and transportation so **the benefits available from more efficient sourcing have been included in the**

quantification presented below. It should be noted however that introducing a narrow specification might present a barrier and would not deliver a benefit from efficient sourcing.

- More efficient transportation of gas:
  - gas would no longer be prevented from entering a local market and therefore would no longer require displacement to an alternative market and transportation along an indirect route. **The benefits of this have been quantified as being between €120m and €370m per annum**. In net present terms (assuming 5% discount rate over 20 years), this translates to between €1.6bn and €4.8bn with a central view of €2.6bn. Given that this assessment is the result of modelling perfect competition this is a conservative figure.

1.9.3 Costs required to achieve compliance

81. The costs of realising these benefits depend on how much change in gas quality might be expected in the future. Our central view on the costs of implementation is predicated on an assumption that:

- the main sources available to the EU will be as reflected in the modelling;
- that these sources will have the ranges of gas quality that we have assumed; and
- that TSOs can blend all sources within an integrated national network.

Under these assumptions much of the transition to a standard specification can be done at a lower cost.

82. We have considered the potential costs to the TSO and consumers from introducing a harmonised standard. We have identified four possible situations that might arise when applying a new specification, and examined the relative investment requirements for the transition to each of three possible specifications for each of 18 MSs.

83. There are two important observations made from the analysis we have undertaken:

- the lowest cost of transition is to be expected when any new specification is wide relative to current specifications; and
- the lowest cost of transition is to be expected where the requirement to enrich gas is minimised at the expense of requiring derichment.

84. Our analysis indicates that in general gas qualities are not anticipated to change significantly under normal circumstances, and whilst there may be local impacts because of future gas qualities, these costs would be incurred anyway and would therefore not be triggered by gas quality harmonisation.

85. If our assumptions on gas quality specifications and future flows are correct, there will be a minimal requirement for investment to accommodate the transition to a standard specification. **We estimate that the immediate costs required achieving compliance range between zero and €9.6bn**, depending on the specification selected and the validity of other assumptions. A wide specification would present immediate costs of €4bn, whereas the UK/IE specification would present immediate costs of €9.6bn. The costs that are expected to occur to a large extent stem from a relatively small group of countries.

86. However, the transition introduces risks which may induce further costs to mitigate; we discuss these in the following section.

1.9.4 Potential other costs to mitigate

87. If patterns of flow and/or quality differ from those shown in our analysis, there are two potential risks that could materialise:

- interruption to gas supplies might be required; and
- there could be significant safety issues.

Resolving these risks increases costs, potentially requiring large investments in either gas processing equipment or appliance replacement programmes.

88. However the extent of this risk and the need for insurance investment is something that we would expect to be determined by MSs economic and safety regulators in discussion with the TSOs. There is a potential outcome that MSs decide to mitigate the safety risks using more extreme solutions.

89. These potential costs fall into a broad range because of the number of variables involved in determining them, including:

- which MSs choose to apply extreme solutions;
- whether MSs seek efficient trade-offs between upstream (processing) and downstream (appliance replacement) investment;
- whether the TSO has opportunities for blending any new gases;
- the extent to which appliance adjustment or retrofitting is or can be employed instead of appliance replacement;
- the extent to which appliance replacement can be phased to take advantage of some natural replacement; and
- the differences between the existing specifications/gases and the new specifications – noting that the larger the difference, the larger the potential cost.

90. The latter variable provides an important influence in selecting any particular specification, and allows us to add another important observation:

- the lowest cost of transition arising from the risks of extreme solutions being adopted is to be expected when any new specification is narrow relative to current specifications.

91. Some of the risks might be mitigated by the generation of forecasts of potential gas quality problems, which could be used to flag more precisely when and where investment might be required.

1.9.5 Recommendation to CEN

92. There is an indication that there might be a benefit from adopting a relatively wide specification. In order to determine this CEN would need to examine the risks we've flagged in greater detail.

93. Noting the contrasting observations that:

- the lowest cost of transition is to be expected when any new specification is wide relative to current specifications; and
- the lowest risks are to be expected when any new specification is narrow relative to current specifications;

We note that the selection of a narrow or a wide specification will depend on the materiality and extent of the risks.

94. There is insufficient information on:

- the actual details of inflowing gas qualities;
- the materiality of off-specification gas to the integrity of gas system; and
- the extent to which reasonable endeavours could be used to overcome potential issues.

95. Our study has focussed primarily on the Wobbe index parameters. CEN will also need to understand other parameters and the extent to which they cause integrity problems and require remedial investment.

96. In particular, CEN should consider the extent to which, and where, appliance adjustment or retrofitting is or can be employed instead of appliance replacement.

1.9.6 Summary

97. Table 2 provides a summary of the costs, benefits and risks.

Table 2 – Summary of benefits, costs and risks

		€bn, present terms	
		Lower	**Upper**
Benefits	Efficient sourcing & transportation	1.6	4.8
Costs	Ensuring existing gas is compliant with new specification	(9.6)	0
Net quantified benefit		(8.0)	4.0
Additional (unquantified) benefits	Security of supply	Significant	
	Gas market competition	Potentially significant	
	Appliance market	Small/insignificant	
	Efficiency/emissions	Small/insignificant	
Potential additional costs	Non-Wobbe index parameters	Low	
	Appliance incompatibility	High	
Other risks	Risks that assumptions in this analysis are incorrect		

Values are presented in present terms, assuming a 5% discount rate over 20 year. It is expected that the "high" and "significant designations in the table would have a similar value to the empirical values given above.

2. INTRODUCTION AND BACKGROUND

2.1 Objectives of this cost benefit analysis

98. Disparate gas quality specifications might present barriers to the free trade of gas across Europe, raising costs to consumers through inefficient sourcing decisions, deleterious effects of gas market and appliance competition, and potential security of supply concerns. The EC has commissioned GL and Pöyry to undertake a cost-benefit analysis of harmonising Europe's gas quality specifications. This report presents the analysis undertaken to explore the costs and benefits of harmonising EU gas quality specifications.

99. The original scope was intended to undertake an analysis to enable the definition and provision to CEN of the most economic common gas quality standard that should be applied throughout the EU. The study was to take an overall view of the EUs gas industry, from upstream production throughout the value chain and physical networks to the 'burner tip' (appliances). The study is part of an overarching aim to define EU-wide gas quality standards to contribute to the creation of an internal market for gas.

100. This study was intended to produce "a recommendation to CEN for a definition of gas quality standards that are the broadest possible within reasonable costs."

101. The mandate to CEN states, "The goal is to define standards that are as wide as possible within reasonable costs. This means that the standards enhance the free flow of gas within the internal EU market, in order to promote competition and security of supply minimising the negative effects on efficiency and the environment and allow the maximum number of appliances to be used without compromising safety."

102. The original scope was intended to consider the impact and potential costs and benefits of a harmonised gas quality specification for TSOs, producers, shippers, traders and suppliers, large industrial consumers, gas appliance manufacturers, small to medium enterprises and households. The original project scope did not include consideration of 'L-gas' or odourisation, but focussed on the key parameters specified in the proposed EASEE-gas specification for natural gas quality.

103. It has not been possible to deliver the original scope because obtaining relevant and robust information from stakeholders and other sources has proved difficult and has consequently taken significantly longer than planned. Based on this fact, a revised scope was agreed which envisaged using assumed data to generate an initial cost-benefit analysis which could then be used as a 'straw-man' to elicit response and engagement from stakeholders, prior to refining any analysis and producing this final report.

2.2 Pöyry and GL

104. This report has been prepared by a consortium comprising GL and Pöyry. GL, as main contractor to the EC, has led the work to quantify the costs of physical harmonisation, whereas Pöyry, as a subcontractor to GL, has led the work to quantify the value of changes in future gas quality standards, and to analyse the outcomes within the commercial structures and economic frameworks of the European gas market. Data collection activities have been the responsibility of the EC.

105. GL Noble Denton are independent advisors providing consulting, design, assurance and project execution services, combining excellent engineering and analytical skills with operational experience of offshore, maritime and onshore oil and gas assets. GL Industrial Services (UK) Ltd., trading as GL Noble Denton, is based in Loughborough, UK, and is part of Germanischer Lloyd Group registered in Hamburg, Germany.

106. Pöyry Management Consulting provides leading-edge consulting and advisory services covering the whole value chain in energy, forest and other process industries. Our energy practice is the leading provider of strategic, commercial, regulatory and policy advice to Europe's energy markets. Pöyry Management Consulting is a part of Pöyry plc, registered in Helsinki, Finland.

2.3 Background

107. The EU is heavily reliant on supplies of natural gas for a variety of purposes – domestic and commercial, industrial production, chemical processing and production, and power generation. The natural gas markets of Europe were originally developed to meet local demand, exploiting local resources where available. Successive legislative packages, culminating in the 3EP, are creating an internal market where (subject to physical capacity) it should be possible for gas to be bought and sold anywhere within the EU.

108. The contractual model implemented in Europe's gas markets separates the activities of transportation from the ownership of gas. Whilst this maintains regional and national monopoly structures in transportation, it provides the advantage of facilitating a competitive environment for the trading of gas – thereby providing the benefits of competition to all consumers. The physical infrastructure is operated by the transporter who is therefore ultimately responsible for its safe operation. In normal operation, the commercial arrangements that enable the vertical separation place the control of where the gas flows from and to into the competitive environment. Transporters are therefore not normally in control of the flows of gas into their network, but as the control the flows of gas within their network, exert some influence on the gas qualities flowing out of their network: there is no single entity responsible for the end-to-end control of gas quality.

109. Most consumers are not directly concerned with gas quality in the current market. This is because appliances are appropriately designed, installed and/or maintained to meet required safety standards; asset performance (efficiency, emissions) is often not considered. Large consumers do have a variety of interests in gas quality, however.

2.3.1 Historical development

110. Historically, Europe's gas markets were distinct, vertically integrated regional monopolies, where a single entity was responsible for the import of the majority of the required gas supply (as well as its transportation and modulation). The monopoly supplier could therefore rely on a single, long-term contract with each of its chosen upstream counterparts and consequently could control the mix of gas in the network and hence control the specification of gas exiting its network. Local gas quality specifications evolved on the basis of local gas traditionally and continuously supplied from importation and production; local appliance manufacture and installation reflected local practices.

111. Different regions have developed to use different sources of gas with different components and therefore variable chemistry. As such, locally developed specifications evolved to capture local concerns, using measurements and understanding contemporary at the time. Responsibility for setting and enforcing gas quality specifications has been assigned to different organisations in different regions, sometimes with gas treatment being considered as a separate legal activity to gas transportation, requiring different licences/regulation.

112. Generally, the responsibility for ensuring the delivery of gas quality fell to the vertically integrated dominant incumbent who was largely in control of the full value chain. The vertical separation of the industry into independent TSOs and competitive shippers, whilst delivering a competitive environment that will limit monopoly rents and lower costs for

consumers, makes it difficult TSOs to control gas quality as they have limited foresight of flows and/or qualities.

113. The 3EP does not involve itself with safety legislation, and does not explicitly require the definition of a gas quality specification. It is currently expected that the interoperability framework guidelines and resultant network code might require some consideration of gas quality. The remit of the 3EP is such that if the interoperability arrangements were to define gas quality limits, TSOs would need to align this with applicable safety legislation/arrangements.

2.3.2 Parameters

114. Gas quality parameters are the individual metrics that are used to describe the acceptable limits for the physical properties of the gas. They include a mixture of derived descriptive properties such as Wobbe index, physical properties such as density and dewpoints, compositional amounts such as methane content, composition equivalencies such as methane number, and more conceptual properties such as odour. The parameters currently used within the existing European specifications are set out in Table 3.

Table 3 – List of parameters currently used within Europe

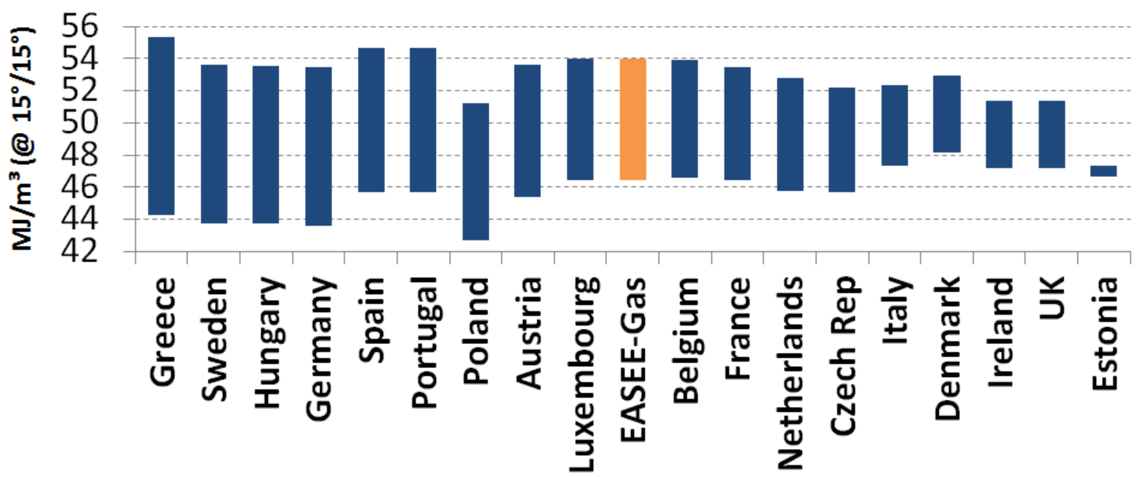
- Wobbe index (WI)
- calorific value (CV)
- density & relative density (RD)
- sooting index (SI)
- incomplete combustion factor (ICF)
- hydrocarbon dewpoint (HCDP)
- water dewpoint (WDP)
- total sulphur (S)
- carbonyl sulphide (COS)
- methane / methane number (MN)
- hydrogen sulphide (H2S)
- Mercaptans / Thiols (RSH)
- Oxygen (O2)
- nitrogen (N2)
- carbon dioxide (CO2)
- halogens
- ammonia (NH3)
- impurities
- particulates / solids / liquids
- odour

115.

The Wobbe index is a measure of heat input to gas appliances derived from the orifice flow equation. Heat input for different natural gas compositions is the same if they have the same Wobbe index, and operate under the same gas pressure. The Wobbe Index is calculated as the calorific value, on a volumetric basis, at specified reference conditions, divided by the square root of the relative density at the same specified metering reference conditions (as detailed in EN ISO 14532:2005 – "Natural gas — Vocabulary").
The most common measure of gas interchangeability worldwide is the Wobbe Index. For many EU member states the acceptable Wobbe Index range defines an operational region in which the gas quality and composition is suitable for use in domestic, commercial and industrial equipment. Excursions in gas quality and composition outside of this range may lead to incorrect operation of equipment and appliances, potentially resulting in high emission levels.

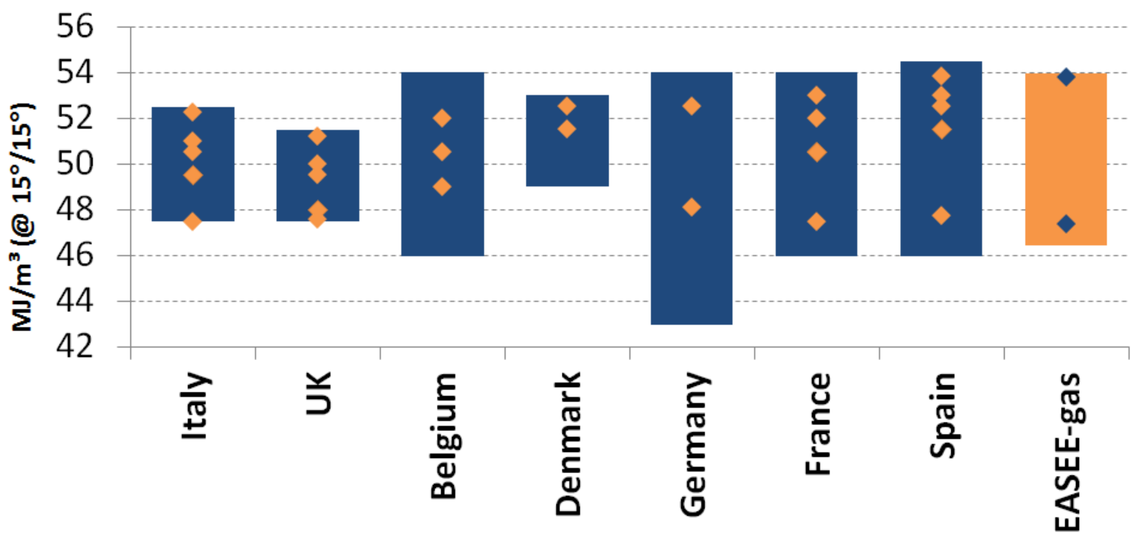
Figure 1 shows a selection of existing Wobbe index specifications, which highlights the disparate specifications; Figure 2 shows selected specifications against the gases typically experienced.

Figure 1 – Existing specification for Wobbe index



Source: GL Noble Denton. Note: This table includes gas specifications that cover L & H gas families

Figure 2 – Distributed gases compared to specifications



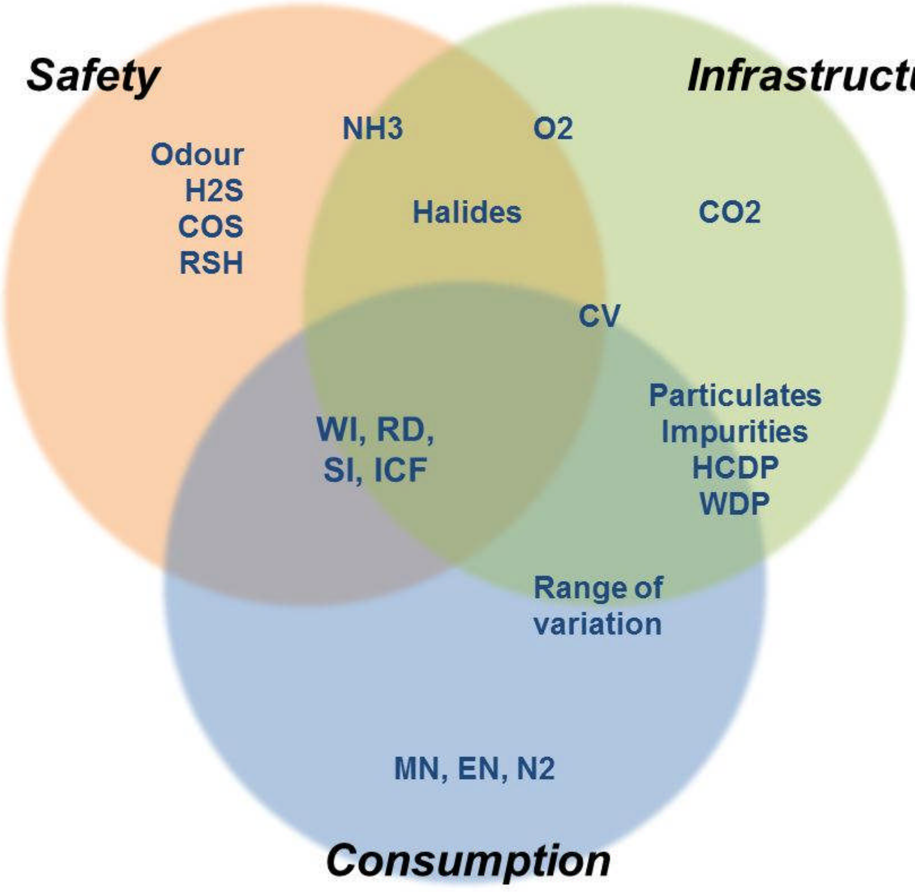
Note: The figure includes EASEE-gas as a reference; this gas is not currently distributed. Source: GASQUAL, Marcogaz

116. There are several other potential parameters which might be included within a specification. They can be loosely categorised into three sets: safety related, gas infrastructure related, and consumption related. Some parameters might span more than one category, and there is sometimes substitution between different parameters (e.g. sooting index and incomplete combustion factors can be substituted by a density parameter), however parameters are usually included for independent reasons, so there is no catch-all parameter that describes a particular category, e.g. there is no single parameter that covers all safety-related issues.

117. We have produced a suggested mapping of the parameters into these sets and included them within a Venn diagram, shown in Figure 3.

118. This mapping shows that different entities in the gas industry will have different concerns and strengths of opinion pertaining to gas quality parameters. Interestingly, the trade of gas on wholesale markets is essentially disinterested in the precise selection of parameters to define a gas quality specification – if the specification is harmonised across the border then they are not faced with risks.

Figure 3 – Venn diagram of European parameters



119. Clearly, safety related parameters are of particular importance, and it seems sensible that any requirement to have a specification, or any centrally defined specification, should ensure that safety parameters are included. We note it is rare to include ammonia or halide limits, and that there are several other potential constituents that could be considered as safety related, for example mercury content.

120. Infrastructure related specifications are of particular importance to regulated monopolies. It is often the case that contractual relationships, (e.g. applied to the transporter yet established by the old vertically integrated incumbent, or established by the transporter under a different market structure, e.g. point-to-point) have gas quality constraints which could be very costly to renegotiate. This has led to the inclusion of gas quality constraints within hub-based transportation arrangements – it is the only way a TSO can limit its exposure to a pre-existing contract without investment. Historically this approach has not

been cause for concern because typically the mix of gases presented to the network allowed compliance to the specification and the mix did not change substantially during establishment of the transportation arrangements – the risks (which were low) became absorbed by shippers who were willing to take it.

121. It is noteworthy that safety related and infrastructure related parameters are driven by fundamentally different concerns (safety of consumers and costs of operation), yet they both manifest themselves in the same way in a specification.

122. Non-safety, consumption related parameters are often not included in specifications, probably largely because vertically integrated monopolies had no interest in them, and that this lack of interest has been translated to the vertically separated nature of the industry. There are potentially a great many of other consumption-related parameters that could be required for example methane content is of particular interest to agrichemical processes, where natural gas is procured for its methane rather than energy content.

2.4 Objectives of harmonisation

123. The overarching goals of gas quality harmonisation might seek to:

- ensure that consumers are not being exposed to unnecessary, inefficient costs, thereby ensuring the effectiveness of the internal market;
- limit damage to appliances, infrastructure and the environment;
- help the gas system to deliver the security, reliability and performance demanded of it; and
- ensure that gas quality-related constraints don't hinder market expansion and integration.

124. It might be possible to achieve the goals of gas quality harmonisation through the application of:

- an all-encompassing single gas quality specification that includes many parameters; or
- a minimal single gas quality specification (with few parameters) which may or may not be supported by complimentary specifications at a local or regional level (with any number of parameters).

It would not be possible to deliver the full benefits of harmonisation by maintaining a disparate set of gas quality specifications be they similar or different to the existing specifications) and pragmatically managing the emergent issues, because of changing gas flow patterns and potential new gas qualities.

125. There are other factors that should be considered:

- for each parameter included, the 'width' of the specification – i.e. the range of gases that any specification would describe;
- the time period over which any specification or specifications could be introduced;
- the geographic region or regions where it will apply; and
- where, within the value chain, the specification(s) apply.

126. The primary thought when considering what gas quality harmonisation should involve usually focuses on consideration of Wobbe indices, as it is the primary descriptor for understanding the interchangeability of different gases, has (arguably) the biggest safety

impact, and at high level appears to be very similar in many markets. For example, the GASQUAL project is predominantly focused on the interchangeability and performance of appliances: Wobbe index is the key measure used.

127. Often, within the industry, attention is next directed to oxygen or carbon dioxide content (as there are obvious cross-border incompatibilities, and each is of concern to particular types of gas storage facilities) and hydrogen sulphide content. Beyond these parameters, there is a great variety of opinions as to what should or should not be included in a gas quality specification.

128. Whilst it is perhaps obvious to ensure that at a minimum, safety-related parameters are included in any study of gas quality specifications (especially those that pertain to small consumers with uncontrolled and unmonitored systems) we note that the trading risks exist for all cross-border differences in specifications.

129. It is unclear what the original justifications are for many of the parameters in the existing specifications. If a particular parameter's specification is substantially different across a border, standardisation will remove trading risk but we do not know whether this will materially affect the reliability or cost of operating a system.

2.5 Existing approaches to handling non-compliant gas

130. We note that the majority of gas that flows into Europe is already processed to some degree, either as an integral part of production, liquefaction or regasification: a significant proportion of the production and import capacity needed for future flows already accommodates the existing specifications in its design. In order to enter the TSOs' systems, it is usually the case that gas should meet the applicable specification: either the gas is processed or blended to meet the specification or the specification has been defined[6] to accommodate the gas (although there are exceptions). Non-compliant gas must either be made compliant or will be rejected.

2.5.1 Measurement

131. In order to ascertain whether a gas is compliant or not, it is necessary to measure the parameters for which it must be compliant. To prevent the flow of non-compliant gas, it is necessary to measure its particular qualities in real or near-real time. Non-measurement of any particular parameter may indicate that the parameter is not considered important.

132. If it is discovered after the fact that a gas flow has been non-compliant, there could be liabilities that the injured parties might seek to recover from the contractual counterparty, however we have not been made aware of any such incidents. The ability to prove non-compliance by any particular party is extremely difficult because of both the contractual path (a single TSO is connected with another single TSO through a multiple shipper to multiple shipper contractual path) and the complexity of the physical chain.

133. Gas chromatography is generally the preferred method for determining a compositional analysis, typically in less than five minutes, from which physical properties (calorific value, Wobbe index, relative density, etc.) can be calculated. Extended analysis can also provide calculated hydrocarbon dew points. Various techniques have been developed for determining other parameters but there is no clear single practice. It seems likely that

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6 Within the applicable contract which, because of legacy issues, might be different to the legally applicable specifications yet still be non-discriminatory.

measurement practices vary throughout Europe, which might complicate the collation of standardised datasets.

134. It is not possible to enforce compliance with a specification through cessation where the offending parameter is not measured, although it might be possible to recover costs if contractual arrangements have been breached.

2.5.2 Blending

135. TSOs can sometimes accept a non-compliant natural gas into the network where it can blend it with another natural gas stream such that the resulting gas stream is compliant – a process usually referred to as 'blending' or sometimes 'fortuitous commingling'. It is similar to a practice widely employed in both gas and oil production to tune the products delivered to a refinery.

136. Blending is reliant on the availability of the compliant stream of gas. Unavailability of the compliant stream can result in interruption or reduction of the non-compliant stream. As TSOs are generally not in direct control of the compliant stream (volumes and/or qualities), blending services are often only provided by TSOs on a reasonable endeavours basis (although we note the potential for contracts to exist that may guarantee availability of the compliant stream.)

137. The majority of blending practices usually involve increasing the Wobbe index of non-compliant low-Wobbe index gas.

138. Some interconnection agreements (agreements between adjacent TSOs) require TSOs to communicate regarding changes to gas quality and to cooperate on controlling gas quality (e.g. wherever non-compliant gas might be presented at an interconnection point). This sometimes affords the opportunity for an upstream TSO to present non-compliant gas to a downstream TSO.

2.5.3 Processing

139. Some TSOs are actively involved in processing gas – i.e. manipulating the characteristics of the gas through something other than blending. In most cases this involves derichment through nitrogen or air ballasting. This approach is generally used where the TSO has specific obligations to manage gas quality, usually because of the presence of L-gas.

2.5.4 Rejection

140. Ultimately, non-compliance that cannot be accommodated might result in rejection – a physical cessation of flows. It might be the case that this does not result in commercial interruption where the situation can be resolved within the applicable balancing period, however prolonged cessation will result in a requirement for shippers to rebalance.

141. Rejection due to non-compliance has rarely happened and evidence provided by ENTSOG to Pöyry/GL suggests that there have only ever been five instances with commercial consequences – once for Wobbe index concerns, and the other occasions for water dew point issues. These are shown in Table 4 below.

Table 4 – Instances of gas quality related interruption

Country	Company	Flow interruptions (Y/N)	If Yes --> reason
Austria	BOG	N	
	OMV	-	
Bulgaria	Bulgatransgaz	Y	Change in **water dew point parameter** for short periods of time created a problem in natural gas transmission in September 2010 and September 2011. In two instances, neighboring TSO refused to accept gas quantities due to water dew point parameter non-compliance with contractual conditions. Deterioration in the parameter is allowed during repair
Greece	DESFA	N	
Spain	Enagas	N	
Denmark	Energinet	N	
France	GRTgaz	N	
Hungary	FGSZ	N	
Netherlands	GTS	-	
UK	NG	N	
	Interconnector	N	
Ireland	Gaslink	N	
Germany	Ontrans	-	
	OGE	-	
	GUD	N	
Slovenia	Plinovoldi	N	
Belgium	Fluxys	Y	**Wobbe Index** issue between Belgium (and generally speaking continental Europe) and UK.
Italy	SRG	-	
Poland	Gaz - System	Y	**Water Dew Point**
Sweden	Swedegas	N	

2.6 Summary

142. The existing approaches to managing gas quality already mitigate some of the potential impacts that disparate gas quality specifications have. However, whilst no persistent physical implications of different gas qualities between adjacent TSOs are evident, there may be some cost implications arising from:

- excessive investment prior to entry;
- excessive investment or costs incurred by TSOs to manage gas qualities; and/or
- higher wholesale market prices.

3. BENEFITS OF HARMONISATION

143. We have identified five broad categories of benefits that would materialise from the adoption of a single pan-EU gas quality specification. These are:

- **more efficient sourcing of gas**, because if a wider gas quality specification was introduced, the EU would have access to a more diverse set of supplies;
- **more efficient transportation of gas**, as gas would no longer be prevented from entering a local market and therefore would no longer require displacement to an alternative market and transportation along an indirect route;
- **better competition in the gas supply market**; because of the risk that gas is prevented from flowing where cross-border specifications are different, and because shippers bear the ultimate contractual responsibility for gas quality, the development of a competitive gas supply market is potentially hampered;
- **better functioning of the gas appliance market**, as existing appliances are often designed to operate only within a restricted range of gas qualities which limits the economies of scale that might be available, or are required to be tuned during installation thereby increasing installation and maintenance costs; and
- **enhanced security of supply**, where more supplies would be able to enter a local market.

144. This chapter discusses each of these and, where possible based on the information available, quantifies the potential benefits.

3.1 Efficient sourcing and transportation

145. Whilst the current flow patterns are compliant with the existing disparate gas quality specifications, there is a risk that the overall cost of supplying the EU market is inefficiently high because there is the potential that some gas is prevented from directly entering a local market or potentially from entering the EU market at all, i.e. that gas flows are distorted. There is therefore both a potentially inefficient arrangement of the gas transportation network where the particular gas enters a non-local market and displaces gas towards the local market, and a potentially inefficient set of supplies to the EU.

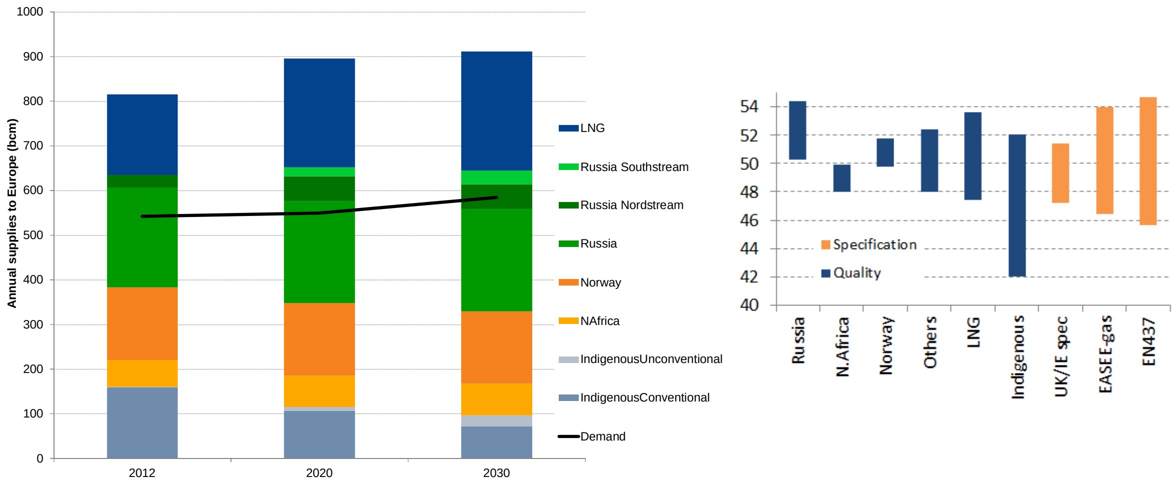
146. Furthermore, the flows anticipated into the future may suggest a material change in the average gas quality a TSO faces and this exacerbates these costs.

147. Whilst this does not appear to present a noticeable problem today (there have been very few instances of gas quality related interruptions), there is the potential for this to be impacted by the future flows of gas in the network. This is illustrated in Figure 4 below, which shows predicted changes in supply capacity between 2012 and 2030: there is a notable decline in conventional indigenous supply capacity, but this is more than compensated with the greater increase in LNG and Russian import capacity. The Wobbe index ranges of associated supply sources in 2020 is also presented; these ranges are not expected to change into the future.

Figure 4 – Predicted EU import capacity growth; ranges of gas qualities

Import capacity growth

Wobbe index ranges (2020)



Note: Gas quality ranges are the Wobbe indices assumed within our modelling for 2020. ‘Russia’ therefore accommodates potential high Wobbe index gas from Shtokman which would be supplied via Nordstream. The Wobbe index ranges are not expected to change in 2030 (although the volumes will). Indigenous qualities include L-gas and unconventionals.

3.1.1 Quantification

148. In order to estimate the potential benefit that can be obtained by changing or removing gas quality constraints, we have considered the potential future flows of gas to and within the EU, and how they might be transported and blended with other gases to meet a given set of gas quality specifications. Different sets of specifications have been applied to examine the effects on the total costs to serve EU consumers, assuming that these costs are minimised and that the underlying long-run costs of supply and transportation are fully recovered.

149. Given the requirement to consider these impacts in a forward looking context, we have quantified the potential benefits through the use of a gas market model. The principal gas quality assumptions used within the model are:

- that the modelled networks produce a blended single gas quality which is the flow weighted average of all inflowing gas qualities, i.e. it assumes all gas can and is blended by TSOs; and
- that the future gas qualities available from existing sources of gas do not change.

3.1.1.1 Modelling technique

150. Pöyry maintains a suite of sophisticated European energy market fundamentals models for modelling gas, electricity, carbon, renewables, oil and coal markets. For the purposes of this project, the pan-European gas market model, ‘Pegasus’ has been extended by developing and incorporating a technique for modelling gas qualities for specific economic optimisation problems.

151. Pegasus uses mathematical optimisation techniques to minimise the cost to serve all modelled demands for gas, subject to a series of constraints that describe the physical and commercial reality of Europe’s gas market, on the basis of long-run marginal costs. Pegasus is therefore a useful tool for quantifying the impact of particular constraints on the market.

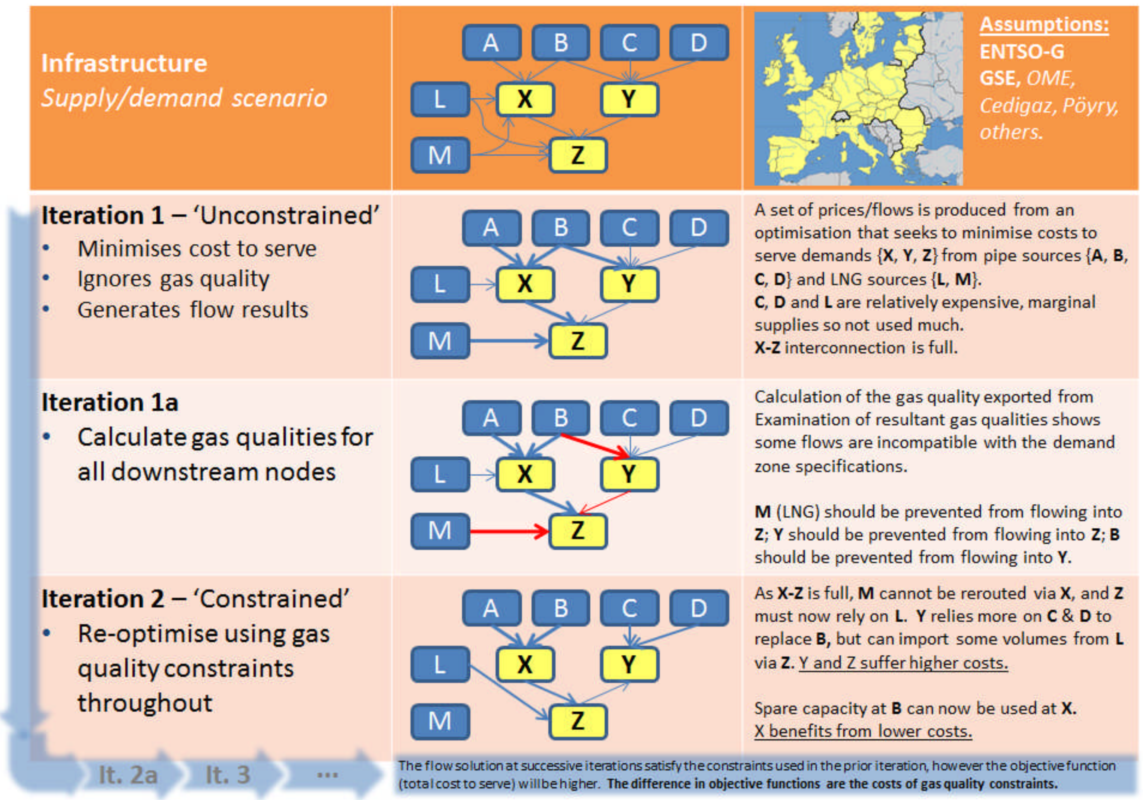
152. Pegasus and the developments implemented for this project are described in detail in Annex J.

153. In its normal mode of operation, Pegasus assumes that all natural gas is fungible: where gas can flow from and to is only constrained by physical capacities of infrastructure and the objective function (i.e. the minimisation of the costs to serve) of the model.

154. In order to examine the possible benefits that arise from harmonising gas qualities, we have developed Pegasus to restrict flows of gas to respect gas quality constraints. The larger inaccuracies that arise from imperfect information are handled by maintaining all other things equal in the model.

155. The model uses an iterative technique, which is explained in Figure 5 and further explained in Annex J.

Figure 5 - Iterative technique used in modelling



156. The steps involved in the calculation are:

- an initial 'unconstrained' run – the model minimises the costs to serve all modelled demand, subject to constraints pertaining to infrastructure capacities, contractual obligations such as take-or-pay obligations, daily balancing;
- calculation of gas qualities – from the flows established in the preceding step, calculate the flow weighted gas quality parameter at every node (equivalent to a balancing zone) within the network;
- re-optimise applying gas quality constraints – the model minimises the costs to serve all modelled demand, subject to the same set of constraints but also subject to

constraints that the gas quality flowing into any node must be compatible with the applicable specification – this interrupts some flows of gas, requiring the model to rebalance;

- re-calculate gas qualities and iterate as necessary.

157. The starting point is therefore to generate an 'unconstrained' analysis, where gas quality considerations do not hamper the free movement of gas. This is then compared to a fully iterated 'constrained' run, where a set of gas quality specifications is respected. Given that all other things between the two models are equal, the difference between the two objective functions provides a quantification of the costs of the gas quality specification.

158. Within the model, the gas quality therefore assumed at cross-border points is the flow weighted average of gas qualities flowing into the relevant MSs on a daily basis.

3.1.1.2 Scenarios and results

159. To examine the effects that the harmonisation of gas quality specifications might have on the prices within Europe's markets, we have constructed a series of gas quality scenarios which, in combination, build a representation of the current situation of disparate gas quality specifications. These different gas quality scenarios can then be compared against the unconstrained scenario to estimate the benefits arising from gas quality harmonisation.

160. The scenarios we have examined are:

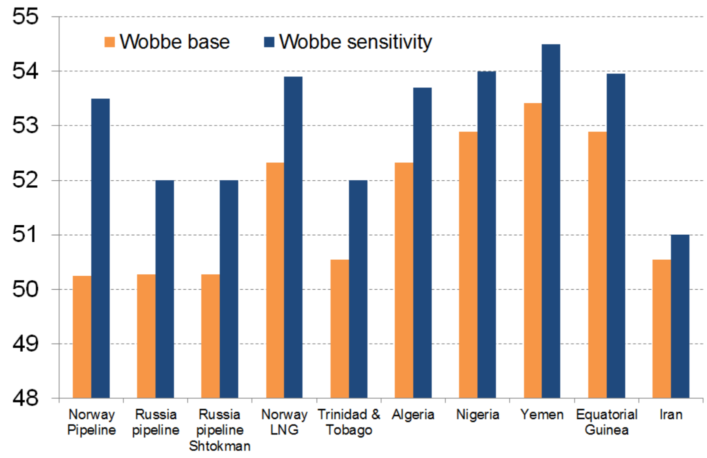
- The unconstrained scenario – a scenario where there is an absence of gas quality constraints across the EU, i.e. that any gas can be accepted and used anywhere within the EU;
- Multi-quality scenario, where we have assumed that existing national specifications in respect of Wobbe index, CO2, O2, N2 and H2S continue to prevail – this scenario represents the baseline counterfactual situation assuming our basis assumptions for upstream gas quality;
- Calorific value scenario, where we have assumed that existing national specifications implied by Wobbe index and relative density prevail – this scenario was included to test the linearity of the modelling and is of limited interest;
- Wobbe (base) scenario, where we have assumed that existing national Wobbe index specifications prevail – this scenario was included to test the sensitivity of the modelling to upstream gas quality assumptions (in this scenario we used our basis assumptions for upstream gas quality);
- Wobbe (sensitivity) scenario, where we have assumed that existing national Wobbe index specifications prevail – this scenario was included to test the sensitivity of the modelling to upstream gas quality assumptions (in this scenario we used more extreme assumptions for upstream gas quality); and
- EASEE-gas specification, where we have assumed that existing national Wobbe index specifications are replaced with the relatively wide EASEE-gas specification.

161. The baseline counterfactual situation is most closely represented by the multi-quality scenario, although it is sensitive to the assumptions made about upstream gas qualities, and it does not include consideration of all the various gas quality parameters.

162. We have tested the sensitivity of our modelling to the upstream gas quality assumptions by examining the effect of assuming wider upstream Wobbe indices within the two Wobbe

scenarios. The two sets of Wobbe assumptions are shown in Figure 6 below. This shows that benefits are sensitive to the input assumptions by possible orders of magnitude of 2 (in 2020) or 3 (in 2030) times.

Figure 6 – Upstream Wobbe number sensitivities



163. The potential benefit of harmonising gas quality specifications is uncertain. Depending on the structure of the new gas quality specification and the assumed/projected gas qualities for individual sources, the additional benefits that we have been able to quantify may range from between €120m and €370m per annum. Given that this assessment is the result of modelling perfect competition this is a conservative figure. This range reflects several aspects of the modelling and changes over time. The detailed figures are presented in Table 5 below, with more detailed results provided in Annex I.

Table 5 - Summary results of the modelling of partial harmonisation benefits

Name	Description	Para-meters	Width	Modelling name (used Annex I)	Value of benefit (compared to an unconstrained situation) (€m per annum) 2020	2030
Baseline	Baseline counterfactual – the value reflects the benefits compared to a fully unconstrained situation	Wobbe index + CO_2 + O_2 + N_2 + H_2S	Narrow	Multi-quality	139	120
Unconstrained		N/A		Uncon-strained	0	0
Sensitivity	The benefits that would be realised if future gas qualities were wider than assumed in the baseline counterfactual	Wobbe index + CO_2 + O_2 + N_2 + H_2S	Wide	N/A (implied)	310	370
EASEE-gas	The benefit that would be lost if EASEE-gas were applied throughout the EU	Wobbe index	Narrow	EASEE-gas	3.7	0
Wobbe only	The benefits attributable to harmonising only the Wobbe index	Wobbe index	Narrow	Wobbe (base)	44.4	20.0
Wobbe only (sensitivity)	The benefits attributable to harmonising only the Wobbe index if future gas qualities were wider than assumed in the baseline counterfactual	Wobbe index	Wide	Wobbe only (sensitivity)	99.1	61.7
Implied CV	The benefits attributable to harmonising only CV	CV	Narrow	Calorific Value	176	122

164. The incremental cost to gas supply does not appear high for two main reasons:

- day-to-day pipeline flows are usually not impeded because the destination specification is fixed, and the source gas has a known quality – most pipeline gas is already compatible with its destination markets (or has sunk investment to ensure compliance); and
- Europe's LNG reception terminals include facilities to enable processing to meet local specifications and, whilst these facilities are usually designed with reference to a particular LNG production facility and so local specifications could therefore prevent LNG entering a local market, the LNG is often acceptable at another EU entry point – LNG is therefore only prevented entering the EU where it does not meet any of the available EU specifications.

165. The figures for 2020 are generally higher than the figures for 2030 because LNG is diverted at marginal transportation costs so, as Europe imports proportionately more LNG in the future, existing local specifications present less of a constraint to Europe as a whole.

3.1.2 Limitations of the modelling

166. Whilst we have captured the sensitivity of the model to upstream gas quality assumptions, there are some other assumptions that might limit the reliability of the modelling:

- we have an incomplete set of gas supply contract information and have made assumptions about certain parameters such as price and take-or-pay quantities;
- after the contracts specified within the model have been met, that marginal demand anywhere within the EU can be met from the marginal supply to the EU taking into account transportation costs – i.e. the modelling assumes perfect competition;
- the modelling assumes that there is a perfect mixing of gas quality within each modelled zone;
- the modelling does not consider that LNG is delivered in batches; and
- the modelling dispatches gas storage with perfect foresight of future gas prices.

167. This means that additional benefits might be discovered in the real market, although we have been unable to estimate the impact of these.

3.2 Gas market competition

168. We note that the benefits that might be realised from the facilitation of trade should, according to economic theory, result in more competition and more effective prices. This may represent the biggest potential benefit from mitigation, potentially more promising than the efficient transportation benefits.

169. In a vertically separated market TSOs have the contractual right to reject gas that does not comply with the specification without recompense to the injured party. This presents a risk to entities (shippers) trading or moving gas across a border.

170. Where non-compliant gas is rejected by the TSO, the importing shipper will in many cases become “short”, and consequently the exporting shipper (which might be the same entity) will become “long” – requiring upstream and downstream systems and markets to be rebalanced. If the underlying markets are sufficiently competitive, the immediate additional costs of the importing shipper (acting as a distressed purchaser in the wholesale market) and the opportunity costs of the exporting shipper (acting as a distressed seller in the wholesale market) are ultimately absorbed by their shareholders; if they are not sufficiently competitive the costs would be absorbed by consumers. This is because (where sufficient competition exists) other shippers in the same market that do not make use of the interconnection capacity are not exposed to the imbalance risk, and because counterparties to the rebalancing actions can create additional returns for their shareholders.

171. However, in such circumstances it also follows that a new price level would be found in each market, affecting all volumes trading at the hub – the “short” market may experience a price ‘spike’, and the “long” market would experience a lower price. Historical evidence appears to suggest that liquid gas markets tend to push prices upwards when they are short more readily than pushing prices down when they are long, however the data to

support this observation is limited and suffers from strong interactions with other observations (such as the perception of security of supply risk).

172. Whether the new price levels result (across both markets) in costs to consumers requires an understanding of how these risks are quantified and mitigated in the markets, how they differ between short markets and long markets, and how they feed through to retail margins. Assuming that all entities trading in each market are operating rationally, there is no immediate reason to suspect that the risks and mitigations of being short are inherently different to the risks and mitigations of being long (ultimately both require access to other flexible supplies such as gas storage, LNG regasification or, ironically, other interconnector flows). Therefore the net cost to consumers should be limited to the loss of the marginal demand/supply, and the risk premium charged by shippers for cross-border transportation where there is no gas quality related interruption. However, where there is insufficient competition in the underlying markets, the impacts may not be limited to marginal differences.

173. To quantify the risk premium would need quantified evidence from shippers, which has not been provided (and is unlikely to because of commercial confidentiality). We have therefore been unable to quantify the existing or potential future costs trading entities face because of potential interruption of their trading routes. We would expect that the current gas quality risks currently materialise as a premium on prices (i.e. higher transaction costs).

174. It has not been possible to isolate gas quality problems from other market competition problems.

3.3 Enhanced appliance competition

175. Standardisation to a single gas quality specification applicable throughout Europe will enable appliance manufacturers to directly compete throughout Europe. This should offer consumers a wider range of products, allow technological improvements to permeate the marketplace more rapidly, and lower appliance prices.

176. A recent report[7] published by DG-ENTR examined the competitiveness of the gas appliance sector, and concluded that any future harmonisation of gas quality is seen as an opportunity for manufacturers, as gas appliances are currently designed to operate only within a certain gas quality range.

177. The report focussed primarily on an analysis of the domestic appliance manufacturing market. The report noted that:

- the implementation of GAD has helped competition as it has removed barriers that prevent free circulation of gas appliances around the Member States (this is part of the baseline situation and therefore any improvements are assumed to be already captured);
- national installation rules and practices sometimes impact free trade;
- gas appliances are viewed as being price competitive compared to other non-gas domestic appliances;
- the market in new Member States has developed quickly, with many smaller independent companies becoming established. It was also noted that many of these become affiliates or sub-contractors to much larger firms in EU-15.

[7] Ecorys, 'Study on the Competitiveness of the EU Gas Appliances Sector', August 2009.

3.4 Security of supply

178. Disparate gas quality specifications could lead to more rejection and risks of supply interruptions as gas sources change into the future. We have been unable to quantify these because, as shown in Table 4 above, there is of a lack of historical data which could be used to generate forward looking analysis.

179. Our modelling does not identify a lack of available supply, however in particular circumstances (high demand, unforeseen import/supply outages, concentrated import/supplies), a gas quality problem could have particularly serious implications for security of supply. We note that security of supply concerns arising from gas quality issues are to be mitigated through the application of Article 9 of the security of supply regulation (EC/994/2010)[8].

180. Should gas be prevented from flowing because of gas quality specifications, this could result in a supply security problem. Harmonisation would mean that more supplies would be able to enter a local market during emergency situations. We have been unable to quantify the impact of this but, as it is the subject of specific directive and potential action by MSs, consider that it might represent a significant benefit.

3.5 Emissions and efficiency

181. Replacing a wide specification and variable gas qualities with a narrower specification and/or less variance in gas quality might provide benefits in terms of increased operational efficiencies being achieved by various gas appliances (from domestic appliances to CCGTs), and may also lower costs of installation by removing the need to tune appliances.

182. For domestic appliances it is difficult to estimate the impact of this because:

- some of the existing appliance population is already tuned to be efficient for the gas quality observed locally – evidence of how many appliances are tuned and where, when and how they have been tuned, is not available (we suspect that it does not exist or is incomplete). It is therefore difficult to assess the extent to which there could be an improvement in efficiencies across the appliance population; and
- some proportion of gas quality variance is due to unforeseen changes to flow patterns in operational timescales (i.e. within-day), for example caused by plant failure and trips. Evidence to understand the magnitude of the impact of such unforeseen flow changes on the gas quality variance observed at appliances is not available (we suspect that it does not exist).

183. There is a similar lack of information pertaining to industrial applications and gas turbines, although we note that relevant consultation responses suggest that replacing a narrower specification with a wider specification would be expected to decrease efficiencies.

184. We note that this only delivers a benefit where the chosen specifications have a narrower Wobbe index. We have therefore not considered this benefit further.

[8] An example of the consideration can be found in Risk assessment for the purpose of EU Regulation 994/2010 on security of gas supply', Department for Energy and Climate Change (UK Government), November 2011.

3.6 Summary

We have summarised the above benefits in Table 6, below.

Table 6 – Summary of identified benefits

Nature of benefit	Description	Quantification	Relative impact from specification 'width'
Efficient sourcing & transportation	Increasing the ability to receive various gases, and enabling them to be imported close to demand, increasing the efficiency of gas transportation	Estimated through modelling: between **€120m and €370m** per annum	Larger benefit with wider range
Gas market competition	Decreasing the risk premium attached to cross-border trading that arises from the risks of gas quality related interruptions	To quantify this would need quantified evidence from shippers, which is unlikely to be provided because of confidentiality	No differences
Appliance competition	Standardisation would increase the size of the appliance manufacturing market	GAD has already generated a largely competitive market, so the impact of appliance prices is not thought to be significant	No differences
Security of supply	Disparate gas quality specifications could lead to more rejection and risks of supply interruptions as gas sources change into the future.	Lack of detailed historical data on which to produce forward looking analysis. Historical evidence suggests that gas quality has not led to material security of supply issues.	Larger benefit from wider range
Emissions and efficiency	Reduction of specification width and/or deviations of actual gas qualities could enable appliances (large and small) to operate more efficiently and emit less	Difficult to quantify because there is no evidence to isolate the effect of interdependent factors such as the existing extent of appliance tuning.	Larger benefit with narrower range

4. ACHIEVING EUROPEAN HARMONISATION

185. During the course of the project a large variety of different approaches to assessing the impacts of harmonisation have been considered, and different ways that the benefits explained above might be achieved. These approaches fall into three broad categories:

- considering what the likely impact of adopting a variety of specifications in a variety of situations might be, and identifying associated risks and possible mitigations;
- information provision approaches that deliver some of the benefits without altering gas quality specifications; and
- extreme approaches that cover for all risks and all eventualities.

186. These approaches are presented within this chapter. The first four sections of this chapter describe the first category, with the final two sections of the chapter summarising each of the other two categories. Supporting calculations and considerations for latter two categories are presented in Annex P.

4.1 Consequences of a new specification

187. Within this section the potential impacts for a single TSO of adjusting to a new gas quality specification are outlined. This is intended to illustrate where investment may be required, upstream or downstream and the trade-offs between them, dependent on the relationship between the existing and new specifications.

188. An understanding of the scale and form of investment that may be required under alternative situations helps map the likely costs to individual TSOs of any new standard. An uneven distribution is anticipated because disparate existing specifications influence the ease of complying with changed specifications. In section 4.2 this analysis to a sample of countries has been applied.

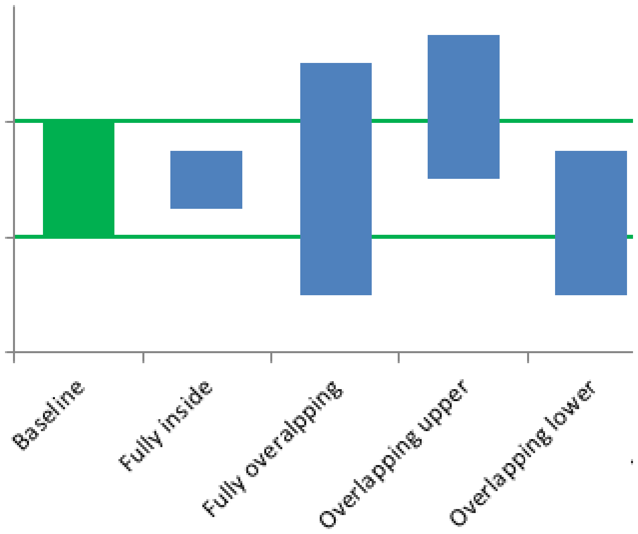
189. There are potentially four situations for any change to specification. These are that the new specification describes gas that:

- is completely within limits of the baseline specification ('fully inside');
- can be both above and below the maximum and minimum limits of the baseline specification ('fully overlaps');
- can be above the maximum of the baseline specification but whose minimum is above the minimum of the baseline specification ('overlapping upper');
- can be below the minimum of the baseline specification but whose maximum is below the maximum of the baseline specification ('overlapping lower').

190. Other situations (i.e. that the new specification is always above the maximum limit, or below the minimum limit, of the baseline specification) are not considered to be realistic.

191. These scenarios are outlined in Figure 7 below. In the figure, blue bars represent the new specification.

Figure 7 – Potential situations arising from a change to specification



4.1.1 Potential actions required for compliance with the new specification

192. When there is a change in specification, one, or both, of two effects on the system have to be dealt with:

- the TSO may now be required to accept gas that is outside of its current specification; and
- existing appliances may now not be compatible with the feasible gas quality range within the national system.

193. Consequently, investment may be required. Whether this is upstream or downstream depends not only on the potential situation (described above) that the change introduces, but also potentially on the relative cost of adapting upstream or downstream and the timing of when issues may emerge. In the section that follows, the potential investments that may be required upstream and/or downstream under each of the four potential situations are highlighted.

4.1.1.1 Fully inside

194. If the new specification is fully inside the baseline, then there is a possibility that some existing gas will not comply with the new specification and would be unsuitable for export (assuming also that the new specification is applied in the downstream market).

195. Furthermore, while existing appliances would be assumed to be able to continue safe operation because the new specification is fully covered by the existing specification. As new appliances should potentially conform only to the new specification they are unable to use any existing gas that does not comply with the new specification.

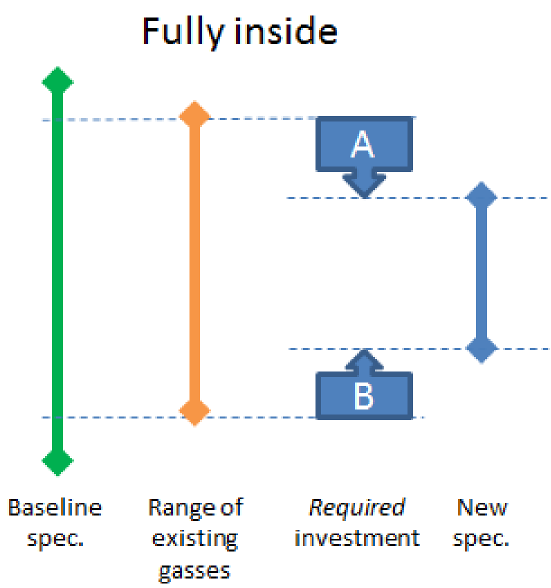
196. These two observations will result in a need to treat existing gas that is outside the new specification. This will require investment in some processing capability (illustrated in Figure 8 below):

- derichment where the gas is above the upper limit of the new specification (A); or
- enrichment where the gas is below the lower limit of the new specification (B).

197. The required investment only needs to cover the extent to which existing gases are not compatible with the new specification – it does not need to consider the extent to which the baseline specification is different to the new specification.

(Note, this is labelled as 'required investment' in this and subsequent figures, but it is acknowledged that it is only required if existing gases are incompatible with the new specification).

Figure 8 – Processing requirements in 'fully inside' situations



4.1.1.2 Fully overlaps

198. Here, all gas currently flowing into the system is compatible with the new specification and therefore there is no requirement to process them.

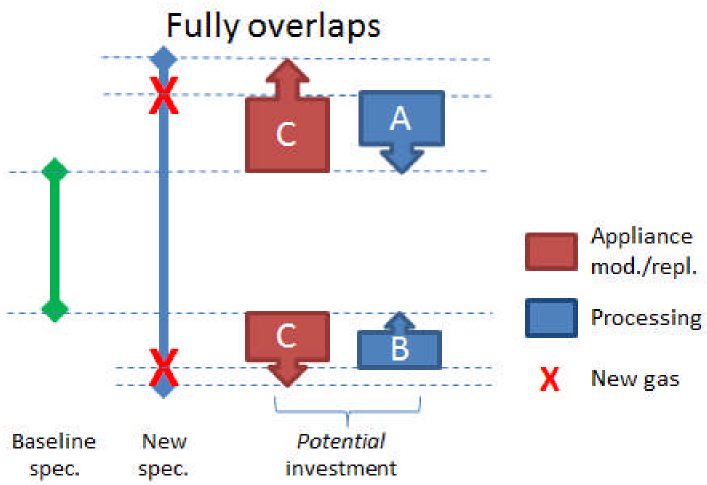
199. Similarly, all existing appliances are compatible with current flows and therefore, in the short-run, there is no need to replace or modify them.

200. However, by changing the specification, the potential exists for shippers to present gas to the system that is not compatible with the pre-existing appliance population and this may give rise to some remedial investment. This potential investment could be (as illustrated in Figure 9, below) either:

- downstream, through the replacement or modification of the pre-existing appliance population to meet the full range of the new specification (C); or
- within the network, processing the new gas to ensure its compatibility with any remaining pre-existing appliances (A or B).

201. In the second of these two options, the incompatible pre-existing appliances will continue to be naturally replaced over time by new appliances capable of operating over the full range of the new specification. This means that, over time, the processing equipment that has been installed becomes redundant.

Figure 9 – Potential investment in 'fully overlaps' situations



4.1.1.3 Overlapping upper

202. This situation results in a mix of the different outcomes from the previous two situations.

203. As all existing gases are compatible with the pre-existing appliances, there is no need to replace or modify appliances unless new gas is presented to the system that is outside of the baseline specification. Should new gas be presented to the system that is not compatible with the pre-existing appliance population, there may need to be some form of remedial investment. This could be (as illustrated in Figure 10, below) either:

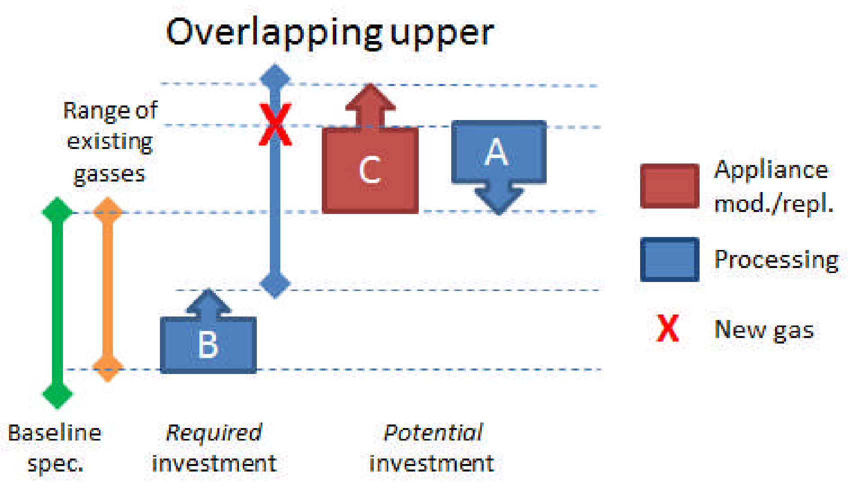
- downstream, in through the replacement or modification of the pre-existing appliance modification/replacement (C); or
- within the network, processing the new gas to ensure its compatibility with any remaining pre-existing appliances (A).

204. As in previous situations, in the second of the two options, the incompatible pre-existing appliances will continue to be naturally replaced over time by new appliances capable of operating over the full range of the new specification. This means that, over time, the processing equipment that has been installed becomes redundant.

205. However, in this situation, because both replacement appliances (designed to meet the new specification) and exports are potentially incompatible with some of the existing gases, there will be a requirement for investment in enrichment processing (B).

206. These investments are illustrated in Figure 10 below.

Figure 10 – Investments in 'overlapping upper' situations



4.1.1.4 Overlapping lower

207. The 'overlapping under' situation is the inverse situation to the 'overlapping over' situation.

208. As all existing gases are compatible with the pre-existing appliances, there is no need to replace or modify appliances unless new gas is presented to the system that is outside of the baseline specification. Should new gas be presented to the system that is incompatible with the pre-existing appliance population, there may need to be some form of remedial investment. This could be (as illustrated in Figure 11, below) either:

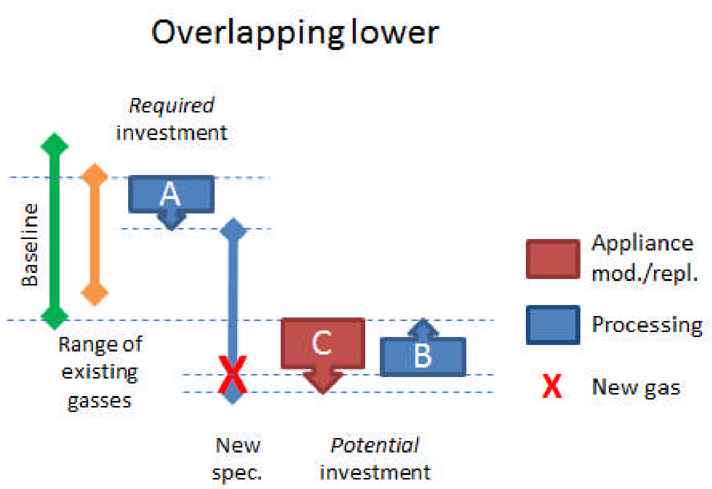
- downstream, in through the replacement or modification of the pre-existing appliance modification/replacement (C); or
- within the network, processing the new gas to ensure its compatibility with any remaining pre-existing appliances (B).

209. As in previous situations, in the second of the two options, the incompatible pre-existing appliances will continue to be naturally replaced over time by new appliances capable of operating over the full range of the new specification. This means that, over time, the processing equipment that has been installed becomes redundant.

210. However, in this situation, because both replacement appliances (designed to meet the new specification) and exports are potentially incompatible with some of the existing gases, there will be a requirement for investment in derichment processing (A).

211. These investments are illustrated in Figure 11 below.

Figure 11 – Investments in 'overlapping lower' situations



4.1.2 Summary of the four situations

212. Table 7 below summarises the impacts of the four situations described above.

Table 7 – Impacts of the four situations

Situation	Possible investment *required* for existing gases	*Potential* investment for new gases
Fully inside	Enrichment + derichment	None
Fully overlaps	None	Enrichment + derichment
Overlapping upper	Enrichment	Derichment or appliance modification/replacement
Overlapping lower	Derichment	Enrichment or appliance modification/replacement

4.1.3 Relative costs

4.1.3.1 Enrichment and derichment

213. Generally, it is expected it to be cheaper to de-rich gas rather than enrich it. For a typical enrichment from 39 MJ/m^3 to 41 MJ/m^3 capex costs in the range of €0.75m/mcmd to €1.75m/mcmd with annual opex costs in the range of €1.65m/mcmd to €3.85m/mcmd are estimated. For a typical derichment from 41 MJ/m^3 to 39 MJ/m^3 capex costs in the range of €1.5m/mcmd to €3.5m/mcmd with annual opex costs in the range of €0.14m/mcmd to €0.32m/mcmd are estimated. In general therefore harmonisation should seek a specification that requires more downward adjustment than upward adjustment, however it is noted that the requirement for upward adjustment is tempered by the GASQUAL observation that appliances receiving gases with low Wobbe indices present fewer safety concerns.

214. The lowest impact from harmonisation might therefore be expected where the requirement to enrich gas is minimised at the expense of requiring derichment.

215. Where there are other streams of compliant gas, there may be the potential for some blending (additional to the blending used in the current situation). This could lower the potential costs of enrichment or derichment although it will only be available is specific locations. Access to sufficient information has not been granted to be able to understand whether this might be possible to any greater extent than current practice.

4.1.3.2 Appliance replacement and processing

216. It is assumed that the baseline situation, appliance replacement occurs only due to natural replacement cycles (asset life and deterioration as well as human factors, discussed in Annex P).

217. Where it is necessary to undertake remedial action to replace existing appliances as a consequence of new gases entering the system, a gradual replacement will present significantly lower costs than a ‘big-bang’ replacement.

218. It is likely to be the case (but not necessarily) that processing new gas such that it is compatible with pre-existing appliances will be a cheaper option and in the long-run will have a lower impact than replacing the appliances. This will be dependent on both the extent to which the new specification is different to the baseline specification, but also to the number and types of appliances connected to the system.

219. The situation where existing gases are not compliant with the new specification will require investment in processing facilities to enable those existing gases to continue to flow. Without the investment, the existing gases would be prevented from flowing, impacting on the prices seen within the market.

220. In summary, generally, investment in processing would be required to ensure the compatibility of:

- pre-existing appliances where new gas enters the market; and
- new appliances where non-compliant existing gases continue to flow.

4.1.4 Risks and deficiencies

221. Selection of a single gas quality specification introduces a risk that eventually, the specification is not optimal. This risk could be mitigated through thorough analysis and study at inception, and with an on-going review process.

4.1.4.1 Parameters

222. The above analysis relates only to Wobbe index. Other parameters may only have a minimum (methane) or a maximum (others) element within a specification, and so the set of situations pertaining to these parameters will be narrower.

223. These risks are discussed in greater detail in section 4.3.2 below.

224. It will therefore be necessary to establish which additional parameters need to be included within a new specification.

4.1.4.2 Appliance performance

225. Some of the investments identified are predicated on being able to meet anticipated new specification gases, so there is still a residual risk that gas at either end of the new specification may turn up and, at the moment, the investment would not guarantee that it could be accommodated. This risk can only be removed if extreme investment solutions were applied.

226. The extent of this risk and the need for insurance investment is something that is expected to be determined by Member States/NRAs in discussion with the TSOs.

4.1.4.3 Implementation risks

227. An unintended consequence of applying a new specification would be that shippers stop utilising existing commercial gas quality management services. The most efficient solution to this might be that that the physical activities continue, so there may need to be a payment from TSO to shipper or the service provider if the obligation to apply the new specification is placed on the TSO.

4.2 Costs of applying a new specification

228. To test the above situations on a sample of countries selected harmonised specifications have been used to estimate the impact on some MSs.

229. The following specifications have been chosen to apply:

- the EN437 ‘Second Family H-gas’ specification, with a Wobbe index range of 45.65 - 54.7 MJ/m^3, has been chosen to represent a wide specification;

- the Ireland/UK specification, with a Wobbe index range of 47.20 - 51.41 MJ/m^3, which has been chosen to represent a narrow specification; and
- the EASEE-gas specification, with a Wobbe index range of 46.45 – 53.99 , MJ/m^3 which has been chosen to represent a specification in the middle.

(Reference conditions are 15 °C for combustion, 15 °C and 101.325 kPa for volume).

230. Each of the three specifications has been examined against the currently applicable MS specification, to understand which particular situation the MS would find itself in. This is shown in Table 8, below.

231. The potential unit costs of processing existing gases to meet each new specification have been estimated, using the unit costs identified in section 4.1.3.1. This calculation is based on the old specification rather than the actual gases experienced, because of a lack of sufficient data (good quality data pertaining to flows, gas qualities and existing quality management potential would enable a better quantification), and calculated these unit costs in net present terms over 20 years assuming a discount rate of 5% and a load factor of 50%[9].

232. These unit costs are then applied to an estimate of the processing capacity that might be required. In the face of insufficient data, these capacity requirements have been estimated assuming that existing gases are uniformly distributed across the existing gas quality range, so the volume of capacity required in each market is the product of a peak day demand and the proportional change to the specification.

233. Two values have been computed, based on upper and lower estimates for the unit costs identified in section 4.1.3.1. The costs that are expected to occur to a large extent stem from a relatively small group of countries.

234. The assumption of a uniform distribution potentially increases the capacity and volumes of gas that are assumed. It is expected that a normal distribution might provide a better description of the real gases, however there is insufficient information to be able to specify the parameters for the distribution. If a normal distribution were used, lower the costs would be expected.

235. This analysis shows that the lowest immediate impact is expected when a new specification is wide. The analysis demonstrates that where a new specification is wider than the existing specification, then there is no immediate cost because existing gases are already compliant. It also shows that MSs with low lower Wobbe limits may face larger immediate impacts that average because of the possible need to enrich existing gas: costs of enrichment are significantly greater than costs of derichment. The analysis is shown in Table 8 to Table 10, below.

236. There is a limited set of data that describes the typical gas qualities experienced in some MSs (shown in Figure 2 on page 20). Applying this sample gas data within the above framework demonstrates that there might be no need to process any of the existing gases to meet the EN437 or EASEE-gas specifications. For these specifications, the **lower bound of costs is therefore zero**.

237. Applying the sample data to the IE/UK specification suggests that costs might be between 10% and 39% of the upper range presented in Table 10, with an average of 26%. This approach has been used to estimate a lower bound for these costs of 2.5€bn.

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9 A higher load factor would increase the influence of enrichment costs on total costs.

Table 8 – Immediate costs of applying the EN437 specification

EN437		Enrichment						Derichment						Total cost	
		Process	Capacity 2020	Capacity 2030	Unit cost	Cost (net present) 2020	Cost (net present) 2030	Process	Capacity 2020	Capacity 2030	Unit cost	Cost (net present) 2020	Cost (net present) 2030	2020	2030
	Category	(MJ/m3)	mcmd	mcmd	€m/mcmd (net present, assuming 50% load factor)	€m	€m	(MJ/m3)	mcmd	mcmd	€m/mcmd (net present, assuming 50% load factor)	€m	€m	€m	€m
Austria	OU	0.23	2.73	3.25	26.06	71	85				3.81			71	85
Belgium	FO				26.06						3.81				
Czech Republic	FO				26.06						3.81				
Denmark	FO				26.06						3.81				
Estonia	FO				26.06						3.81				
France	FO				26.06						3.81				
Germany	OU	2.03	91.84	91.26	26.06	2394	2378				3.81			2394	2378
Greece	FI	1.36	2.66	2.85	26.06	69	74	0.62	1.21	1.30	3.81	5	34	74	108
Hungary	OU	1.94	12.49	12.05	26.06	326	314				3.81			326	314
Ireland	FO				26.06						3.81				
Italy	FO				26.06						3.81				
Latvia	OU	6.59	4.18	4.70	26.06	109	123				3.81			109	123
Luxembourg	FO				26.06						3.81				
Poland	OU	2.95	37.14	46.03	26.06	968	1200				3.81			968	1200
Portugal	FO				26.06						3.81				
Spain	Same				26.06						3.81				
Sweden	OU	1.92	0.97	0.97	26.06	25	25				3.81			25	25
United Kingdom	FO				26.06						3.81				
						3963	4199					5	34	**3967**	**4233**

FI = fully inside; FO = fully overlapping, OU = overlapping upper; OL = overlapping lower.

Table 9 – Immediate costs of applying the EASEE-gas specification

EASEE-gas		Enrichment						Derichment						Total cost	
		Process	Capacity 2020	Capacity 2030	Unit cost	Cost (net present) 2020	Cost (net present) 2030	Process	Capacity 2020	Capacity 2030	Unit cost	Cost (net present) 2020	Cost (net present) 2030	2020	2030
		(MJ/m3)	mcmd	mcmd	€m/mcmd (net present, assuming 50% load factor)	€m	€m	(MJ/m3)	mcmd	mcmd	€m/mcmd (net present, assuming 50% load factor)	€m	€m	€m	€m
Austria	OU	1.03	12.24	14.57	26.06	319	380				3.81			319	380
Belgium	FO				26.06						3.81				
Czech Republic	OU	0.75	5.24	7.15	26.06	137	186				3.81			137	186
Denmark	FO				26.06						3.81				
Estonia	FO				26.06						3.81				
France	FO				26.06						3.81				
Germany	OU	2.83	128.04	127.22	26.06	3337	3316				3.81			3337	3316
Greece	FI	2.16	4.23	4.53	26.06	110	118	1.33	2.61	2.79	3.81	10	11	120	129
Hungary	OU	2.74	17.65	17.02	26.06	460	444				3.81			460	444
Ireland	FO				26.06						3.81				
Italy	FO				26.06						3.81				
Latvia	OU	7.39	4.69	5.27	26.06	122	137				3.81			122	137
Luxembourg	Same				26.06						3.81				
Poland	OU	3.75	47.22	58.51	26.06	1231	1525				3.81			1231	1525
Portugal	FI	0.75			26.06			0.71			3.81				
Spain	FI	0.80			26.06			0.71			3.81				
Sweden	OU	2.72	1.38	1.38	26.06	36	36				3.81			36	36
United Kingdom	FO				26.06						3.81				
						5752	6142					10	11	**5762**	**6152**

FI = fully inside; FO = fully overlapping, OU = overlapping upper; OL = overlapping lower; there are no situations where the new specification is fully above or fully below the existing specification.

Table 10 – Immediate costs of applying the IE/UK specification

IE/UK spec		Enrichment: Process	Enrichment: Capacity 2020	Enrichment: Capacity 2030	Enrichment: Unit cost	Enrichment: Cost (net present) 2020	Enrichment: Cost (net present) 2030	Derichment: Process	Derichment: Capacity 2020	Derichment: Capacity 2030	Derichment: Unit cost	Derichment: Cost (net present) 2020	Derichment: Cost (net present) 2030	Total cost 2020	Total cost 2030
		(MJ/m3)	mcmd	mcmd	€m/mcmd (net present, assuming 50% load factor)	€m	€m	(MJ/m3)	mcmd	mcmd	€m/mcmd (net present, assuming 50% load factor)	€m	€m	€m	€m
Austria	FI	1.78	21.15	25.17	26.06	551	656	2.21	26.26	31.25	3.81	100	119	651	775
Belgium	FI	0.59	6.77	6.52	26.06	177	170	2.49	28.58	27.52	3.81	109	105	285	275
Czech Republic	FI	1.50	10.48	14.29	26.06	273	373	0.79	5.52	7.53	3.81	21	29	294	401
Denmark	OL				26.06			1.52	6.10	6.08	3.81	23	23	23	23
Estonia	OU	0.55	0.83	0.83	26.06	22	22				3.81			22	22
France	FI	0.73	27.41	34.41	26.06	714	897	2.07	77.73	97.57	3.81	296	372	1011	1269
Germany	FI	3.58	161.97	160.93	26.06	4222	4195	2.05	92.75	92.15	3.81	353	351	4575	4546
Greece	FI	2.91	5.70	6.10	26.06	149	159	3.91	7.66	8.19	3.81	29	31	178	190
Hungary	FI	3.49	22.48	21.68	26.06	586	565	2.16	13.91	13.42	3.81	53	51	639	616
Ireland	Same				26.06						3.81				
Italy	OL				26.06			0.92	73.15	73.50	3.81	279	280	279	280
Latvia	FI	8.14	5.16	5.81	26.06	135	151	0.26	0.16	0.19	3.81	1	1	135	152
Luxembourg	FI	0.75			26.06			2.58			3.81				
Poland	OU	4.50	56.66	70.21	26.06	1477	1830				3.81			1477	1830
Portugal	FI	1.50			26.06			3.29			3.81				
Spain	FI	1.55			26.06			3.29			3.81				
Sweden	FI	3.47	1.76	1.76	26.06	46	46	2.19	1.11	1.11	3.81	4	4	50	50
United Kingdom	Same				26.06						3.81				
						8350	9063					1269	1366	**9619**	**10429**

FI = fully inside; FO = fully overlapping, OU = overlapping upper; OL = overlapping lower; there are no situations where the new specification is fully above or fully below the existing specification.

238. The costs of applying each specification are summarised in Table 11.

Table 11 – Summary of costs

	Total cost €bn (net present, 20 years, 5%) Lower	Upper
EN437	0	4.0
EASEE-gas	0	5.8
IE/UK spec	2.5	9.6

4.3 Quantification of risks

239. There are risks associated with the implementation of a new Wobbe index specification. These are:

- that the existing appliance fleet is incompatible with gases supplied that are compatible with the new specification; and
- that there are costs associated with other, non-Wobbe, parameters.

240. This section provides high-level estimates of the potential magnitude of these problems.

4.3.1 Incompatible appliances

241. As noted above, the risk that existing appliances are incompatible with new specification can only be removed if extreme investment solutions are applied, and the extent of this risk and the need for investment is something that we would expect to be determined by MSs (economic and safety regulators) in discussion with the TSOs.

242. Without intervention, a situation where there are installed appliances that are known to be incompatible with the full range of a new specification presents a safety risk where it is possible that those appliances will receive a new gas quality that is compatible with the

new specification but incompatible with the appliance. This could have fatal consequences. Intervention would therefore be necessary where new, incompatible gases are likely to be presented to the market within the natural replacement cycles of the appliance fleet.

4.3.1.1 Risks of new gas

243. The modelling work suggests that over this timeframe most new gas presented to Europe will come from LNG sources which, because of the derichment capability of current LNG regasification terminals, would not present a new gas quality to the appliance population. One new source of gas appears to have gas quality that might be incompatible with the existing specification/infrastructure.

244. This potential new gas is expected to come from the Shtokman field in the Barents Sea, due to be delivered via Nordstream into the German market by 2016[10]. The modelling has assumed that the Wobbe index of the gas coming from Shtokman is 54.41 MJ/m^3 [11] and in our unconstrained analysis, this gas is not blended with other Russian gas before transportation in Nordstream. This compares with the existing German upper Wobbe index specification of 53.46 MJ/m^3[11], a difference of 0.95 MJ/m^3.

245. The two mitigations to overcome this issue are:

- to replace/modify appliances. There are approximately 12 million domestic appliances in Germany that might be impacted. An upper end for the range of costs of appliance modification/replacement in Germany has been estimated at €9.94bn (see Table 41, Table 48, Table 49, and Table 50); or
- process the gas on entry. Assuming nitrogen ballasting would be required, and assuming there is no opportunity for other forms of blending, we estimate the upper range of the costs of processing this gas would be:
  - based on 55bcm/annum capacity, capex of €150m;
  - assuming a load factor of 70%, opex of €16.8m per annum; so
  - applying 5% discount rate over 20 year, a NPV of €370m.

246. It is noted however, that **these costs would not be attributable to the harmonisation** (they would be incurred regardless of harmonisation), although harmonisation might impact on the distribution of these costs (i.e. the extent to which they are borne by TSOs or upstream).

247. Therefore it is considered that there are no costs attributable to harmonisation that materialise because of the delivery of new gases to the system.

4.3.1.2 General safety considerations

248. There is a potential outcome that MSs decide to mitigate the safety risks using more extreme solutions. These extreme solutions to mitigating gas quality risks fall into two broad approaches:

- modification and/or replacement of entire appliance populations (i.e. downstream investment); or

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[10] gazprom.ru

[11] Wobbe indices quoted at 15 °C for combustion, 15 °C and 101.325 kPa for volume

- installation of processing equipment to cover for all possible gas quality discrepancies (i.e. upstream investment).

Further detail on these approaches are in section 4.6, below.

249. These costs would fall into a broad range because of the number of variables involved in determining them, including:
    - which MSs choose to apply the approach;
    - the differences between the existing specifications/gases and the new specifications;
    - whether MSs seek efficient trade-offs between upstream and downstream investment;
    - the extent to which appliance adjustment or retrofitting is employed instead of appliance replacement; and
    - the extent to which appliance replacement can be phased to take advantage of some natural replacement.

250. Broadly, these approaches could present one-off costs of between zero and €109bn (explained further in section 4.6 and Annex P). The upper end of this range this is an extreme situation where all MSs decide to replace all appliances.

4.3.2 Non-Wobbe index parameters

251. As noted in section 4.1.4.1, another possible risk is that other parameters present issues that we have not accounted for in the above analysis, and that solving these additional issues imposes additional costs.

252. The potential issues from non-Wobbe parameters are related to the categorisation presented in Figure 3. The categories are:
    - safety related parameters;
    - consumer related parameters; and
    - infrastructure related parameters.

253. Most of these parameters include only a single limit (usually a maximum; although methane content is typically a minimum). Harmonisation of these parameters could be achieved by:
    - adopting the more stringent (lower) limit, which might trigger the requirement for some investment to enable existing gases to continue to flow; or
    - adopting the less stringent (higher) limit, which might have consequential impacts on infrastructure operators or consumers.

254. If the more stringent requirements are implemented then there is a possibility that investment is required to enable existing gases to flow. Because of a lack of adequate data, it has not been possible to estimate the likely costs of this.

255. Costs have been assessed of a subset of the additional parameters. This analysis (presented in section 4.6) assumes the use of two types of gas processing plant:
    - acid gas removal based on liquid absorption technology is assumed for removal of:
        - sulphur & sulphur compounds (hydrogen sulphide, carbonyl sulphur, mercaptans); and

  - carbon dioxide; and
- solid bed technology, for the removal of oxygen.

256. The upper range of costs of processing these gas quality parameters cannot be ascertained with any degree of certainty due to the low likelihood of investment being required.

257. If the less stringent parameters were selected, the consequential impacts on infrastructure and consumers for various parameters are set out in Table 12 below. It has not been possible to quantify these impacts because of a lack of adequate data.

Table 12 – Consequential impacts of less stringent parameters

Parameter	Impact: Infrastructure	Impact: Consumer	Safety related?
Density & relative density **Sooting index** **Incomplete combustion factor**	None	**Decreased appliance safety**	**Yes**
Oxygen	May decrease some storage facilities asset lives (notably FR)	None	No
Nitrogen	None	Increased NOx emissions (IED compliance)	No
Carbon dioxide	Can precipitate hydrate formation and form carbonic acid, increasing maintenance costs and decreasing pipeline asset lives	None	No
Hydrocarbon dewpoint	Increased maintenance costs	Usually none	No
Water dewpoint	Increased maintenance costs, possible impact on pipe asset lives	Usually none	No
Odour	Impact on odorisation practices	None (though most odorants are sulphurous)	No(2)
Total sulphur Carbonyl sulphide Mercaptans / Thiols		Low	
Hydrogen sulphide		**Decrease in pipework integrity – increased maintenance costs**	**Yes**
Methane / number	None	Efficiency of chemical feedstock plant	No
Ethane / equivalency	None	Efficiency of chemical feedstock plant	No
Range of variation of Wobbe index	None	Efficiency, tripping	Yes(1)
Halogens	Increased maintenance costs on treatment plant, impact on pipeline asset lives (3)	Corrosion and toxicity (3)	Yes
Ammonia	Increased maintenance costs on treatment plant, impact on pipeline asset lives (3)	Corrosion and toxicity (3)	Yes
Impurities Particulates / solids / liquids	Increased maintenance costs, possible impact on pipe asset lives	Possible impact on asset lives	No

Notes: (1) this is being determined by the GASQUAL project; (2) mismanagement of odourisation might lead to safety related impacts; (3) unclear what the impacts are from Halogens and Ammonia as it is quite rare to find them in natural gas.

258. It is noted that changing most non-Wobbe index parameters does not impact the majority of the appliance population. Table 12 highlights those parameters which would impact domestic appliance population. The majority of infrastructure related impacts are limited to increased operating costs for transporters. It is not anticipated that these costs would be very large. This would mean that most of the non-Wobbe index parameters can be changed without a large impact.

4.4 Summary of the impacts of applying a new specification

259. There are two broad investment impacts from the application of a new specification:

- a requirement to invest to ensure that existing gases continue to remain compatible with the new specification; and
- a potential need to invest so that existing appliances are compatible with any new gases that are not compliant with the old specification.

260. The former of these is minimised by selecting a specification that accommodates a wide Wobbe index range. The latter of these is minimised by selecting a specification that accommodates a narrow Wobbe index range.

261. In addition, the analysis demonstrates that:

- where a new specification is wider than the existing specification, then there is no immediate cost because existing gases are already compliant; and
- generally, the lowest impact from harmonisation might be expected where the requirement to enrich gas is minimised at the expense of requiring derichment.

262. The modelling suggests that there are no new gases that are expected to be presented to the EU that would trigger costs associated with harmonising gas qualities.

263. **This analysis shows that the lowest immediate impact is expected when a new specification is wide.** The analysis demonstrates that where a new specification is wider than the existing specification, then there is no immediate cost because existing gases are already compliant. It also shows that MSs with low lower Wobbe limits may face larger immediate impacts that average because of the possible need to enrich existing gas: costs of enrichment are significantly greater than costs of derichment.

264. There are risks associated with the implementation of a new Wobbe index specification. These are:

- that the existing appliance fleet is incompatible with gases supplied that are compatible with the new specification; and
- that there are costs associated with other, non-Wobbe, parameters.

265. The modelling suggests that there are no new gases that are expected to be presented to the EU that would trigger costs associated with harmonising gas qualities.

266. However the extent of this risk and the need for insurance investment is something that would be expected to be determined by Member States/NRAs in discussion with the TSOs. There is a potential outcome that MSs decide to mitigate the safety risks using more extreme solutions which might present a range of additional costs of between zero and €109bn.

4.5 Realising benefits without harmonisation

267. The benefits identified in Chapter 3 might be partially achievable through active management of gas qualities by TSOs and through information provision to the market. This should help to minimise gas quality associated risks assumed by shippers, and should foster the development of pragmatic network operation at an EU level.

268. This is achieved through:

- extending the observation made in section 2.5.2 that TSOs sometimes coordinate to manage gas quality issues that have or may emerge within operational timescales, such that it is required of all TSOs to cooperate and coordinate with neighbouring TSOs;
- requiring TSOs to publish comprehensive gas quality and flow data; and
- requiring TSOs to produce and publish forecasts of potential future gas qualities, both in operational timescales and including consideration of unforeseen outages (i.e. plant and pipeline trips).

assumed that TSOs are provided with a mechanism to recover the reasonable costs of meeting these obligations.

269. All of the possible management options presented below are subject to a risk that the do not impact on the risks assumed by shippers because the legal obligations on TSOs in respect of their disparate gas quality specifications are not impacted. In other words, these options might not deliver significant benefits.

4.5.1 Coordination

270. If an obligation were placed on TSOs to seek to cooperate with each other to actively manage the flows of gas on their systems to overcome any actual or potential gas quality issues, it may mitigate the potential for gas quality related interruptions. Such an obligation would require the establishment of communication channels and the dedication of resources, and may involve the use of commercial actions by the TSOs.

271. It is not known to what extent the TSOs currently cooperate with each other in either operational or longer-term timescales with respect to managing the gas quality of their networks and interconnection points. Interconnection agreements can place an obligation on the upstream TSO to meet the downstream specification, but:

- if present, that this isn't translated to an obligation on the upstream TSO in respect of his users (the upstream TSOs obligation to his users relates to his exit specification); and
- wherever non-compliant gas is acceptable by the downstream TSO, it will do so only on a 'reasonable endeavours' basis.

272. From the few interconnection agreements that have been made available, there are general obligations in respect of communication regarding gas quality as soon as one of the TSOs becomes aware of an emerging or potential future issue. ENTSOG have confirmed that many TSOs (CZ, DE, ES, FR, AT & BE were mentioned) comply with their obligations under interconnection agreements to communicate and cooperate on gas quality issues, and that they are in regular communication whenever it is necessary. Costs associated with these actions are not known, they are expected to be significant if the actions are considered reasonable.

273. To the extent that existing cooperation practices do not impose significant costs where the practice is currently adopted (i.e. at least CZ, DE, ES, FR, AT & BE), it is not expected that extending this practice to the rest of the EU to impose significant costs. However, the extent to which this potential obligation delivers a benefit will rely, in any given situation, on the interpretation of what might be considered by the TSO as reasonable. This interpretation will be different in different jurisdictions and will rely on the detail of each TSOs regulatory settlement.

274. Obliging TSOs to cooperate with a neighbouring TSO to actively manage gas quality might induce costs associated with, for example, inefficient network configurations or flow management contracts. The obligation could be extended to require neighbouring TSOs to identify and jointly optimise the costs for actively managing the situation. This would entail:

- the upstream TSO identifying the potential costs of managing its outflowing gas quality;
- the downstream TSO identifying the potential costs of configuring its network to accept the upstream gas quality; and
- the identification of the potential costs arising from any gas quality related interruption of flows – whether in part or in whole.

TSOs could then agree on the appropriate course of action between the two TSOs.

275. The management actions that might be considered by a TSO include:

- reconfiguring their network; and/or
- exercising flow management contracts (interruption, locational actions, buy-backs, etc.).

276. If TSOs were able to recover the reasonable costs of action via their regulatory settlement (perhaps involving some regulatory oversight or intervention by NRAs).

277. The costs associated with this approach are essentially administrative and associated with the increased level of analysis to identify options and potential costs of action that the TSOs are required to undertake. There may also be an increased administrative cost where NRA involvement becomes necessary.

278. TSOs may be unable to estimate the potential costs arising from any gas quality related interruption. There is therefore a risk that physical or commercial intervention is often deemed by the TSOs as more expensive than the potential costs arising from any gas quality related interruption and therefore that it delivers little or no benefit (i.e. costs are not lowered, as shippers do not change their interpretation of risk and efficient flows continue to be frustrated). Regulatory oversight and review of specific actions could be used to confirm whether the identified costs are accurate and therefore whether the TSOs actions have been efficient.

4.5.2 Publication of data

279. The current legal provisions to publish gas quality data do not extend to other parameters included within applicable gas quality specifications, and allow TSOs to restrict publication of averaged values. Users therefore have insufficient information on which to judge the risk of gas quality issues emerging. This option seeks to redress this particular issue by requiring:

- the timely publication of an appropriate set of good quality (i.e. void of data errors) measured data (e.g. if not all data, including minima and maxima, percentiles and averages over defined periods) pertaining to any of the parameters included within neighbouring TSOs specifications; and
- publication of an opinion of the current level of risk of non-measured parameters becoming gas quality issues within operational (e.g. day-ahead, day-to-day) timescales, and the methodology and assumptions used at deriving the opinion.

280. This option is expected to decrease the overall risk assumed by users at cross-border points. This should:
   - lower the costs of cross-border trade;
   - increase flows and reliance at points where there is an apparently low risk (i.e. there is a relatively large gap between measured data and applicable specification);
   - decrease flows and reliance at points where there is an apparently higher risk (i.e. there is a smaller gap between measured data and applicable specification).

281. This option will require TSO to increase the amount of data that they publish, with consequential impact on computing and manpower resources. It is noted that the amount of data required to be published is relatively small compared to other transparency obligations, and as such the impact is considered to be marginal. The data cleansing element of the obligation might introduce additional costs, but these are not anticipated to be particularly high.

282. There is a risk that the methodology and assumptions used at deriving the opinion of the current level of risk of non-measured parameters is inappropriate and not fit for purpose. This risk could be mitigated by requiring the network code to set out high level requirements for the methodology and assumptions.

4.5.3 Forecasting services

283. If an obligation were placed on TSOs to provide forecasts of gas quality and gas quality related problems, this might indicate the levels of risk that shippers might face in the future. By making assumptions about the most likely pattern of near-term gas flows, it should be possible for TSOs to calculate the gas qualities that might be presented at different network points using suitable network analysis software.

284. Alongside this would be a need to show the potential patterns of flow that, assuming gas flowed at historically normal gas qualities, would give rise to gas quality problems at relevant cross-border points (i.e. where the downstream specification could not be met.) This could be a potentially onerous exercise because of the numerous flow scenarios that might need to be considered (especially in more complex networks), however it is likely the analysis would have a relatively long 'shelf life'.

285. This set of information would allow gas traders to accommodate any near-term risk in the price signals within the market, for example by allowing prices of secondary capacity to vary by location according to the attractiveness or otherwise of the gas quality available at that point. This information would also potentially be beneficial to gas consumers, so it would be useful to specify this for exit points as well as cross-border points. If the task is accomplished for cross-border points, this should be a trivial exercise.

286. In addition to this, a longer-term view of the potential changes to gas quality that could arise as a result of capacity changes on the network would also allow the market to factor in gas quality concerns into price signals. This might be accommodated in TSOs long-

term capacity development plans or in ENTSOG's Ten Year Network Development Plan. However, it is noted that there is no data relating to future upstream gas qualities, so there would be a limit to the accuracy of these forecasts.

287. One of the most significant concerns with respect to sudden gas quality changes is associated with unforeseen changes to gas flows, so an integral requirement under this option is that it would accommodate scenarios that considered specific pipeline and plant failure.

288. This option is expected to further decrease the risk assumed by users at cross-border points. This should:

- further lower the costs of cross-border trade;
- provide better reliance information; and
- decrease the potential for gas quality related incidents by providing users with insight into the potential patterns of flow that can help or hinder gas quality issues.

289. There would be potentially significant administrative costs for the TSOs. It is estimated that each TSO would require 1 or 2 FTE equivalents on a full time basis to produce the forecasts, depending on the complexity of their transmission network(s). Assuming €100k per FTE, an average of 1.5 FTEs per TSO, and 41 TSOs, and this option would present a cost of €6.1m per annum. It has been assumed that the TSO already has access to appropriate network analysis software and licences.

290. There is a risk that publication of the network analysis uncovers confidential information (e.g. gas flows at individual connections). One possible way to mitigate this would be to require the publication of a subset of results/assumptions, however this may not deliver the full benefits.

291. There is a risk that the forecasts are insufficiently accurate or not updated frequently enough for users to adequately manage their gas quality risks.

4.6 Extreme, risk averse solutions

4.6.1 Full physical harmonisation to a wide specification

292. In this situation, MSs choose to make the entire system fully compatible with a wide specification (e.g. EN437). This approach provides a complete solution, however it is extremely expensive and difficult or impossible to achieve in short timescales and so the benefits would only be realised under longer timescales.

293. It is conceptually achieved by ensuring that all elements of the gas supply chain are capable of using the full range of the new specification. It requires that the transmission system, distribution system, gas storage facilities, and consumption applications should all be compatible with a given specification.

294. This option would necessitate significant investment by consumers to replace or modify various appliances and would also require some investment by infrastructure operators.

295. Within the consumption applications it is necessary to consider all uses of natural gas – gas as chemical feedstock, a power generation fuel, and its use in industrial processes and within commercial premises, as well as it use in the household environment.

296. Full details of this analysis are presented in Annex P.

4.6.1.1 Costs

297. There are over 167 million installed domestic gas appliances and the only guaranteed way of ensuring their continued safe operation if gas quality were to vary to extremities of a wide specification would be to carry out a full survey, inspection and retrofitting/replacement programme. However the recent GASQUAL study concluded that a number of appliance types showed no adverse effects when tested using a range of natural gas compositions that covered possible future limits in Wobbe index. This represents 70 million domestic appliances.

298. Tuning costs are predicted to be smaller than replacement installation and maintenance costs. The modelling assumes that 67% of the identified ‘at risk’ appliances (i.e. those appliances that are highly or moderately impacted by changes to gas quality) would need to be replaced, and that the remainder could be adjusted or retrofitted at 25% of the cost of replacement. Three ranges of Wobbe index have been considered as a proxy for three different gas quality specifications:

I) appliances with high or moderate impact to gas quality variation over a Wobbe index range from 46.7 to 54.7 MJ/m^3 (similar but not identical to EN437) – a one-off capital cost of €66.9bn;

II) appliances with high or moderate impact to gas quality variation over a Wobbe index range from 46.7 to 53.4 MJ/m^3 (similar but not identical to EASEE-gas) – a one-off capital cost of €36.5bn; and

III) appliances with high or moderate impact to gas quality variation over a Wobbe index range from 46.7 to 52.0 MJ/m^3 – a one-off capital cost of €7.92bn.

299. In addition to these costs, options II and III require investment in gas processing equipment to accommodate existing gas which is outside each specification. Assuming a similar extreme position from MSs where all residual discrepancies are covered through investment, these investments would have one-off capital costs of €1bn and €3.7bn, and on-going opex costs of €3.1m per annum and €13m per annum respectively.

300. Other applications’ (commercial, industrial, gas engines and gas turbines) replacement costs have been estimated on the assumption that ***all*** equipment would also need to be replaced, modified or adjusted with a capital cost of between €42bn (option I) and €8.5bn (option III). This assessment has been based upon the conclusion from the GASQUAL study that further work is necessary to understand the impact of gas quality on non-domestic equipment and that a common understanding had not been reached with the respective manufacturers.

301. The cost of the impact on other infrastructure (transport, storage, import) has not been quantified as it is expected to be significantly below the figures already identified.

302. Replacement of appliances with equipment capable of operating over a wide range of gas qualities will potentially increase emissions of carbon dioxide and nitrogen oxides.

303. It might be possible to reduce the effective costs of appliance replacement through a regionally managed roll-out and support mechanisms to encourage replacement.

4.6.1.2 Risks and unintended consequences

304. Stakeholders expressed concern over the ability of industrial and commercial, gas engines and turbines to operate safely, efficiently and with low emissions over a wide Wobbe index range.

305. This extreme solution would force the replacement of the appliance population over a relatively short period of time. This might cause a similar heightened level of activity as those appliances reach the end of their natural life in the future. This would cause cyclical instability in the appliance manufacturing market. The manufacturing and installation capacity of the industry may also be insufficient to enable a speedy roll-out of this option.

4.6.2 Cross-border point investments

306. This extreme solution seeks allow traders to flow gas across cross-border points, at all times and regardless of the gas quality, by placing obligations on TSOs, either to:

- always accept gas compliant with the upstream TSOs specification, or
- always only present gas to downstream TSOs compliant with their specification.

307. It enables the trade of gas across EU borders unhindered by gas quality concerns. The existing disparate specifications would remain, however they would only have effect where gas enters the EU, and as they apply to appliance manufacturing and installation.

308. TSOs would complete this obligation through investing in gas processing equipment or through contracting with the market for specific flow management services.

309. This is an extreme solution, as it identifies investments that would have little or no practical use in real operation. It requires that the TSOs absorb the gas quality risk that currently vests with shippers, and assumes that TSOs invest or contract to retain their existing levels of risk.

310. There are two ways in which this solution might be implemented by a TSO:

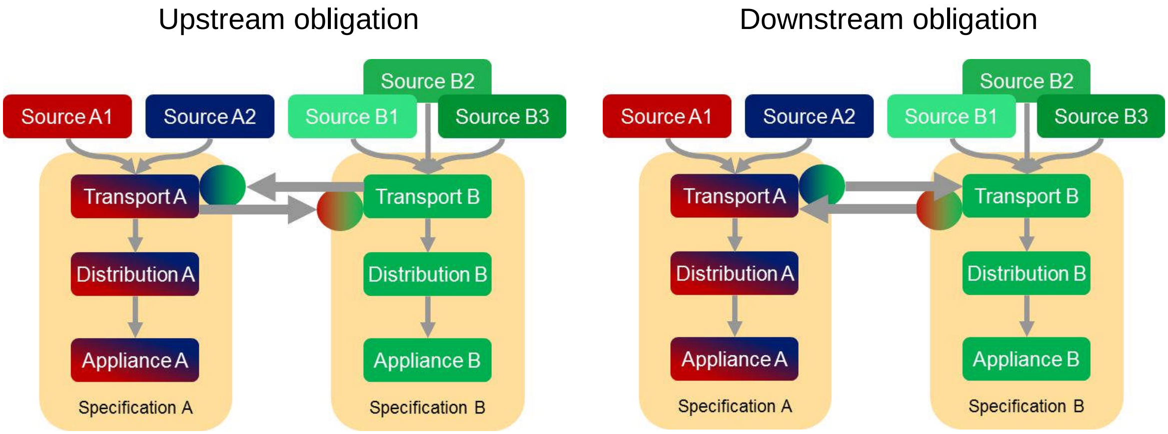
- investing in gas processing technologies at relevant points (i.e. the interfaces between specifications). This means that the physical flow of gas within the EU is not impeded by gas quality specifications, but ensures that gas transported within a local network meets the local specification; or
- through contracts to provide flow management services, allowing the TSO to manipulate the flows of gas on the system.

311. There are two possible approaches that could be used to implement this option:

- placing an obligation on TSOs to always accept gas compliant with the upstream specification (the ‘upstream obligation’); or
- to only present gas compliant with the downstream specification (the ‘downstream obligation’).

312. Where these obligations are discharged via investment in processing solutions there are two approaches, illustrated in Figure 12, below.

Figure 12 – TSO processing options



These diagrams show two imaginary systems with different specifications that are not fully compatible, each with its own sources of supply. The systems are interconnected. The circles represent potential investment to facilitate flows in the incompatible regions of the systems' specifications.

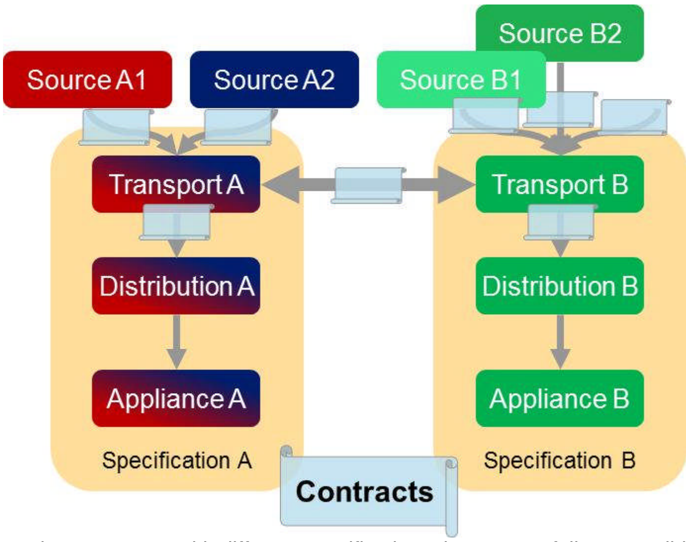
313. The investment should ensure that the full amount of exit and entry capacity at any particular cross-border point could cope with the maximum difference in specifications. Any amount of processing less than this would require that the TSO absorb the risk of, and indemnify the losses which stem from, any interruption (in practice, we would expect interruption would occur through commercial action – e.g. buy-backs – rather than indemnifying upstream and downstream imbalances).

314. Where the obligation is discharged through the use of contracts, combinations of nominations/flow that would either (depending on whether it is an upstream or downstream obligation) lead to:

- gas flowing which is not compliant with the local specification; or
- presenting gas to a downstream network that is not compliant with the downstream specification,

managed through two different varieties of commercial tools – flow management services and capacity buy-backs. This option is illustrated in Figure 13.

Figure 13 – Commercial transmission system unification



This diagram shows two imaginary systems with different specifications that are not fully compatible, each with its own sources of supply. The systems are interconnected. The document symbols represent potential contracts between TSOs and shippers to facilitate flows that enable compliant flows at cross-border points.

315. This approach builds on existing 'reasonable endeavours' type practices that rely on gas blending, allowing non-compliant gas to be blended with the contracted gas such the commingled stream is compliant with the local or downstream specification.

316. The financial risk of gas quality problems is shifted from shippers to the TSO, and all cross-border capacity is therefore fully commercially firm so, from a shipper's perspective, resilient to gas quality issues. The existing disparate, local specifications remain in place for the physical system, meaning there is no impact to downstream operators and consumers.

4.6.2.1 Potential costs of investment in processing

317. For the costing of this option the focus is on the upstream obligation option on the basis that the two options would probably present very similar costs. It is assumed that the upper end of the range of costs will be defined by the investment in and operation of physical gas processing equipment.

318. Three processing requirements have been identified: Wobbe index processing (enrichment or derichment, as appropriate); acid gas removal; and Oxygen removal. Various other technologies are available and the preferred method is normally selected after a detailed technical and financial assessment. These particular technologies were assumed to apply only where appropriate (i.e. where there were differences in specifications), and sized for the maximum difference in specification. Two scenarios were considered for cross-border capacities – a 100% case and a 50% case – which were then used to categorise plant as small (<50mcm/d), medium and large (>100mcm/d), for capital costing purposes.

319. Opex costs were then estimated using the flow results from the modelling work.

320. The capital costs of processing were estimated at €6.3bn and €10.4bn for the 50% and 100% capacity scenarios respectively. Opex costs were estimated at €510m per annum and €814m per annum respectively. The analysis used to generate these numbers is presented in Annex P.

321. There would be significant environmental costs because of the requirement to construct large chemical process plants at each cross-border point.

De facto specifications

322. There is a possibility that the existing specifications are not rigidly adhered to, and that it might be common practice to accept gas that doesn't meet the existing specification as a matter of course such that the written specification cannot be enforced. This gives rise to the concept of a 'de facto specification'[12]. It is noted that some TSOs provide specific blending services on a reasonable endeavours basis, and these cases should not be considered as giving rise to a 'de facto specification'.

323. Data provided by ENTSOG suggests that the impact of a 'de facto specification' would be relatively modest in reducing the costs identified above – the 100% capacity case reduces to one-off capex of €10bn with on-going opex of €800m per annum. We note however that the data is effectively limited to Wobbe indices as the data provided for other parameters is patchy and insufficient to assess whether there are data errors.

4.6.2.2 Potential costs of contracted solutions

324. This option is difficult to quantitatively assess because, assuming that TSOs contract to retain their existing levels of risk they would seek to do so on a forward basis, for which they would pay a premium. If the TSOs did not fully mitigate their risks via contracting, they would be exposed to additional risks (market prices) for which they would seek recompense through their regulatory settlement.

325. Assuming that:

- the underlying gas market is liquid and competitive;
- the flow management contracts are efficiently executed (and concluded with pricing structures that reflect the true costs of the counterparties);
- the day-to-day commercial actions of the TSO are economically optimal;
- the underlying capacity buy-back market does not suffer from market concentration issues; and
- there are no significant transaction costs;

then the costs incurred by the TSO should reflect the true commercial costs of the constraint. We would expect this to reflect the costs that this approach is intended to avoid (i.e. the benefits of harmonisation).

326. We note that a similar approach has been adopted in Germany to facilitate L-gas and H-gas zone mergers where TSOs procure 'control energy' from incumbent shippers. It appears as if there has been no quantitative assessment of the value of the benefit (the main benefit is enhanced market liquidity arising from the larger, merged zone), and that the costs are obscured by the procurement of other flow management contracts.

[12] 'de facto' being defined in a legal sense as 'as practiced', and contrasted with 'de jure' meaning 'as written'.

5. CONCLUSIONS

5.1.1 Problem

327. The current situation of a disparate set of gas quality specifications means that:

- it can difficult for a shipper to buy or import gas at one location in the EU and then sell it at another location within the EU;
- there is a restriction to the free movement and trade of gas appliances within the EU;
- there could be security of supply problems in unusual circumstances.

328. The current flow patterns are compliant with the existing disparate local gas quality specifications. Evidence provided by ENTSOG suggests there have historically been only five incidences of rejection of gas due to incompatibility with the local gas quality specification.

329. However the current level of compliance has been accomplished via a variety of different types of investment at a local level, and there remains a residual possibility that some gas is prevented from directly entering a local market or potentially from entering the EU market at all.

330. As indigenous supplies in the EU decline, the flows of gas into Europe are expected to change significantly over the coming decades, with a more diverse set of importation routes and a more diverse set of sources of supply. This may increase exposure to a wide variety of gas qualities. In addition, the completion of the IEM might be expected to impact the physical pattern of flows within the EU.

5.1.2 Benefits

331. There are therefore some benefits that might arise from adopting a single pan-EU gas quality specification. These are as follows.

- Enhanced security of supply:
  - more supplies would be able to enter a local market. Quantification of impact has not been possible, as it is the subject of specific directive and action by MSs, **consider that it represents a significant benefit**.
- More efficient fuel utilisation/fewer emissions:
  - this only delivers a benefit where the chosen specification has a narrower Wobbe index; a wider specification would not deliver benefits. Whilst harmonisation might therefore deliver small benefits in some MSs, at an EU level (assuming a wide specification), the results show **that the benefits would be insignificant**.
- Better functioning of the gas appliance market:
  - existing appliances are often designed to operate only within a restricted range of gas qualities which limits the economies of scale that might be available, or are required to be tuned during installation thereby increasing installation and maintenance costs. Quantification has not been possible, however it is **considered that the benefits would be relatively small**: tuning costs are small in relation to overall installation and maintenance costs, and GAD has already established a competitive appliance market.

- Better competition in the gas supply market:
  - because of the risk that gas is prevented from flowing where cross-border specifications are different, and as shippers bear the ultimate contractual responsibility for gas quality, the development of a competitive gas supply market is potentially hampered. Quantification of this impact has not been possible because it is not possible to isolate gas quality problems from other market competition problems. As the 3rd Energy Package will deliver the internal energy market in 2014, we consider **the incremental benefit of standardising specifications would be potentially significant**.
- More efficient sourcing of gas:
  - if a wide gas quality specification was introduced, the EU would have access to a more diverse set of supplies. This benefit in isolation cannot be quantified, and observe that the potential benefits are limited because of the fungible nature of LNG. The modelling integrates both sourcing and transportation so **the benefits available from more efficient sourcing have been included in the quantification presented below**. It should be noted however that introducing a narrow specification might present a barrier and would not deliver a benefit from efficient sourcing.
- More efficient transportation of gas:
  - gas would no longer be prevented from entering a local market and therefore would no longer require displacement to an alternative market and transportation along an indirect route. **The benefits of this have been quantified as being between €120m and €370m per annum**. In net present terms (assuming 5% discount rate over 20 years), this translates to between €1.6bn and €4.8bn with a central view of €2.6bn. Given that this assessment is the result of modelling perfect competition this is a conservative figure.

5.1.3 Costs required to achieve compliance

332. The costs of realising these benefits depend on how much change in gas quality might be expected in the future. The central view on the costs of implementation is predicated on an assumption that:

- the main sources available to the EU will be as reflected in the modelling;
- that these sources will have the ranges of gas quality as assumed; and
- that TSOs can blend all sources within an integrated national network.

Under these assumptions much of the transition to a standard specification can be done at a lower cost.

333. The potential costs to the TSO and consumers have been considered from introducing a harmonised standard. Four possible situations have been identified that might arise when applying a new specification, and examined the relative investment requirements for the transition to each of three possible specifications for each of 18 MSs.

334. There are two important observations from the analysis we have undertaken:

- the lowest cost of transition is to be expected when any new specification is wide relative to current specifications; and
- the lowest cost of transition is to be expected where the requirement to enrich gas is minimised at the expense of requiring derichment.

335. Analysis indicates that, in general, gas qualities are not anticipated to change significantly under normal circumstances, and whilst there may be local impacts because of future gas qualities, these costs would be incurred anyway and would therefore not be triggered by gas quality harmonisation.

336. If the assumptions on gas quality specifications and future flows are correct, there will be a minimal requirement for investment to accommodate the transition to a standard specification. It is **estimated that the immediate costs required achieving compliance range between zero and €9.6bn**, depending on the specification selected and the validity of other assumptions. A wide specification would present immediate costs of €4bn, whereas the UK/IE specification would present immediate costs of €9.6bn. The costs that are expected to occur to a large extent stem from a relatively small group of countries.

337. However, the transition introduces risks which may induce further costs to mitigate; we discuss these in the following section.

5.1.4 Potential other costs to mitigate

338. If patterns of flow and/or quality differ from those shown in the analysis undertaken, there are two potential risks that could materialise:

- interruption to gas supplies might be required; and
- there could be significant safety issues.

Resolving these risks increases costs, potentially requiring large investments in either gas processing equipment or appliance replacement programmes.

339. However the extent of this risk and the need for insurance investment is something that we would expect to be determined by MSs economic and safety regulators in discussion with the TSOs. There is a potential outcome that MSs decide to mitigate the safety risks using more extreme solutions.

340. These potential costs fall into a broad range because of the number of variables involved in determining them, including:

- which MSs choose to apply extreme solutions;
- whether MSs seek efficient trade-offs between upstream (processing) and downstream (appliance replacement) investment;
- whether the TSO has opportunities for blending any new gases;
- the extent to which appliance adjustment or retrofitting is or can be employed instead of appliance replacement;
- the extent to which appliance replacement can be phased to take advantage of some natural replacement; and
- the differences between the existing specifications/gases and the new specifications – noting that the larger the difference, the larger the potential cost.

341. The latter variable provides an important influence in selecting any particular specification, and allows us to add another important observation:

- the lowest cost of transition arising from the risks of extreme solutions being adopted is to be expected when any new specification is narrow relative to current specifications.

342. Some of the risks might be mitigated by the generation of forecasts of potential gas quality problems, which could be used to flag more precisely when and where investment might be required.

5.1.5 Recommendation to CEN

343. There is an indication that there might be a benefit from adopting a relatively wide specification. In order to determine this CEN would need to examine the risks identified in greater detail.

344. Noting the contrasting observations that:

- the lowest cost of transition is to be expected when any new specification is wide relative to current specifications; and
- the lowest risks are to be expected when any new specification is narrow relative to current specifications;

The selection of a narrow or a wide specification will depend on the materiality and extent of the risks.

345. There is insufficient information on:

- the actual details of inflowing gas qualities;
- the materiality of off-specification gas to the integrity of gas system; and
- the extent to which reasonable endeavours could be used to overcome potential issues.

346. The study has focussed primarily on the Wobbe index parameters. CEN will also need to understand other parameters and the extent to which they cause integrity problems and require remedial investment.

347. In particular, CEN should consider the extent to which, and where, appliance adjustment or retrofitting is or can be employed instead of appliance replacement.

5.1.6 Summary

348. Table 13 provides a summary of the costs, benefits and risks.

Table 13 – Summary of benefits, costs and risks

		€bn, present terms	
		Lower	**Upper**
Benefits	Efficient sourcing & transportation	1.6	4.8
Costs	Ensuring existing gas is compliant with new specification	(9.6)	0
Net quantified benefit		(8.0)	4.0
Additional (unquantified) benefits	Security of supply	Significant	
	Gas market competition	Potentially significant	
	Appliance market	Small	
	Efficiency/emissions	Small	
Potential additional costs	Non-Wobbe parameters	Low	
	Appliance incompatibility	High	
Other risks	Risks that assumptions in this analysis are incorrect		

Values are presented in present terms, assuming a 5% discount rate over 20 year. We would expect significant/high elements to present values of similar magnitude to the quantified elements.

ANNEX A – EXISTING GAS QUALITY SPECIFICATIONS

349. A review of the national gas quality specifications for every EU country, obtained either from the network codes of each of the TSOs or from the Regulator and, where necessary, conversion of parameters to the same reference conditions it is possible to assess the possible impact of introducing the EASEE-gas specification. These are tabulated in Table 14 below.

350. Luxemburg is the only country that has a gas quality specification the same as the EASEE-gas specification. Mata and Cyprus are yet to develop a gas network. In some cases the EASEE-gas Wobbe index range is narrower than that currently in place. Greece, Ireland, and Spain have an upper Wobbe index limit above that of the EASEE-gas limit whereas Austria, Greece, Czech Republic, Hungary, Latvia, Netherlands, Poland and Sweden have a lower limit below that of EASEE-gas. Spain, France, Belgium and Germany have specifications that are comparable to EASEE-gas. Introduction of the EASEE-gas specification may restrict the use of gas, typically from indigenous sources, that is currently acceptable. In some circumstances gas processing may be required if the EASEE-gas specification is adopted despite the fact that the local market has not required different gas quality, for example the water dewpoint limits for Hungary, Estonia, Latvia and Lithuania are either less stringent than the EASEE-gas specification or not specified.

351. Whilst the table allows many of the gas parameters to be compared, there is still significant variation in the definition of the limits, for example water dewpoints specified at different pressures or conditions. It will be essential if a harmonised gas quality specification is to be introduced across the EU that all countries agree a standard set of reference conditions and definition for each gas parameter.

Table 14 – Comparison of specifications

	H2ODP	**HCDP**	**Total sulphur**	**H2S & COS**	**RHS**	**O2**	**CO2**	**RD**	**Lower WI**	**Upper WI**
	Celsius	*Celsius*	*mg/m3*	*mg/m3*	*mg/m3*	*mol %*	*mol %*		*MJ/sm3*	*MJ/sm3*
EASEE-GAS	-8 at 70 bar*	-2 at 1-70 bar	30	5	6	0.001**	2.5	0.555 – 0.7	46.45	53.99
Austria	-8 at 40 bar	-0 at OP	100	5 [H2S]	15	0.02	2	0.55 – 0.65	45.42	53.62
Belgium	-8 at 69 bar	-0 at 69 bar	150	5	-	0.1	2	-	46.61	53.90
Bulgaria	-5	-	20	xcskdmsp2 [H2S]	5.6	0.1	1	-	-	-
Czech Republic	-7	0	30	2 [H2S]	5	0.02	3	0.56 – 0.70	45.7	52.20
Denmark	-8 up to 70 bar	-2 up to 70 bar	30	5	6	0.1	2.5	0.555 – 0.70	48.19	52.93
Estonia		-5 winter 0 summer at 40 bar					Total inerts 1.5 mol%	0.55 – 0.58	46.65	47.31
Finland								-	-	-
France	-5 at OP	-2 at .01 to 70bar	30	5	6	0.01	2.5	0.555 – 0.700	46.47	53.48
Germany	Soil temperature at OP		30	5 [H2S]	6	3.0 (dry), 0.5 (wet)		0.55 - 0.75	43.62	53.46
Greece	5 at 80 bar	3 at 80 bar	80	5.4 [H2S]		0.2	3	0.56 - 0.71	44.29	55.32
Hungary	0.17g/m3 vapour		100	20 [H2S]		0.2		0.55 – 0.71	43.71	53.57
Ireland	50 mg/m3	-2 up to 85 bar	50	5 [H2S]		0.2	2	0.55 – 0.70	47.2	51.41
Italy	-5 at 70 bar	0 in range 1 – 70 bar	150	6.6 [H2S]	15.5	0.6	3	0.5548 – 0.8	47.31	52.33
Latvia				20 [H2S]	35	1		-	39.06	51.67
Lithuania								-	-	-
Luxembourg	EASEE_gas specification							0.555 – 0.700	46.45	53.99
Netherlands			45	5 [H2S]	10	0.5		-	41.23	42.13
Poland	3.7 summer, -5.0 winter at 55 bar	o	40	7 [H2S]	16	0.2	3	-	42.7	51.20
Portugal	-5 @ 84 bar		50	5 [H2S]				0.555 - 0.700	45.70	54.70
Romania	-15 at delivery pressure	0 at delivery pressure	100	6.8 [H2S]	8	0.02	8	-	-	-
Slovakia	-7 at 39.2 bar	0 at OP	20	2 [H2S]	5.6	Nil	3	-	-	-
Slovenia	-7 at 39.bar	-5 at 39-69 bar	105	6.3 [H2S]	15.57	Nil	1.575	-	-	-
Spain	2 at 70 bar	5 at 70 bar	50	15	17	0.01	2.5	0.555 - 0.700	45.65	54.70
Sweden	-3 up to 80 bar	-3 up to 80 bar	10	5 [H2S]				-	43.73	53.60
United Kingdom			50	5 [H2S]		0.2		-	47.20	51.41

* at certain cross border points a less stringent limit is imposed. This can continue to be used but parties should agree how CBP can be met in the longer term. ** limit is 0.001 mol % daily average. Daily average levels of up to 0.01 mol% will be accepted if due to UGS operation existing before 2006. Spain plan to adopt EASEE-gas specification. Sweden Total Sulfur excludes odorant. WI - 15 °C for combustion, 15 °C and 101.325 kPa for volume.

ANNEX B – LIST OF COMPANIES THAT RETURNED QUESTIONNAIRES

B.1 Data

B.1.1 Questionnaire responses & requirement for assumptions

352. To carry out a robust cost benefit analysis it was important to assess the impact, both positive and negative on all interested parties. With this aim information was sought from stakeholders across the gas industry from appliance manufacturers, users, distributors, transporters, shippers, traders and producers. Information relating to domestic end users and domestic appliances was outside of the scope of this project and has been supplied by the GASQUAL project. It was decided that the most efficient method of collecting the necessary information and data was to issue questionnaires to all interested parties and given a suitable opportunity, hold workshops with industry associations.

353. Questionnaires were developed for the various industry sectors including:

- manufacturers of gas fired industrial equipment;
- operators of natural gas fired industrial equipment;
- producers, shippers/traders, suppliers and transporters; and
- industrial users of natural gas as a feedstock.

354. A total of 91 questionnaires were returned: 14 from manufacturers, 6 from feedstock consumers, 23 from operators, 12 from producers, 24 from shippers, 15 from transporters. A list of responders is provided below.

355. An incomplete set of existing specifications was provided by NRAs.

356. Generally the responses were helpful in ensuring that the many nuances of gas quality harmonisation were identified, however it was disappointing to realise that there was scant data provided. It became obvious that in order to progress the quantification of costs and benefits it would be necessary to make assumptions about a number of elements.

B.1.2 Preliminary report, consultation responses & December workshop

357. Following the initial analysis the EC published a preliminary report in July 2011. This was accompanied by a series of consultation questions, and responses were requested prior to the XX Madrid Forum to allow the project to report.

358. The initial report triggered significant amounts of interest, and a number of important points were raised in the consultation responses. Due to the significant level of interest a workshop was held in December 2011, where a number of useful presentations were received by invited stakeholders. In addition, ENTSOG offered to collate and provide a body of historical data to enable the identification of 'de facto specifications', and to help identify the potential for regional solutions.

359. A number of key points were raised in the consultation responses and the workshop. These responses have been invaluable in shaping the conclusions of this study in a number of areas. The consultation responses and our replies are detailed in 0.

Table 15 – Questionnaire responders

No.	Name	Abbreviation
1	FGSZ Ltd.	FGSZ
2	GRTgaz	GRT
3	GASSCO	GASSCO
4	GasTerra B.V.	GT
5	E.ON Ruhrgas AG	EON
6	AB Lietuvos dujos	AB
7	HSEQ & Energy	HSEQ
8	MAN Diesel & Turbo SE	MD
9	RIELLO S.p.A.	RIELLO
10	Hamworthy	H
11	GAS NATURAL SDG S.A	GN
12	E.ON Engineering	EONE
13	Corus Strip Products Ijmuiden	CORUS
14	WIENSTROM GmbH (Vienna Electric Power)	VEP
15	Storengy (underground storage France & Europe)	S
16	SCA Graphic Laakirchen AG	SCA
17	Lumius Slovakia, s.r.o.	LS
18	E.ON Ruhrgas AG	EONR
19	British Ceramic Confederation	BCF
20	Max Weishaupt GmbH	MW
21	FLUXYS	FLUXYS
23	GPN	GPN
24	SHELL Slovakia, s.r.o.	SS
25	Utility Support Group BV Urmond The Netherlands	USG
26	MTU Friedrichshafen GmbH	MTU
27	Gaslink	G
28	GrDF	GrDF
29	Clyde Energy Solutions Limited representing UK manufacturers	CESL
30	Alstom	A
31	AES Elsta	AES
32	Commission de Régulation de l'Energie	CRE
33	Gerdau Sidenor*	GS
34	Adisseo France SAS	AF
35	RWE Supply & Trading GmbH*	RWE

No.	Name	Abbreviation
36	Elster GmbH	Elster
37	SPP - distribúcia, a.s.	SPPD
38	Commission for Energy Regulation -ESB's - Electricity Supply Board	ESB
39	Centrica	C
40	GrowHow UK Limited	GH
41	Shannon LNG	SLNG
42	Shell Gas Direct	SGD
43	Phoenix Energy	PE
44	Akzo Nobel Industrial Chemicals B.V.	Akzo
45	Electrabel GDF-SUEZ	EGDF
46	Premier Transmission Limited	PTL
47	poweo	P
48	Shell U.K. Limited	SUK
49	Geoplin plinovodi d.o.o.	Gp
50	Rhodia Energy	RE
51	Bulgargaz EAD	BEAD
52	MWM GmbH	MWM
53	ČEZ, a. s.	CEZ
54	Slovenský plynárenský priemysel, a. s.	SPP
55	EDF Energy*	EDF
56	ExxonMobil Gas & Power Marketing*	EX
57	Statoil (U.K.) Limited	SL
58	Corus Group	CG
59	AmbiRad Limited	AR
60	TEDOM ENERGO s.r.o.	TE
61	Eneco Energy Trade	EET
62	Hamworthy Combustion	HC
63	EconGas GmbH	EG
64	eustream, a.s.	e
65	DSM AGRO	DSM
66	Enagás'	E
67	Centrica Energy	CE
69	Association of Electricity Producers	AEP
70	UNION FENOSA GAS	UFG
71	Carburos	Car

No.	Name	Abbreviation
72	E.ON Gastransport GmbH	EONG
73	Snam Rete Gas S.p.A.	SRG
74	National Grid	NG
75	Industrial Association of House, Heating and Kitchen Technology [HKI - Association]	HKI
76	National Grid Grain LNG	IOG
77	GNL Italia	GNL
78	FLUXYS LNG	FL
79	Enagás S.A	E
80	Terminal GNL Adriatico Srl [Adriatic LNG]	TGNL
81	Wärtsilä	W
82	GE Turbines	GE
83	The European Association of Internal Combustion Engine Manufacturers - EUROMOT	EUR
84	Mol PLC	MOL
85	Gas Natural Europe	GNE
86	Shell Energy Deutschland GmbH, Hamburg.	SED
87	Shell Espania	SE
88	Shell Energy Europe	SEE
89	Nederlandse Aardolie Maatschappij B.V	NAM
90	Shell UK - Ireland	SI

ANNEX C – STAKEHOLDER MEETINGS

360. As a result of stakeholder meeting a position paper was published by EUROMOT. The paper, 'Gas quality aspects of reciprocating engines', was issued in May 2011. ETN, already concerned at the possibility of the adoption of the EASEE-gas specification had issued their position paper, 'The impact of natural gas quality on gas turbine performance', in February 2009.

361. The papers are available at http://www.euromot.org/news/positions/stationary%20engines and http://www.etn-gasturbine.eu/positionpapers.aspx and their position is summarised below.

C.1 Summary of ETN position paper: The impact of natural gas quality on gas turbine performance

362. For the gas turbine operator, the most likely issues associated with fuel composition variation are associated with the combustion system in the gas turbine and include:

- high levels of pollutant emissions, especially oxides of nitrogen and carbon monoxide;
- component life and integrity issues due to factors such as flame flashback and unstable combustion; and
- operability issues such as ignition problems and flame failure.

363. Potential costs associated with operability issues and failures are difficult to quantify because of the variation in problems that can occur and variation in electrical power trading regimes. However, for a large utility power generation combined cycle gas turbine with of the order of 350MW electrical output, penalties incurred and other costs for single engine trip would typically be in excess of 100,000 Euros. In the worst case if serious damage occurred (for example due to flashback) resulting in consequential damage to the turbine, then a major overhaul of the gas turbine would be necessary with costs potentially of the order of tens of millions of Euros.

364. In addition to the cost impact on operators, lost generating capacity would probably be replaced by plant producing higher carbon emissions and should such failures occur at times of high demand, then security of supply could be compromised.

365. Original Equipment Manufacturers (OEMs) are starting to address the issue, but solutions are in the early stages of development and may not be viable for all existing gas turbines.

366. Therefore, ETN invites the EC to initiate a study investigating the following areas in more detail:

- current and potential future rates of change of Wobbe index in distribution networks;
- actual capability of gas turbines to accommodate changing fuel composition;
- methods of compensation for changes in fuel composition such as:
  - controlled gas heating as a retrofit Wobbe index control system;
  - manufacturers' control system modification for automatic Wobbe index compensation and the potential for applying solutions developed across the existing gas turbine fleet;
  - application of H-Gas to L-Gas switching experience to range switching in nominally single fuel areas;

- rapid fuel composition measurement methods;
- issues associated with increased H-Gas to L-Gas switching; and
- the potential for changes or additions to the EASEE-gas requirements to address the issues of Wobbe index range, rate of change of Wobbe index and high levels of higher hydrocarbons.

C.2 Summary of EUROMOT position paper: Gas quality aspects of reciprocating engines

367. The engine sector is concerned that introducing gas quality specifications like the EASEE-gas specification could lead to excessive variations in gas quality with negative implications for the operation of gas appliances and especially gas engines. For example, lower gas qualities can result in a high variability of the knock resistance of the gas and lead to reduced performance (or even shut downs), higher fuel consumption and higher emissions of gas engines. Importantly adapting existing gas engine installations will incur high costs.

368. Currently, most regions in Europe receive close to constant gas compositions which allow gas engines to be tuned adequately to the relevant gas composition. EUROMOT understands that diminishing European resources of natural gas, intentions to promote gas exchange between member states and worries about security of energy supply as well as the expectation of increased use of shale gas result in the wish among some stakeholders for wider gas quality ranges in the gas grid within Europe.

369. As an alternative approach the engine sector strongly advocates the concept of proper gas treatment at each point of reception of imported gas in Europe to address these issues.

370. EUROMOT urges EASEE-gas, gas companies and regulators to take into account further important parameters – such as the Methane Number – when setting gas specifications. EUROMOT have proposed a gas quality specification as given in Table B1. If not proposed then the EASEE-gas value will be used.

371. EUROMOT have estimated costs that would be incurred due introduction of the EASEE-gas specification as follows:

- where available control systems might cost €10,000 per engine;
- where a control system has to be developed the cost is estimated at €50,000 per engine;
- adapting the turbocharger and camshaft timing between €80 per kW and €300 per kW; and
- costs of adapting engines <250 kW will be excessive.

372. EUROMOT have estimated the number of installed units and estimate that an investment of €6.8 billion would be required.

Table 16 - EUROMOT proposed gas quality specification

Parameter	Units	EUROMOT	Comment	EASEE-gas
Wobbe index	kWh/m3		Maximum variation of ± 2% and providing a MN of 80 -100	13.6 – 15.81
Methane Number		80 - 100	EASEE-gas spec gives 48 - 102	
Ignitability	Lambda range	2.2		
Laminar Combustion Velocity	cm / s	28 - 32		
Relative Density	m3/m3		Ensuring the right Wobbe index range	0.555 – 0.700
O_2	mol%			<0.001
S	mg/m3	< 5		< 30
H_2S + COS (as S)	mg/m3			< 5
RSH (as S)	mg/m3	0	Preferably no S in odorant	<6
CO_2	mol%			2.5
H_2O DP				-8 @ 7000kPa
HC DP		< -10	To avoid condensation in cooler stretched of gas pipelines	-2 @ 7000kPa
Supply Pressure	Bar (gauge pressure)	8	Many applications (engines and turbines) need a higher pressure than domestic appliances	

C.3 Clarification issued by EUTurbines on behalf of GE

373. Following the initial response by European Turbine Network, a series of follow-up points for clarification were received.

- List of installed GE turbines per 27 EU countries supplied.
- Estimation of 40 gas turbines to be installed per annum by GE in EU until 2020.
- If EASEE-gas range stays within ±5% Wobbe index variation then all gas turbines can operate in this range with slight modification on emission levels.
- 4-5% Wobbe index variation may impact emission levels by around 20%
- Tuning solution to meet emission when changing fuel within EASEE-gas specification might be around $300k per unit.

- GE estimates that none of the gas turbines will be obsolete if EASEE-gas specification is with ±5% Wobbe index variation.

ANNEX D – STAKEHOLDER QUESTIONNAIRE RESPONSES

D.1 Manufacturers of natural gas-fired equipment supplied for use in countries within the EU

374. Questionnaires were received from 13 appliance manufacturers and two associations, HKI – Industrial Association of House, Heating and Kitchen Technology (Germany) and EUROMOT, The European Association of Internal Combustion Manufacturers.

Q1. What generic type of natural gas firing equipment does your company sell within the EU Community

375. Fourteen responses were received from 8, 9, 10, 20, 26, 29, 30, 36, 52, 59, 62, 75, 81, 82 and 83 representing manufacturers of burners, gas engines, turbines, commercial heaters and catering equipment.

Q2. Into which EU countries is your equipment sold

376. All respondents supply the EU with the exception of Hamworthy [10] whose market base is Belgium, Spain, Italy, Eire, Poland and the UK

Q3. Can you provide details of your equipment:

377. The manufacturers that responded supply burners with a capacity from 40 to 120MW with one [36] stating that control systems to ensure complete combustion are fitted on more than 80% of the units whilst another [62] stated that control systems may comply with EN676 and EN298 or be bespoke. Power burners are supplied [20] for commercial water heaters, space heaters, catering, industrial process heaters, furnaces and boilers

378. The gas turbines have heat inputs between 18 and 80MW and have PLC based unit and safety control systems. They include diffusion and lean premix designs and have applications in CCGT/steam turbines and gas fired power generation

379. The catering appliances are designed to operate on all gas qualities according to EN 437 but adjustment or modification of the equipment is necessary. The typical heat input varies between 500W and 200kW. The burner systems, as well as gas controls and safety systems are produced by the manufacturers of catering equipment themselves or bought from other manufacturers.

380. The warm air systems are rated between 7 and 700KW and the radiant tube heaters between 11KW and 60KW. Individual gas engines can vary in electric power capacity between 2 MW and 20 MW, while power plants based on the multiple unit concept can have an electric power capacity exceeding 300 MW.

Q4. Do you believe your equipment will continue to operate safety and efficiently if the gas quality specification of H family natural gas was widened to the EASEE-gas limits? If not, what are the key parameters. In addition, if possible please advise whether you expect any impact on the operation of your equipment with respect to emissions, efficiency, product life or additional maintenance.

381. Burners can operate safely and efficiently over a limited range but will need adjustment, either fuel gas pressure or air/fuel ratio controlled by oxygen trim to operate over the wider range of the EASEE- gas limits. Burners can be designed to operate with natural gas with

a Wobbe index in the range of ± 5% of specified value If the Wobbe index of the fuel changes then it may be necessary to make adjustments in air/fuel ratio, apply oxygen trim control or to change burner gas tips to maintain maximum efficiency and lowest emissions. Power burners above 60KW and heating systems will not operate safely and efficiently. One boiler manufacturer [29] reports that operation over the EASEE-gas range is dependent on the burner design with one being more sensitive to Wobbe index and concluding that it will not operate over the EASEE-gas range without modification. In addition there may be sooting issues and consequential maintenance problems from the widened range of Incomplete Combustion Factor and Soot Index. This would present a real problem to modern, high efficiency and low water content gas-fired boilers with very compact heat exchangers that are both very difficult to clean and would be very seriously affected by even a light coating of soot.

382. One manufacturer [8] reported that their turbines are designed for Wobbe index range 40 – 53 MJ/Nm^3, ± 10% and can operate across the EASEE-gas range. However did highlight that contaminants and higher hydrocarbons are not included in EASEE-gas specification. GE [82] reported that their turbines will operate if the EASEE gas range stays within ±5% Wobbe index variation but with a slight modification on emission levels estimating that a 5% Wobbe index variation may impact emission levels by around 20%. It is predicted that there will be an impact on reliability if changing many times in the year.

383. The water and space heater manufacturers each report that over the long term their equipment will not operate safely over the EASEE-gas range. They predict that that soot will probably be produced which would shorten the life of products due to clogging of components. Other considerations to be taken into account are CO and NOx emissions, efficiency, ignition and flame stability. Appliance temperatures and operation of key safety devices. They expect an adverse impact on longevity, performance issues and resultant maintenance. One [59] raised safety concerns with direct gas fired warm air units where the products of combustion are in the occupied space being heated.

384. RIELLO [9] reported the incident in 2000/2001 when high Wobbe index gas was distributed in Denmark and in those North Germany areas supplied with Danish gas. The main problems were failures of heat exchangers and burners. This is because gas appliances are adjusted for reference gas G20 so, when supplied with higher Wobbe index gas, they are roughly, 10 to 15% overloaded. Some manufacturers have modified the design of the burners or the heat exchangers, RIELLO, for installed appliances, were allowed by DGP to reduce the burner gas pressure in order to get the nominal heat input. This solution was possible only because the gas quality in Denmark is constant.

385. The Industrial Association of House, Heating and Kitchen Technology [75] state that installed and current production models of commercial catering appliances will not operate over the EASEE-gas range.

386. Gas engine manufacturers [81, 83, 86] reported that problems can be expected with respect to power capacity, fuel efficiency, reliability as well as emissions. Gas engines could operate across EASEE-gas range however only with reduced performance and probably higher emissions. Manufacturers of gas engines need to consider the lower heat value and the methane number, which gives the knocking resistance of the gas . Lower quality gases leads to increased variability in knocking resistance of the gas that can induce damage and result in unsafe conditions. The other parameters widened to EASEE-gas specification: H2S, S, O2, CO2, water dewpoint are workable. The hydrocarbon dewpoint is critical as has an impact on the methane number. Lower the methane number, lower the power of the gas engine and greater the loss of efficiency. If the gas engine manufacturer in the future has to work with a lower methane number

recent developments of engine efficiency will be lost. Installed engine control system can adjust for a range of gas quality but usually cannot cope with step changes in gas quality.

Q5. Can you advise on the likely modifications that would be necessary to mitigate the affects of gas quality change ?

387. A range of responses from the burner manufacturers: no modification possible to power burners [29], no modification required but performance across the EASEE-gas range will not be consistent, settings would need to be reset to accommodate new gas quality and if a single burner is required to accommodate the full EASEE-gas specification and maintain the efficiency and emission requirements, additional costs would be incurred by customer to upgrade the control system to possibly include oxygen trim, gas supply monitoring and emissions monitoring. In addition more operator vigilance would be required and there would be increased maintenance costs due to additional instrumentation.

388. Turbine manufacturers design units to operate at maximum efficiency and with minimum emissions over a narrow range and can do so over the EASEE-gas range and as such do not see that modifications are required provided that the gas quality remains with the design specification. GE identified the need for a tuning solution to meet emission limits for a change in gas quality.

389. The manufacturers of space heaters state no modification is possible. Hamworthy [10] suggest that product development on burner construction/geometry, controls (gas valve or micro-processor electronics – governing fan speeds), ignition devices and systems may resolve the issues and estimates a timeframe of 2 years.

390. HKI [75] state that it is not possible to modify the existing catering equipment but propose that it should be possible to design equipment that will operate across the EASEE-gas range and estimate a timeframe of two years.

391. Engines without control systems will need to be upgraded and for obsolete engines this will require new control systems to be designed and manufactured. In many cases the compression ratio of the engines will need to be adapted to accommodate lower quality gases and may also involve adapting the turbocharger and the camshaft timings

Q6. Are you planning the release of a new model in the near future as a direct response to wider gas limits. If so please provide details of current or planned development including the proposed range of operation, the timescales for introduction and the increased production costs as a percentage of the existing cost

392. One engine manufacture [81] reported that their latest generation of gas engines will be equipped with in-cylinder pressure sensors and adequate control equipment to accommodate wider gas limits. However, this does not mean that such a system can avoid a deteriorating performance if gases are supplied with a low knock resistance and poor ignition properties

Q7. If modification of existing appliances would be necessary do you have sufficient trained engineers available to carry out the work or can you estimate the additional cost of providing such a service.

393. Only one response received however it is thought to be representative of all industries. As in every modern company, our dedicated and specialized workforce has been optimised to handle the normal maintenance actions and normally no time is available for activities such as unscheduled modifications caused by unforeseen gas quality variations.

Q8. Please provide any additional comments that you feel are relevant to this study

394. A range of additional comments were made including:

- We have the feeling that the gas industry has insufficiently taken into account the sensitivities of many gas fuelled installations to variations in gas composition. Gas properties such as ignitability and flame speed, very relevant for modern gas engines, gas turbines and processes, have been neglected in the proposals, [81]
- Our focus is to improve the efficiency of the gas engine to reduce CO2 emissions. Wider ranges of gas limits don't support this. We need highest methane numbers for best efficiency. To reduce the knocking sensitivity of engine is a continuously development work but with the item to improve the power output of the engine and the efficiency. Reacting on "bad gas quality" is not the intension of our customers [26]
- Many non-GAD appliances are still in field; who will be responsible for non domestic appliances. GASQUAL laboratories are going to test mainly new appliances but anybody is aware that used appliances may be adjusted/modified in field so they could be different from new ones. Moreover they could be installed/serviced in a wrong way. All these aspects are not taken into consideration. [9]
- Alstom does not see a major issue with gas quality harmonization. As long as the gas quality is within our specified Wobbe index and reactivity limits, it is more important for Alstom and other gas turbine and power plant manufacturers to know how fast the changes in Wobbe index and reactivity take place. Rapid variations in gas composition pose a more difficult problem than designing our equipment for a given gas specification [30]

D.2 Industrial users of natural gas as a feedstock

395. Six responses were received; these were from 7, 23, 40, 65, 34 and 71.

Q1. What process requiring natural gas do you operate

396. Manufacturer of ammonia, hydrogen, carbon dioxide, nitric acid,

Q2. In which EU country are you based? Was this location specifically selected

397. Plants based in Austria, France, UK, Netherlands and Spain. The site in Austria was selected for the quality of the gas supply whilst the site in Spain was designed specifically for the expected gas quality

Q3. Please quantify annual usage of natural gas per plant

398. Usage ranges from 24M to 700M m3 pa

Q4. Can you provide details of why the site was selected, and of any gas clean up process.

- The site in Austria was selected for the quality of the gas supply as no clean-up of the gas is required, whist two sites were built irrespective of the expected gas quality one of these sites was designed specifically for the expected gas quality.
- Where stated, preference is for high methane content and low sulfur, nitrogen, higher hydrogen carbons, and carbon dioxide.
- 4 sites operate desulfurisation plants and in addition one operator removes all chlorides.

5.1.6.1 Q5. Has the impact of varying gas quality on your process been assessed and documented.

399. For the site in Austria calorific value and composition are critical resulting in a shut down if the gas supply is out of range. One operator receives advance warning of gas quality changes from the TSO. Four operators report that a higher sulfur level would increase the load on the desulfurisation plants and increase the frequency of change out. Higher Wobbe index gas would result in increased carbon laydown. One operator estimated that a 1% decrease in methane has a financial impact of a few hundred thousand Euros pa.

400. One operator noted that EU plant operations are optimised to reduce emissions, typically each tonne of ammonia creating 2 tonnes of carbon dioxide. Increased carbon dioxide content in the gas will impact directly on the Emission Allowances that will need to be purchased within the EU Emission Trading Scheme

Q6. Do you believe your equipment will continue to operate safety and efficiently if the gas quality specification of H family natural gas was widened to the EASEE-gas limits ? In addition, if possible please advise whether you expect any impacts on the operation of your plant, with respect to emissions, efficiency, plant life or additional maintenance and on the product produced.

401. The Austria site does not clean up the gas prior to use and an increase in carbon dioxide above 2% could deem the process unsafe or inefficient. One response [65] advises that sudden changes in gas quality may be too fast for the plant operation to be modified and result in dangerous situations. Increased higher hydrocarbon content will reduce ammonia production, increase fuel gas consumption and carbon dioxide production. The increased annual processing cost is estimated at 5M€ based on an increase of 2% in the feed gas and in addition plant modifications would be required.

Q7. Do you think it will be possible to modify the plant to enable gas over the EASEE-Gas range to be used? Can you advise cost, timescale and availability of funding.

402. Two operators stated they did not know if the plant could be modified and three operators considered modification would be necessary.

403. One response [65] provided details of an automated predictive control system to replace the current manual system to optimise plant operations with changing gas quality and analysers to monitor desulfurisation plant. Installation of monitoring for sulfur and a control system estimated between 900 and 1600 K€. Installation would be scheduled with planned annual shutdowns and could be achieved over a period of 2-4 years but funding is not available.

404. Another noted that to process gas with higher hydrocarbons a new plant will be required but without details of the gas composition no costing for design and build can be estimated, however timescale would be 2 to 3 years. A third [71] estimated that a study of the engineering modifications required would take 6 months but could not estimate the cost. In common with all operators any modifications would be carried out during a scheduled shut-down.

Q8. Are you planning to replace your plant in order to continue to operate over a wider gas range. If so what is the timescale for delivery and the estimated cost

405. No operator reported plans to replace or undertake modifications to operate over a wider gas composition.

Q9. Please provide any additional comments that you feel are relevant to this study

406. Two operators [50, 65] provided comments:

- Problems were predicted relating to plant design, emissions, efficiency and safety
- The absence of a methane limit in proposed gas quality specifications as highlighted by the Methane Task Group. Requirement on TSO to advise end user of changing gas quality was suggested.

D.3 Transporter system operators (TSOs)

407. Responses received from 21, 27, 46, 49, 57, 64, 72, 73, 74 and 1 representing transporters (TSO), 66 a TSO, regasification and UGS operator, 6 a TSO and shipper, 28 and 37 Distributors (DSO) and the French Commission de Régulation de l'Energie [32]

Q 1. As a transporter please state country, or countries of operation

408. The DSOs operate in France and Slovakia. The TSO's operate in Belgium, France, Germany, Hungary, Ireland, Italy, Lithuania, Slovakia, Slovenia, Spain and the UK.

Q 2. Do you currently process or blend gas to meet a specific specification. If so please provide details

409. National Grid [74} stated that they do not blend or process gas however some processing is carried out by gas producers, terminal operators and/ or LNG importers in order to meet the requirements of the Gas Safety and Management Regulations (GSMR).

410. Zee platform (wheeling service in the Zeebrugge area) as well as some border to border contracts are operated at UK specifications, and Fluxys provides the relevant shippers with a free (and reasonable endeavours) blending service by substituting non-UK compliant gas with UK-compliant gas, insofar available. This service is conditional to operational conditions (including but not limited to linepack and UK compliant gas availability) and provided free of charge.

411. Statoil [57] advised that gas from different sources on the Norwegian continental shelf (NCS) is co-mingled in the Norwegian pipeline system enabling the gas to be blended to the required specifications, including tighter UK specification.

412. FGSZ [84] reported that Hungary does not have the infrastructure/technology and nor enough gas sources to carry out blending.

413. GRTgaz [2] stated that the gas is processed at the German border to dry it and that the plant operates at full capacity.

414. The remaining TSO's and DSO's advised that they have neither blending nor processing capabilities.

Q3. Can you estimate the cost of this

415. No estimates provided. Fluxys advised that the blending service they provide is free of charge but provided on reasonable endeavours.

Q4. Would the introduction of the EASEE-gas specification relax or increase the process or blending requirement on your operation. Please explain how.

416. SPP – distribúcia [37] introduction of the EASEE-gas specification would not have an impact provided that gas entering the distribution network meets the EASEE-gas

specification. However if this was not the case then SPP - distribúcia has no facilities or capacity to modify gas composition. If the dew point of water in gas at the entry points is higher that the EASEE-gas specification, it would mean excessively high costs for construction and operation of facilities for drying of gas. This would increase the price of natural gas and it would not bring any added value when compared to the current state in case of majority of customers.

417. [72] advised that no major impact would be expected, as the gas quality specifications in the German DVGW Technical Rule G 260 are broadly similar to the EASEE-gas specification.

418. National Grid [74] advised that it has no control over the quality of the gas that enters its network except through the application of entry specifications within the Network Entry Agreements. We cannot therefore guarantee any source of blendable gas at any particular point in time. Should National Grid be required to offer a blending service, it is difficult to foresee how this could operate on a consistent and equitable basis without a major interference with the normal market flows of gas. In addition there are potentially security of supply issues arising from blending multiple sources of gas in order to comply with any particular gas specification. The potential for this type of impact may have to be taken into account when establishing a preventative action plan and this could in turn lead to major capital costs that would not otherwise have been required.

419. Eustream [64] stated that Slovakia receives 99% of their gas from Russia. To meet EASEE-Gas specification would require building of process plants notably for water dewpointing

420. Gas delivered by the shippers at the border points of the Italian gas network must be compliant with the specification defined by the decree of the Ministry of the Economic Development and published on the Snam Rete Gas Network Code. The EASEE_gas specification would impose a need for processing and also the wider Wobbe index range could impact on consumers.

421. Storengy [15] commented that if the maximum oxygen content is lower than 100 ppm, the desulfurisation process which is used (activated carbon) will need to be changed at a cost of between 50 to 100 million euros

422. The Commission de Régulation de l'Energie draws attention to the fact that introducing an oxygen limit below 100ppm would require significant investment by storage operators in desulfurization units estimated between 50-100 million Euros for France.

5. If additional processing is required do you have spare capacity in existing process plant

423. No responses.

Q6. If you do not have spare capacity do you have an estimate of the cost to build/operate a new process plant

424. Fluxys [21] estimate that a plant capable of delivering sufficient nitrogen to ballast the full flow between Belgium and UK with a maximum Wobbe index of 56 MJ/m^3 would cost around 30 M EUR to build and with the existing liquid nitrogen storage facility have an opex of around 5 and 10 million euros per year respectively

425. Storengy [15] estimated the cost of replacing their desulfurisation process to comply with a tighter oxygen limit would be between 50 to 100 million Euros.

Q7. If you would be required to blend the gas is the infrastructure and various sources of gas available to you. If you would need to update your blending facilities please estimate cost and timescale

426. No responses.

Q8. If less processing is required please estimate the overall financial impact

427. No responses.

Q9. If investment is required will your company have access to necessary funding

428. Fluxys [21] raised the important question of recovery of costs. If the UK does not adopt the EASEE-gas specification processing will be required. The problem as such is not the necessary funding, but it relates to how the costs can be recovered in a nationally regulated environment, in which tariff design might be an issue. In other words, must the EU continental citizen to pay for a problem located in the UK?

Q10. Are you planning to replace your plant / operations in order to continue to operate over a wider gas range. If so what is the timescale for delivery and the estimated cost

429. No responses.

Q11. Please provide any additional comments that you feel are relevant to this study

430. GrDF [28] predicts that the main impact would be on combustion parameters. The EASEE-gas combustion parameters are not used in France and the higher limit of Wobbe index is restricted by French regulations to 15.66kWh/m3 (25°C, 0°C)] compared to the EASEE-gas upper limit of 15,81 kWh/m3(n) (25°C, 0°C). There is no evidence that French appliances can work safely with a Wobbe index higher than 15,66 kWh/m3(n). In particular, some industrial customers may not accept a gas with a higher Wobbe index for their process. Imposing the EASEE-gas range may require the development of blending facilities to meet industry gas quality requirements.

431. Fluxys [21] comment that the introduction of the EASEE-Gas specification across the whole EU would suppress the need to provide the existing blending service and would increase the firmness of the deliveries to UK. Failure to change the specifications in the UK (or to process the gas accordingly at the entry of the NTS operated by National Grid) would create an unbridgeable gap between continental Europe and UK.

432. National Grid [74] stated that the primary consideration should be given to safety implications arising from any changes to the gas quality standards. One concern that they have is that the CEN study of gas appliances will only report on domestic appliances produced to be compliant with GAD. This was not fully introduced until 1996. Any study must also include all potential safety issues associated with older domestic appliances and non-domestic appliances.

433. FGSZ [84] believes the producers and UGS could extend existing processing rather than they develop new facilities. However they also report that some gas producers already have difficulty to meet existing total sulfur and carbon dioxide limits.

434. Geoplin plinovodi [49] commented that a unified specification throughout Europe should not be at the detriment of the existing blending capability which allows the maximum production from indigenous reserves. In addition they stated that different sources and different composition of the gas will cause higher requirements regarding the measurement, cross border point control and gas network operation

435. Statoil [57] believe the GS(M)R gas quality specification currently recognised in the UK, is a cause for concern as this narrower specification and has the potential to impact on the volume of gas that can be delivered to the UK both from the NCS and the continent. The Norwegian pipeline system operator (GASSCO) has installed blending facilities in the UK, to ensure that on the limited number of days that gas quality from the NCS is an issue, volumes meet the required specification before final delivery to the UK transmission system but this is not a long term solution. The UK currently runs the risk of flows from the continent being curtailed, particularly on days of high demand, due to the mismatch in gas quality specifications. This loss of supply could result in a gas deficit emergency. Following harmonisation supply to the UK would be increased and gas would be able to move freely in and out of the UK without any impact on deliveries to and from the wider 'European' system. As Europe's reliance on LNG increases and with the delivery of gas from 'richer' fields the issue of gas quality is going to become more and more relevant in ensuring security of gas supply.

D.4 Shippers/traders and suppliers

436. Responses received from 18, 24, 38,39, 86 and 87 representing shippers, 4, 11, 17, 42,42,45, 476, 63, 67, and 85 representing shippers and suppliers and 8, 51, 56 and 54 from suppliers.

Q1. What is your role and what is your country of operation

437. Company role and the country of operation detailed in the responses is shown in Table 17.

Table 17 – Shipper/trader/supplier responses

	Shipper/trader	Shipper/trader and supplier	Supplier
Austria	1	2	1
Belgium	1	2	0
Bulgaria	0	0	1
Czech Republic	1	1	0
Denmark	1	0	0
France	1	4 (inc. 1 storage)	0
Germany	2	4	1
Hungary	1	2	0
Ireland	1	1	0
Luxembourg	1	0	0
Netherlands	1	4	0
Poland	1	1	0
Romania	1	0	0
Slovakia	2	1	1
Slovenia	1	0	0
Spain	3 (inc. 1 LNG)	1	0
Sweden	1	0	0
United Kingdom	1	3	0

Q2. Do you currently process or blend gas to meet a specific specification. If so please provide details

438. Electrabel GDF-SUEZ. [45] blend ZPT gas within the Zeebrugge area to meet UK specifications if UK non compliant gas arrives at ZPT. No charge is made but is done on best endeavours

439. [86] reported that in Germany propane is used to lift the heat content of boil-off gas flowing into the Local Distribution Zone (LDZ), though this is reduced when boil off gas is available.

440. [18] reported that nitrogen ballasting is used at Grain and in the Netherlands. [67] reported that UK import terminals have processing capacity but no details are provided.

441. All others advised that they do not have blending or processing capabilities, it was not applicable and one advised it was an issue for the TSO.

442. Q3. Would the introduction of the EASEE-Gas specification relax or increase the process or blending requirement on your operation. Please explain how.

443. Centrica [67] reported that National Grid provided an approximate cost of a ballasting plant at Bacton to manage gas quality from mainland Europe. In 2008 this was estimated to be of the order of £200m.

444. Gas Natural Europe [85] stated that there would be no impact as their TSO's (GRTgaz and TIGF) are already imposing EASEE-gas specifications in Transportation Agreement. It is further stated that should the EASEE-Gas specification be adopted across all mainland European pipelines, this would cause severe difficulties for UK supply.

445. GAS NATURAL [11] commented that the Spanish network code (NGTS) provides for a wider gas range than EASEE-gas specifications. Accordingly, the Spanish gas system has been adapted (thanks to investments done by different Spanish companies and operators in gas industry) to operate with gas specifications as wider as possible permitting the use in our system the maximum of natural gas and LNG supply sources, facilitating gas exchanges and increasing flexibility and security of supply. The lower limits of the EASEE-gas specification would mean that some natural gas and LNG would be out of specifications. In other words, any reduction of gas range provided for by EASEE-gas specifications would result in entry barriers for some of our gas supply sources as well as barriers for gas exchanges across Europe

Q4. If additional processing is required do you have spare capacity in existing process plant

446. No responses.

Q5. If you do not have spare capacity do you have an estimate of the cost to build/operate a new process plant

447. Slovenský plynárenský priemysel [54] stated that the EASEE-gas specification for water and hydrocarbon dew point are much higher than that of the usual supply of natural gas in Slovak Republic. Estimate that such investment would be tremendous with huge negative impact on domestic natural gas market. To date no customer has requested such high quality of gas.

Q6. If you would be required to blend the gas is the infrastructure and various sources of gas available

448. No responses.

Q7. If less processing is required please estimate the overall financial impact

449. No responses.

Q8. If investment is required will your company have access to necessary funding

450. Centrica [67] commented that if investment is required, for example at Bacton to process gas from mainland Europe, it would most likely be undertaken by a TSO, provided that the regulatory approval for the investment were obtained. Alternatively, investment could be undertaken by a group of interested parties given the necessary regulatory certainty about access and use by third parties.

451. E.ON Ruhrgas [18] recommended that if investment in infrastructure is necessary in order to harmonise the gas quality specification within Europe it should be ensured that the related costs are assigned to all market participants in a way that does not distort competition and hamper the further development of a European gas market.

452. Q9. Please provide any additional comments that you feel are relevant to this study

453. Shell Energy [86] stated "Shippers" have usually no exposure to gas quality issues. Gas is traded at virtual hubs, at end-consumer gate or market area/country borders. Contracts refer to national gas quality norms and end-consumer gate or market area/country borders. Contracts refer to national gas quality norms and costs occurring to blend gas in a way that it is aligned with national quality norms usually are an issue for grid operators, domestic upstream companies and supplier from third countries.

454. Electrabel [45] stated that the gas quality is a daily constraint/incertitude on cross border flows. Common specifications will facilitate the gas exchanges between and within regional markets. These specifications will also increase the security of supply.

455. EconGas [63] commented that changes in quality specification may lead to additional costs for producers (gas treatment), TSO's (treatment at interconnection points) or at customer sites (e.g. burner, exchange of equipment). These costs should be kept as low as possible and should be charged in a non discriminatory way and should not lead to market distortion caused by additional costs for specific supply sources by defining a standard in favour of other sources.

D.5 Producers of natural gas supplying the EU

456. 11 questionnaires were returned. 4 from producers, [1,90, 89, 48], one from a producer and TSO [3] and 5 from LNG operators [76, 77, 78, 79, 80] and one from an operator at the design stage [41].

Q1. As a Producer please state country, or countries of operation

457. The countries of operation include: Ireland, UK, Hungary, Netherlands, Norway, Italy, Spain and Belgium.

Q2. Do you currently process or blend gas to meet a specific specification. If so please provide details including cost estimate.

Blending

458. Five responses state that no blending takes place.

459. GASSCO [3] stated the gas may be blended in the transmission system.

460. NAM [89] mixes gas from different sources in order to meet contractually agreed quality specifications at the delivery point. One operator advised that gas is blended for H2S, CO2, HC dewpoint, water dewpoint and Wobbe index to meet UK specification at an annual cost of approximately €110K.

461. GNL Italia [77] advised blending that blending is limited to drawing LNG from two separate tanks. Blending is not necessary because of the wide limits applied within Italy.

462. Enagás [79] state that blending is not necessary since gas from all sources meets the national specification in Spain.

463. Fluxys [78] advise that the infrastructure for blending is available following considerable investment in the Zeebrugge area, but offer no guarantee as to the availability of UK compliant gas from other sources. LNG is non-UK compliant in around 90% of the cases and Wobbe index at ZPT (Norwegian gas) has been increasing steadily since October 2006. Eynatten flows which could potentially flow to Zeebrugge zone depend on price difference between NBP/Zeebrugge and Gaspool/NCG and are not predictable.

Processing

464. LNG operators in Ireland and the UK ballast with nitrogen to control the Wobbe index and estimate the cost between €30 million and €100 million per annum. LNG in Italy is ballasted with air or nitrogen again for Wobbe index control however it may not be possible to accept gases with a Wobbe index above 53.17 MJ/m^3.

465. Fluxys [78] report that nitrogen ballasting is sometimes used to meet the requirements of the ZEE Platform which is operated at UK specifications. However where possible the lower cost of option of exchanging non-UK compliant gas for UK-compliant gas with adjacent TSO's is preferred, subject to availability of gas supplies and linepack. Indicatively, a plant capable of delivering sufficient nitrogen to cover full flow between Belgium and UK would cost around 30 M EUR to build and if operated with the existing liquid nitrogen storage facility would have an opex of around 5 and 10M EUR per year respectively.

466. GASSCO [3] process the upstream gas to produce liquids and at one LNG facility ballast with nitrogen.

467. NAM [89] processes all its gas to meet contractually agreed specifications

468. In Hungary there are three processing plants plus smaller ones to meet country specification for CV, Wobbe index, H2S and H2.

Q3. Would the introduction of the EASEE-gas specification relax or increase the process or blending requirement on your operation. Please explain how.

469. For LNG operators a relaxation in the Wobbe index would remove the requirement to ballast with nitrogen or air. Grain LNG [76] estimates that it would achieve approximately £15 million per year reduction in cost, based on present delivered LNG. For the planned site in Ireland [41] it is estimated that saving could be as high as €100 million per annum. GNl [77] estimate savings of between €100K and €200 per annum.

470. Enagás [79] advise that since the EASEE-gas specification is narrower than the one applied in Spain it could have a detrimental effect by requiring investment in facilities that are not presently required. The Spanish System has always fulfilled rules on harmonization of gas qualities. The Wobbe index range is between the limits set in the EN-437, which is the European Standard approved in 2003.

471. One LNG operator is considering an investment of between 31 and 70MEuro to meet User requests to process rich LNG. Adopting EASEE-gas specification would remove the need for this investment.

472. NAM [89] advises that most gases would fall within the EASEE-Gas specification. Certain fields which are currently blended away by the TSO (NAM as a producer has very limited blending facilities) would not be compliant with the EASEE-Gas specification. Additional processing would not solve this issue as some field have a low Wobbe index also none of our current fields could justify new processing plant.

473. GNL [77] state that if in the future they receive an LNG with a Wobbe index above the EASEE-Gas limit then they would not be able to ballast with air because of the very low limit applied to oxygen (0.001 % mol instead of 0.6 % mol which is the current limit for the Italian gas network)

Q4.If additional processing is required do you have spare capacity in existing process plant

474. No responses

Q5. If you do not have spare capacity do you have an estimate of the cost to build/operate a new process plant

475. Shell [90] state that they have no spare processing capacity and that the introduction of the EASEE-gas specification would incur very significant additional cost and delay

Q6. If you would be required to blend the gas is the infrastructure and various sources of gas available to you. If you would need to update your blending facilities please estimate cost and timescale

476. MOL [84] advise that it would be expensive to upgrade plant to meet EASEE-Gas Specification

Q7. If less processing is required please estimate the overall financial impact

477. GASSCO [3] report that costs would be reduced as the UK specification would be relaxed, however additional cost would be incurred due to tighter CO2 limit that would apply to the supplies to St.Fergus

Q10. If investment is required will your company have access to necessary funding

478. GNL [77] proposes that investments should be covered by the tariffs of the regulated business

479. Fluxys [78] argue that the problem as such is not the necessary funding, but it relates to how the costs can be recovered in a nationally regulated environment, in which tariff design might be an issue In other words, why should Belgian grid users pay a higher tariff to solve a problem in the UK?

480. Enagás [79] is a basic infrastructure operator (transmission, regasification and underground storage) subject to very stringent ownership unbundling provisions to ensure its total independence from supply/trading interests

Q11. Are you planning to replace your plant / operations in order to continue to operate over a wider gas range. If so what is the timescale for delivery and the estimated cost

481. No response or none planned

Q13. Please provide any additional comments that you feel are relevant to this study

482. NAM [89] commented that a unified specification that would be applicable at each entry point into the European TSO grid would decrease the available indigenous production as some fields would not be capable of meeting this specification and could not justify any additional cost or alternatively there is no technical solution to the constraint.

483. Shell [90] concluded that tightening of the specification would result in major adoption of the plant. The preferred route is to continue to operate over a wider range

484. Fluxys [78] state that the introduction of the EASEE-gas specification across the whole EU would remove the need to provide the existing ballasting/blending service and would increase the firmness of the deliveries to UK. Failure to change the specifications in the UK (or to process the gas accordingly at the entry of the NTS operated by National Grid)

would create an unbridgeable gap between continental Europe and UK, taking into account gas quality forecasts of future gas flows in NW Europe.

485. Enagás [79] observes that Spain has a long history of dealing with a wide variety of LNG without experiencing any problem with gas that might exceed the proposed EASEE-gas specification but in line with EN-437. There is no need for reduction of Wobbe index limits. Restricting the access of high calorific gas may harm diversification of sources and international LNG trade and hence competitiveness of trading of LNG can be affected.

486. Terminal GNL [80] state that difference in gas quality specifications are a barrier to trade. It is a burden for LNG suppliers to modify their specification or pay for gas to be corrected. This adds cost to transportation costs, hence adds to cost of LNG into EU. It is a barrier to liquid market, especially with respect to the spot market.

D.6 Operators of Gas Fired Appliances in the EU

487. Responses were received from 17 operators and collective responses from Association of Electricity Producers, British Ceramic Confederation and the European Turbine Network (ETN).

Q1. What generic type of natural gas firing equipment does your company use

488. All types of appliance are represented including: commercial water heaters, space heaters and commercial catering, industrial process heaters, furnaces and industrial boilers, CCGT/Steam turbines, gas engines and gas fired power generation. In additional operator(s) of incinerators for waste gases, steel melting and flares are represented. The major companies that responded CORUS [13, 58] and USG [25] operate a wide range of appliance types.

Q2. In which EU country is you appliance based

489. Operations are based in Netherlands, Germany, Austria, UK, Ireland, France, Czech Republic, and Spain. AEO and ETN represent operators in UK, Germany, Italy, Spain, France, Netherlands, Hungary, Slovakia, Sweden

490. Strong representation from the operators of gas fired turbines, (over 60% of responses) operating in excess of 100 units. The large manufacturers including CORUS, CEZ and USG have a wide range of gas fired appliances.

Q3. Can you provide details of your equipment, in particular information about the following.

- *The gas quality and supply pressure operating ranges over which your equipment will operate.*
- *State heat inputs or gas flow rates.*
- *The type and manufacturer of the burner system incorporated.*
- *Details of the gas controls and safety systems fitted.*

491. Details of systems were provided, including manufacturer's literature and data sheets.

Q4. Is performance data for your equipment available and if so can it be provided

492. Reference was provided to manufacturer's data sheets and brochures

Q5. Is your equipment adjusted to operate on a specific range – if yes please state range. If it has a control system describe design and operating range

493. [44] Equipment is designed for local gas quality and no control system for monitoring gas quality is in place

494. [25] Furnaces generally do not have automatic fuel/air ratio control and operate at fixed ratio, air excess 3 - 4 % oxygen is critical for NOx, SOx, CO and efficiency. Boilers have fuel/air automatic control. The excess air is controlled to 2 % oxygen. Other apparatus have fixed air/fuel ratio and no control systems, critical for NOx, SOx, CO, excess air, efficiency, These operate on realized gas qualities and within design data. Gas quality data is supplied by TSO and typical Wobbe index range is 50.5 to – 52.5 MJ/m^3 with fluctuations < 1%.

495. [31] uses mixing stations before each CCGT to control gas at acceptable quality. The limits are 10% H2 (from the site gas) after the mixing station and a maximum mix of 45% low CV site gas and 55% high CV gas.

496. One operator advised that GE Turbines are designed for ±5% on modified Wobbe index around the design point, which is specified based on predicted gas quality for each location and adjusted for our expectations of future gas quality. Another reported that once the design value is set, the manufacturer guarantees performances of the plant only if Wobbe index stays in a ± 5% range around the design value, with variation ramp below 0.1% per second. DSM AGRO [65] reported that their gas turbine is optimized for fuel gas with a Wobbe index of 51.5 MJ/m^3 with a maximum acceptable variation of the Wobbe index of ± 5 %. The gas turbine is optimized for fuel gas with higher hydrocarbon content of 6 – 10 vol %. There is no control system that automatically re-tunes or re-optimizes the gas turbine in response to fuel changes.

497. DSM AGRO [65] operating in the Netherlands operate three furnaces. Gas flow is controlled by a set temperature of the process outlet of the furnace. The air supply is controlled manually by the operator to maintain an excess oxygen concentration of 1 – 3 % in the flue gas. When the oxygen concentration is too low, there is a risk of post-combustion in the flue gas channel. When the oxygen concentration is too high, energy is lost through the flue gas. The furnaces have various monitoring including flue temperature, oxygen and CO concentration in flue gas is measured. The equipment is designed and the parameters in the process control systems are adjusted such that the plant is optimised around the typical gas specification of gas supplied over the past decennia

498. [39] have a online continuous combustion dynamics monitoring system that comprises a gas chromatograph that causes GT runback / trip if gas supply is out of specification.

Q6. Do you believe your equipment will continue to operate safety and efficiently if the gas quality specification of H family natural gas was widened to the EASEE-gas limits. In addition, if possible please advise whether you expect any impacts on the operation of your equipment with respect to emissions, efficiency, product life or additional maintenance.

499. Five operators expected no or little impact, (including one that blends the gas on site to meet a quality specification) three did not know. Corus [58] reported that there is a wide range of combustion systems in steelmaking and processing, ranging from small gas cutters and shapers to multi million tonne furnaces operating on mixed fuels. There will have to be an extensive program to assess viable operating ranges. To accumulate all the individual specifications and descriptions will be very labour intensive task. A series of

projects will be needed to assess potential product quality, lifetime impacts, and operability studies. Immediate concerns would be for the impact on combustion dynamics, safety aspects related to flame stability, NOx, CO and CO_2 emissions, thermal input & efficiency

500. Turbine operators provided responses that were similar:

501. [12] reported that typically turbine manufacturers specify an acceptable variation in Wobbe index or Heating Value of ±5%, but some specify ranges as wide as ±10% or as narrow as ±2%. Thus increasing the acceptable Wobbe index range to the EASEE-gas specification would allow gas outside the acceptable range for the majority of modern gas turbines currently in operation. However the levels of higher hydrocarbons that would be allowed by the proposed EASEE-gas specification (taking into account restriction on relative density) will allow gases with higher levels of C2+ or C4+ than specified by some manufacturers to be distributed. It is likely that this would lead to unacceptable combustion performance in some gas turbines. This is likely to be manifested as higher NOx emissions, increased combustion dynamic and significantly increased risk of flashback. The key concern is around heavy carbon content of the gas – there is no mention of limits with regard to C2, C3, C4, etc. content and this raises concerns over potential flashback or start-up issues. [16] reported CCGTs in the UK, particularly those close to entry points have encountered problems when the gas specification changes rapidly; such problems include; increased emissions, combustion dynamics, flame temperature/stability problems, unit trips and hardware failures. These occurred following fluctuations of the Wobbe index within the current UK specification. If the specification was to be widened to the EASEEE-gas specification such problems may become more extreme and more frequent. In the limit where gas quality excursions cause trips or plant damage, hence reducing plant availability there could be a consequential impact on security of electricity supply. Thus if the specification is widened to the EASEE-gas limits and gas towards the extremes is delivered to sites there will be a range of issues including:
    - Increased risk of flashback leading to damage to combustion components and possible consequential damage to turbine components
    - Increased risk of high levels of combustion dynamics leading to gas turbine trips and/or reduced component life or failure
    - Increased risk of high NOx emissions resulting in increased environmental impact and/or gas turbine trips
    - Increased risk of high CO, particularly at part load resulting in increased environmental impact and/or gas turbine trips and reduced operational flexibility
    - Increased risk of failed starts

502. Operators of other types of appliances reported the following:

503. Akzo [44] stated the band is too wide, especially for our dry-low-NOx burners. Instability of combustion is expected with possible accompanying damage to the hardware. The EASEE-gas gas specification is not sufficient for us to determine if our equipment can cope with different types of gas or changes in gas quality. It is important to know how fast gas quality will be changing and therefore norms with respect to the dynamics of gas quality should be included in the specification of EASEE-gas

504. Corus [13] predicted no safety related problems when adjusted for the highest air demand but efficiently would be affected where there is no feedback control system and predicted minimum impact with respect to emissions, product life and additional maintenance. In

addition need to check to be sure that each type of ignition burner can operate without interruption on the whole Wobbe index range of 13.6 – 15.8 kWh/Nm3. The reason behind this is the importance of a failure free operation of the ignition burner otherwise the main burner and consequently the whole process installation cannot be operated.

505. WIENSTROM [14] expected reduced efficiency and reduced life time in power plant operation. Also expects damage effects by corrosion due to the higher total sulphur levels for longer periods of operation

Q8. Can you advise on the likely modifications that would be necessary to mitigate the affects of gas quality change ? What would be the likely costs per unit and timescale for introducing these modifications ? Will your business be able to fund this work.

506. Akzo [44] stated new burners and adjustable gas pre-heaters would be required. A rough estimation is 100-200 €/Nm3/h over a period of 3 years

507. DSM AGRO [65] propose a control system that automatically adjusts the air supplied to the burners based on the oxygen concentration measured in the flue gas. Estimated cost €5M and at an earliest of 2013 to fit in with planned maintenance.

508. WIENSTROM [14] suggests the replacement of existing heat exchangers in the boiler flue gas zone by heat exchangers of a new material, however this will cause extreme additional costs in engineering and installation and would also require extended plant down-time, even if it is feasible. With respect to turbines, if the gas quality does not meet the required quality standard defined by the turbine manufacturer, plant operation is not possible. Do not know if modifications are possible.

509. CORUS [13] stated that when the upper Wobbe index limit of the site gas supply was to rise from 14.8 kWh/m3 to 15.2 kWh/m3 they initiated a project involving company experts to ensure the change did not impact on operations. The project required two years of project time and as a result the company have developed their knowledge of gas burner systems.

510. Responses by turbine operators:

511. ETN [12] state that in principle it is possible to produce systems that will deal with a wider range of gas composition variation, but standard offerings are not currently available to upgrade the existing fleet. Manufacturers are developing such systems, but for some applications they are in a more advanced state of development than others. Range of different control systems are being developed. For solutions based on software and control upgrades that do not require additional hardware or significant hardware upgrades: £200,000 to £500,000. For solutions including additional hardware (such as fuel heaters) or significant hardware upgrades: £1,000,000 to £1,500,000. Implementation 3 -5 years

512. ESB [38] states the gas turbine hardware is configured to operate within specific MWI limits (42.2 +/- 5%). Fuel nozzles are designed for a specific range and this can be modified by changing out orifice plates, but the +/- 5% range would still remain. Under EASEE-gas specification Wobbe index is too high and plant would not operate and would shut down safely. One possible modification would be to upgrade the combustion system to DLN 2.6 which has wide Wobbe index capability circa MWI +/- 7.5% versus current limits of MWI +/- 5%. Cost of complete change out of gas module - €10M

513. ESB [38]operating in Ireland advises that currently OEM designed for GSMR and not able to modify.

514. ETN [12] concluded that modern gas turbines are finely tuned pieces of equipment and the operation, protection and control systems have to balance the following key factors:

- Emissions
- Efficiency
- Operation flexibility
- Component life

515. To accommodate wider ranges of fuel flexibility, the system must either be less critically tuned giving higher emissions, lower efficiency and possibly reduced life, or alternatively the control system must be made more sophisticated, which increases risk of nuisance trips and overall cost of the system. Any future reduction in emissions requirements will make this balance even more difficult to achieve

516. DSM AGRO [65] stated that if anything, we could introduce a new control system when the need arises. We expect several problems including contradictions with design gas qualities, permits for emissions, safety issues and efficiency requirements. We are focussed on contracting acceptable gas qualities within our design, our safety requirements and permits.

517. One responded commented that some turbines can be modified by the addition of such technology as GE Autotune but this is not available for all models to accommodate the EASEE-Gas specification, however clarification is required on the C2, C3, C4, etc. specification . Where possible to modify the cost is estimated at 1M$ per unit

518. Association of Electricity Producers [65] report that Siemens/ALSTOM have developed a measurement system that can quickly determine key fuel properties (e.g. Wobbe index, higher hydrocarbons) to allow control. We are staying informed with them to check the applicability and costs. Cost estimate >€1M, earliest 2013.

Q10. Are you planning to replace your plant in order to continue to operate over a wider gas range. If so what is the timescale for delivery and the estimated cost

519. No responders reported plans to upgrade their facilities.

Q11. Please provide any additional comments that you feel are relevant to this study

520. Corus [58] stated that the scale and scope of this issue relating to a plethora of burner control systems within the steel industry means that we are unable to respond comprehensively to your study in the required timescales. We would intend to commission an internal study to scope out the issue provided the matter is of sufficient concern at national level and indicated as same by DECC.

521. Capital investment is focussed on decarbonisation and efficiency. The possible variation in gas specification is a controversial area where in our view the market should provide. If necessary and of sufficient urgency, we can commission detailed studies on this issue. However, at present we have insufficient context and information to commission such a study.

522. We are assuming this matter will be lead at a national level by UK government and await further direction from relevant authorities on this. On a technical matter, we note the provided EASEE-gas specification does not comment sufficiently on gas composition and the rate of change of the parameters; this would be a further factor in technical study

523. Association of Electricity Producers [69] commented that gas turbine combined cycle plant forms a significant proportion of the UK generating capacity and issues such as fuel quality that have an impact on gas turbine availability could affect security of supply. Gas turbine plant is particularly flexible in operation and plays a significant role in balancing variations in supply and demand. As less predictable energy sources such as wind power and small scale distributed renewable power become more significant this role will become more important in ensuring continuity and quality of supply. Wider gas quality specification could have a significant adverse impact on this by reducing gas turbine availability, operational flexibility and start reliability.

ANNEX E – DATA OBTAINED FROM MEMBER STATE REGULATORS REGARDING GAS USERS

524. National Regulatory Authorities (NRAs) were contacted as part of the data collection process, to provide information on the total number of natural gas users segmented into the main user categories (Domestic, Small/Medium businesses, Large businesses, Industrial/Commercial and Power Stations/Large Industrial). The values provided cover the number of "gas meter" points and not the total number of appliances/equipment at the site.

525. To provide additional, separate validation of the Regulator data, EuroGas data on the total number of consumers was used. The data is shown in Table 18.

Table 18 – NRA responses

Country	**Total consumers** (2009 Eurogas data)	Total Users or Meter Points	Domestic	Small & Medium Business	Large Business	Larger I&C	Large or Daily Metered (PS)
Austria	1,350,696	1,351,000	689,000				662,000
Belgium	2,834,850	2,877,976	2,552,453			324,593	930
Czech Republic	2,871,547	2,852,436	2,647,752	196,935	7,006	741	2
Denmark	394,647	400,895	380,000			20,000	895
Estonia	42,543	42,543					
Finland	36,825	36,825					
France	11,480,000	11,450,018	3,279,318	8,060,018		107,812	2,870
Germany	19,300,000	13,577,290	13,392,423		178,459	5,434	974
Greece	220,580	243,929	231,496	12,073	142	207	11
Hungary	3,545,000	3,529,000	3,318,000	207,010	3,600	380	10
Ireland	635,297	643,567	619,646	21,945	1,716	216	44
Italy	21,767,000	21,767,000					
Latvia	442,100	442,714	434,500	5,900		2,300	
Lithuania	549,900						
Luxembourg	80,465	81,638	78,376	3,133	44	5	80
Netherlands	6,800,000	6,743,270	6,700,000	43,000	270	86	
Poland	6,601,956	6,601,956					
Portugal	1,097,291	1,175,629	1,161,082	13,092		1,451	4
Romania	2,833,190	2,833,190				0	**0**
Slovakia	1,482,857	1,482,857					
Slovenia	150,000	150,000					
Spain	7,101,563	7,207,441	7,043,685	64,362		99,343	51
Sweden	47,000	47,012	44,400		2,600		12
UK	22,877,570	24,040,088	22,500,000	1,500,000		40,000	66
TOTALS	**114,542,877**	**109,578,274**	**65,072,131**	**11,134,061**	**343,949**	**107,863**	**5,949**

526. It has not been possible to obtain data from all member states, resulting in differences between the total number of gas users from the two data sets. The total number from the Eurogas study was 115 million compared to 77 million based upon the Regulator's data. However, if the Eurogas totals are used for the missing data then close correlation is obtained.

ANNEX F – ODORISATION ISSUES WITHIN THE EU

527. The following is a summary of the responses provided in the stakeholder questionnaires regarding motorisation of natural gas

528. In France, natural gas is currently odorised with THT, in a centralized way, at the entry points to the main transmission network. It is a historical practice of the French gas system. This method appears to be cheaper and more reliable than an odorisation at the level of distribution network namely at the delivery points from transmission networks (i.e. city gate). We therefore consider that the common specifications on gas quality harmonisation should include odorised gas. Moreover, THT odorised gas fits to the upper limit recommended in EASEE-gas sulphur specifications. Implementing odorisation as the level of distribution network in France would have a very important cost (several hundreds million Euros) which will have to be supported by the shippers and the French consumers through the transmission networks use tariff. Finally, THT odorised gas coming from France is at present accepted by adjacent transmission networks in Spain, in Switzerland and in Italy. However odorising in the transmission system leads to interoperability issues at the border points with Belgium and Germany. In order to create firm reverse flows at these border points, deodorisation plants have been envisaged, even if there are only pilot projects for the moment and their efficiency is not proved. We think, on an European point of view, TSO's/DSO's and regulators should work on a standardization of the gas odorisation (or deodorisation) in order to create a better interoperability and real bidirectional cross-border points [32]

529. This situation considerably limits cross-border flows and can potentially threaten security of supply, as observed during the Russia-Ukraine crisis in January 2009. Besides, this odorisation is incompatible with the integration of the European market where flows should be able to freely flow both ways. This lack of harmonisation regarding odorisation has an impact on the security of supply of Europe especially in the context of the development of supply from the South to the North of Europe (ERGEG South GRI) and the development of LNG import capacity. Consequently, we believe that harmonisation of H gas quality across the EU on Transport networks should also rule on odorisation [47]

530. If the harmonize odorisation in Europe is going to be base in THT, there is no need to introduce new investments. If odorisation is going to be base in a mix between THT and Mercaptan the cost of the investment is going to be around 1.000.000 € [11]

531. We use central odorisation system, but we have some transit routes without odorisation. In some cases the odorized gas is hindering the cross border transmission. We have studied the Austrian/Hungarian transmission route, which is currently central odorized. If we change alternative/individual odorisation facilities along the pipeline system, the estimated cost would be about 8-10 MEuro. If we have to realize some project related to these issues according to EU's demand. In this case we are able to finance the projects with the support of National regulator. Guaranteed rate of return is required. EU funds would accelerate the realization of the projects [84]

532. Ireland odorises its gas at the entry to the transmission system while the UK odorises its gas at entry to the distribution system. This has the potential to cause difficulties in moving gas from Ireland to the UK [41]

533. As a reminder, the CBP Harmonization of Natural Gas Quality 2005-001/02 applies only to high-calorific gas without added odorants and does not address possible future interoperability issues arising from differences in odorisation practices. Given the potential technical problems arising from the deliveries of odorized gas at a cross-border

points (including but not limited to mixing different odorants, over- and under odorisation, impact on industrial processes and on emissions), those issues are currently being studied within Marcogaz and it seems useless to address them again in the framework of this exercise. [78]

ANNEX G – HISTORICAL EXPERIENCES OF CHANGING GAS QUALITY

534. Around Europe there is only limited information from historical experiences of changing gas quality, based in some cases on the conversion from town gas (first family gas) to natural gas (second family gas).

535. There are two published examples of cost benefit studies have been carried, one for the UK and the other, for which a final report is pending, is for Denmark. The Isle of Man is about to commence the conversion from LPG to natural gas and there are reported incidents where varying gas quality has impacted on end users. These are summarised below.

United Kingdom

536. In 2006 the UK Government consulted on GB's future gas quality specifications . The policy issue was whether to stick with the current regulated specifications, but at the cost of having to process imported gas to bring it within those specifications; or, at some time after 2020, to adjust those specifications, but at the cost of having to check (and potentially change) approximately 45m domestic gas appliances in 22m households, to ensure that they are capable of burning the high energy gas safely (and with a residual safety risk that some appliances are missed). The selected option was "no change". Impact Assessment estimates the total net benefit of the "no change" option at £1.5bn – 14bn, with a best estimate of £8bn. The risks for gas prices and security of supply were judged to be small. Consequently all gas supplies must be complaint with the UK gas safety specification before it enters the transmission, or distribution, network.

Isle of Man

537. The Isle of Man is to convert to natural gas from LPG and town gas in 2012 . The conversion of 6800 customers will cost an estimated £23.5M and being funded by Isle of Man Government. Before conversion, which will be carried out in sectors comprising 75-100 houses, a pre-conversion survey will assess every appliance to determine the upgrade required. If an upgrade is not possible the appliance will be replaced free of charge. These figures suggest a conversion cost of around 4,000 Euro per household which is higher than that assumed in Section 4.7.2 but it is likely to be for several appliances and includes pre-conversion survey work and project overhead and mobilisation costs.

Denmark

538. RIELLO reported the incident in 2000/2001 when high Wobbe index gas was distributed in Denmark and in those North Germany areas supplied with Danish gas. The main problems were failures of heat exchangers and burners. This is because gas appliances are adjusted for reference gas G20 so, when supplied with higher Wobbe index gas, they are roughly, 10 to 15% overloaded. Some manufacturers have modified the design of the burners or the heat exchangers, RIELLO, for installed appliances, were allowed by DGP to reduce the burner gas pressure in order to get the nominal heat input. This solution was possible only because the gas quality in Denmark is constant.

Source: Appliance manufacturer's questionnaire.

539. Danish customers were traditionally supplied with gas in the Wobbe range from 15.2 to 15.3 kWh/m3, although the contract range was between 14.1 kWh/m3 and 15.5 kWh/m3. As in many places in Europe, the actual quality delivered was much more constant than allowed in the contract. Because of recent imports from Germany, the TSO has now widened the contract range to 13.9 – 15.5 kWh/m3. This is still narrower than the 13.6 – 15.8 kWh/m3 range as proposed by EASEE-gas. The higher end of the range creates problems for reciprocating engines. The Danish gas research institute and the users foresee many problems if the wide range will be common practice, especially since as has been observed that changes in quality can be very abrupt (plug flow).

Source: Jacob Klimstra Consultancy.

540. Denmark has for the last approx. 25 years received constant, high calorific natural gas from the Danish North Sea sector. Danish North Sea gas has a high content of C2-C4 and is characterised by a high Wobbe index. Following an open season process in 2009 requesting expansion of import capacity towards Germany (in light of declining gas production in the Danish North Sea sector), Energinet.dk as TSO and the DSOs in Denmark together with the authorities prepared for a change in gas quality as Denmark from 2010 is periodically, physically importing gas from Germany. Energinet.dk was therefore asked by Danish Safety Technology Authority, the authority for gas quality specifications, to perform a socio-economic cost benefit study of two solutions: either slightly expand the current specification or treat incoming gas from Germany to the Danish gas quality. In October 2010 Denmark actually imported gas which also gave unique information about the consequences of receiving gas with a quality out of the typical range.

Source: Tine Lindgren, energinet.dk.

541. CORUS stated that when the upper Wobbe index limit of the site gas supply was to rise from 14.8 kWh/m3 to 15.2 kWh/m3 they initiated a project involving company experts to ensure the change did not impact on operations. The project required two years of project time and as a result the company have developed their knowledge of gas burner systems

Source: Appliance operator questionnaire.

ANNEX H – GAS PROCESSING OPTIONS AND COST ESTIMATES

542. The two adjustments to Wobbe index specification are derichment (where there is a requirement to reduce the Wobbe index) and enrichment (where there is a requirement to increase the Wobbe index). There are a number of processing techniques to achieve each of the adjustments as detailed below.

H.1 Derichment

543. There are a number of potential techniques to perform derichment of high Wobbe index gas:

- ballasting with Nitrogen (N_2);
- ballasting with Carbon Dioxide (CO_2);
- ballasting with air;
- ballasting with Hydrogen (H_2);
- removal of natural gas liquids (NGLs); and
- removal and reforming of NGLs to methane.

544. GL Noble Denton performed a high-level economic evaluation for these derichment options in a previous study and the results indicated that air ballasting is the most attractive (provided the oxygen specification is not exceeded). Where the resultant oxygen level cannot be tolerated, the first and last options were the next most feasible options. Where air ballasting cannot be used, a more detailed evaluation accounting for the variability in LNG import compositions, the send-out rate and the transportation costs would be required for full economic rigour.

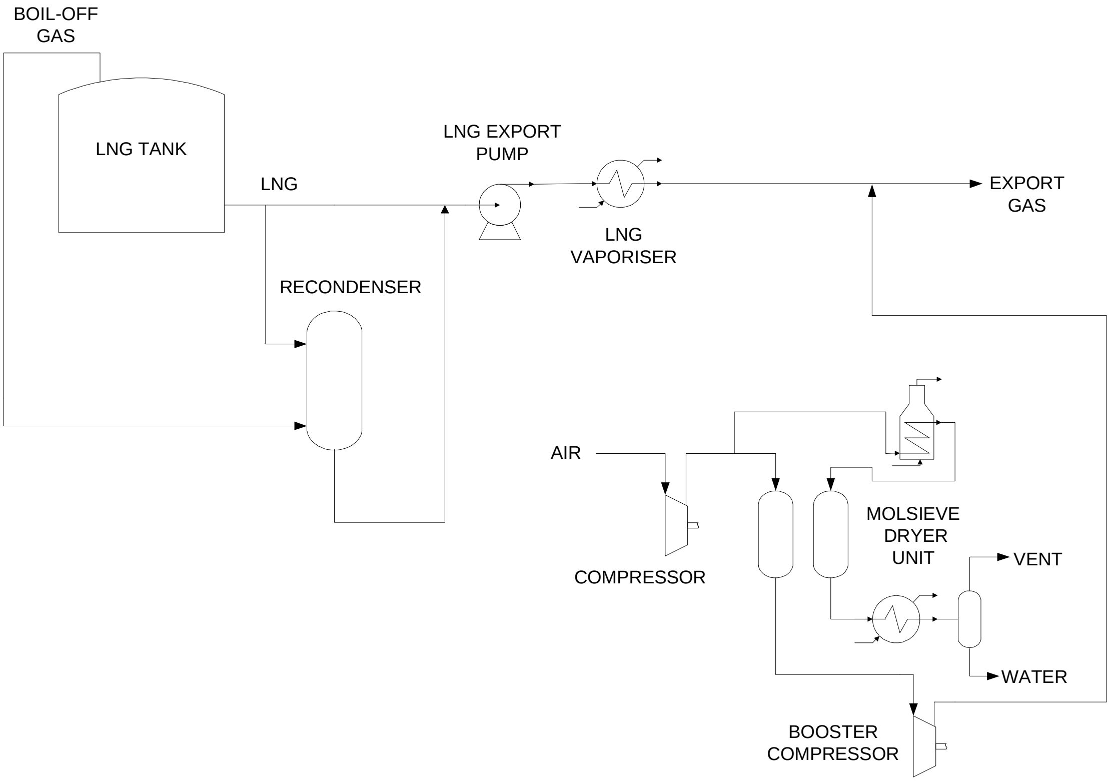
545. However, for high level studies the choice is made between air and N2 ballasting (based on the oxygen specification) due to the reduced plant complexity and lower plant costs. These also have the benefits of a lower initial capital outlay and therefore the economics are less dependent on gas prices over the longer term.

546. For Italy, air ballasting is already practised for the derichment of imported LNG. It is therefore assumed that for Italy air ballasting will be the selected process route where derichment is required. Process details are provided on air ballasting and nitrogen ballasting derichment options.

H.1.1 Air Ballasting

547. Where the oxygen specification will not be exceeded, air ballasting is the simplest technique for derichment. Atmospheric air will be compressed (to approximately 12 bar), dried in a molecular sieve unit and then further compressed (to approximately 70 bar) to allow routing to the gas stream to be ballasted. Figure F.1 illustrates the configuration of the air ballasting system for LNG derichment. A similar configuration will be used for air ballasting on a pipeline import gas stream.

Figure 14 – Air ballasting configuration for LNG import terminal



H.1.2 Nitrogen Ballasting

548. Where the oxygen specification will be exceeded using air ballasting, nitrogen ballasting is the next preference. Nitrogen is produced from atmospheric air and there are several techniques available for nitrogen production:

- cryogenic air separation;
- Pressure Swing Adsorption (PSA) air separation; and
- membrane air separation.

549. Due to the large quantities of nitrogen involved, an on-site cryogenic air separation unit would usually be required. The PSA option is expected to be uncompetitive at high capacities and the membrane option suffers from insufficient nitrogen purity at an acceptable capital outlay.

550. Figure 15 and Figure 16 illustrate the configuration of the nitrogen ballasting system for typical LNG and pipeline gas import schemes.

Figure 15 – Nitrogen ballasting configuration for LNG import terminal

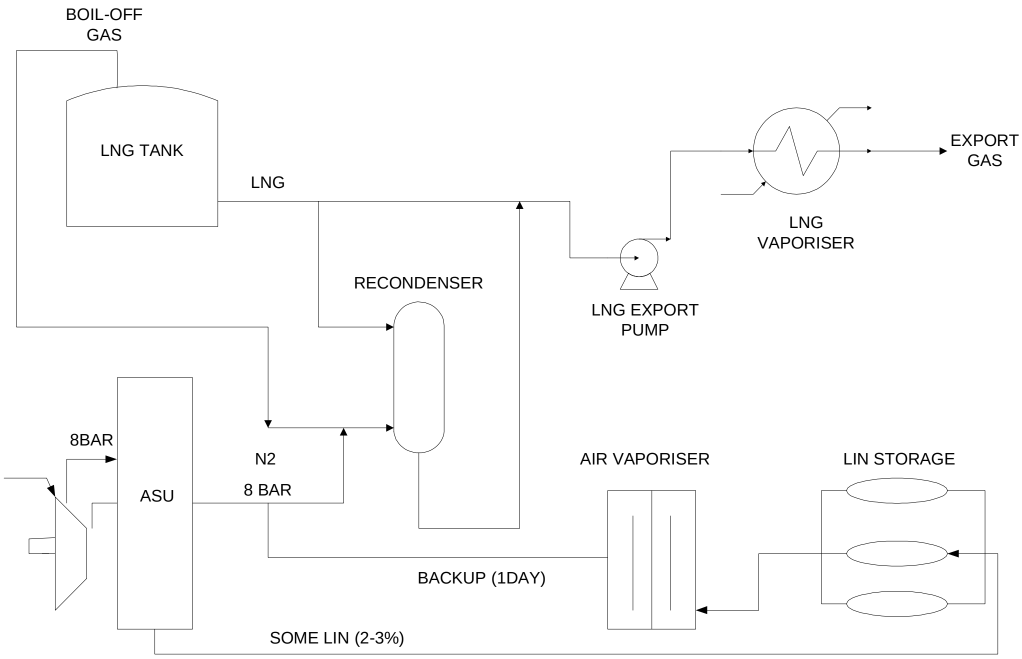
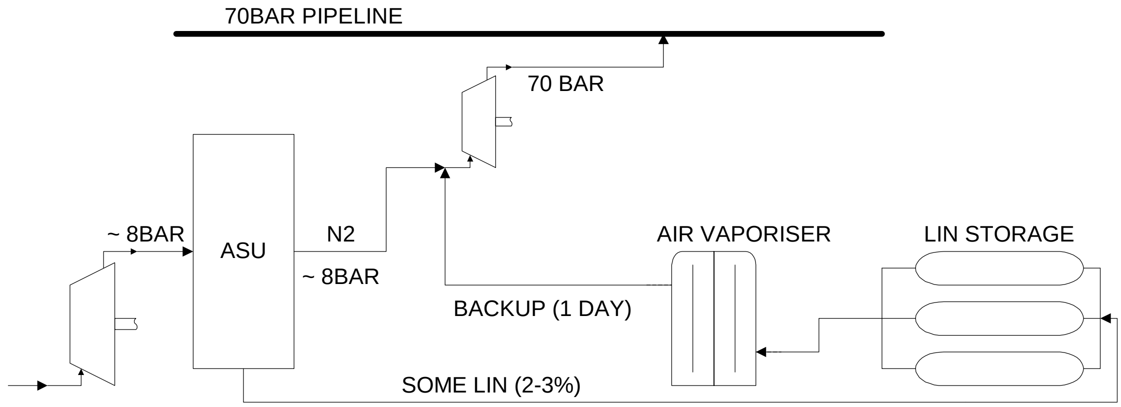


Figure 16 – Nitrogen ballasting configuration for gas reception terminal



551. For the natural gas derichment, it is estimated that 1000 tonnes/day of nitrogen is required to reduce the Wobbe index by 2.5 MJ/sm3 for 21.23 Mscmd (750 MMscfd) throughput. This flowrate of nitrogen could be required for typical import facilities. This quantity is unrealistically large for supply by road tankers, where about 50 tankers will be required on a peak day (each tanker only capable of transporting 20 tonnes of nitrogen per load). Therefore it can be concluded that on-site installation of a cryogenic Air Separation Unit (ASU) plant for the production of the large quantities of nitrogen is the only feasible option. Nitrogen is produced at about 8bar from the Air Separation Unit (ASU). Since ultimately the nitrogen is required in the gas phase, liquid nitrogen was not considered as this avoids the requirement for a more expensive ASU and vaporization equipment.

552. For nitrogen ballasting of LNG, the gaseous nitrogen produced by the ASU is injected into the LNG boil off gas, BOG stream prior to the re-condenser. The nitrogen is absorbed by the LNG along with the BOG and is then pumped to export pressure (typically about 70 bar) before vaporization and send out to the transmission system. For nitrogen ballasting of pipeline supplies, a secondary compressor to lift the nitrogen pressure from 8 bar to 70 bar is installed prior to the pipeline injection point.

553. A dual-train system with two 50% throughout plants is usually proposed to increase the reliability as the turndown of the ASU is only about 70% of the design flow-rate due to limitations in the air compressor. The plants are inherently reliable but a one-day emergency backup supply of liquid nitrogen storage is considered prudent. The capex calculation for the nitrogen ballasting plant takes into account the total installed costs of the ASU sized at peak flow and one-day backup storage facilities including the LIN storage cascade and air vaporizer. Additional costs for the secondary nitrogen compressor are also included for pipeline ballasting cases. The yearly operating costs including utilities, parts and maintenance are accounted for in the overall plant opex.

H.2 Enrichment

554. There is unlikely to be a requirement for enrichment in Italy based on the expected import and cross-border supply streams as none of them appear to have a Wobbe index lower than the national Wobbe index specification range. If enrichment is required for low Wobbe index gas, there are a number of potential techniques as follows:

- CO_2 removal;
- N_2 removal; or
- LPG injection.

555. CO_2 removal from natural gas is typically performed by liquid absorption processes such as amine systems although other processes can be used. In particular, membrane systems are used for bulk CO_2 removal applications and solid bed adsorption systems find application for polishing duties.

556. N_2 removal from natural gas at large scale is typically performed by cryogenic processing. At smaller scale, solid bed adsorption systems or liquid scrubbing processes may also be feasible.

557. Both CO_2 and N_2 removal processes aim to remove the inert components from the natural gas thereby enriching the gas. The alternative approach is to ballast the gas with LPG as it exhibits a high heating value and therefore boosts the Wobbe index.

558. Both CO_2 and N_2 removal processes are generally expensive and are also much more complex than LPG injection systems. Therefore, for high level studies the process option most likely to be feasible for a moderate enrichment requirement is assumed to be LPG injection. Process details are provided below for the LPG Injection enrichment option.

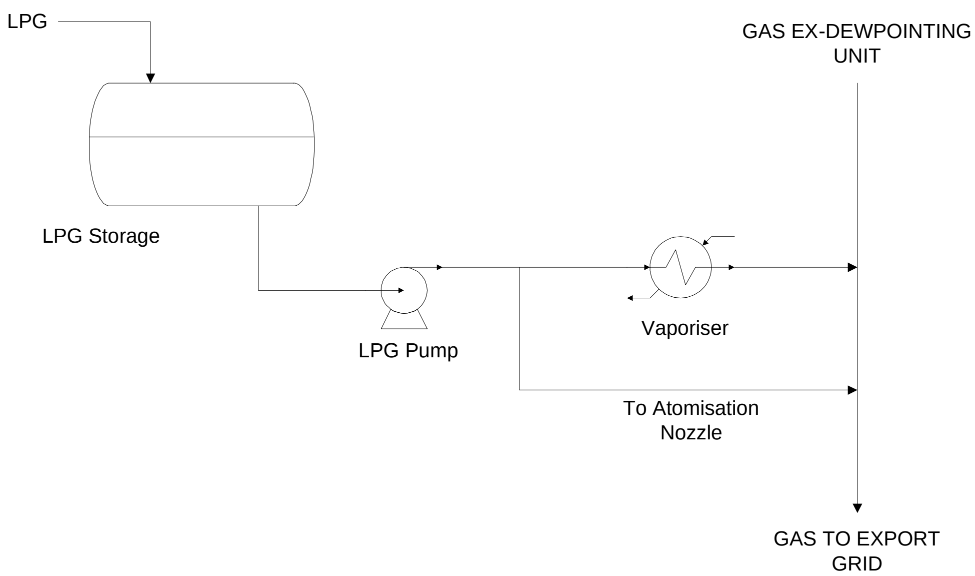
H.2.1 LPG Injection

559. LPG injection directly raises the Wobbe index by increasing the concentration of propane and butane in the natural gas. Compared to other enrichment process, LPG generally incurs lower initial installed capex but higher opex principally due to the cost of the LPG itself, which often has a wholesale price per therm of energy greater than the natural gas spot price. Costs of LPG are linked closely to oil price, leading to significant uncertainties in long-term opex. LPG injection requires large quantities of LPG causing inventory

supply problems and excursions in hydrocarbon dewpoint. Use of propane-rich LPG is generally preferred as it will reduce the hydrocarbon dewpoint impact but the quantities required increase as propane has a lower Wobbe index than butane.

560. Figure 17 illustrates the LPG injection configuration for enriching a pipeline gas. This shows a dual injection system with one stream as vapour and one as liquid through an atomisation nozzle.

Figure 17 - LPG injection for gas reception terminal



561. The low pressure injection option is vaporisation before mixing with pipeline gas. The high pressure option pumps the LPG to high pressure (about 70 bar) and then atomizes it into the pipeline gas via a spray nozzle at the pipeline injection point. It is estimated that a 0.2 MJ/sm3 increase in Wobbe index would be achieved by the addition of approximately 0.475 mol% of LPG into the gas stream, although there would also be a resultant rise in hydrocarbon dewpoint of approximately 0.9ºC.

562. For an import terminal throughput of 21.23 Mscmd (750 MMscfd) this is equivalent to approximately 190 tonnes/day of LPG. With current LPG road tanker capacities of about 16 tonnes, it would therefore require 12 tankers per day to supply this demand. This delivery requirement is acceptable but it is clear that much larger enrichment requirements may require quantities of LPG that are not feasible for road supply. As a result, LPG may need to be supplied either by pipeline, rail or ship depending on the location of the import facility and local infrastructure available. Major infrastructure costs would be incurred if such alternative transportation routes need to be established

H.3 Costing

563. This has included the envisaged flowrates and gas composition to enable an initial indication of the capex (to construct) and opex (to operate) required for suitable gas processing facilities to perform gas quality adjustment.

Derichment (nitrogen ballasting):

564. Capex: The capex of a gaseous nitrogen production and ballasting system from a UK LNG import terminal facility has been obtained and escalated from 2005 to 2010 cost using the "Chemical Engineering" cost index. A scale factor of 0.67 on flowrate has been used to cost the specific facility. It is assumed that the gas processing facilities are added to the existing LNG import terminal or gas reception terminal. The capex is therefore for a brownfield site and assumes the use of common site facilities.

565. Opex: The opex of a gaseous nitrogen production and ballasting system is also based on a UK LNG import terminal facility and has been escalated for the present day cost. A scale factor of 0.67 on flowrate has been used to cost the specific facility.

Derichment (Air Ballasting):

566. Capex: The capex of an air ballasting system from a US LNG import terminal facility has been obtained and escalated from 2000 to 2010 cost using the "Chemical Engineering" cost index. A scale factor of 0.67 on flowrate has been used to cost the specific facility. It is assumed that the gas processing facilities are added to the existing LNG import terminal or gas reception terminal. The capex is therefore for a brownfield site and assumes the use of common site facilities.

567. Opex: The opex of the air ballasting system is based on 15% of capex. A scale factor of 0.67 on flowrate has been used to cost the specific facility.

Enrichment (LPG Enrichment):

568. Capex: The capex of a LPG injection system from a UK LNG facility has been obtained and escalated from 2005 to 2010 cost using the "Chemical Engineering" cost index. A scale factor of 0.67 on flowrate has been used to cost the specific facility. It is assumed that the gas processing facilities are added to the existing LNG import terminal or gas reception terminal. The capex is therefore for a brownfield site and assumes the use of common site facilities.

569. Opex: The opex of a LPG injection system is also based on a UK LNG facility and has been escalated for the present day cost. A scale factor of 0.67 on flowrate has been used to cost the specific facility and the latest LPG wholesale price and latest natural gas spot market price have been used to calculate the LPG loss that in essence is part of the overall plant opex.

H.4 Processing Cost Assumptions

570. The costs have been estimated based on the envisaged flowrates, generated by the Pöyry model, and assumed gas composition thereby enable an initial indication of the capex (to construct) and opex (to operate) required for suitable gas processing facilities to perform gas quality adjustment to meet Wobbe index specifications.

571. The following assumptions have been made to define the processing requirements:

H.4.1 Assumptions relating to capex

- Wobbe index adjustment is calculated using the extreme ends of the sending and receiving country gas specification. For EU-border transfers, the Wobbe index of the flowing gas is assumed to remain constant at a specified value. For within-EU transfers, the theoretical maximum and minimum ranges of the Wobbe index specification have been considered, which results in some scenarios where both an enrichment and a derichment plant is required at a single border.

- For Wobbe index correction the capex is calculated using cost correlations developed by GL Noble Denton from previous operating data, scaled up over time using the Chemical Engineering Plant Cost Index and latest commodity prices and currency conversion factors. For control of other gas quality parameters plant costs have been estimated based on assumed capacity and estimated plant costs
- Where both enrichment and derichment are required, these costs have been calculated separately.
- LPG price assumed €620/ tonne.
- All capex figures are based on plant installation costs on a brownfield site and excludes the costs associated with land, general site buildings / facilities and provision of infrastructure for electrical power and LPG supply to the site.
- For scenarios requiring derichment, it has been assumed that nitrogen ballasting is required and that air ballasting is not suitable. This gives a worst-case scenario. The cost for air ballasting is approximately 34% the cost of an equivalent nitrogen ballasting installation.
- For EU-border flows, there are both pipeline and LNG flows. All the pipeline flows have been included in the total capex value but for the LNG flows, it has been assumed that there is a single entry point for each receiving country. Therefore, it has been assumed that only one processing facility for enrichment and one for derichment is required (according to the Wobbe index value of the gas and the specification of the receiving country); the worst case Wobbe index adjustment has been taken along with the LNG capacity (which is the same for each LNG receiving country). For example Poland, which is listed as having a LNG capacity of 5 MMscmd capacity from several countries, has been considered to require a single derichment plant to process a maximum Wobbe index adjustment of 2.9 MJ/sm3, with a capacity of 5 MMscmd.
- The capacity of individual trains for the additional gas processing requirements has been restricted to within commercial plant sizes. This necessitates multiple trains to satisfy the additional gas processing requirements on most facilities.
- Two cases have been considered: a facility built for 100% capacity, and a facility built for 50% capacity.

H.4.2 Assumptions relating to opex

- Opex for nitrogen ballasting has been calculated using a GL Noble Denton cost correlation, using both plant capex and flow to determine the operating costs.
- The opex figure provided is for operation in the year 2020
- The opex presented is based on predicted gas flows for the year 2020 as calculated by Pöyry. For calculation, the daily flow values supplied were averaged out over the year, defined as 365 operational days.
- The additional processing opex is based on treatment of the full plant capacity as the gas compositional analysis for Sulphur, H_2S / COS, Mercaptans, CO_2 and oxygen species is not available.
- The opex figures are presented for both the 50% capacity and the 100% capacity cases.

H.4.3 Assumptions relating to cross border flow rates

572. Figure 18 below indicates how the cross border flows have been assigned using the scale:

- High = 100+ mcm/d
- Medium = 50-100 mcm/d
- Low = < 50 mcm/d

573. For example to send gas from Germany to Austria is a Low flow (< 50 mcm/d) requirement.

Figure 18 – Assignment of cross border flows

TO

FROM	Austria	Belgium	Bulgaria	Czech Republic	Denmark	France	Germany	Greece	Hungary	Netherlands	Poland	Romania	Slovakia
Austria	N/A			L			M		L				L
Belgium		N/A				M	L			L			
Bulgaria			N/A					L				M	
Czech Rep.	L			N/A									L
Denmark					N/A								
Estonia													
France		L				N/A							
Germany	L	L		H	L	M	N/A			L	L		
Greece			L					N/A					
Hungary	M								N/A			L	L
Ireland													
Italy	L							L					
Latvia													
Luxembourg													
Netherlands		H					H			N/A			
Poland					L		M				N/A		
Portugal													
Romania			L						M			N/A	
Slovakia	H			H					L				N/A
Slovenia													
Spain						L							
Sweden													
UK										M			

Note: H = High, M = Medium, L = Low

ANNEX I – BENEFITS OF HARMONISATION

I.1.1 Base scenario – Pöyry Central

574. To forecast the interaction between the different sources of gas available ten to twenty years into the future, Pöyry uses a scenario based approach. We usually consider three credible future 'worlds' as the backdrop to our three standard scenarios: High, Central and Low. The three scenarios describe general levels of supply, demand and transportation capacity for natural gas, and the effect that these levels would have on the price of natural gas. The scenarios are internally consistent and are used to iterate with our other energy market models, notably the electricity models where gas is often the marginal fuel.

575. For the purpose of this study we have based our gas analysis on the Pöyry Central scenario. The main assumptions of this scenario are summarised in Table 19, with details set out below. In section I.1.2 we also contrast the data with the 2010 PRIMES baseline dataset, for comparison purposes.

576. It should be noted that the charts below are reflective of the data used in Pöyry's Pegasus gas model, which includes mainland Europe, GB, Ireland and Turkey, less Finland, Estonia, Latvia, Lithuania, Malta and Cyprus. Some countries/regions are amalgamated for the purposes of modelling, resulting in Austria/Slovenia, and Belgium/Luxembourg modelled as single zones (AusSlo and BelLux respectively), Sweden included in Danish demand, and the Republic of Ireland and Northern Ireland being referred to as Ireland.

Table 19 – Pöyry Central scenario overview

Drivers	Assumptions
Demand	Demand penetration in I&C and residential sectors continues historic rise, although this is tempered in some markets because of increased energy efficiency.
Indigenous	Central view of indigenous reserves in Europe but oil prices high enough to encourage new development in US.
LNG	Some flows to Europe, but in medium-term limited new LNG landed, despite continued liquefaction growth.
Russia	Russia develops new export routes, but some competition is introduced from other pipelines, notably from the Caspian region.
Prices	Prices delink with over-supply to 2017 before reverting to linkage to oil-indexed contracts. New projects come on line in a timely manner and hubs continue to develop.

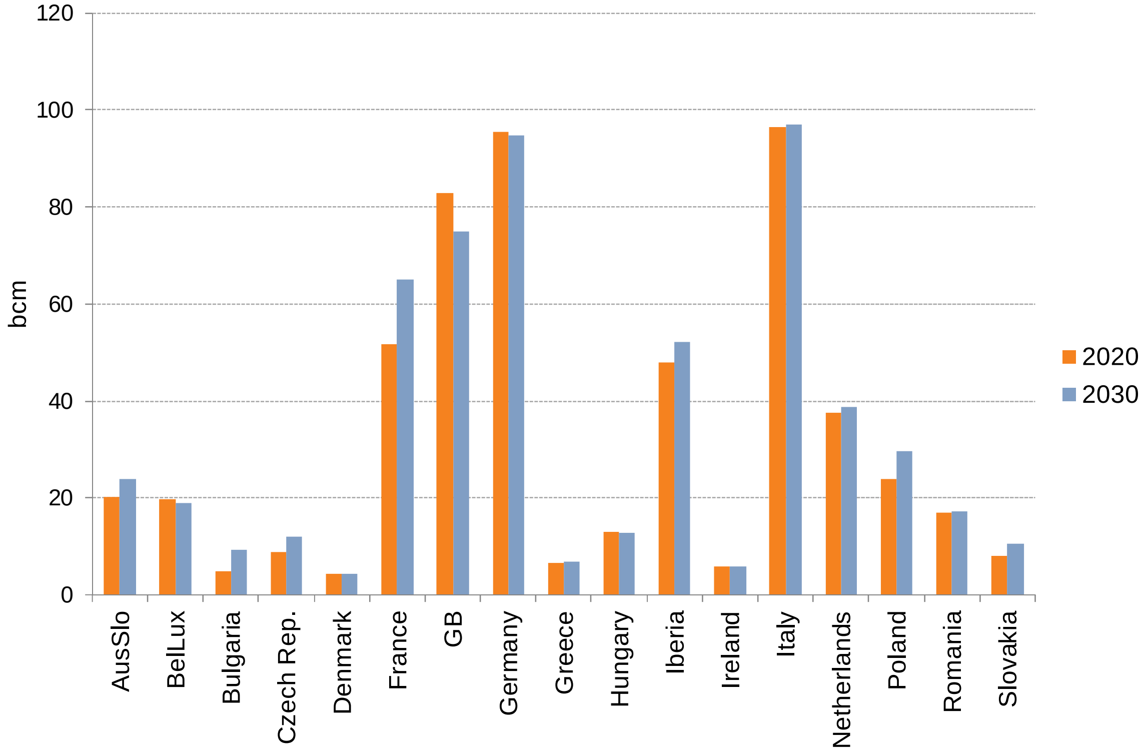
I.1.1.1 Input assumptions

Demand

577. Pöyry's gas demand forecasts are derived from sectorial analysis: demand forecasts excluding power generation are generated separately from demand for power generation, which is obtained from our electricity market model. Our demand assumptions for the

main gas consumption zones in 2020 and 2030 are shown in Figure 19. Italy, Germany and Great Britain are the highest gas consumers in the EU.

Figure 19 – Annual total gas demand assumptions (bcm)

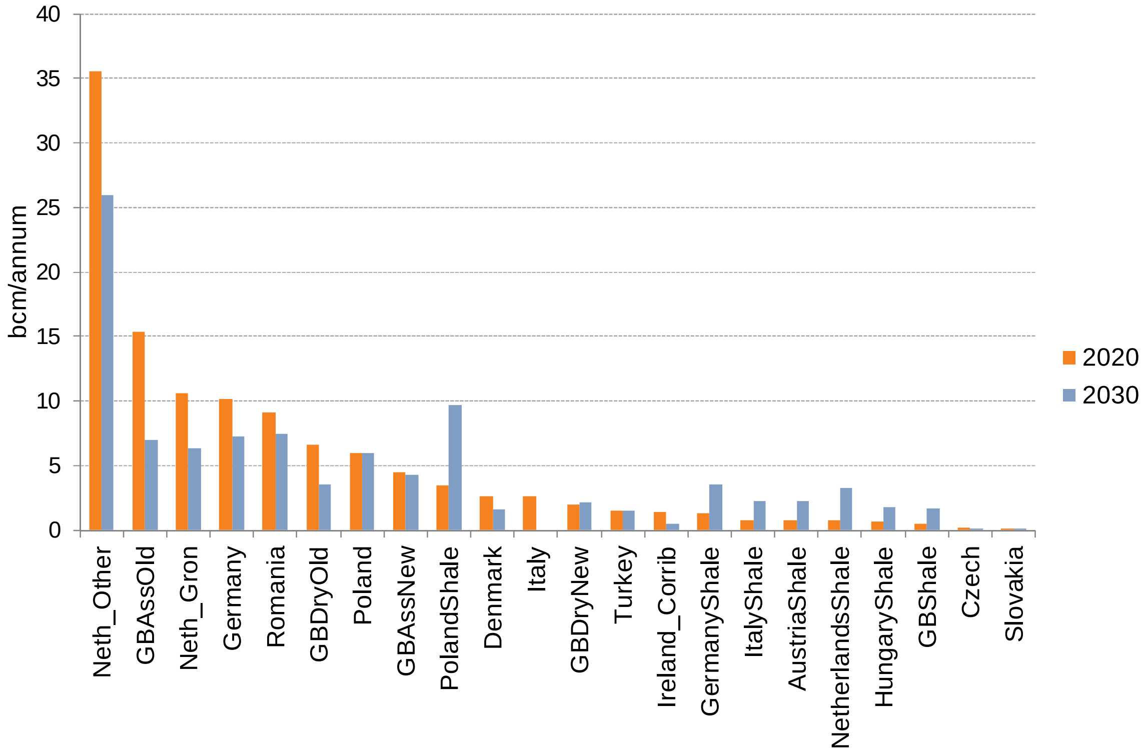


Source capacities

578. One of the main inputs to Pegasus is supply capacities, including indigenous, pipeline and LNG source capacities. Indigenous reserves and production in Europe have been declining rapidly in the past several years and conventional resources are projected to decrease at a faster pace in the future. Unconventional gas, predominantly shale gas, has seen significant growth in the US, and we assume it continues to have a major effect on US fundamentals going forward. We have assumed some nominal volumes of new unconventional sources in Europe, within these timescales studied, although we recognize that projecting the viability of European shale is in its infancy and therefore should be subject to considerable uncertainty.

579. Russia, and Algeria continue to be the top countries having the highest capacity to supply through pipelines, whereas Qatar, Australia and Nigeria will be the largest LNG providers into the global market.

Figure 20 – Average annual capacities of modelled indigenous sources



Note: “GBAss” refers to associated gas from UKCS.

Figure 21 – Average annual capacities of modelled pipelined import production capacity

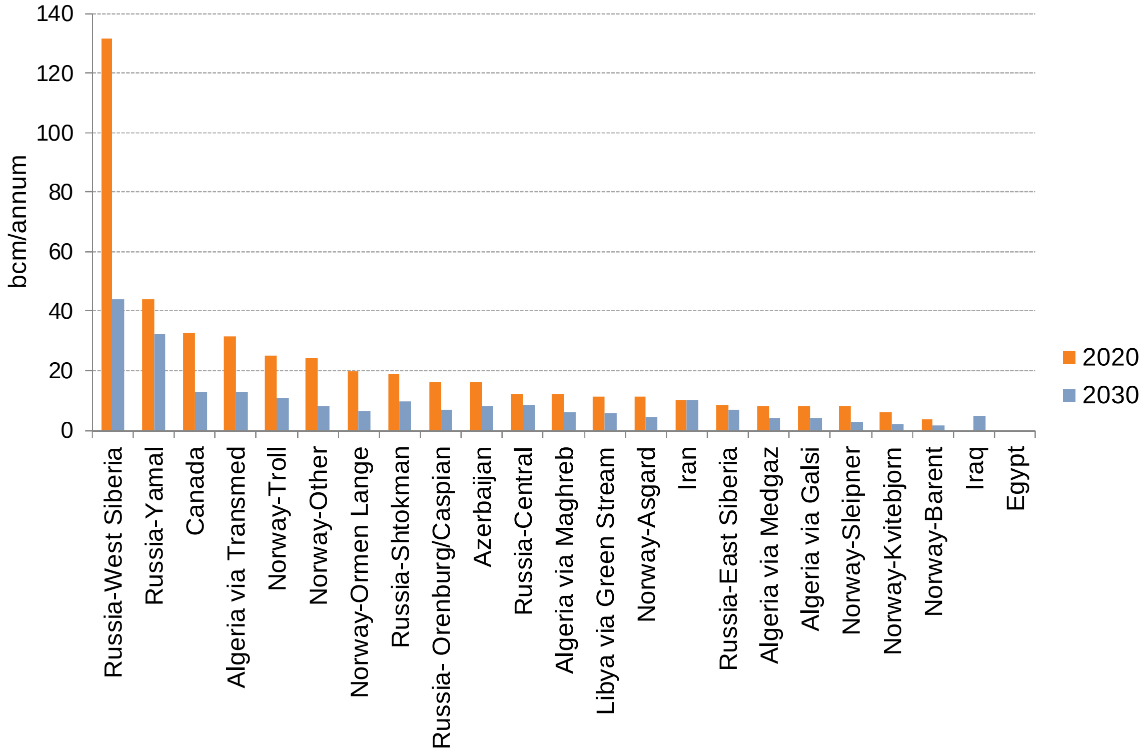
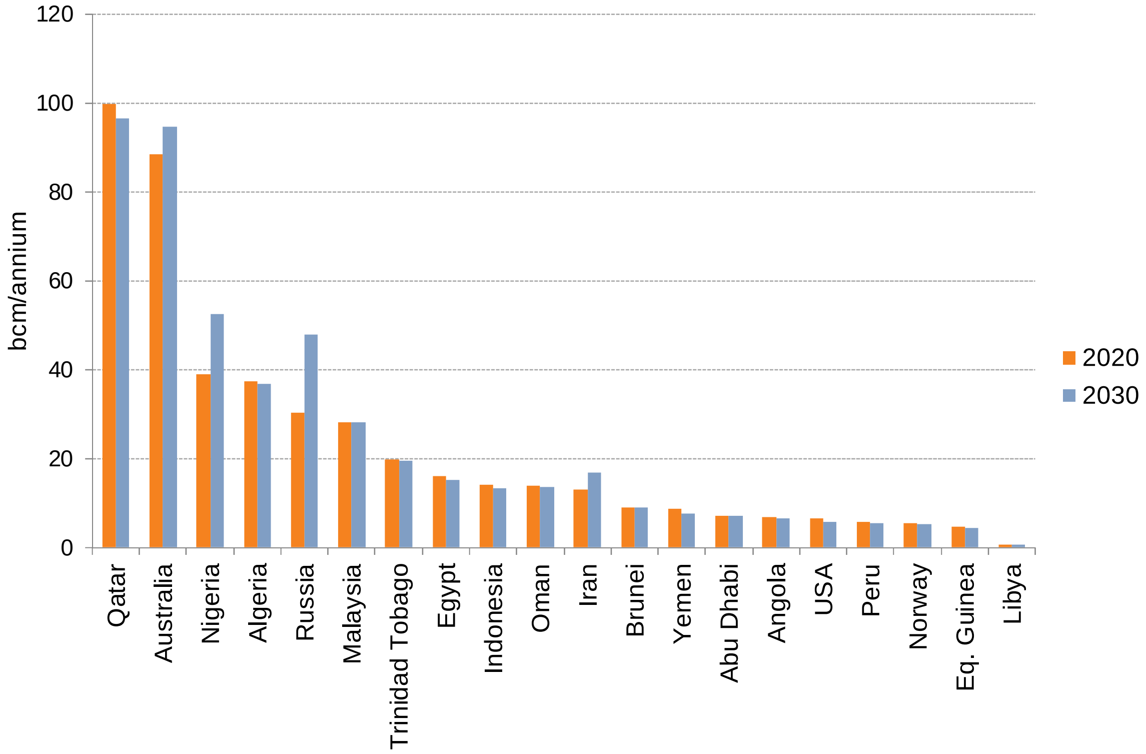
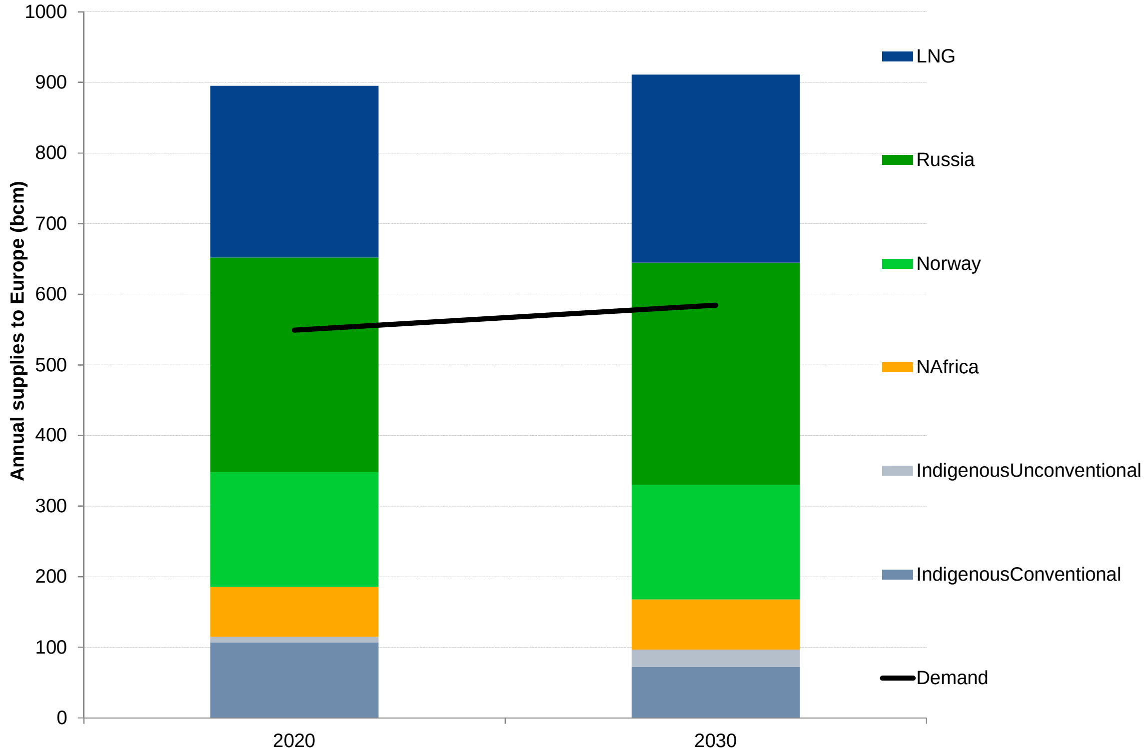


Figure 22 – Average annual capacities of LNG sources



580. These capacities are summarised and compared European gas demand in Figure 23, below.

Figure 23 – Annual demand and capacity for Europe (bcm)



I.1.1.2 Source costs

581. Pöyry maintains a detailed database of the long-run marginal costs of production, delivery, storage and transportation. This database incorporates the influence of contracting practices and the propensity for upstream players to insist on oil-indexation even where it might be detrimental to their sales. Oil-indexation considerations can have a significant impact on the assumed costs of production.

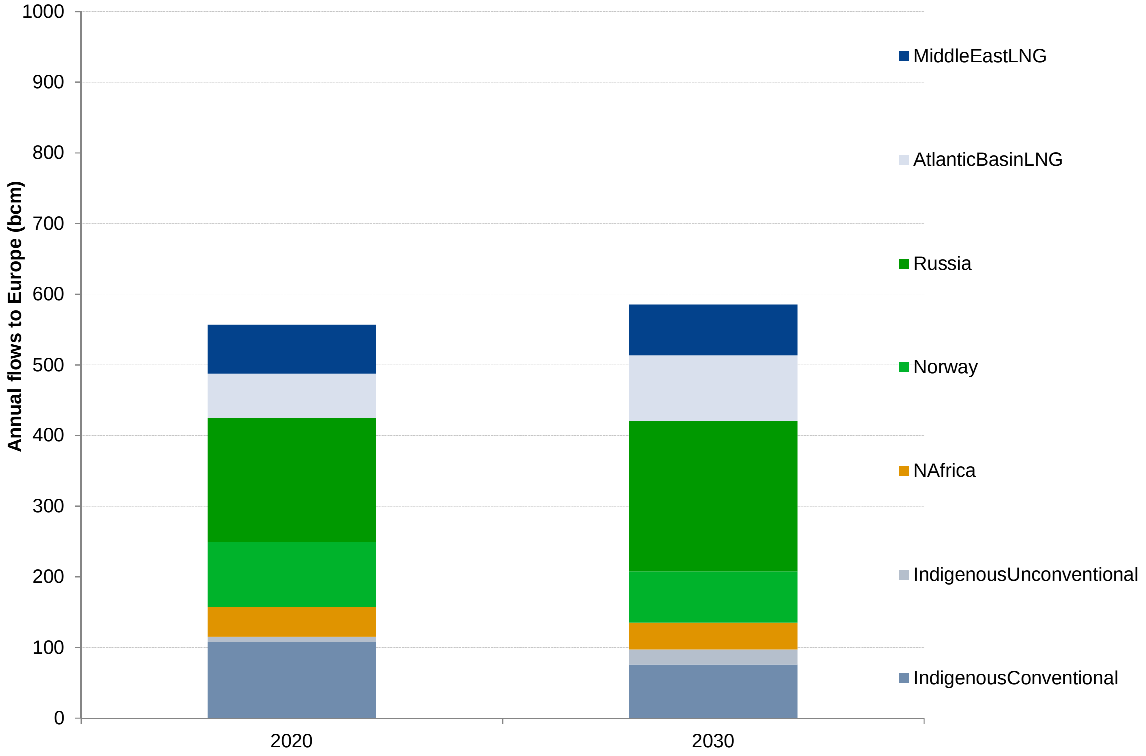
582. The database has been collected, maintained and calibrated over a number of years and contains commercially sensitive information that cannot be published. A ranking of the main sources in terms of average monthly costs is provided in Table 20. This could in simple terms be considered as a merit order, however it does not integrate either the costs that might be involved in delivering volumes of gas to any particular region or the costs of storage utilisation.

Table 20 – Ranking of sources based on their cost

Ranking	Source
1	North West &Central Europe Shale
2	Algeria via Transmed/Maghreb
3	Indonesia/Australia/Malaysia LNG
4	Middle East/Azerbaijan pipeline/Libya via Green Stream
5	Russia Yamal/Siberia/Shtokman
6	Russia Central/Orenburg/Caspian
7	Yemen LNG
8	Norway Barent
9	Iran LNG
10	Norway Other
11	Norway Asgard
12	Algeria via Medgaz
13	Norway Sleipner
14	Norway Kvitebjorn
15	Norway Troll
16	Russia LNG
17	Norway LNG
18	Eastern Europe Shale
19	Peru LNG
20	Ireland Other
21	Nigeria/Libya LNG
22	Egypt LNG
23	Trinidad Tobago LNG
24	GB Dry New
25	Oman LNG
26	Abu Dhabi LNG
27	Algeria LNG
28	Ireland Corrib
29	Angola LNG
30	Eq. Guinea LNG
31	Qatar LNG
32	Iraq LNG
33	Ireland Inch
34	GB Dry Old
35	Denmark indigenous
36	Norway Ormen Lange
37	Central Europe indigenous (exl Czech Rep & Romania)
38	GB indigenous
39	Czech Rep & Romania indigenous

583. The resultant flows of gas to Europe are outlined in Figure 24 below.

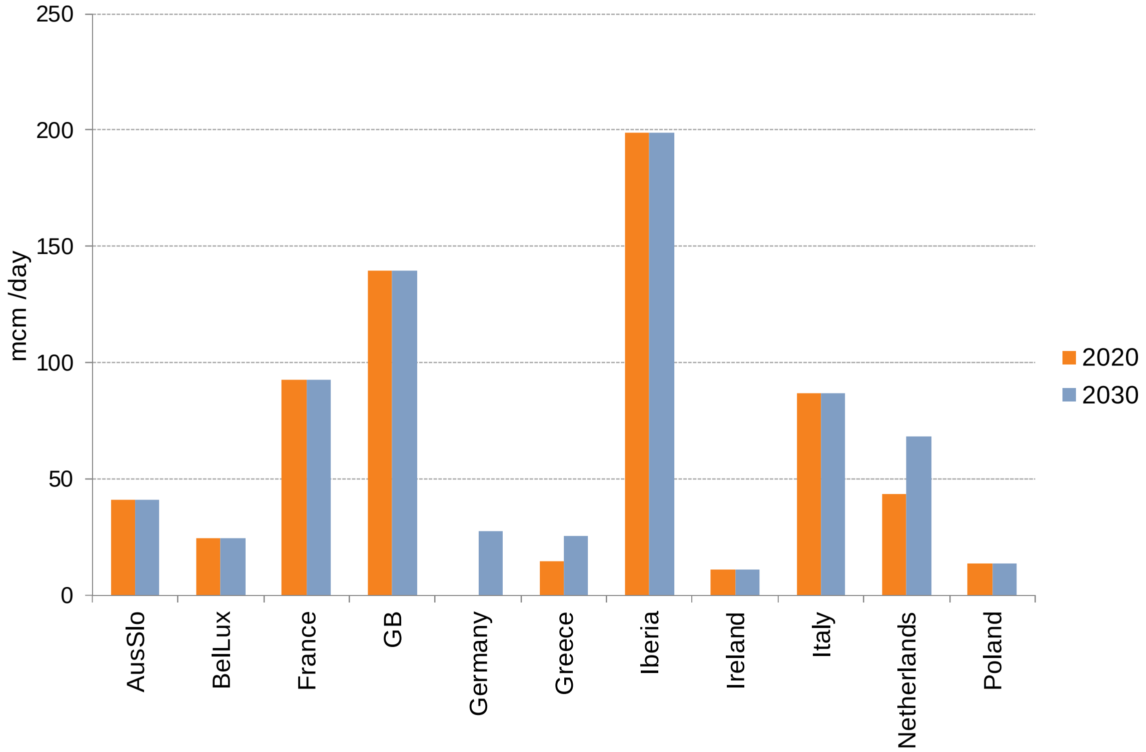
Figure 24 – Annual flows of gas into Europe (bcm)



I.1.1.3 European LNG regasifiction terminal capacities

584. Iberia has the highest average daily LNG terminal capacity (approximately 200mcm/d) among EU countries. Germany, Greece and Netherlands are expected to expand their LNG terminal capacities after 2020.

Figure 25 – Total daily LNG terminal capacities



I.1.2 Comparison to EU Primes

I.1.2.1 Annual gas consumption

585. In this section, Pöyry's annual demand assumptions are compared to the EU 2010 PRIMES baseline assumptions. Generally, Pöyry's demand assumptions are above PRIMES figures, probably as a result of different assumptions regarding energy efficiency and/or the penetration of renewable heat. France, GB and AusSlo also exhibit notable differences in gas-fired power generation demand, probably explained by different assumptions regarding the relative levels of CCGT and coal-fired generation.

Figure 26 – Annual total gas demand comparison in 2020 (bcm)

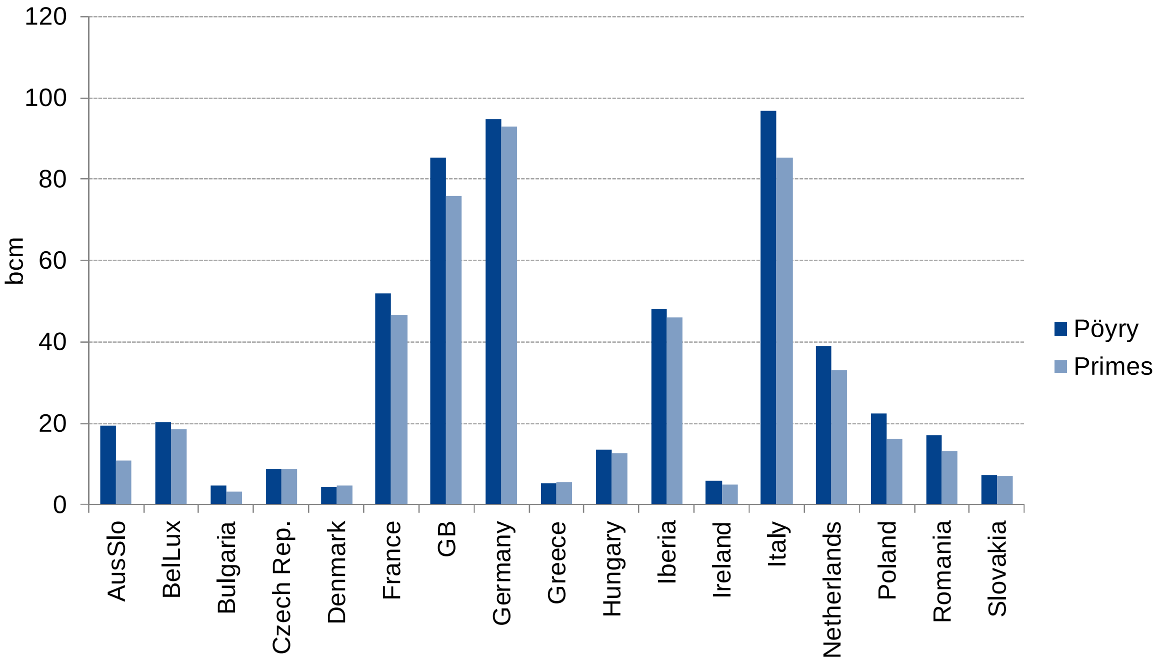
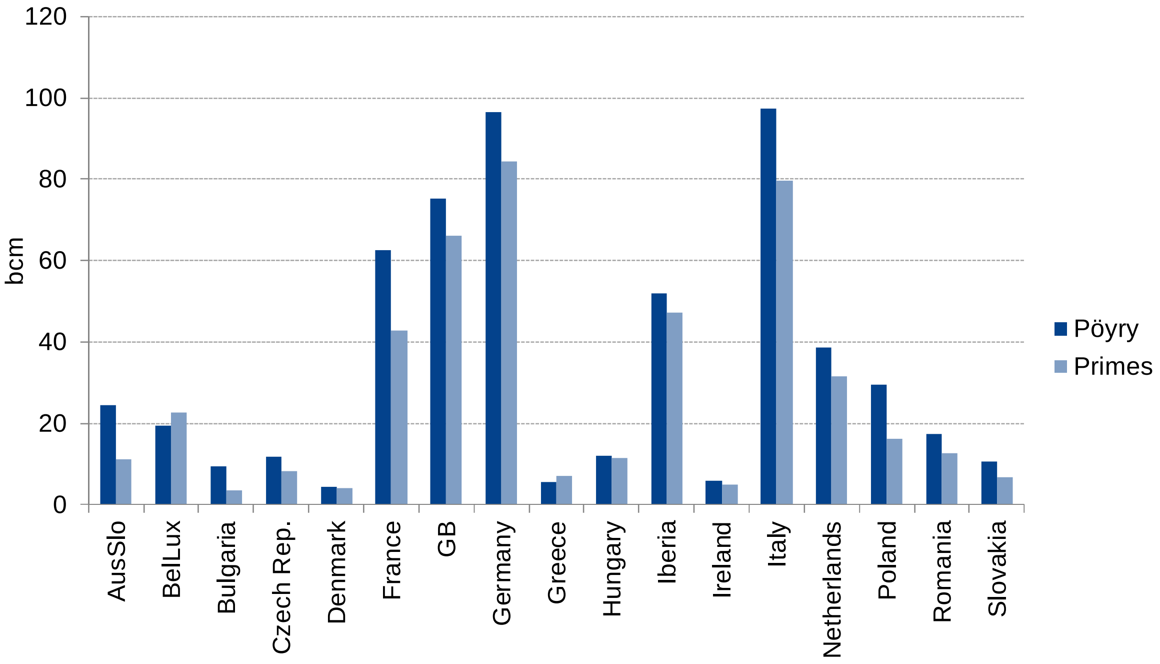


Figure 27 – Annual total gas demand comparison in 2030 (bcm)



I.1.3 Gas qualities assumed in the modelling

586. The upstream gas qualities that we have assumed in the modelling are shown in Table 21.

Table 21 – Source gas quality assumptions

Parameter	**Calorific value**	**Wobbe sensitivity**	**Wobbe Index**	**CO_2**	**H_2S**	**N_2**	**O_2**
Units	MJ/m3	MJ/m3	MJ/m3	ppm	ppm	ppm	ppm
Scenario	CV	Wobbe (sensitivity)	Wobbe (base), EASEE-gas, Multi-property	Multi-property	Multi-property	Multi-property	Multi-property
Abu Dhabi	42.31	53.41	53.41	0.00	5.50	0.10	0.18
Algeria	41.45	53.70	52.33	0.22	5.50	0.92	0.01
Angola	41.90	52.89	52.89	0.00	5.50	4.00	0.20
Australia	41.97	52.99	52.99	0.00	5.50	1.00	0.20
Brunei	41.97	52.99	52.99	0.00	5.50	4.00	0.20
Egypt LNG	41.45	52.33	52.33	0.00	5.00	1.00	0.01
Equatorial Guinea	41.90	53.95	52.89	0.00	5.00	1.00	0.18
Galsi	38.87	49.14	49.14	2.00	8.00	4.00	0.00
Greenstream	38.00	48.04	48.04	2.00	8.00	4.00	0.00
Indonesia	41.49	52.38	52.38	0.00	5.00	1.00	0.18
Iran	40.04	51.00	50.54	0.00	2.00	4.00	0.02
Libya	42.50	53.65	53.65	0.00	5.00	4.50	0.18
Mahgreb	39.50	49.94	49.94	2.00	8.00	4.50	0.00
Malaysia	41.60	52.52	52.52	0.00	5.00	4.50	0.20
Medgaz	38.87	49.14	49.14	2.00	8.00	4.00	0.00
Nigeria	41.90	54.00	52.89	0.00	3.00	1.00	0.01
Norway LNG	41.45	53.90	52.33	1.20	5.00	1.10	0.01
Norway Pipeline	39.68	53.50	50.25	2.14	4.80	1.10	0.00
Oman	40.97	51.72	51.72	0.00	2.00	0.40	0.01
Peru	37.58	46.49	47.44	0.00	5.00	3.00	0.20
Qatar	40.04	49.53	50.54	0.00	2.00	2.50	0.01
Russia LNG	42.00	53.02	53.02	0.00	5.00	2.50	0.20
Russia pipeline	37.88	52.00	50.27	0.16	1.80	1.80	0.00
Russia pipeline Shtokman	37.88	52.00	50.27	0.16	2.50	3.00	0.00
Transmed	38.87	49.14	49.14	2.00	8.00	4.00	0.00
Trinidad & Tobago	40.04	52.00	50.54	0.00	5.00	0.10	0.01
USA	37.58	47.44	47.44	0.00	5.00	3.00	0.20
Venezuela	37.58	47.44	47.44	0.00	5.00	3.00	0.20
Yemen	42.31	54.50	53.41	0.00	2.00	2.00	0.02

I.1.4 GQ constraint analysis

I.1.4.1 Background

Interpretation of 'benefit'

587. The following results describe the 'benefit of harmonisation'. To be clear, this is the benefit realised by removing the modelled gas quality constraint, or alternatively can be considered the cost to consumers of having the modelled gas quality constraint.

Scenarios

588. This section presents the results from the various scenarios we have undertaken to quantify the benefits of harmonising gas qualities. Table 22 describes the scenarios examined.

Table 22 – Gas quality scenario descriptions

Scenario name	Constraint applied	Description	Upstream range
Unconstrained	None	This is the base scenario whose objective function represents the costs of serving the modelled demands assuming there are no gas quality constraints	N/A
EASEE-gas	EASEE-gas Wobbe (only)	The incremental cost (over the base, 'Unconstrained' scenario) to the market of applying the EASEE-gas specification	Narrow
Wobbe (base)	Existing Wobbe (only)	The incremental cost (over the base, 'Unconstrained' scenario) to the market of applying the existing Wobbe specifications	Narrow
Wobbe (sensitivity)	Existing Wobbe (only)	The incremental cost (over the base, 'Unconstrained' scenario) to the market of applying the existing Wobbe specifications, but assuming a wider range of gas qualities from upstream supplies	Wide
Calorific Value	Implied existing CV	The incremental cost (over the base, 'Unconstrained' scenario) to the market of applying the a set of CV specifications which are based on the existing Wobbe specifications (assumed at the average relative density)	Narrow
Multi-quality	Existing Wobbe + CO_2 + O_2 + N_2 + H_2S	The incremental cost (over the base, 'Unconstrained' scenario) to the market of applying the existing specifications for Wobbe, CO_2, O_2, N_2 and H_2S	Narrow

I.2 Zonal impact

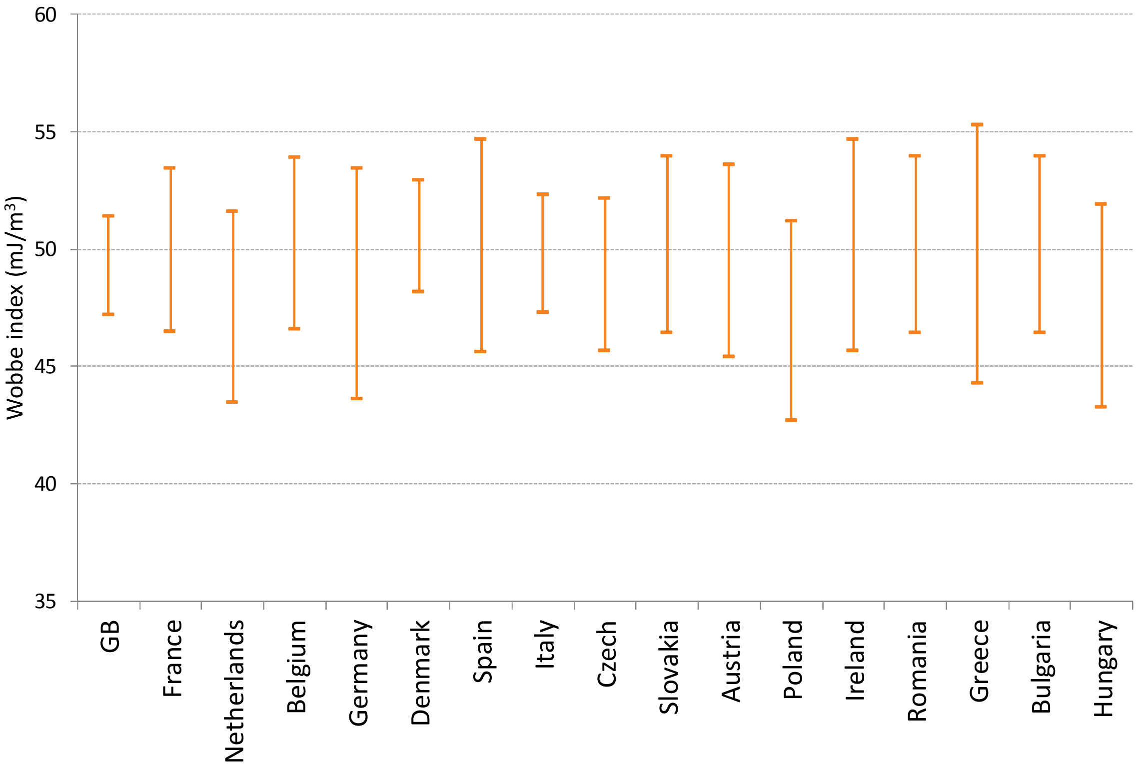
589. Each set of results below provides an estimate of the benefit as it might accrue in each modelled zone. This breakdown is given the tables labelled, 'The benefits of Wobbe harmonisation (€m)'. We note that some zones will observe a negative impact as a result of harmonisation, as cheaper gas is allowed to flow to other markets.

I.2.1 Wobbe number

590. This section presents the results from the Wobbe index modelling. The first section examines the high level results, with the following sections drilling down to examine more detailed results.

591. We have examined the impact of harmonising the Wobbe index ranges. This has considered an infinite harmonised quality, i.e. the analysis explores the benefit of removing all Wobbe index constraints.

Figure 28 – Wobbe index constraints



Source: CEN/AFNOR/WG 197 Gas Quality 2010, Pöyry analysis

I.2.1.1 High-level results

592. The benefit of harmonisation is estimated by comparing the minimised objective function[13] values (total cost in Euros) of the two model runs. First, the model is run without any quality constraints, which represents a case where gas quality specifications are harmonised. Then, quality constraints were added to the model. All other things remain equal, so the difference in the objective function values should represent the costs of the gas quality constraints, which can then be used to estimate the benefits of harmonisation.

593. Benefit of harmonisation is only 0.013% of the objective function value in 2020. In 2030, benefits are estimated to be even lower and to make approximately 0.005% of the objective function value. These are relatively small changes; however they are significant enough in modelling terms to describe a benefit of harmonisation.

594. The term ‘constrained scenario’ below refers to the non-harmonised case, where gas flow is subject to gas quality constraints (which is closest to the real market), and ‘unconstrained scenario’ refers to harmonised case, where gas quality constraints do not apply.

[13] The precise formulation of the objective is commercially confidential, however it can be considered as the total cost of supplying all modelled demand after satisfying all of the appropriate constraints. Further description is given in section J.1.3.

Table 23 – Objective function values (EUR)

Gas year	Scenario	Objective function value (EUR)	Benefit of harmonisation
2020	Unconstrained	354,653,349,115	
2020	Constrained	354,697,721,037	44,371,922
2030	Unconstrained	402,931,504,050	
2030	Constrained	402,951,469,336	19,965,286

I.2.1.2 Flow changes

Great Britain

595. Flows from and to Great Britain do not differ significantly between harmonised and disharmonised cases. Harmonisation of gas quality increases flow from the Netherlands to Great Britain by approximately 350%, however the volume of gas flowing from the Netherlands is significantly less than other flows. In the disharmonised case, Great Britain's narrower gas quality range prevents most of the gas from flowing from the Netherlands to Great Britain.

596. In addition to the interconnection flow change, LNG flows increase slightly and pipeline flows from Norway decrease. This is mainly because the gas quality of some LNG is a better match for Great Britain's quality constraints compared to some Norwegian gas.

597. LNG sourcing also shifts from Algeria, Iran and Trinidad Tobago to Nigeria in the harmonised scenario. Nigerian gas, having a high gas quality, cannot flow to Great Britain in the disharmonised case as its gas quality is too high compared to Great Britain's quality constraints. As a result of more high quality LNG flow, average gas quality in Great Britain is found to be higher in the harmonised case.

Figure 29 – Flows in Great Britain (bcm)

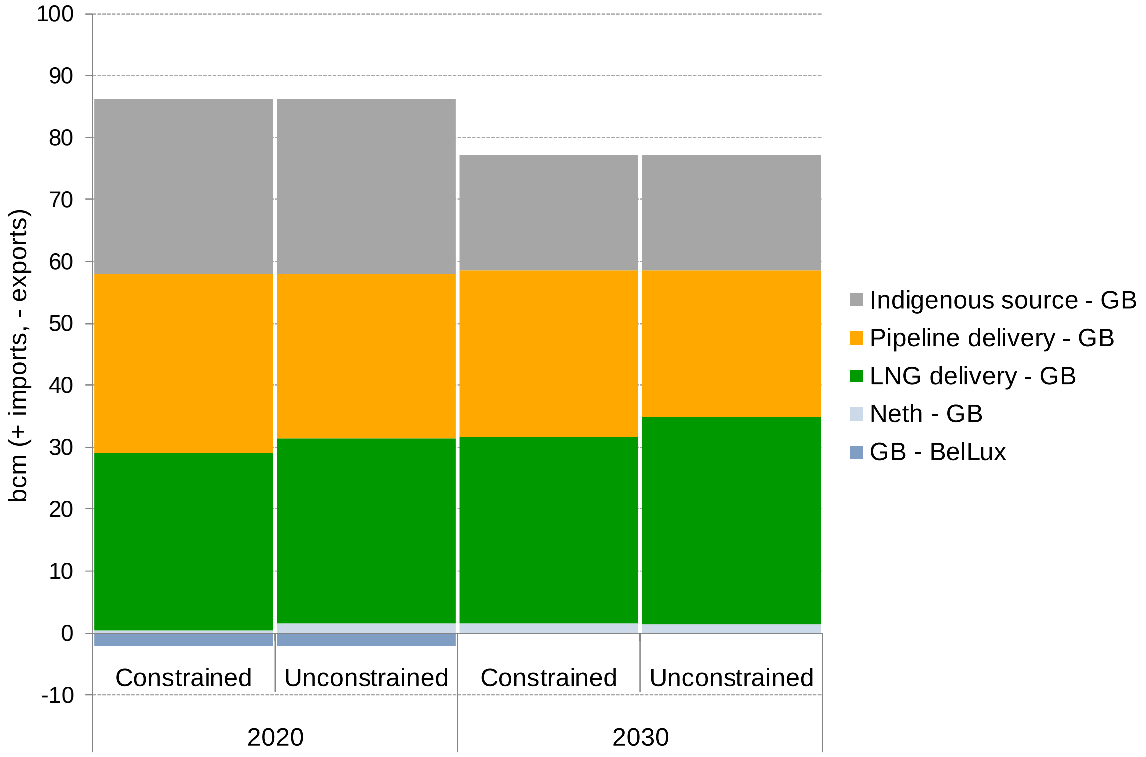


Figure 30 – Interconnection flows in Great Britain (bcm)

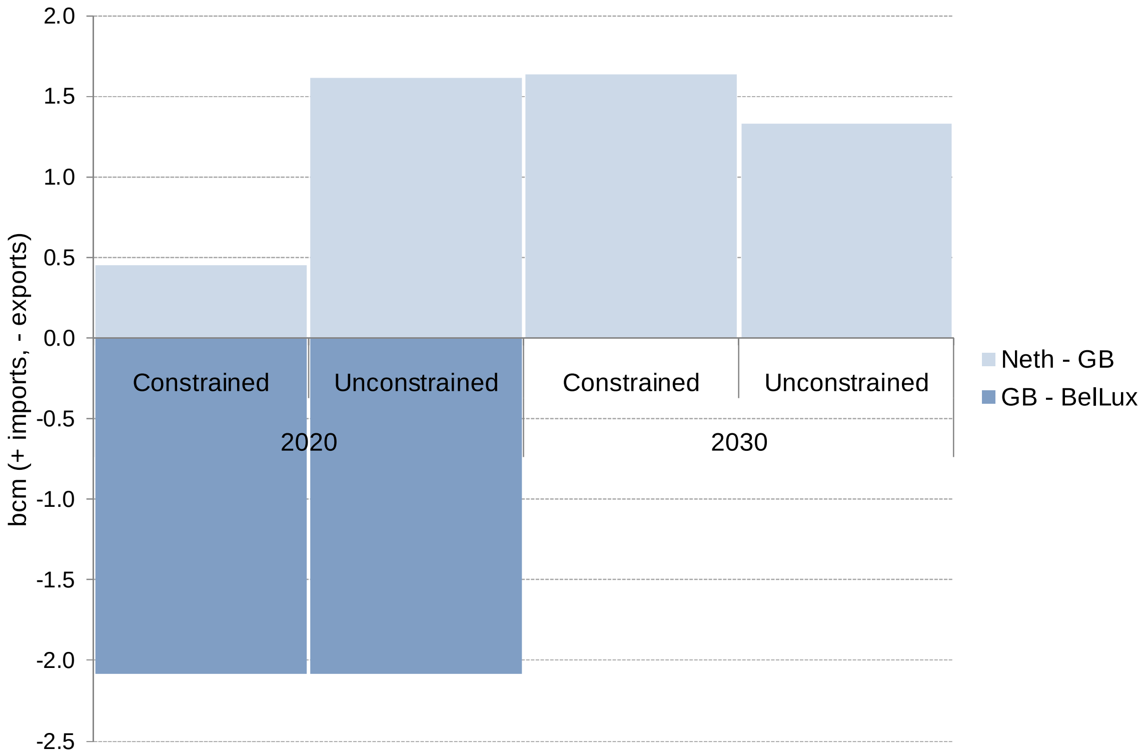
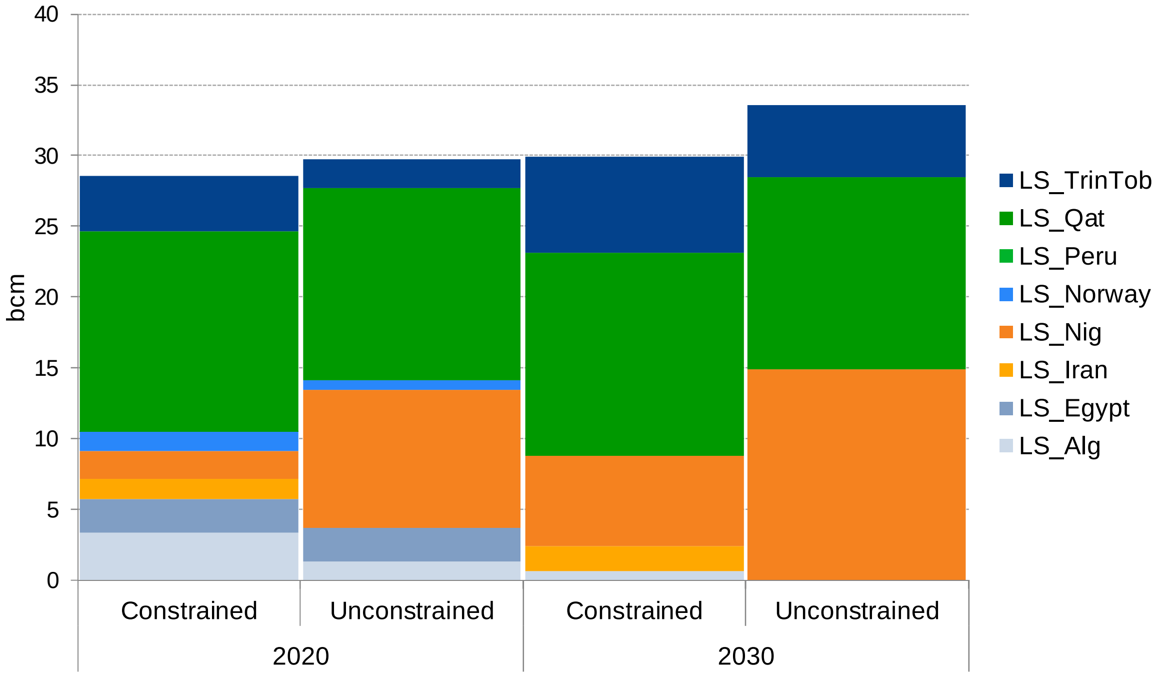


Figure 31 – LNG flows to Great Britain (bcm)



BelLux

598. Similar to flows to and from Great Britain, total flows to and from BelLux remains similar in the harmonised case. Flow mix shifts from LNG and interconnection flow to pipeline flow. More specifically, flows from France are replaced mainly by flows from Norway. Flows from BelLux to Germany also decrease slightly in 2020 in the harmonised case. Eliminated LNG flows mainly consist of Nigerian gas. Average gas quality is lower in the harmonised case as high quality LNG is replaced by lower quality Norwegian gas.

Figure 32 – Flows in BelLux (bcm)

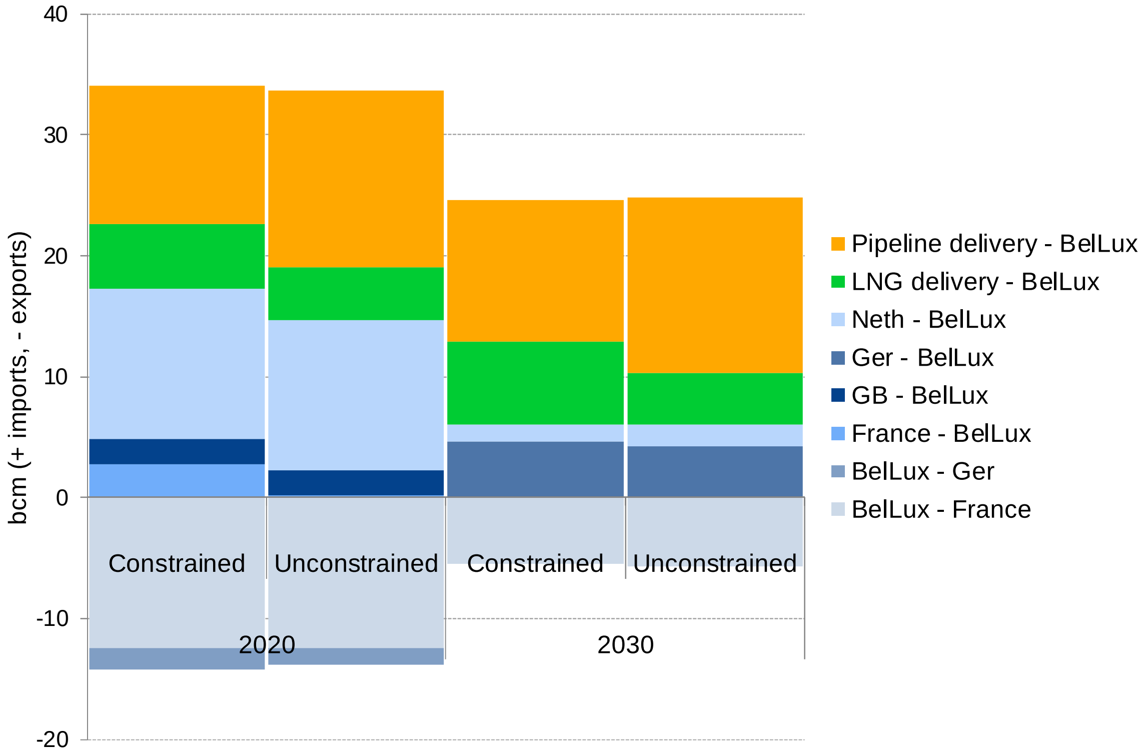


Figure 33 – Interconnection flows in BelLux (bcm)

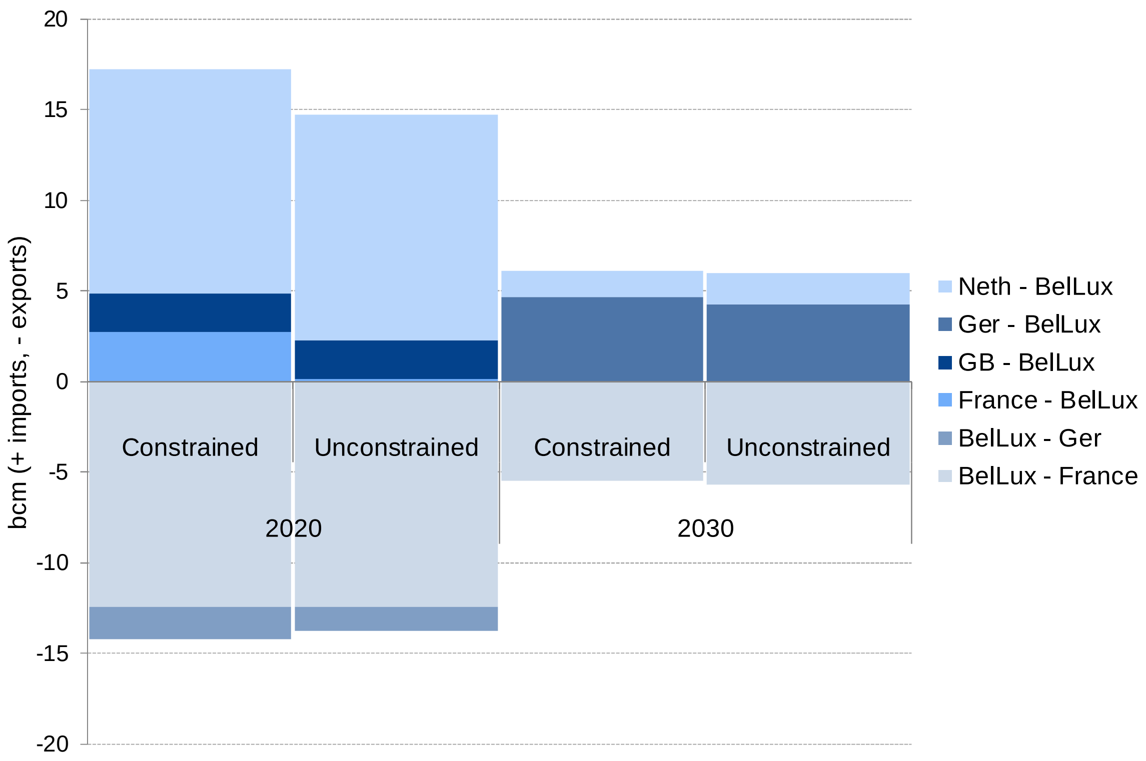
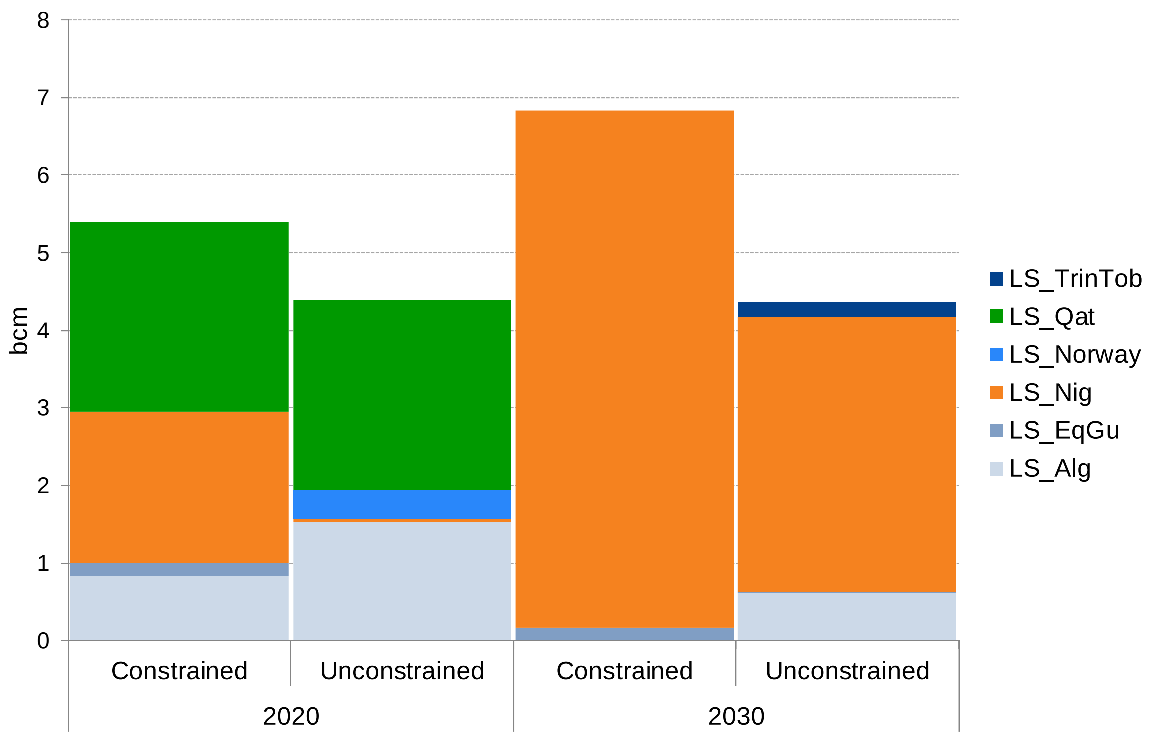


Figure 34 – LNG flows to BelLux (bcm)



The Netherlands

599. The total impact of harmonisation on the Dutch gas flow is limited. In 2020, gas flow mainly shifts from LNG to Norwegian gas. Majority of LNG from Iran and Trinidad Tobago divert from the Netherlands. Export to Great Britain increases, whereas export to Germany decreases in 2020. In 2030, changes in flows are immaterial.

Figure 35 – Flows in the Netherlands (bcm)

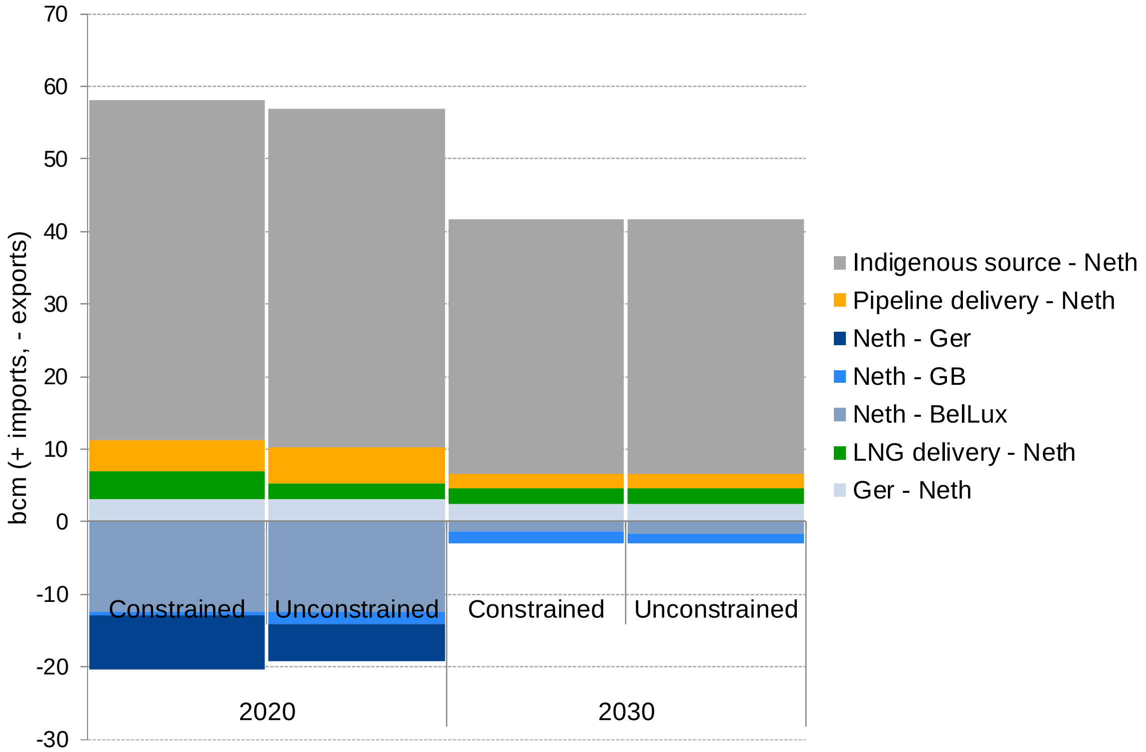


Figure 36 – Interconnection flows in the Netherlands (bcm)

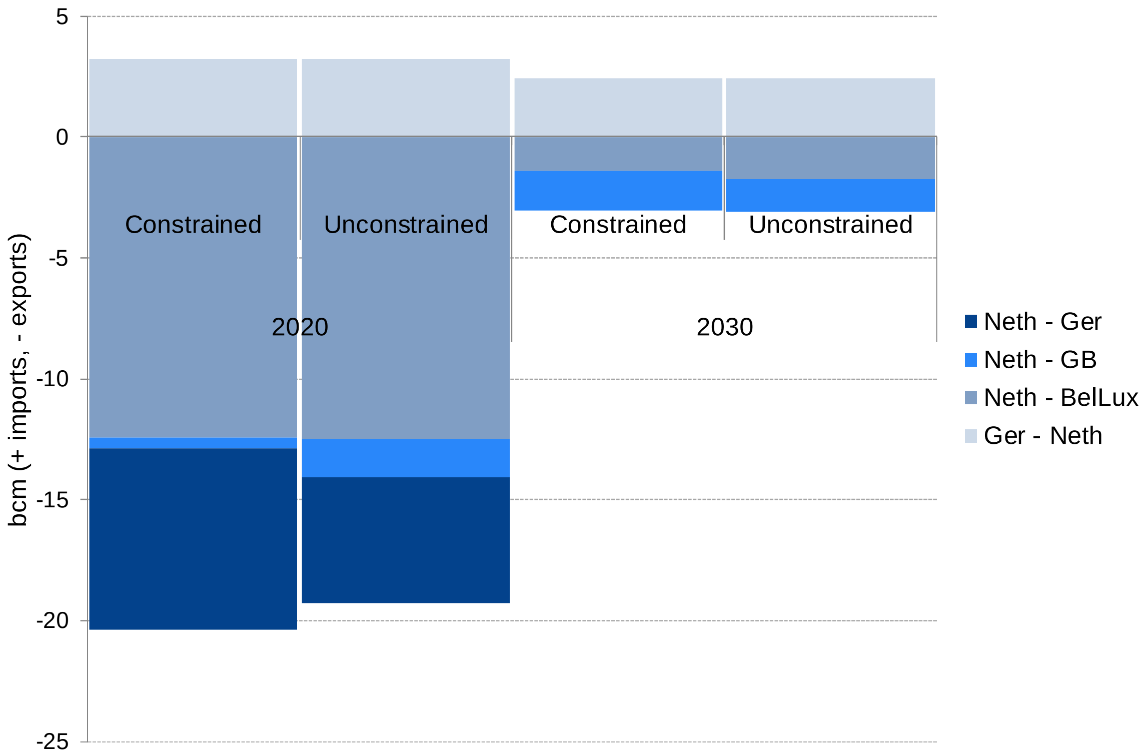
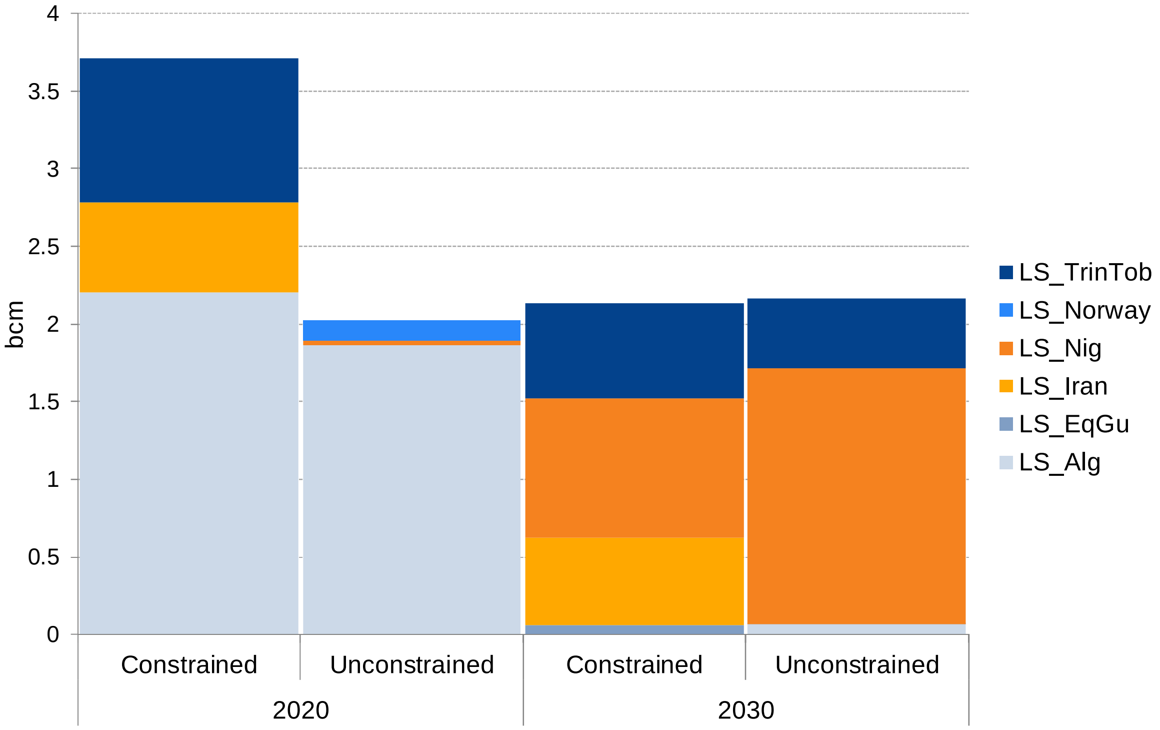


Figure 37 – LNG flows to the Netherlands (bcm)



France

600. Due to the decrease in the LNG flow to the country, total inflow decreases in 2020 in the harmonised case. Changes in the import flows are insignificant in both 2020 and 2030, whereas exports to BelLux stop in 2020 when quality constraints are removed. This is mainly because BelLux offsets gas flowing from France with Norwegian gas in the harmonised case. Due to lower flow of LNG, average gas quality decreases.

Figure 38 – Flows in France (bcm)

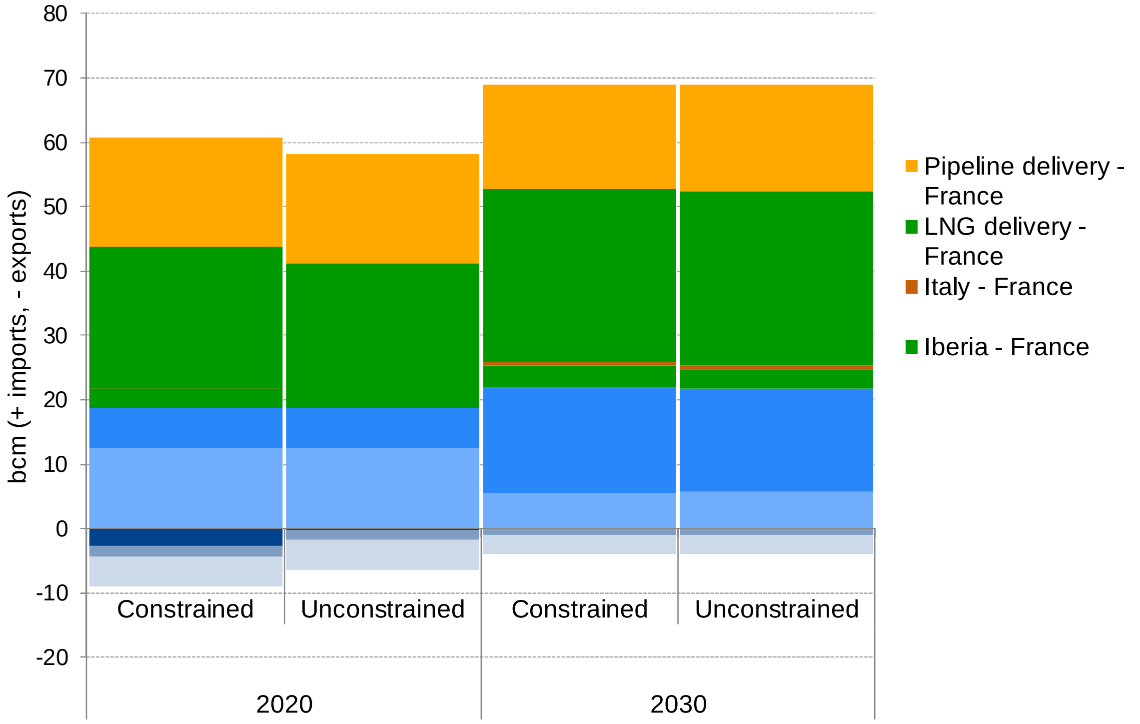


Figure 39 – Interconnection flows in France (bcm)

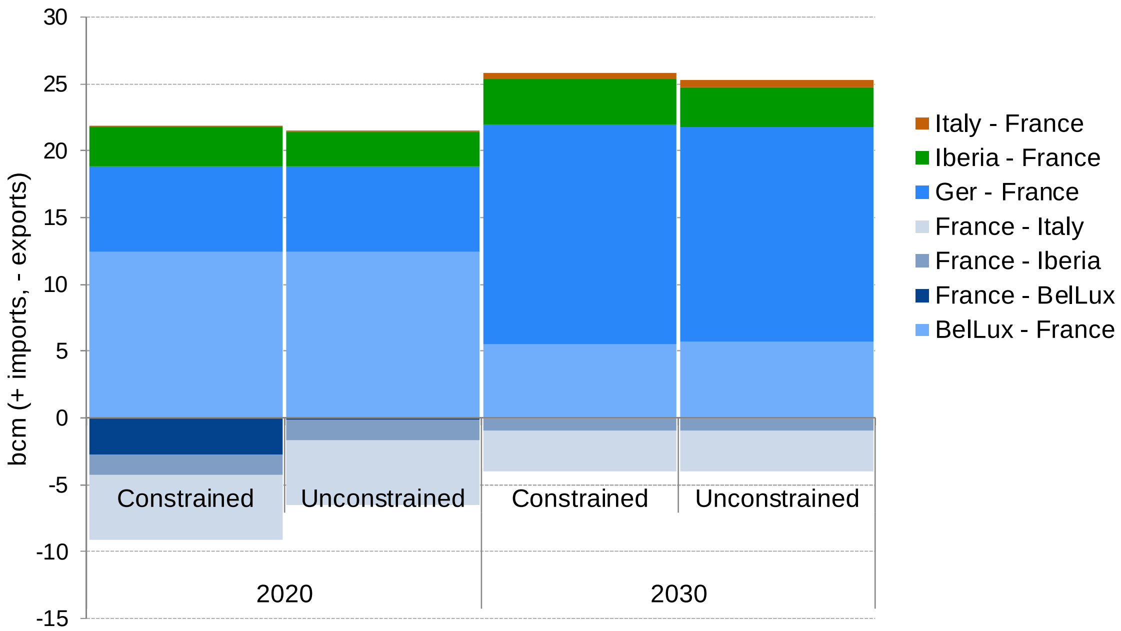
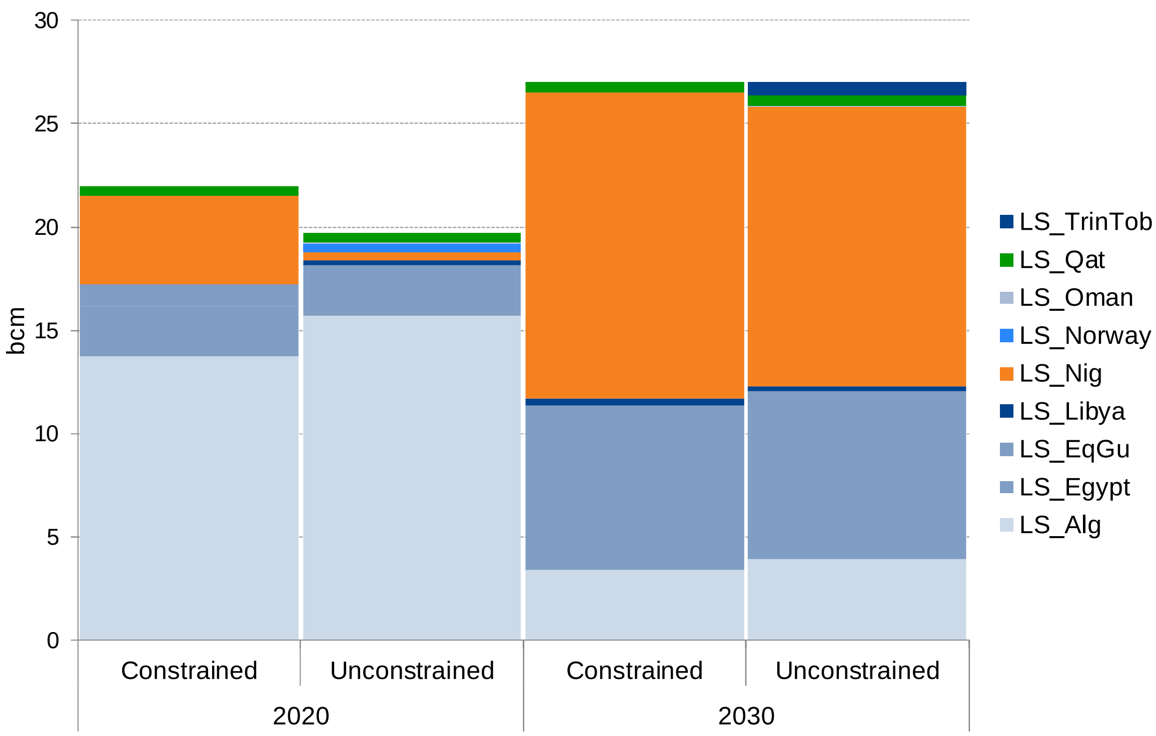


Figure 40 – LNG flows to France (bcm)



Germany

601. German gas flow does not change much when gas is harmonised. In 2020, Norwegian gas, which is delivered through pipeline, part of imports from the Netherlands and BelLux are replaced by imports from Czech Republic. On the other hand, export from Germany remains the same. In 2030, Germany receives limited LNG flows mainly from Norway and Nigeria.

Figure 41 – Flows in Germany (bcm)

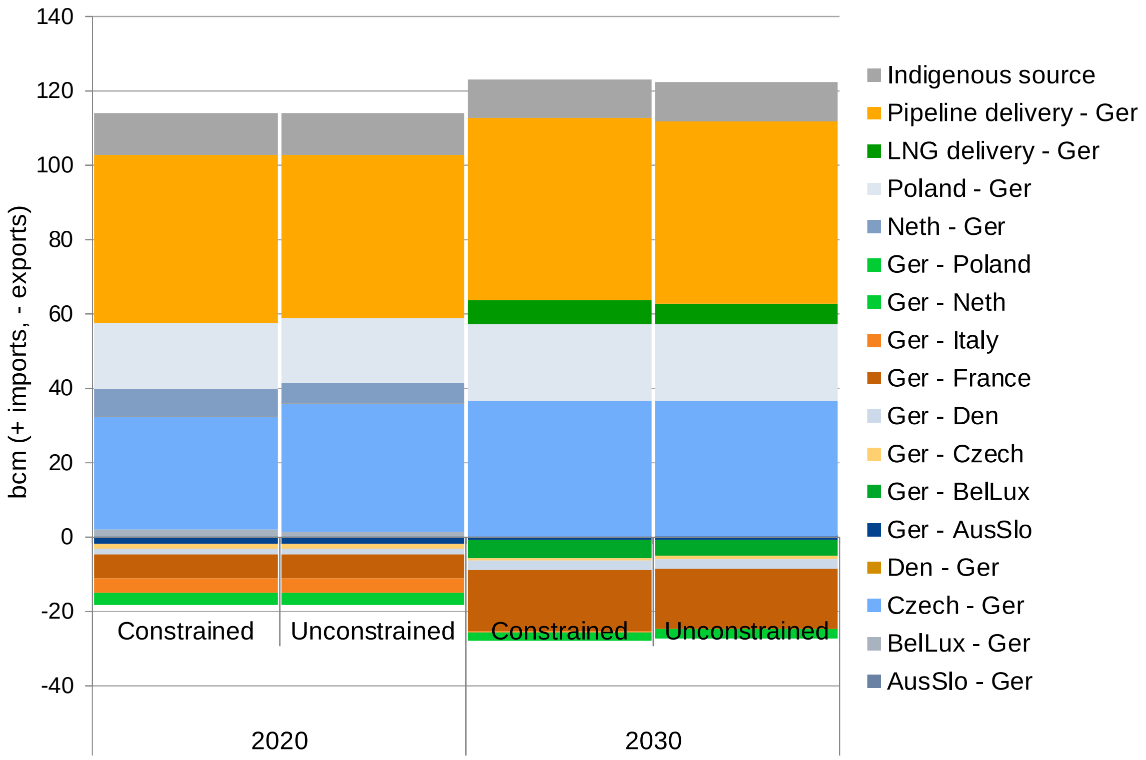


Figure 42 – Interconnection flows in Germany (bcm)

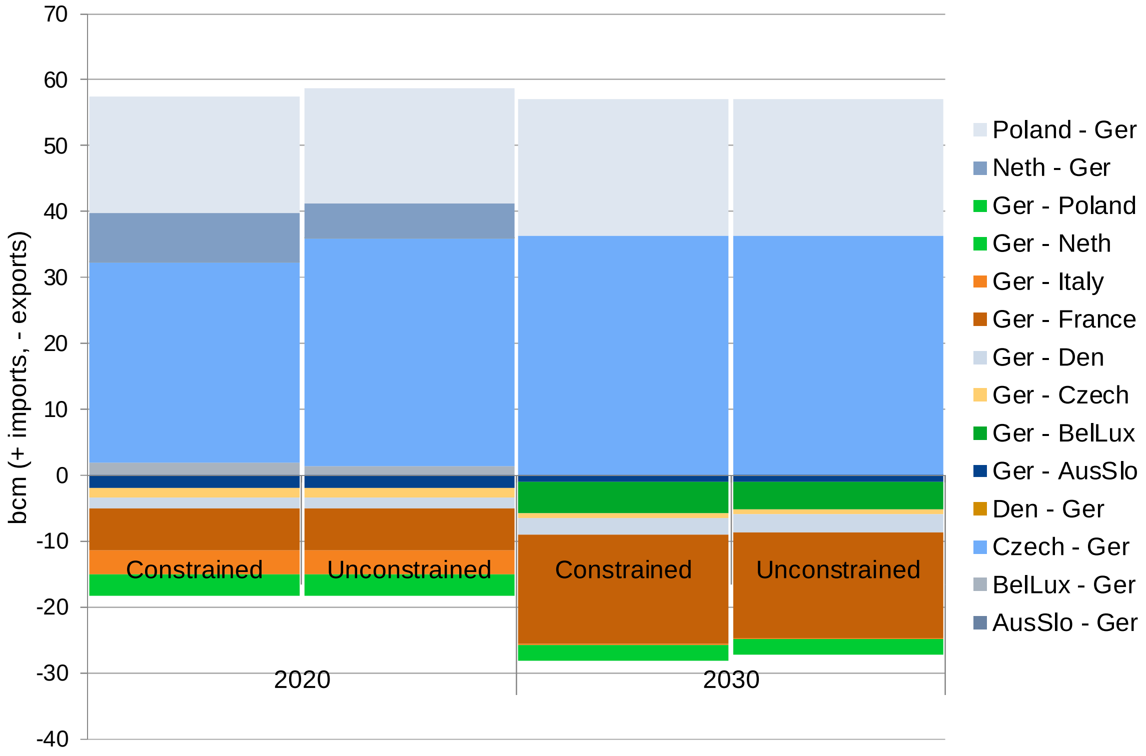
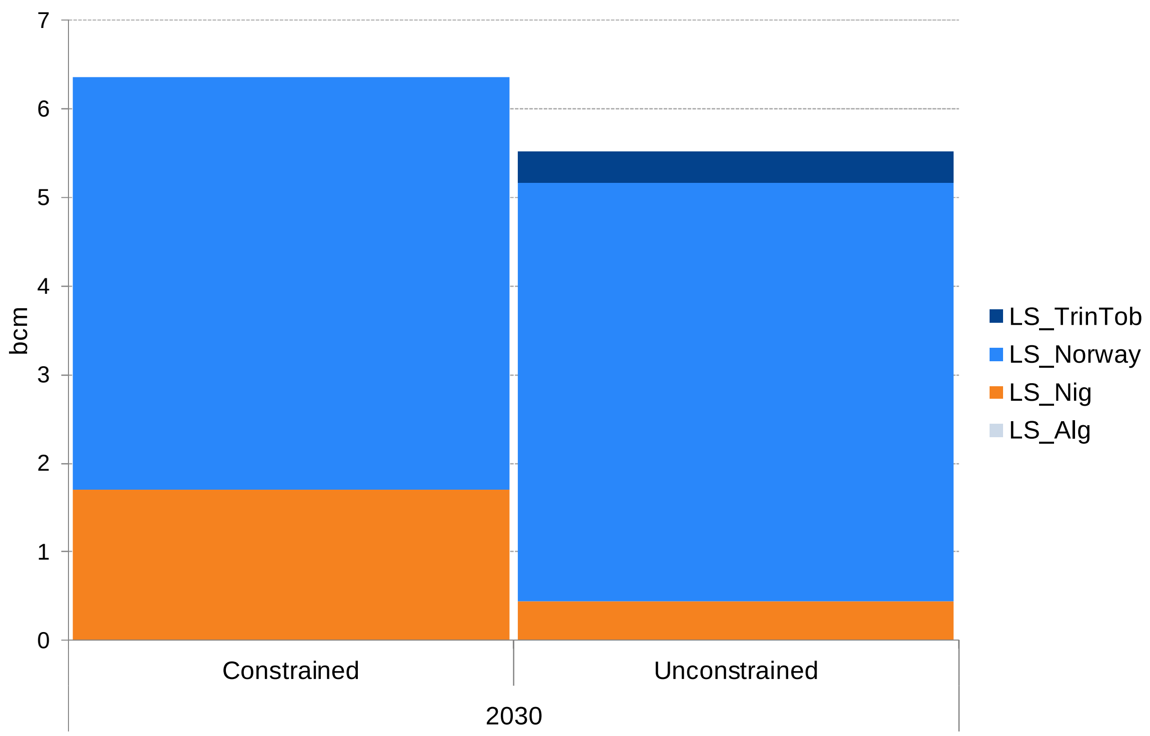


Figure 43 – LNG flows to Germany (bcm)



Italy

602. Similar to flows in Germany, flows in Italy do not change in 2030 in the harmonised case. LNG increases and imports from AusSlo decrease in 2020. Removing gas quality constraints allows Italy to benefit more from LNG sources, which have higher quality. As a result, average gas quality is increased in 2020. Additional LNG flows in the harmonised case mainly come from Iran, Yemen and Oman.

Figure 44 – Flows in Italy (bcm)

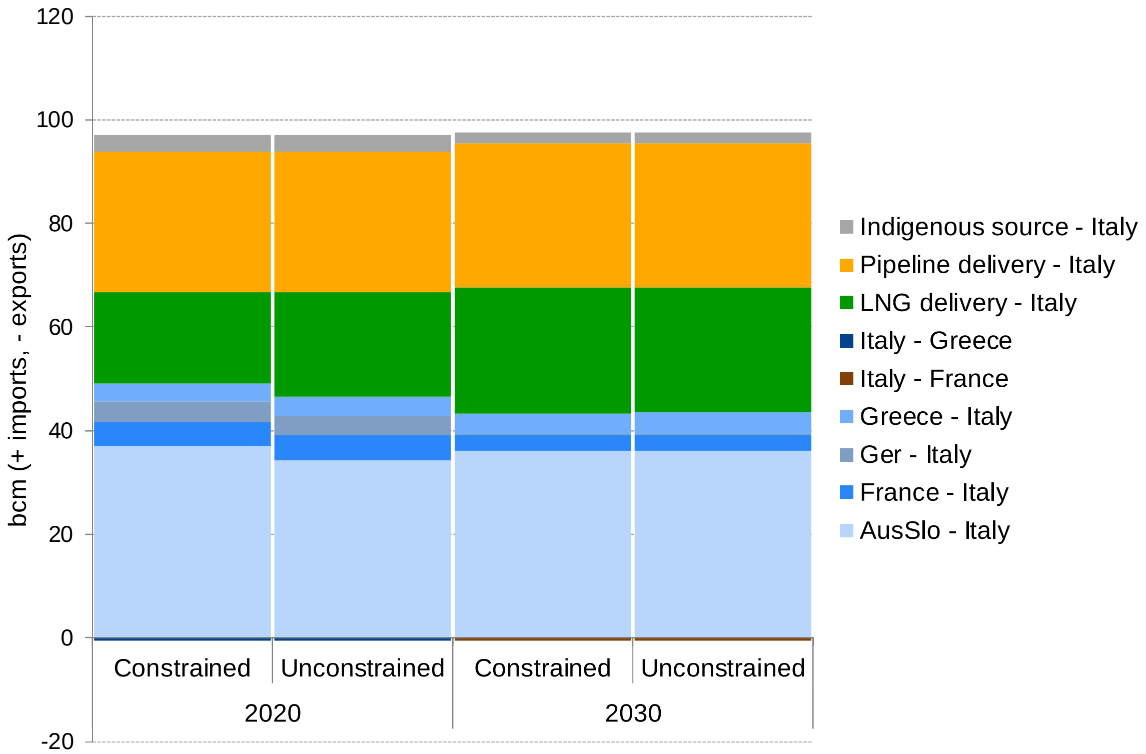


Figure 45 – Interconnection flows in Italy (bcm)

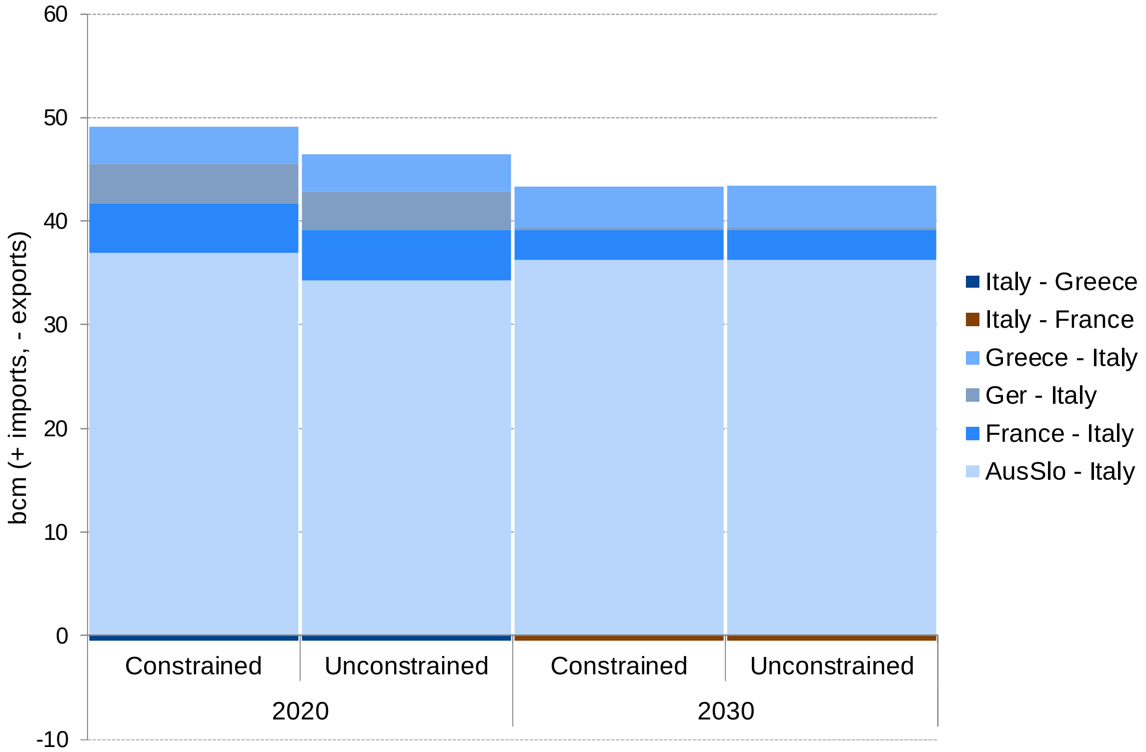
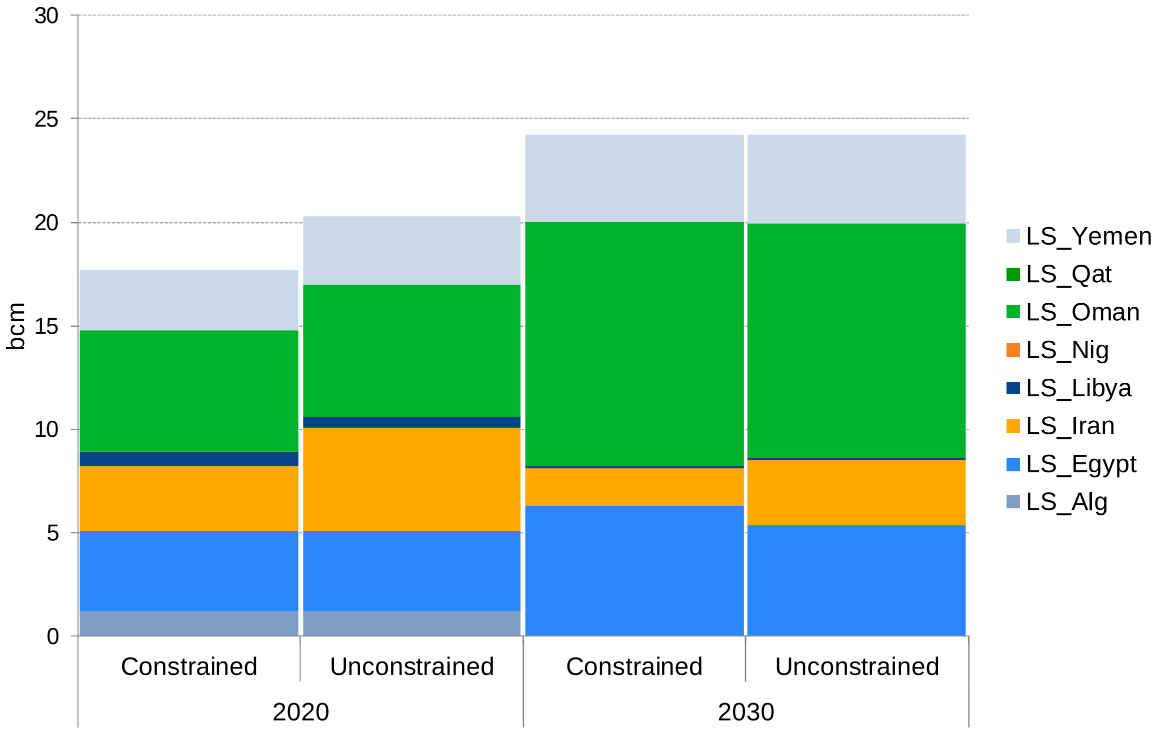


Figure 46 – LNG flows to Italy (bcm)



I.2.1.3 Accumulated flow changes

603. Total interconnection flow decreases by 0.9% (2540 mcm) in 2020 and by 0.3% (752 mcm) in 2030 in the harmonised case compared to disharmonised case. Total LNG flows and pipeline flows remain the same when gas is harmonised.

LNG flow changes

604. Although the total LNG flow does not change between harmonised and disharmonised cases, LNG flows change their routes in the harmonised scenario. LNG flow to BelLux, Netherlands and France decrease, whereas LNG flow to Great Britain, Italy and Poland increase in the harmonised case compared to the disharmonised case.

605. More specifically, main LNG route changes can be summarised as follows:
   - Algerian gas diverts mainly from Great Britain to BelLux and France in both 2020 and 2030;
   - Nigerian gas diverts from BelLux, France, US and BelLux to Great Britain and Netherlands in 2020 and to Netherlands only in 2030;
   - Iranian gas diverts from Great Britain, Poland and Netherlands to Italy and Far East in both 2020 and 2030;;
   - Norwegian gas diverts from Great Britain and US to Netherlands, France and BelLux in both 2020 and 2030.

Table 24 – Flows in 2020 (mcm)

From	To	Constrained	Unconstrained	Difference	Absolute difference
Czech Rep.	Germany	30,456	34,561	4,105	4,105
AusSlo	Italy	36,948	34,316	-2,632	2,632
France	BelLux	2,743	156	-2,588	2,588
Netherlands	Germany	7,515	5,234	-2,281	2,281
Netherlands	GB	453	1,611	1,157	1,157
BelLux	Germany	1,847	1,379	-468	468
Iberia	France	2,921	2,609	-313	313
Netherlands	BelLux	12,420	12,463	43	43
GB	BelLux	2,085	2,085	0	-
BelLux	France	12,420	12,420	0	-
Germany	BelLux	0	0	0	-
Germany	Netherlands	3,200	3,200	0	-
France	Italy	4,800	4,800	0	-
Italy	France	4	4	0	-
France	Iberia	1,536	1,536	0	-
Germany	France	6,400	6,400	0	-
Poland	Germany	17,600	17,600	0	-
Germany	Italy	3,760	3,760	0	-
Germany	AusSlo	1,922	1,922	0	-
Germany	Czech Rep.	1,400	1,400	0	-
Germany	Denmark	1,635	1,635	0	-
Italy	Greece	489	489	0	-
Greece	Italy	3,600	3,600	0	-

Table 25 – Flows in 2030 (mcm)

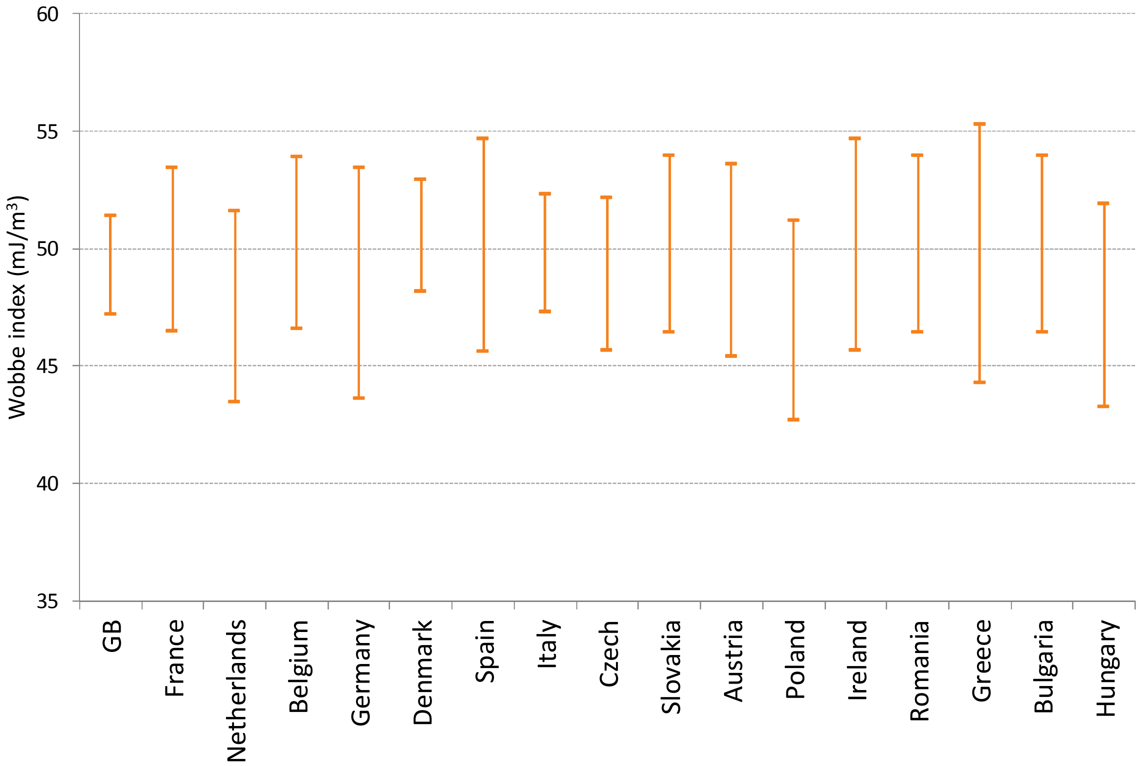
From	To	Constrained	Unconstrained	Difference	Absolute difference
BelLux	France	5,195	5,722	528	528
Germany	BelLux	4,663	4,230	-433	433
Germany	France	16,473	16,053	-420	420
Iberia	France	3,368	2,996	-372	372
Netherlands	BelLux	1,409	1,754	345	345
Netherlands	GB	1,639	1,328	-311	311
Italy	France	465	511	46	46
Germany	Italy	170	217	46	46
Poland	Germany	20,731	20,774	43	43
Czech Rep.	Germany	36,407	36,387	-20	20
GB	BelLux	0	0	0	-
France	BelLux	0	0	0	-
BelLux	Germany	0	0	0	-
Netherlands	Germany	0	0	0	-
Germany	Netherlands	2,400	2,400	0	-
France	Italy	3,000	3,000	0	-
France	Iberia	960	960	0	-
Germany	AusSLo	1,038	1,038	0	-
Germany	Czech Rep.	700	700	0	-
AusSLo	Italy	36,200	36,200	0	-
Germany	Denmark	2,696	2,696	0	-
Italy	Greece	0	0	0	-
Greece	Italy	4,000	4,000	0	-

I.2.2 Wobbe number (sensitivity)

606. This section presents the results from the Wobbe index sensitivity. The first section examines the high level results, with the following sections drilling down to examine more detailed results.

607. We have examined the impact of harmonising the Wobbe index ranges. This has considered an infinite harmonised quality, i.e. the analysis explores the benefit of removing all Wobbe index constraints.

Figure 47 – Wobbe index values (mJ/m^3)



Source: CEN/AFNOR/WG 197 Gas Quality 2010, Pöyry analysis

I.2.2.1 High-level results

608. The benefit of harmonisation is estimated by comparing the minimised objective function[14] values (total cost in Euros) of the two model runs. First, the model is run without any quality constraints, which represents a case where gas quality specifications are harmonised. Then, quality constraints were added to the model. All other things remain equal, so the difference in the objective function values should represent the costs of the gas quality constraints, which can then be used to estimate the benefits of harmonisation.

609. Benefit of harmonisation is only 0.013% of the objective function value in 2020. In 2030, benefits are estimated to be even lower and to make approximately 0.005% of the objective function value. These are relatively small changes; however they are significant enough in modelling terms to describe a benefit of harmonisation.

610. The term ‘constrained scenario’ below refers to the non-harmonised case, where gas flow is subject to gas quality constraints (which is closest to the real market), and ‘unconstrained scenario’ refers to harmonised case, where gas quality constraints do not apply.

[14] The precise formulation of the objective is commercially confidential, however it can be considered as the total cost of supplying all modelled demand after satisfying all of the appropriate constraints. Further description is given in section J.1.3.

Table 26 – Objective function values (EUR)

Gas year	Scenario	Objective function value (EUR)	Benefit of harmonisation
2020	Unconstrained	354,653,349,115	
2020	Constrained	354,697,721,037	44,371,922
2030	Unconstrained	402,931,504,050	
2030	Constrained	402,951,469,336	19,965,286

I.2.2.2 Flow changes

Great Britain

611. Flows from and to Great Britain do not differ significantly between harmonised and disharmonised cases. Harmonisation of gas quality increases flow from the Netherlands to Great Britain by approximately 350%, however the volume of gas flowing from the Netherlands is significantly less than other flows. In the disharmonised case, Great Britain's narrower gas quality range prevents most of the gas from flowing from the Netherlands to Great Britain.

612. In addition to the interconnection flow change, LNG flows increase slightly and pipeline flows from Norway decrease. This is mainly because the gas quality of some LNG is a better match for Great Britain's quality constraints compared to some Norwegian gas.

613. LNG sourcing also shifts from Algeria, Iran and Trinidad Tobago to Nigeria in the harmonised scenario. Nigerian gas, having a high gas quality, cannot flow to Great Britain in the disharmonised case as its gas quality is too high compared to Great Britain's quality constraints. As a result of more high quality LNG flow, average gas quality in Great Britain is found to be higher in the harmonised case.

Figure 48 – Flows in Great Britain (bcm)

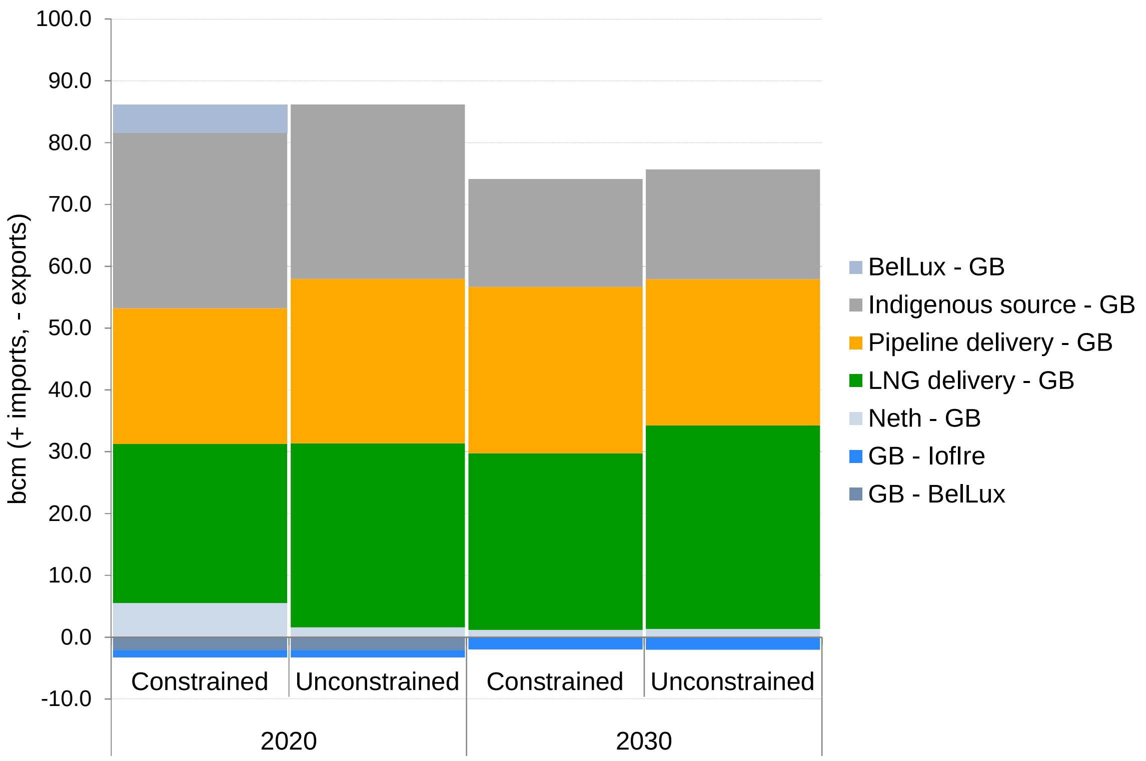


Figure 49 – Interconnection flows in Great Britain (bcm)

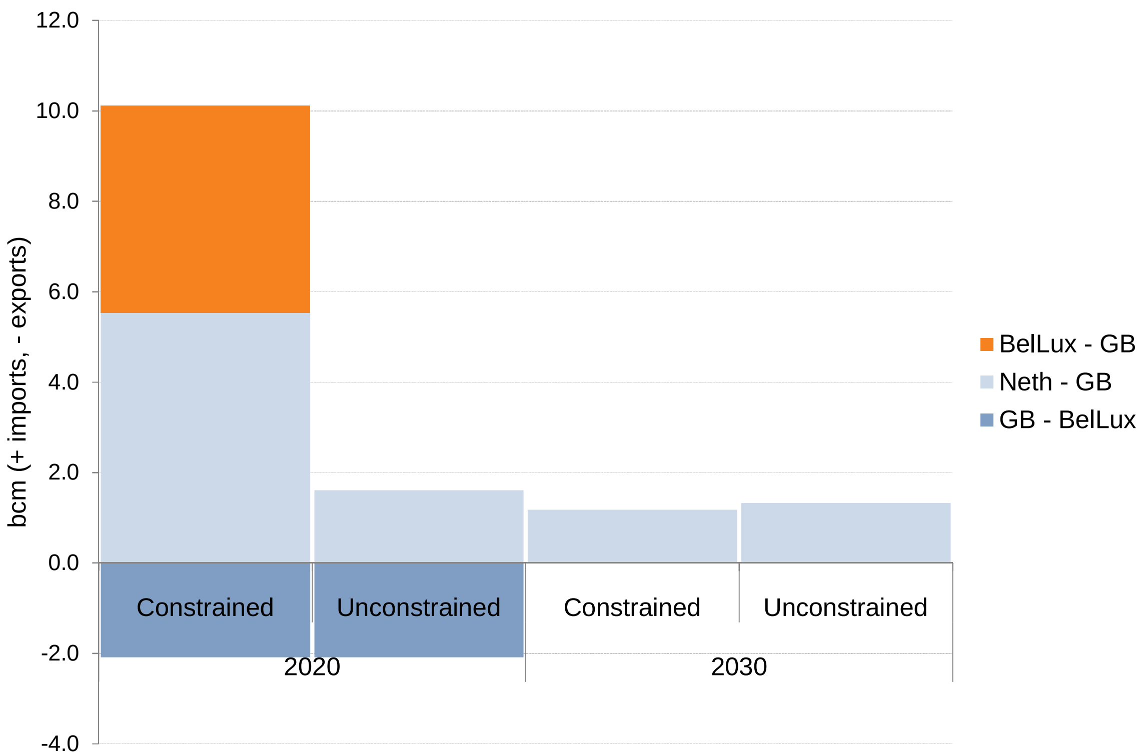
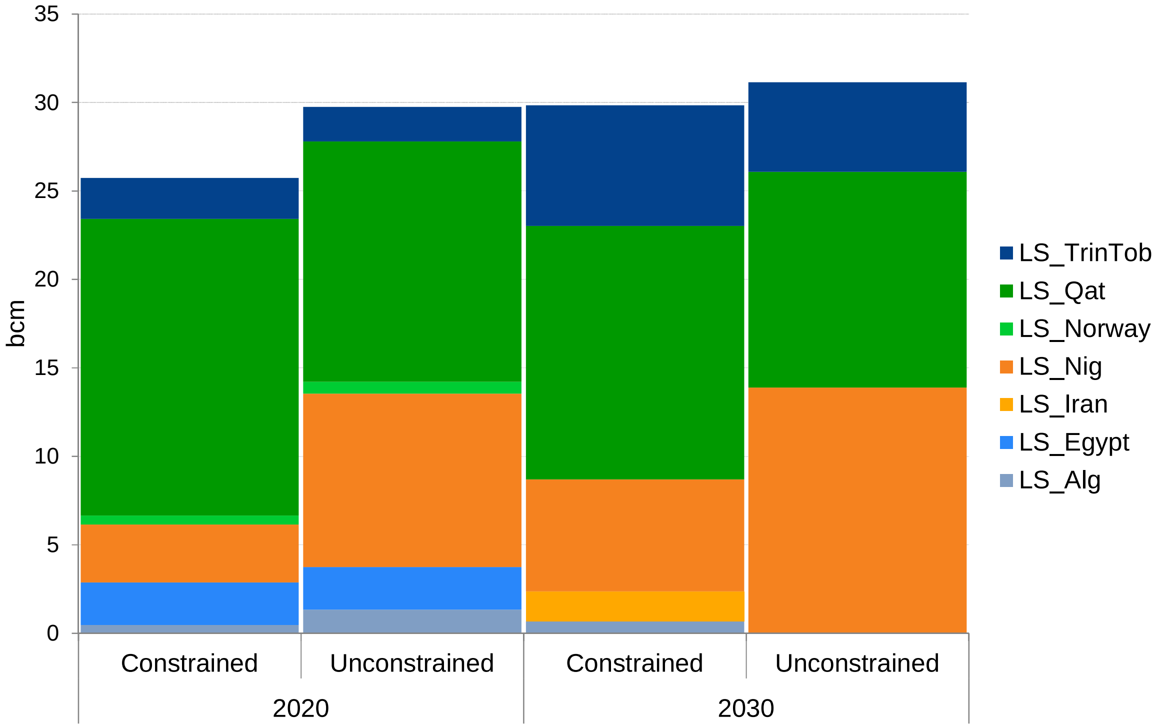


Figure 50 – LNG flows to Great Britain (bcm)



BelLux

614. Similar to flows to and from Great Britain, total flows to and from BelLux remains similar in the harmonised case. Flow mix shifts from LNG and interconnection flow to pipeline flow. More specifically, flows from France are replaced mainly by flows from Norway. Flows from BelLux to Germany also decrease slightly in 2020 in the harmonised case. Eliminated LNG flows mainly consist of Nigerian gas. Average gas quality is lower in the harmonised case as high quality LNG is replaced by lower quality Norwegian gas.

Figure 51 – Flows in BelLux (bcm)

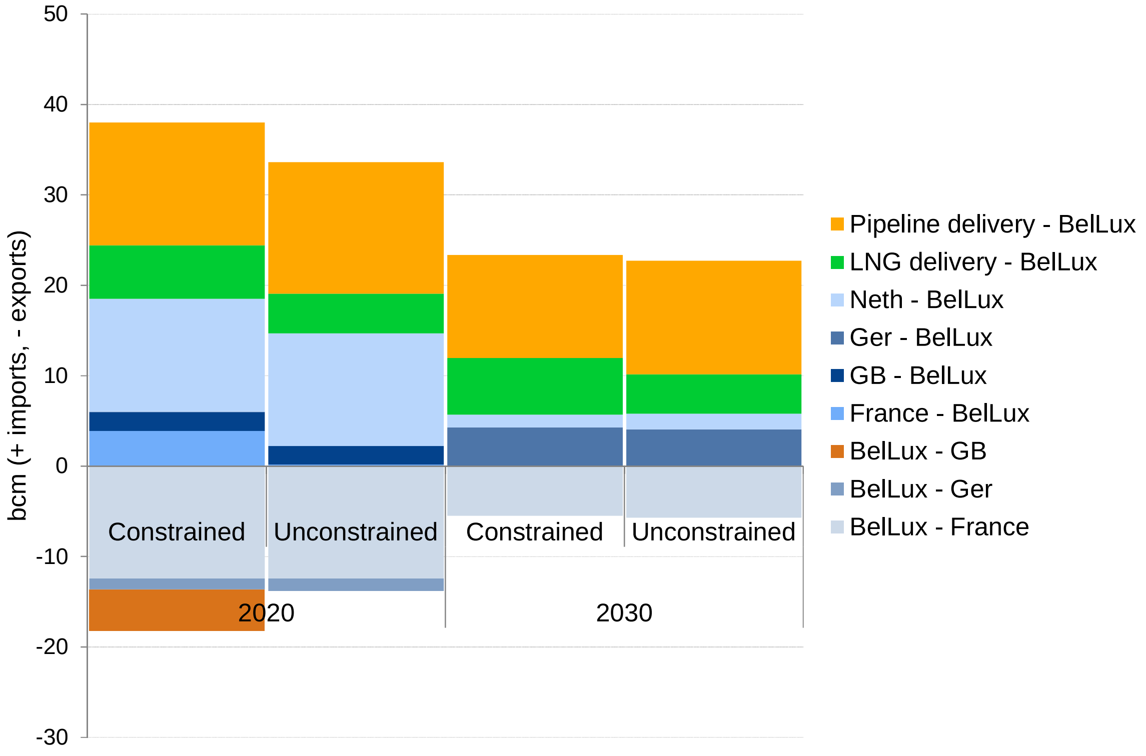


Figure 52 – Interconnection flows in BelLux (bcm)

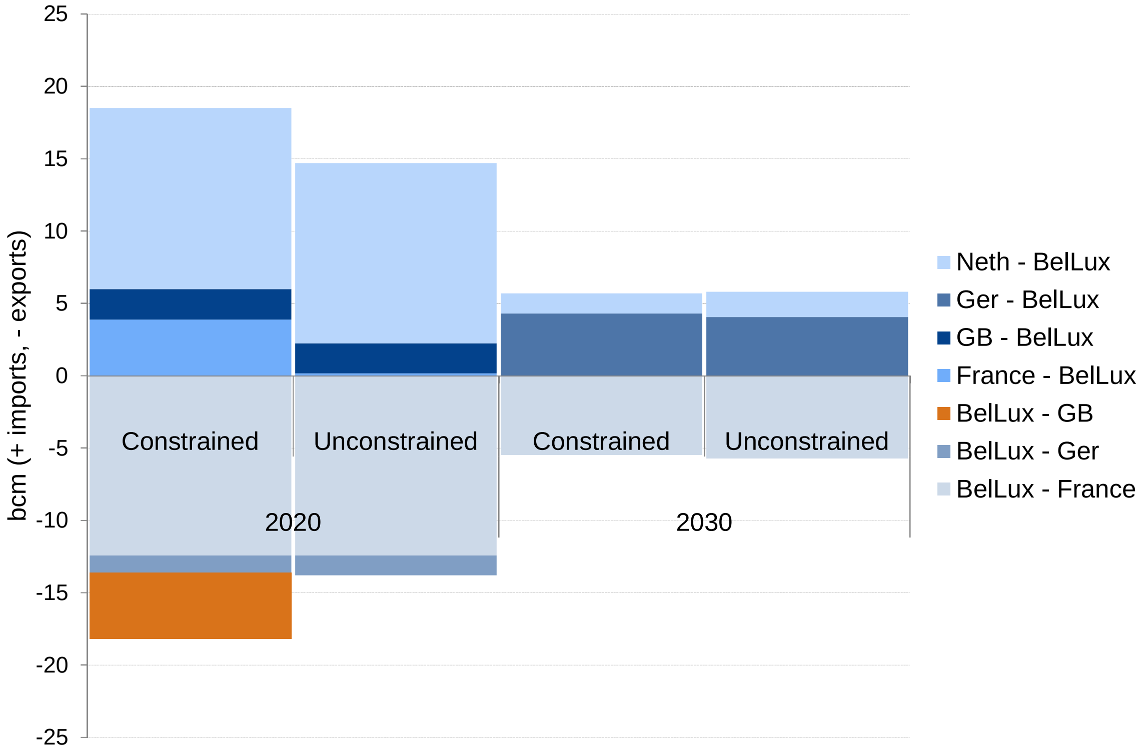
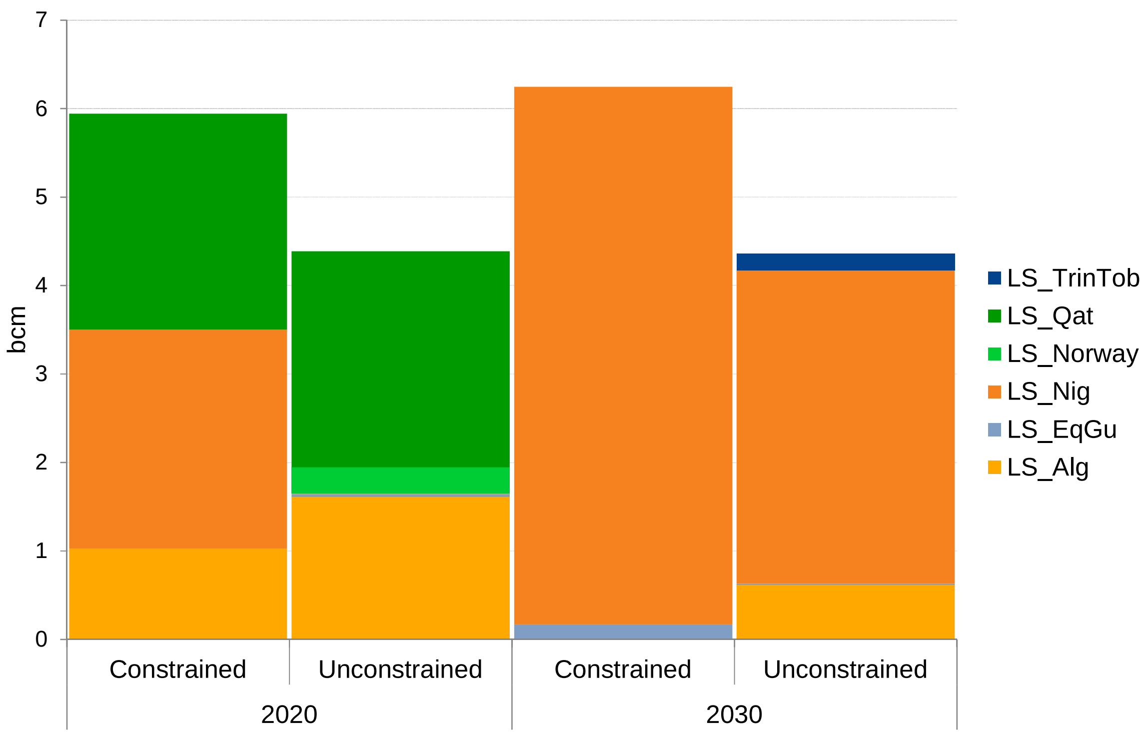


Figure 53 – LNG flows to BelLux (bcm)



The Netherlands

615. The total impact of harmonisation on the Dutch gas flow is limited. In 2020, gas flow mainly shifts from LNG to Norwegian gas. Majority of LNG from Iran and Trinidad Tobago divert from the Netherlands. Export to Great Britain increases, whereas export to Germany decreases in 2020. In 2030, changes in flows are immaterial.

Figure 54 – Flows in the Netherlands (bcm)

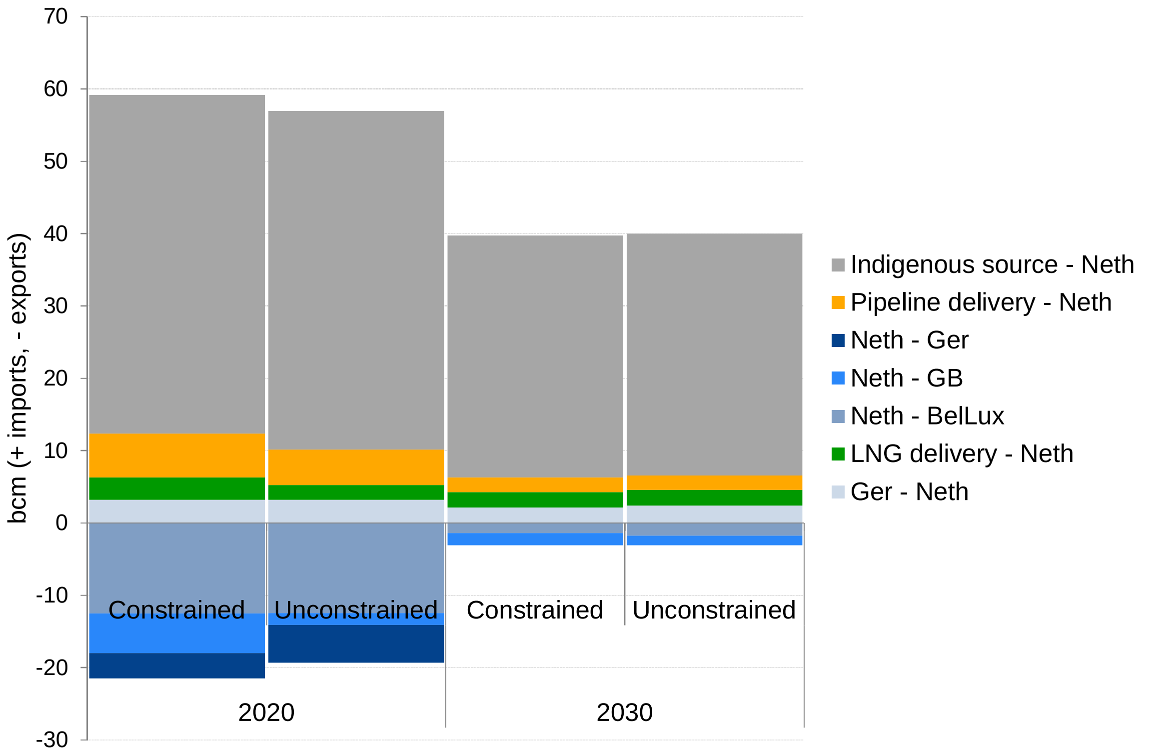


Figure 55 – Interconnection flows in the Netherlands (bcm)

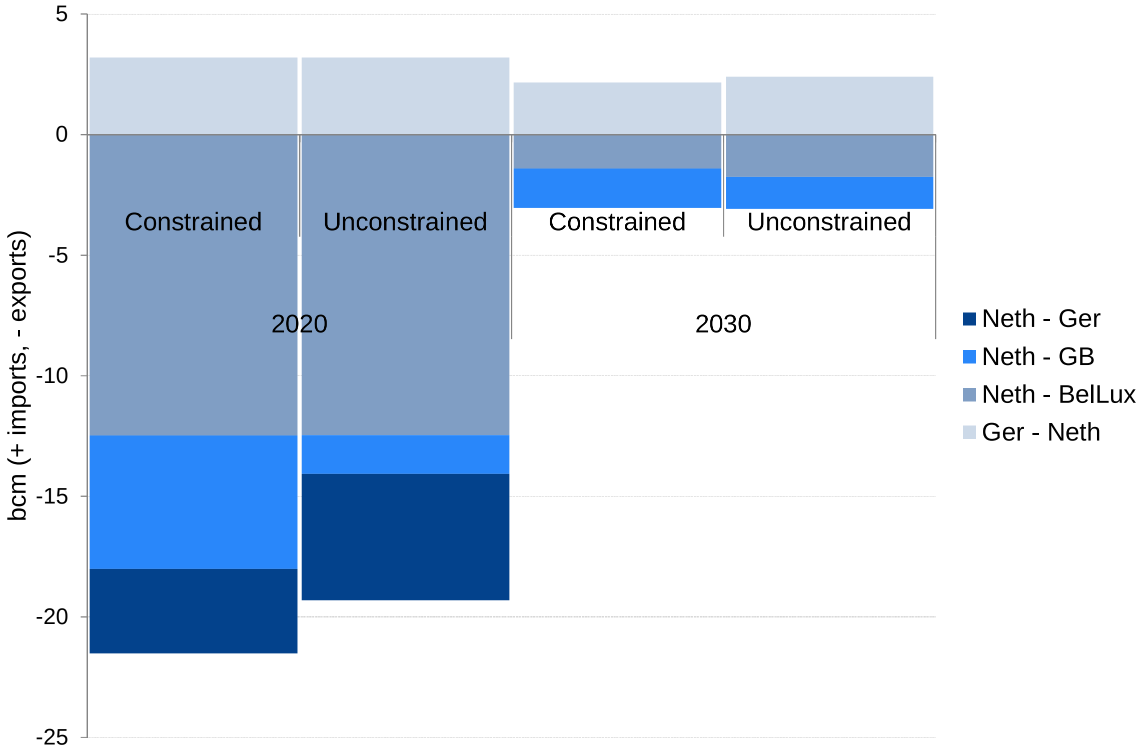
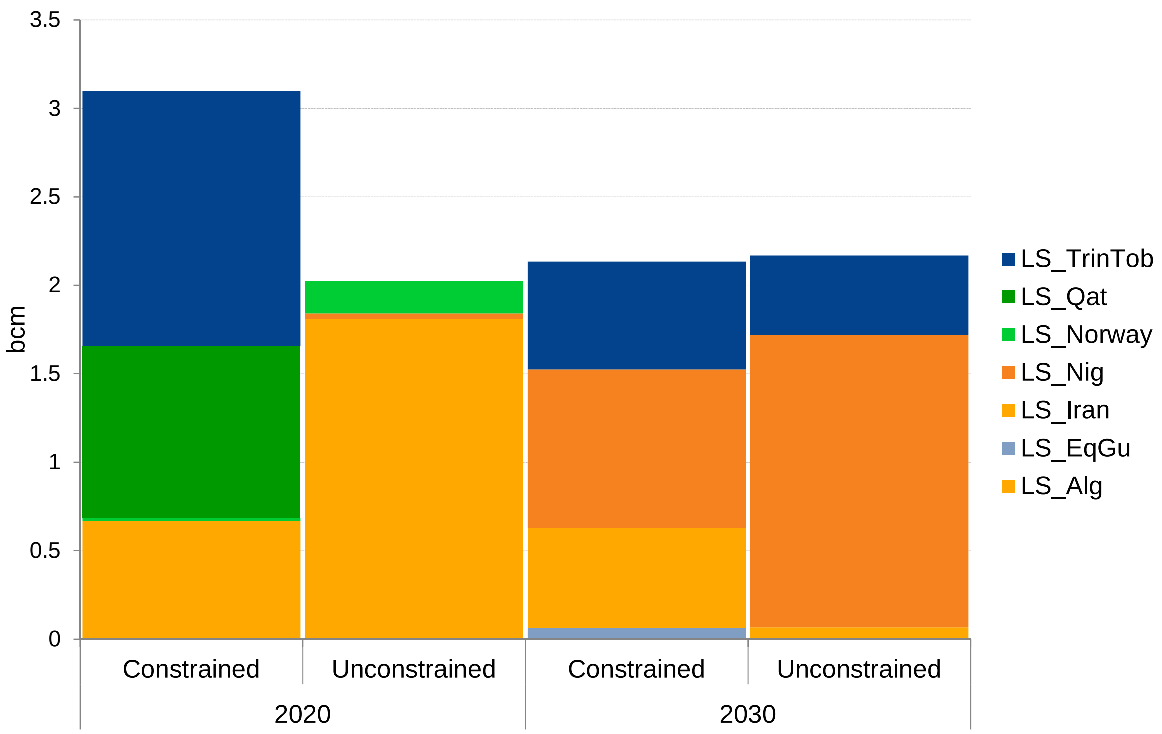


Figure 56 – LNG flows to the Netherlands (bcm)



France

616. Due to the decrease in the LNG flow to the country, total inflow decreases in 2020 in the harmonised case. Changes in the import flows are insignificant in both 2020 and 2030, whereas exports to BelLux stop in 2020 when quality constraints are removed. This is mainly because BelLux offsets gas flowing from France with Norwegian gas in the harmonised case. Due to lower flow of LNG, average gas quality decreases.

Figure 57 – Flows in France (bcm)

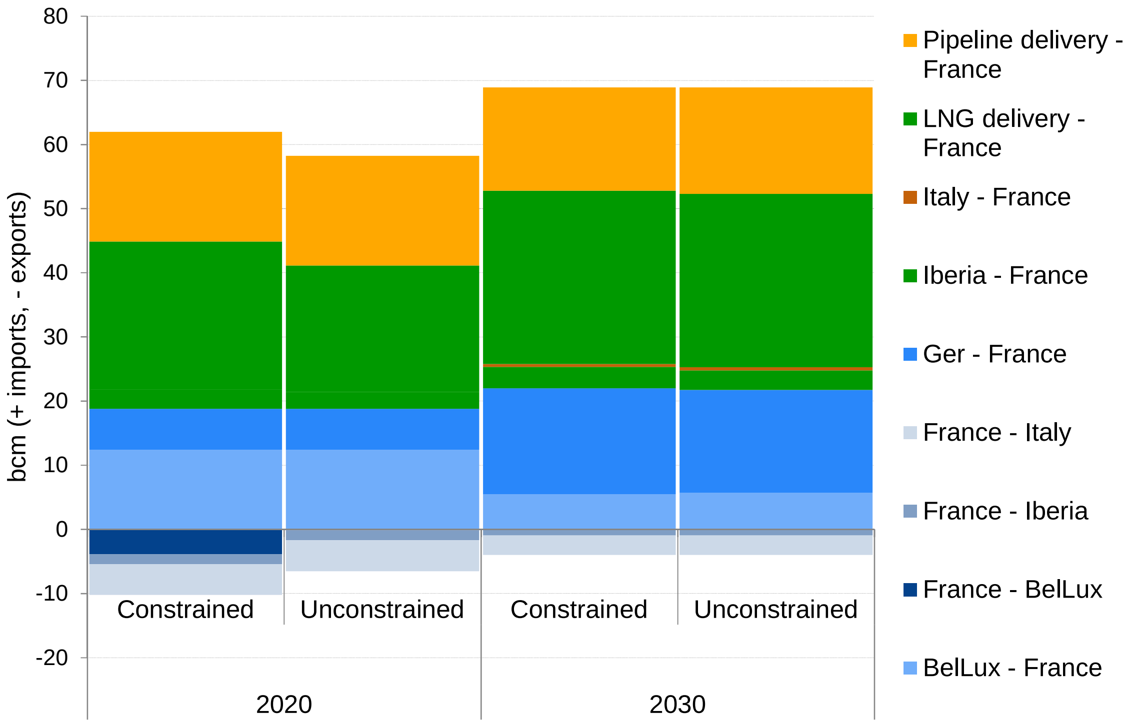


Figure 58 – Interconnection flows in France (bcm)

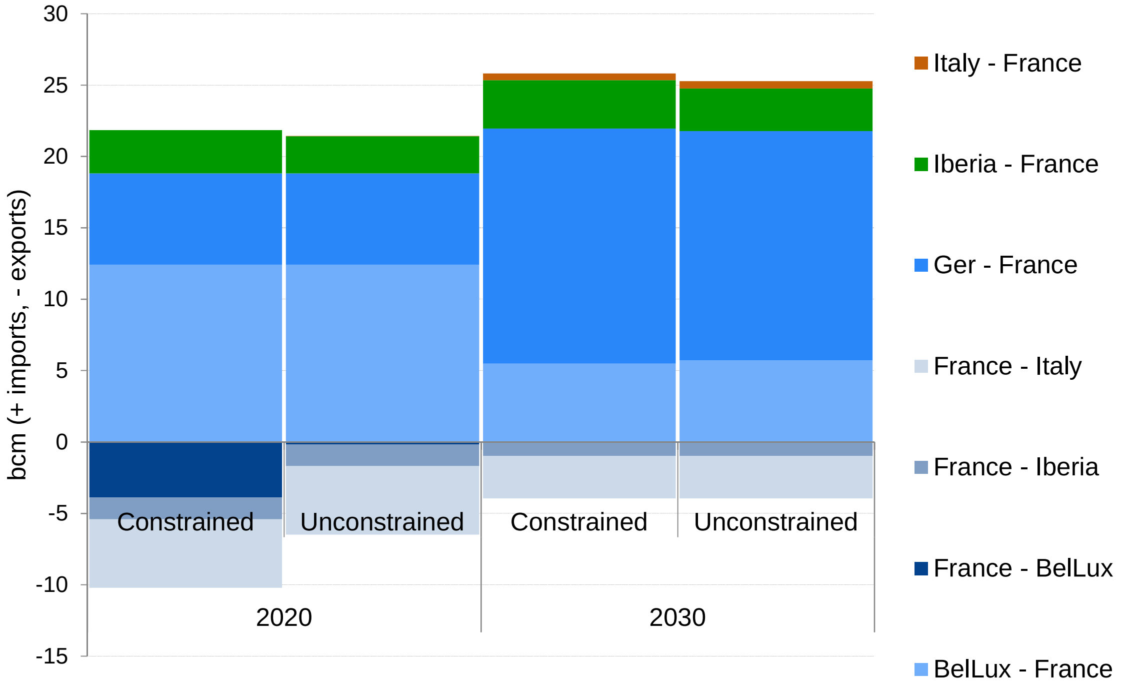
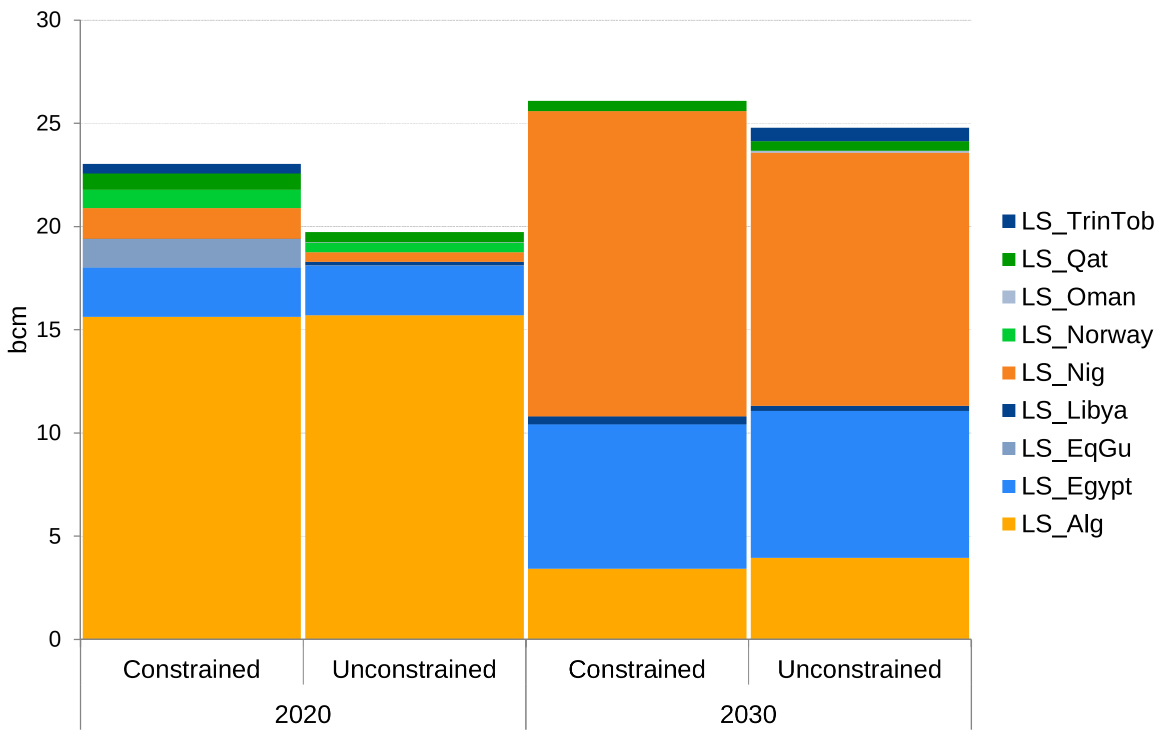


Figure 59 – LNG flows to France (bcm)



Germany

617. German gas flow does not change much when gas is harmonised. In 2020, Norwegian gas, which is delivered through pipeline, part of imports from the Netherlands and BelLux are replaced by imports from Czech Republic. On the other hand, export from Germany remains the same. In 2030, Germany receives limited LNG flows mainly from Norway and Nigeria.

Figure 60 – Flows in Germany (bcm)

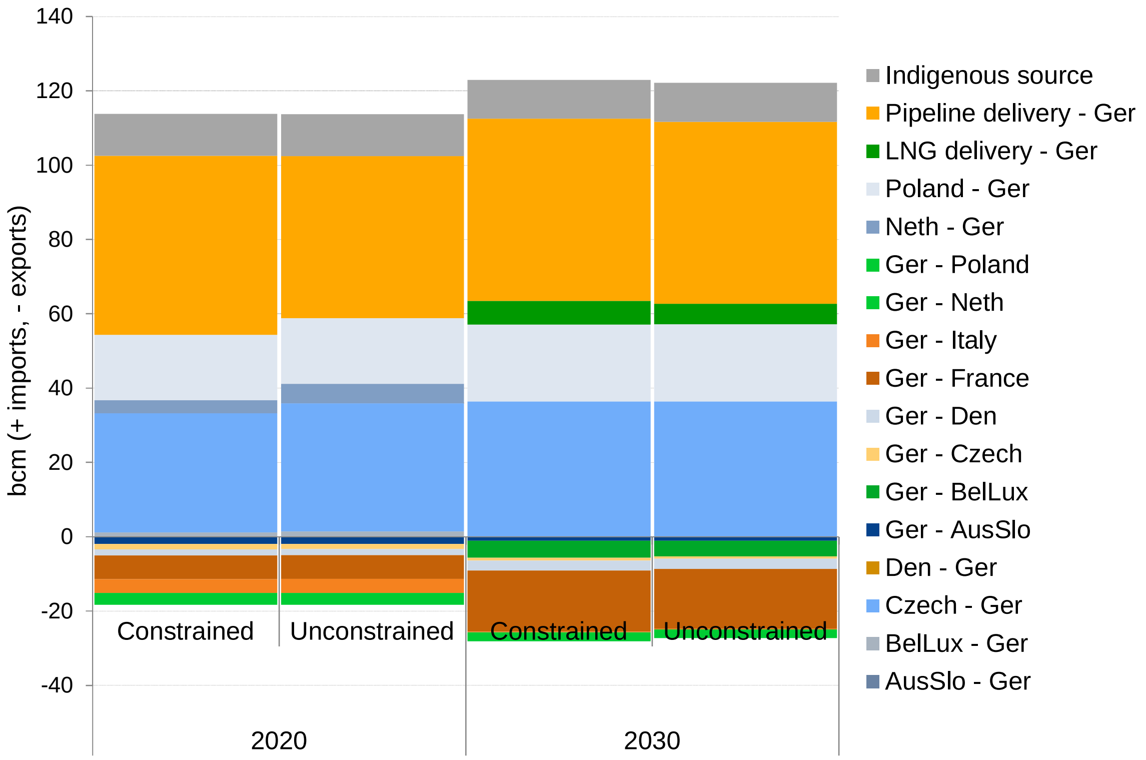


Figure 61 – Interconnection flows in Germany (bcm)

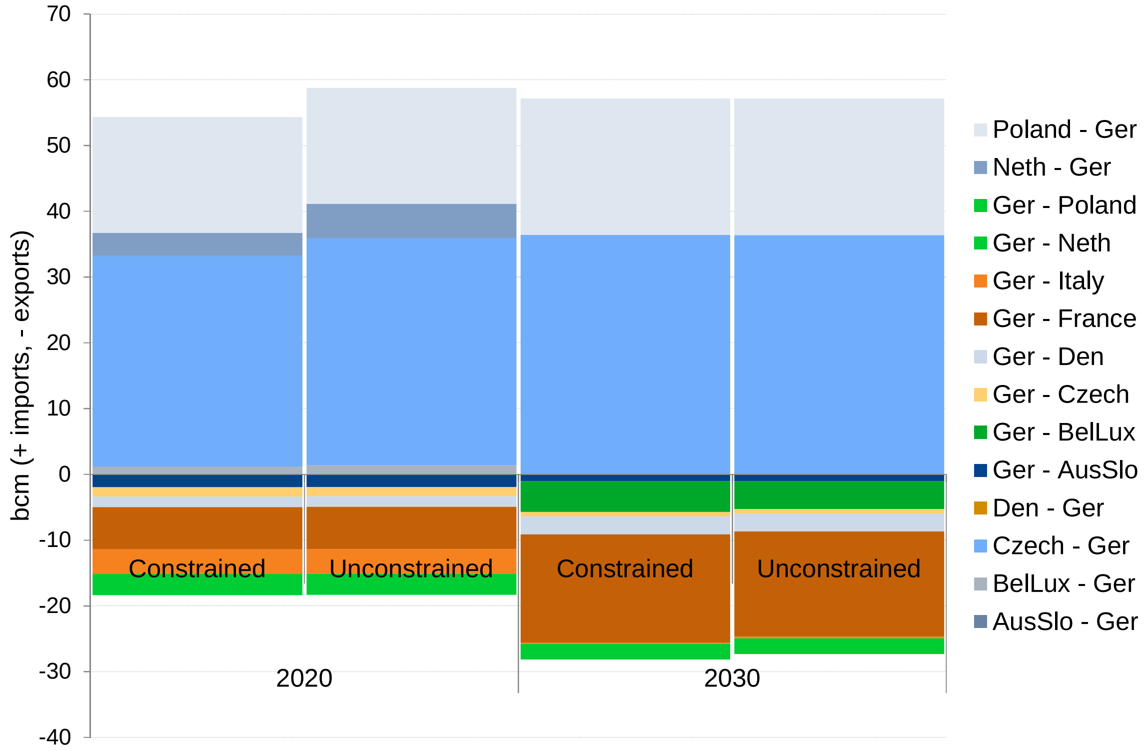
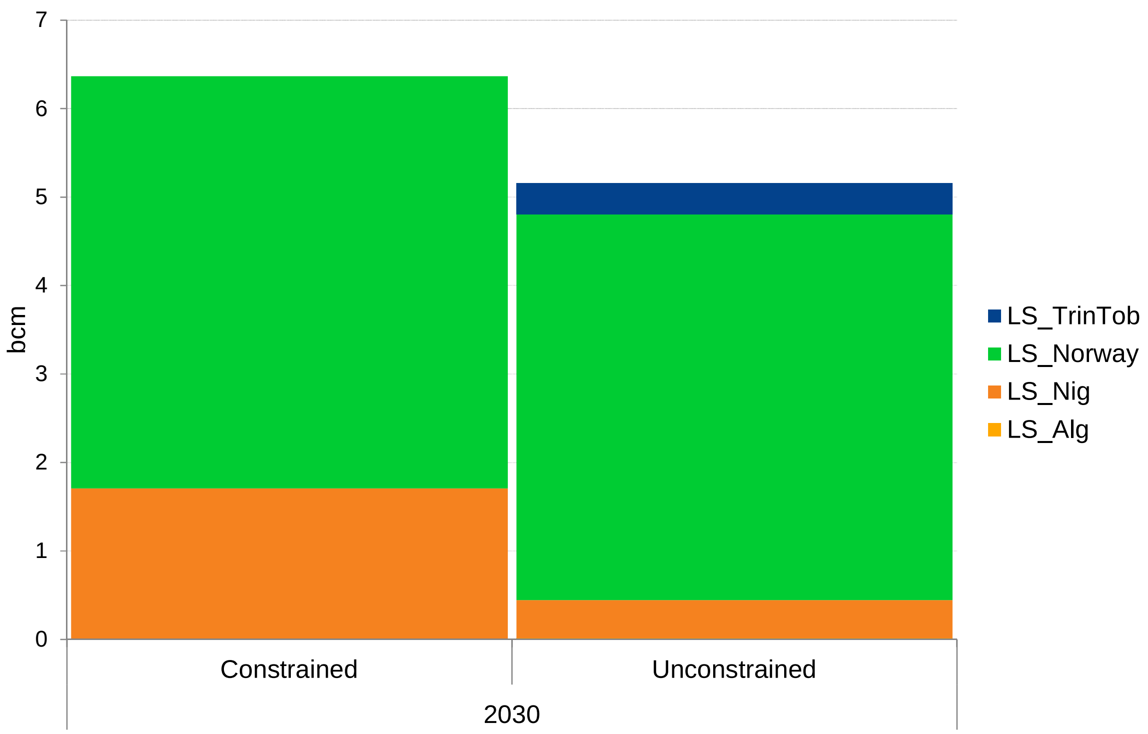


Figure 62 – LNG flows to Germany (bcm)



Italy

618. Similar to flows in Germany, flows in Italy do not change in 2030 in the harmonised case. LNG increases and imports from AusSlo decrease in 2020. Removing gas quality constraints allows Italy to benefit more from LNG sources, which have higher quality. As a result, average gas quality is increased in 2020. Additional LNG flows in the harmonised case mainly come from Iran, Yemen and Oman.

Figure 63 – Flows in Italy (bcm)

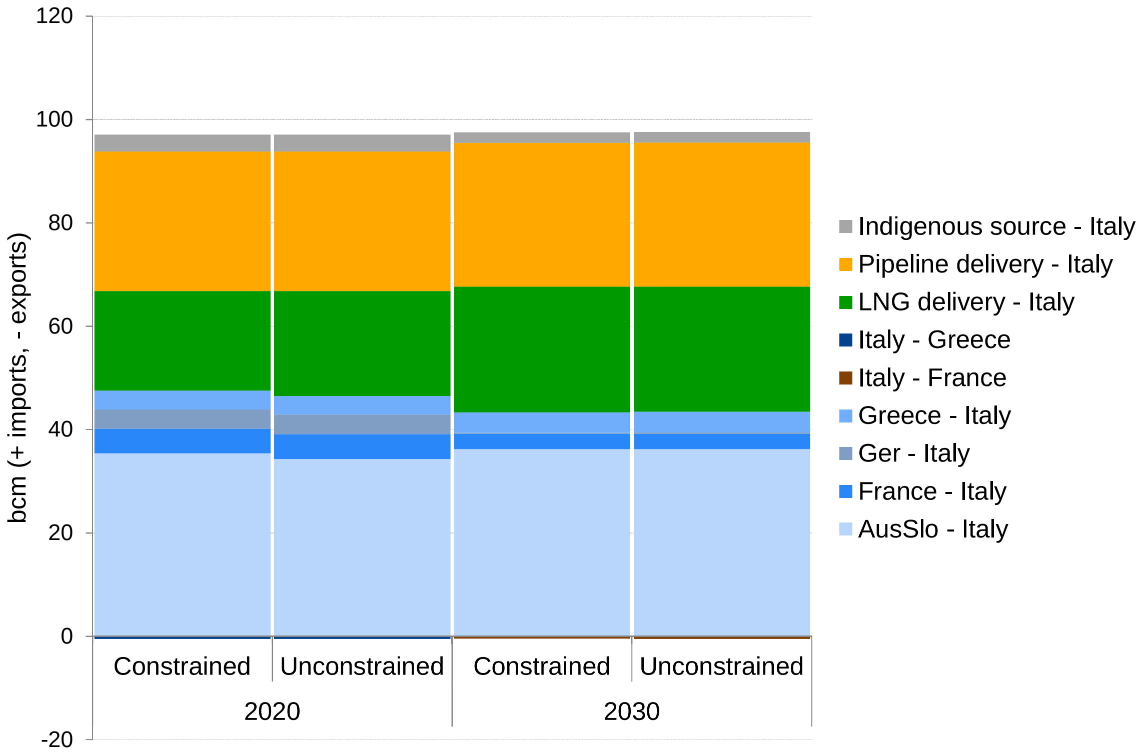


Figure 64 – Interconnection flows in Italy (bcm)

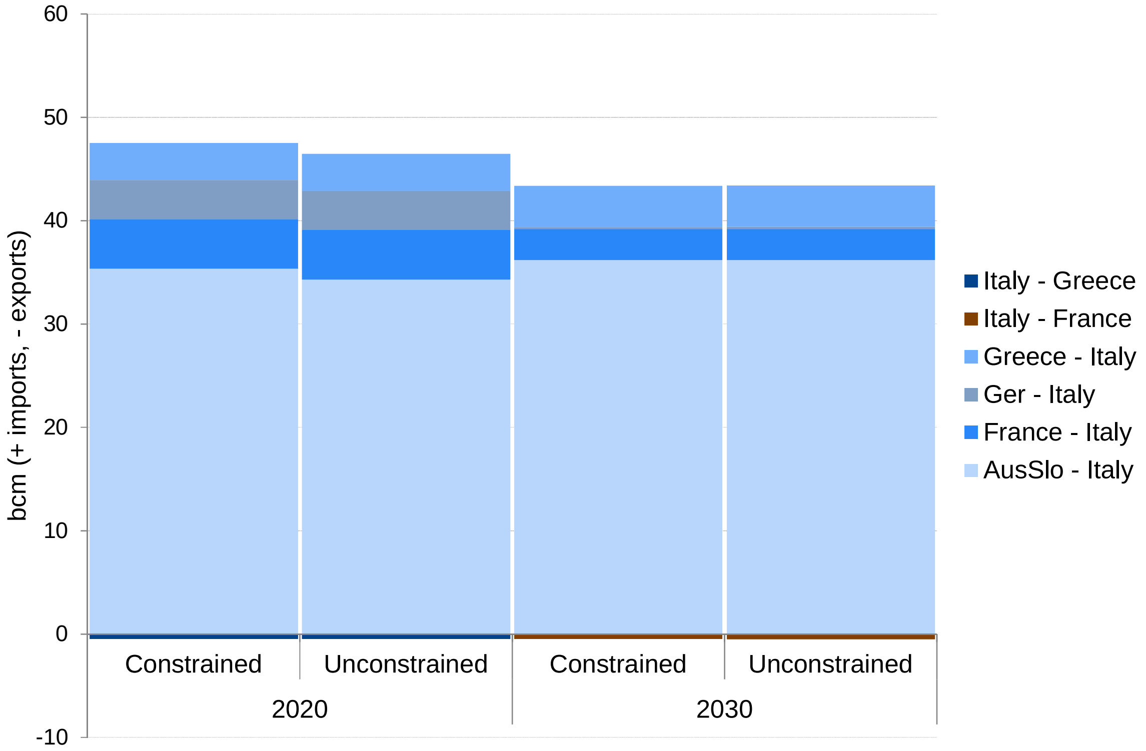
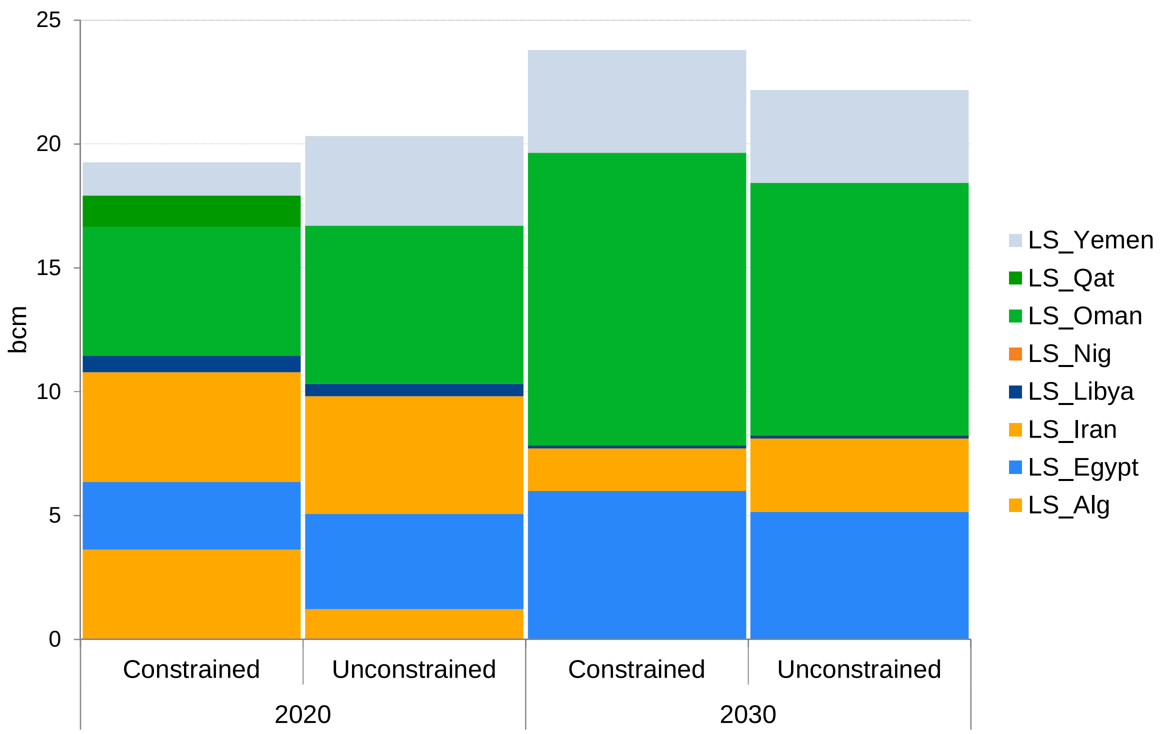


Figure 65 – LNG flows to Italy (bcm)



I.2.2.3 Accumulated flow changes

619. Total interconnection flow decreases by 0.9% (2540 mcm) in 2020 and by 0.3% (752 mcm) in 2030 in the harmonised case compared to disharmonised case. Total LNG flows and pipeline flows remain the same when gas is harmonised.

LNG flow changes

620. Although the total LNG flow does not change between harmonised and disharmonised cases, LNG flows change their routes in the harmonised scenario. LNG flow to BelLux, Netherlands and France decrease, whereas LNG flow to Great Britain, Italy and Poland increase in the harmonised case compared to the disharmonised case.

621. More specifically, main LNG route changes can be summarised as follows:
   - Algerian gas diverts mainly from Great Britain to BelLux and France in both 2020 and 2030;
   - Nigerian gas diverts from BelLux, France, US and BelLux to Great Britain and Netherlands in 2020 and to Netherlands only in 2030;
   - Iranian gas diverts from Great Britain, Poland and Netherlands to Italy and Far East in both 2020 and 2030;;
   - Norwegian gas diverts from Great Britain and US to Netherlands, France and BelLux in both 2020 and 2030.

Table 27 – Flows in 2020 (mcm)

From	To	Constrained	Unconstrained	Difference	Absolute difference
AusSlo	Italy	35,389	34,308	1,080	1,080
BelLux	France	12,399	12,416	-16	16
BelLux	GB	4,589	0	4,589	4,589
BelLux	Germany	1,179	1,369	-191	191
Czech Rep.	Germany	32,016	34,535	-2,519	2,519
Denmark	Germany	0	0	0	0
France	BelLux	3,890	158	3,732	3,732
France	Iberia	1,541	1,539	2	2
France	Italy	4,800	4,814	-14	14
GB	BelLux	2,080	2,086	-6	6
Germany	AusSlo	1,921	1,919	2	2
Germany	BelLux	44	0	44	44
Germany	Denmark	1,639	1,639	0	0
Germany	France	6,420	6,427	-7	7
Germany	Italy	3,752	3,752	1	1
Germany	Netherlands	3,201	3,191	10	10
Greece	Italy	3,602	3,599	2	2
Iberia	France	3,042	2,626	416	416
Italy	France	4	4	0	-
Italy	Greece	492	492	0	0
Netherlands	BelLux	12,462	12,459	4	4
Netherlands	GB	5,568	1,596	3,972	3,972
Netherlands	Germany	3,502	5,226	-1,724	1,724
Poland	Germany	17,581	17,592	-12	12

Table 28 – Flows in 2030 (mcm)

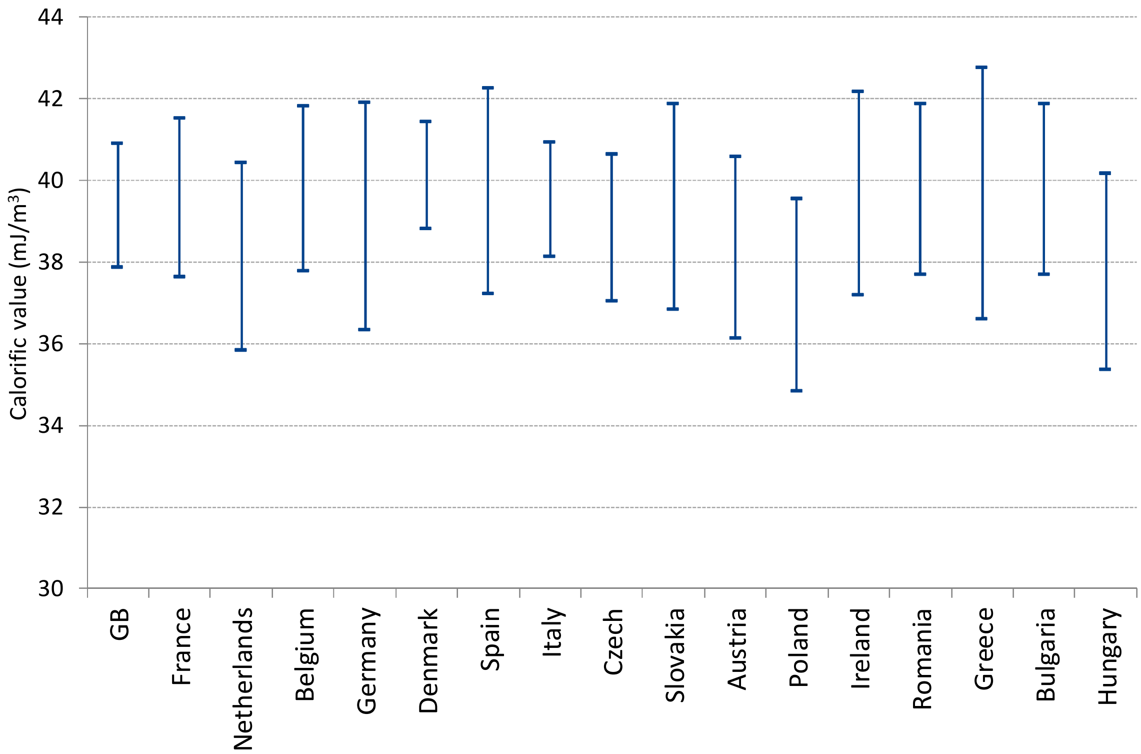
From	To	Constrained	Unconstrained	Difference	Absolute difference
AusSlo	Germany	0	12	-12	12
AusSlo	Italy	36,230	36,228	2	2
BelLux	France	4,338	5,762	-1,424	1,424
Czech Rep.	Germany	36,500	36,332	168	168
Denmark	Germany	0	0	0	-
France	Iberia	960	962	-2	2
France	Italy	3,007	3,006	1	1
GB	BelLux	0	0	0	-
Germany	AusSlo	1,040	1,040	0	0
Germany	BelLux	3,551	4,181	-630	630
Germany	Czech Rep.	700	701	-1	1
Germany	Denmark	2,702	2,701	1	1
Germany	France	17,608	16,104	1,504	1,504
Germany	Italy	173	220	-47	47
Germany	Netherlands	2,402	2,400	2	2
Greece	Italy	4,005	4,004	1	1
Iberia	France	3,892	3,003	889	889
Italy	France	745	512	232	232
Netherlands	BelLux	1,639	1,861	-222	222
Netherlands	GB	1,777	1,322	455	455
Netherlands	Germany	0	0	0	-
Poland	Germany	20,774	20,813	-39	39

I.2.3 Calorific value

622. This section presents the results from the CV modelling. The first section examines the high level results, with the following sections drilling down to examine more detailed results.

623. We examined the impact of harmonising the gas quality specifications from a set of CV constraints (more stringent than the Wobbe constraints presented above). These constraints are presented in Figure 66. This has considered an infinite harmonised quality, i.e. the analysis explores the benefit of removing all the modelled CV constraints.

Figure 66 – Calorific values (mJ/m³)



Source: CEN/AFNOR/WG 197 Gas Quality 2010, Pöyry analysis

I.2.3.1 High-level results

624. Benefit of harmonisation is only 0.05% of the objective function value in 2020. In 2030, benefits are estimated to be even lower and to make 0.03% of the objective function value. Compared to Wobbe index modelling, benefits are higher in both percentage and absolute terms. This is mainly due to more stringent quality constraints applied in the calorific value modelling.

625. The term 'constrained scenario' below refers to the non-harmonised case, where gas flow is subject to gas quality constraints (which is closest to the real market), and 'unconstrained scenario' refers to harmonised case, where gas quality constraints do not apply.

Table 29 – Objective function values

Gas year	Scenario	Objective function value (EUR)	Benefit of harmonisation
2020	Unconstrained	354,653,349,115	
2020	Constrained	354,829,570,824	176,221,709
2030	Unconstrained	402,931,504,050	
2030	Constrained	403,053,282,826	121,778,776

I.2.3.2 Flow changes

Great Britain

626. Flows from and to Great Britain do not differ significantly between harmonised and disharmonised cases. Harmonisation of gas quality increases flow from the Netherlands to Great Britain approximately 350%, however the volume of gas flowing from Netherlands is significantly less than other flows. In the disharmonised case, Great Britain's narrower gas quality range prevents most of the gas from flowing from the Netherlands to Great Britain.

627. In addition to the interconnection flow change, LNG flows increase slightly and pipeline flows from Norway decrease. This is mainly because the gas quality of some LNG is a better match for Great Britain's quality constraints compared to some Norwegian gas.

628. LNG sourcing also shifts from Trinidad Tobago, Iran and Norway to Nigeria in the harmonised scenario. Nigerian gas, having a high gas quality, cannot flow to Great Britain in the disharmonised case as its gas quality is too high compared to Great Britain's quality constraints. As a result of more high quality LNG flow, average gas quality in Great Britain is found to be higher in the harmonised case.

Figure 67 – Flows in Great Britain (bcm)

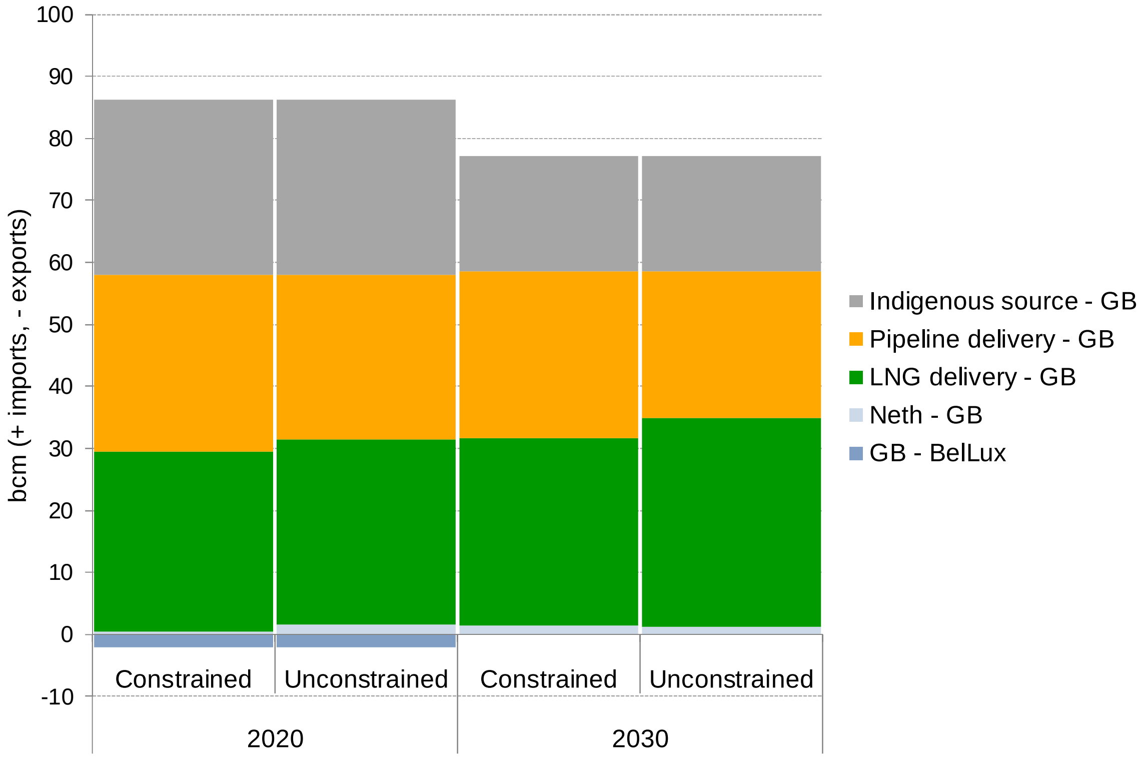


Figure 68 – Interconnection flows in Great Britain (bcm)

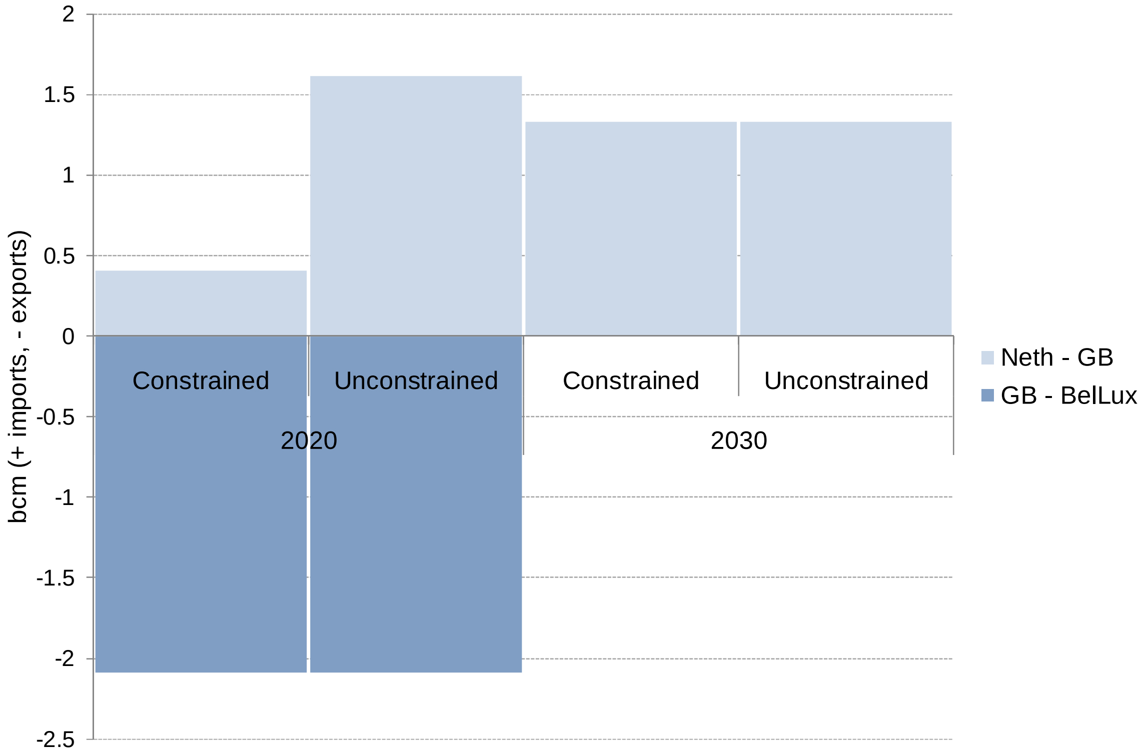
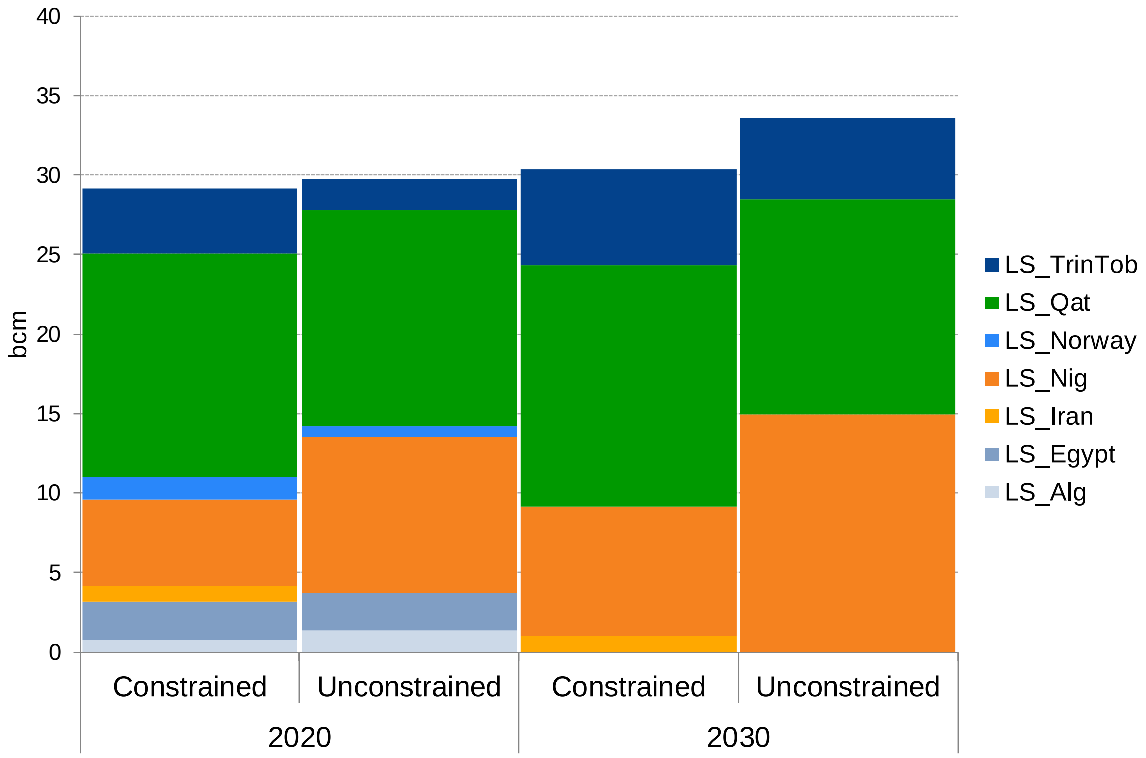


Figure 69 – LNG flows to Great Britain (bcm)



BelLux

629. Total flows to and from BelLux decrease in the harmonised case in 2020. In 2030, however flow changes are insignificant. Flow mix shifts from LNG and interconnection flow to pipeline flow. More specifically, flows from France are replaced mainly by flows from Norway. Flows from BelLux to Germany also decrease slightly in 2020 in the harmonised case. Eliminated LNG flows mainly consist of Nigerian and Equatorial Guinea gas. Average gas quality is lower in the harmonised case as high quality LNG is replaced by lower quality Norwegian gas.

Figure 70 – Flows in BelLux (bcm)

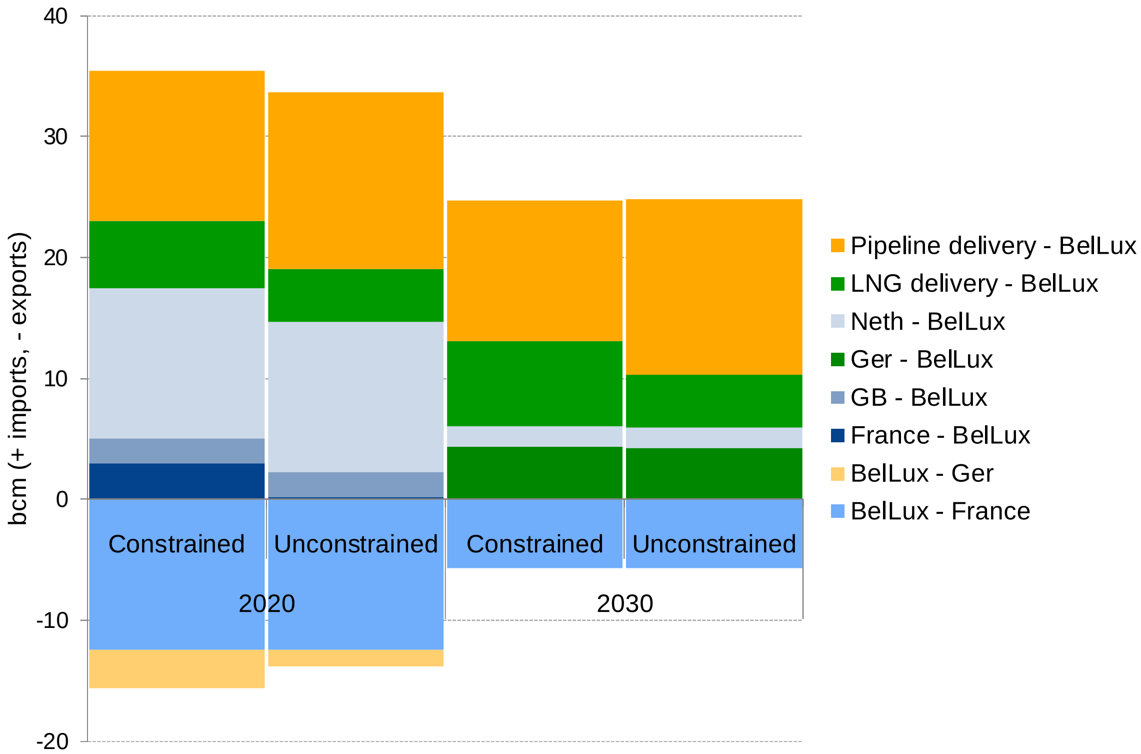


Figure 71 – Interconnection flows in BelLux (bcm)

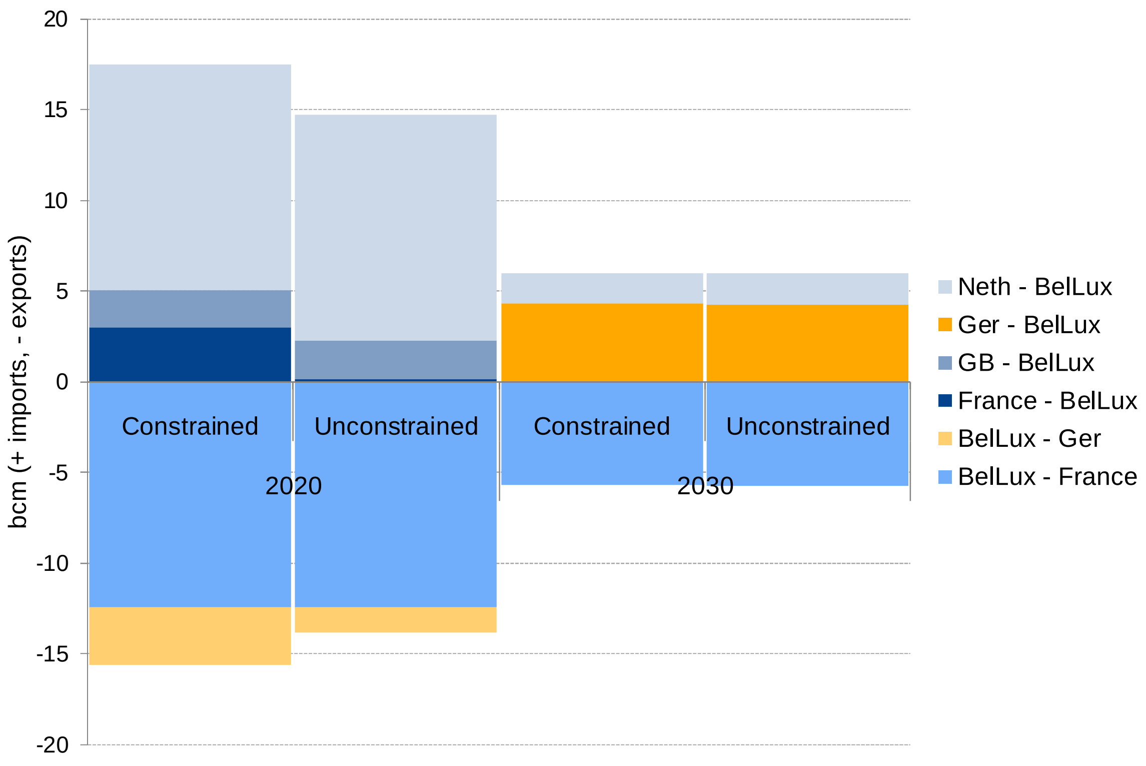
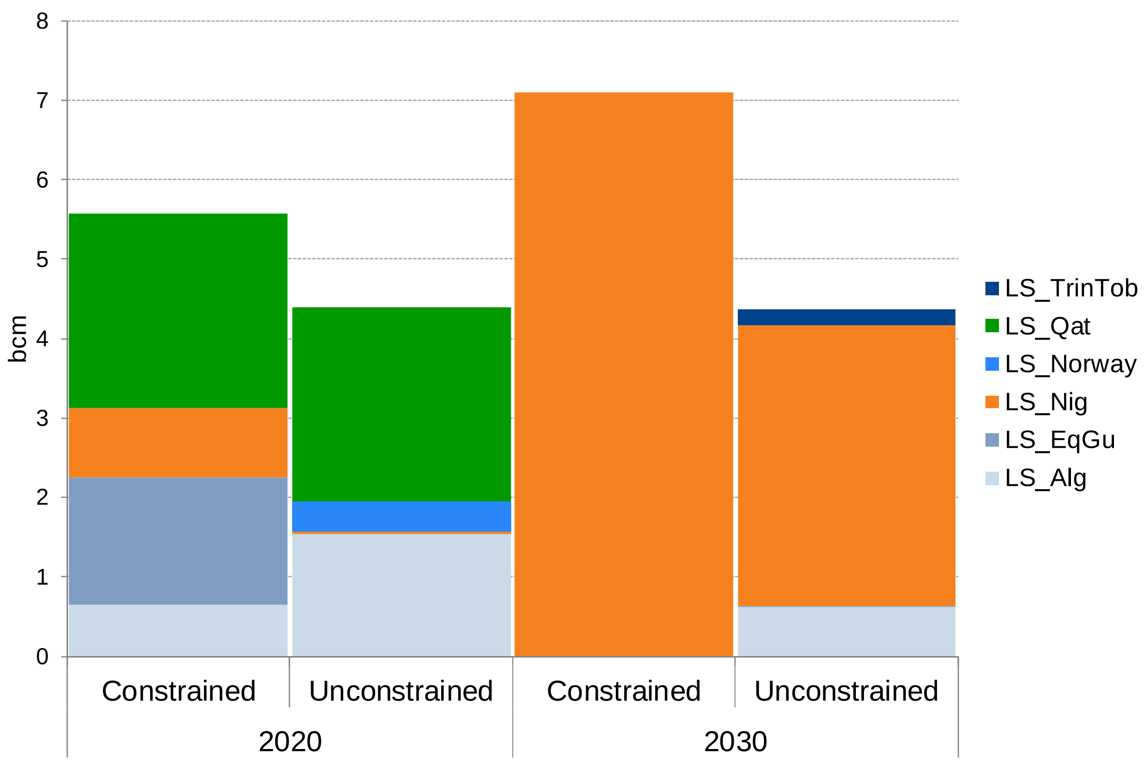


Figure 72 – LNG flows to BelLux (bcm)



The Netherlands

630. Total impact of harmonisation on the Dutch gas flow is limited. In 2020, gas flow mainly shifts from LNG to Norwegian gas. Majority of LNG from Iran, Trinidad Tobago, Equatorial Guinea and Nigeria divert from the Netherlands. Algerian gas' share in the LNG flow increases in 2020. Export to Great Britain increases, whereas export to Germany decreases in 2020. In 2030, changes in flows are immaterial.

Figure 73 – Flows in the Netherlands (bcm)

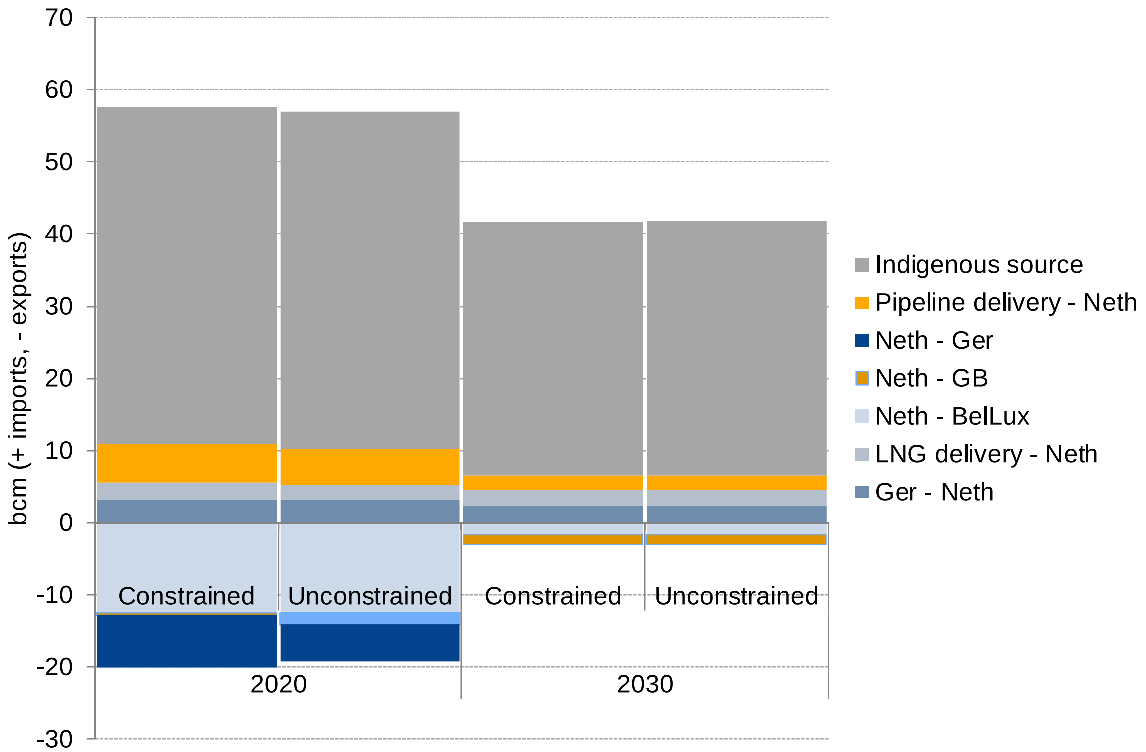


Figure 74 – Interconnection flows in the Netherlands (bcm)

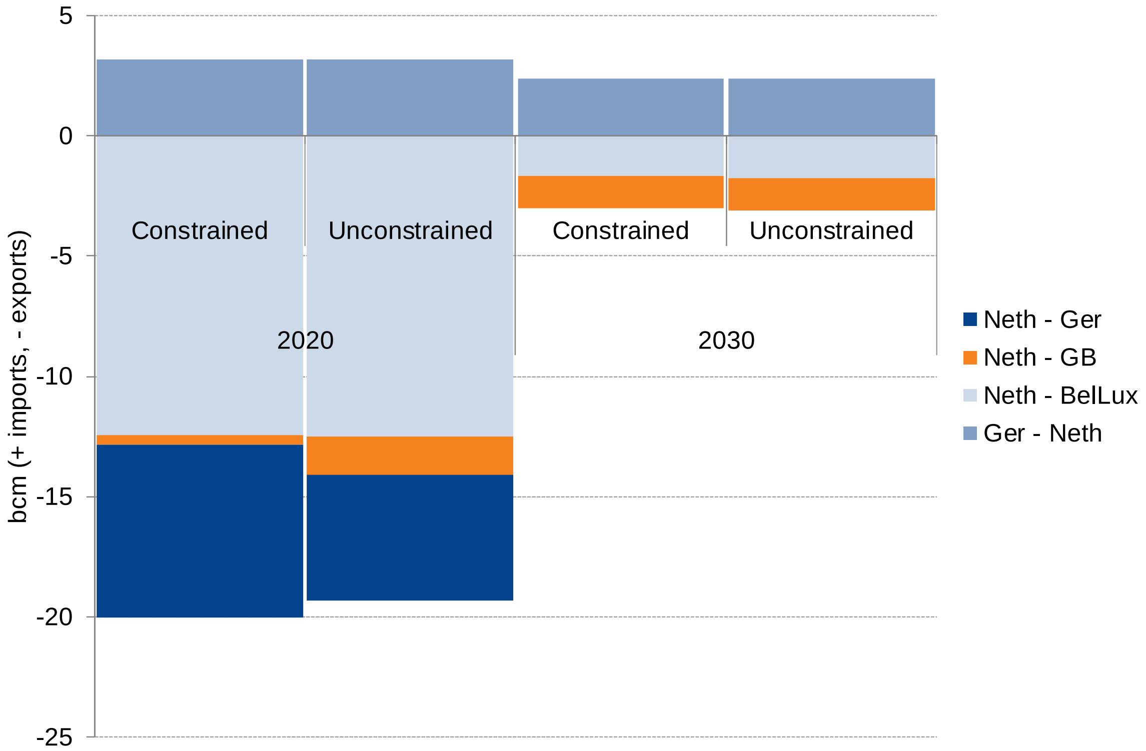
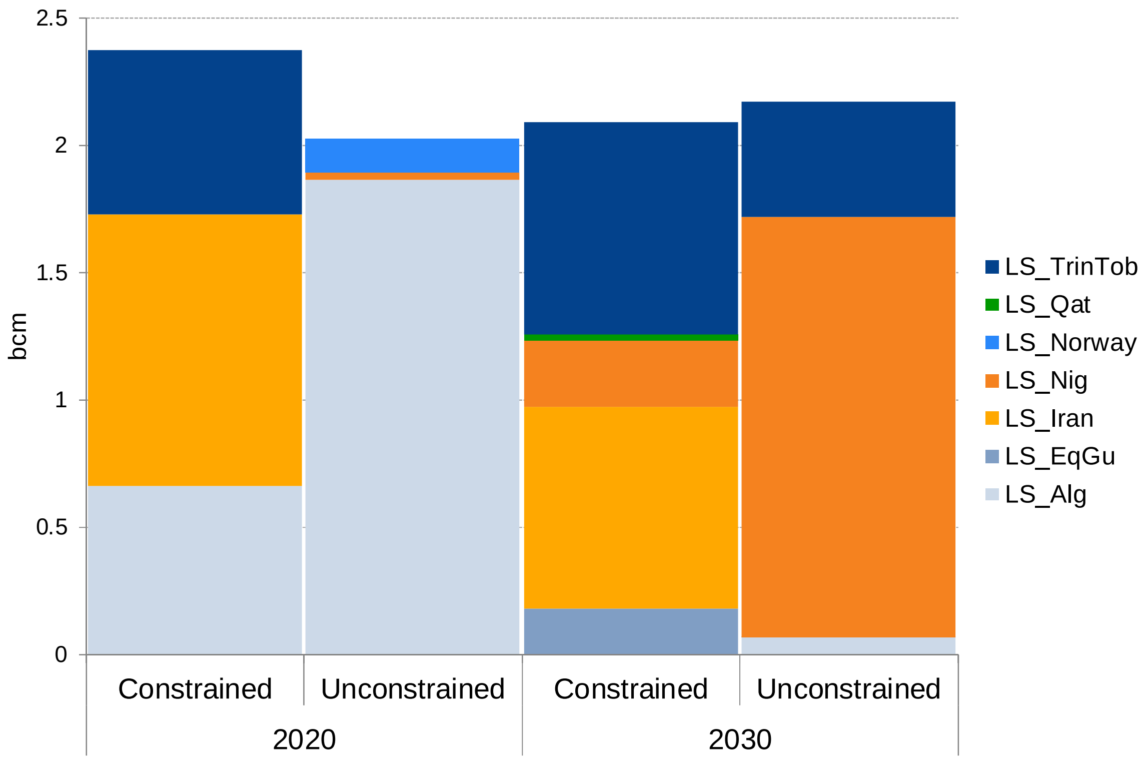


Figure 75 – LNG flows to the Netherlands (bcm)



France

631. Due to the decrease in the LNG flow to the country, total inflow decreases in 2020 in the harmonised case. In 2030, total LNG flow does not change much, but the mix contains more Egyptian and less Nigerian gas. Changes in the import flows are insignificant in both 2020 and 2030, whereas exports to BelLux stop in 2020 when quality constraints are removed. This is partly because BelLux offsets gas flowing from France with Norwegian gas in the harmonised case. Due to lower flow of LNG, average gas quality decreases in 2020.

Figure 76 – Flows in France (bcm)

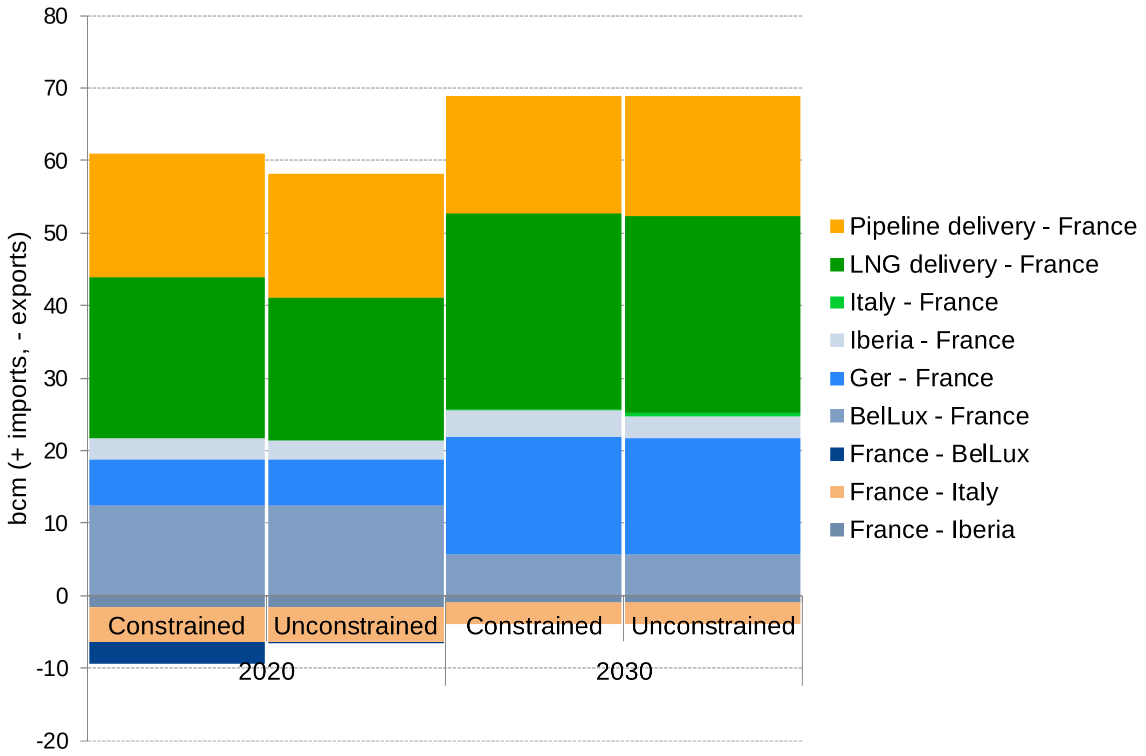


Figure 77 – Interconnection flows in France (bcm)

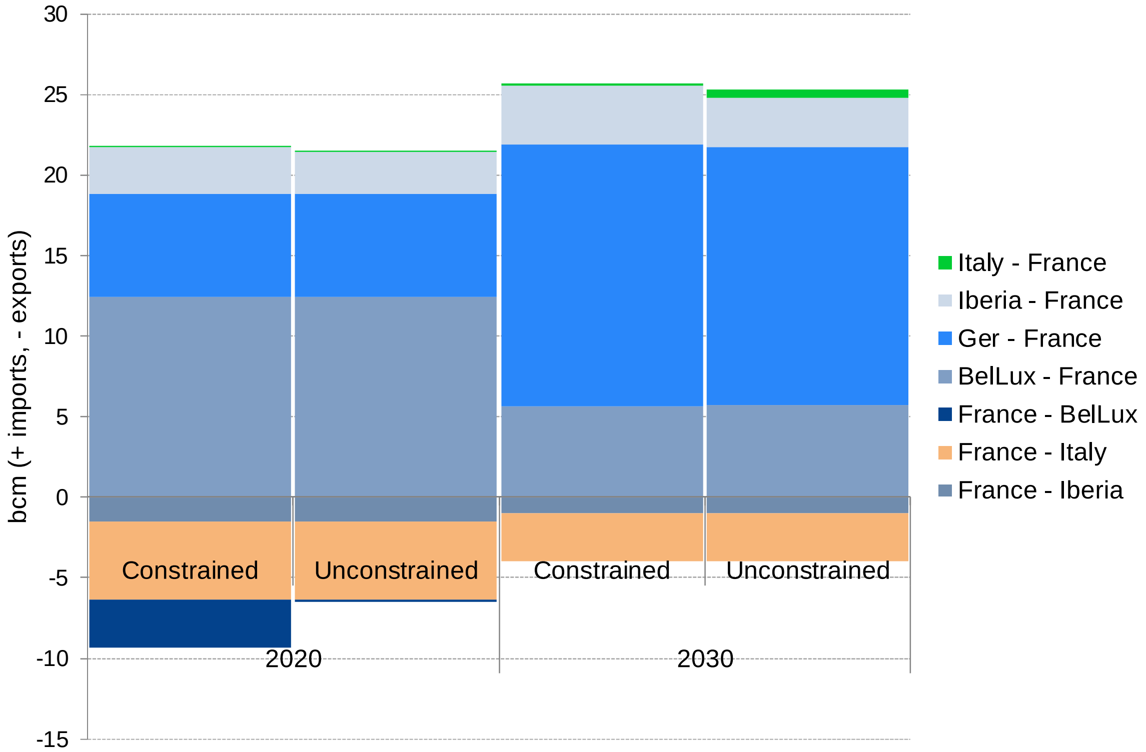
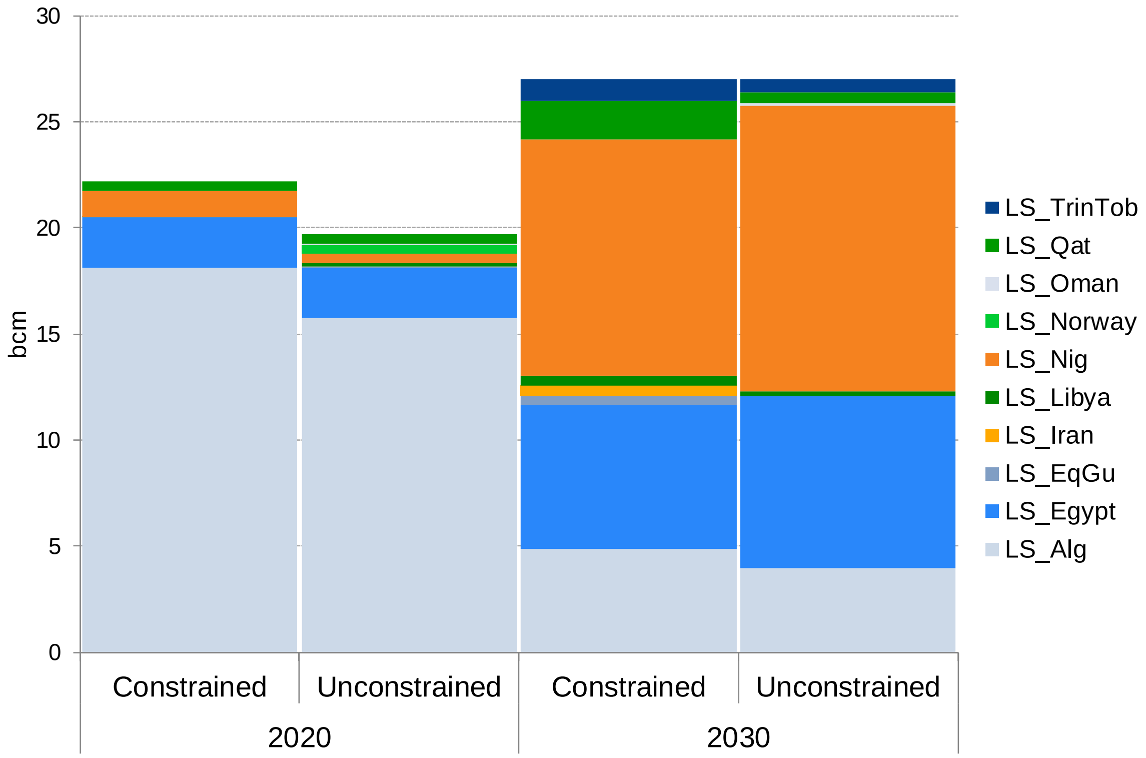


Figure 78 – LNG flows to France (bcm)



Germany

632. German gas flow does not change much when gas is harmonised. In 2030, Germany receives limited LNG flows mainly from Norway and Nigeria.

Figure 79 – Flows in Germany (bcm)

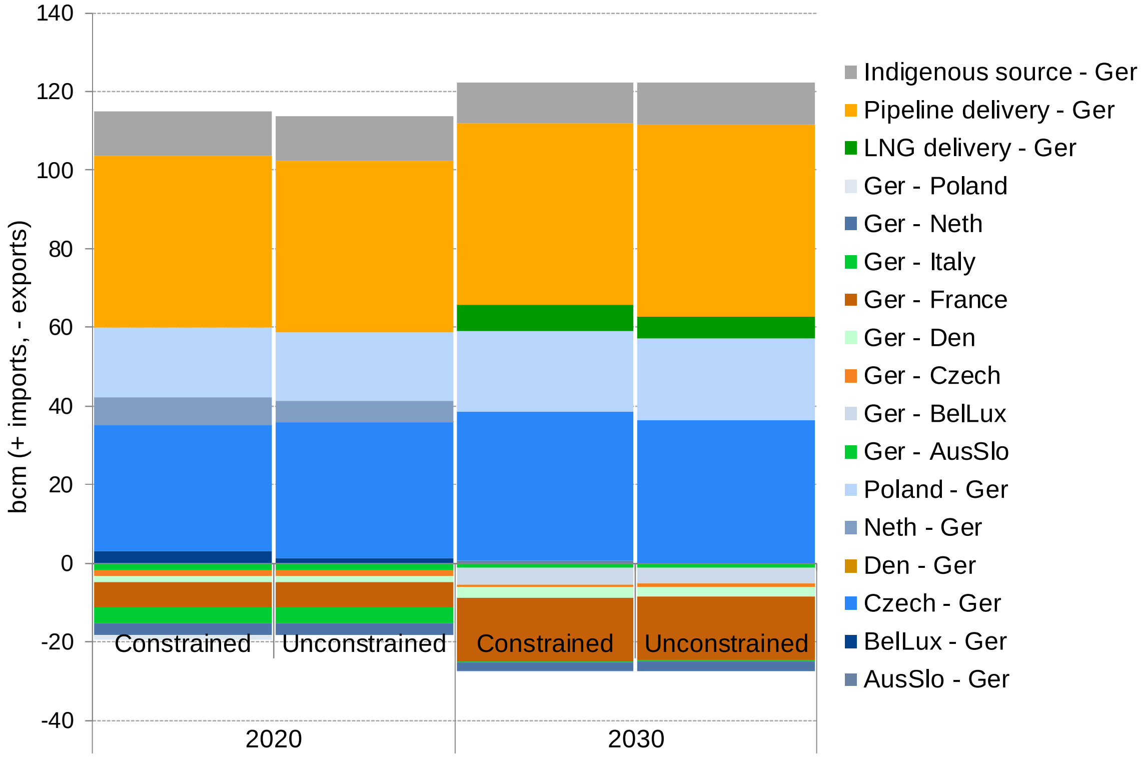


Figure 80 – Interconnection flows in Germany (bcm)

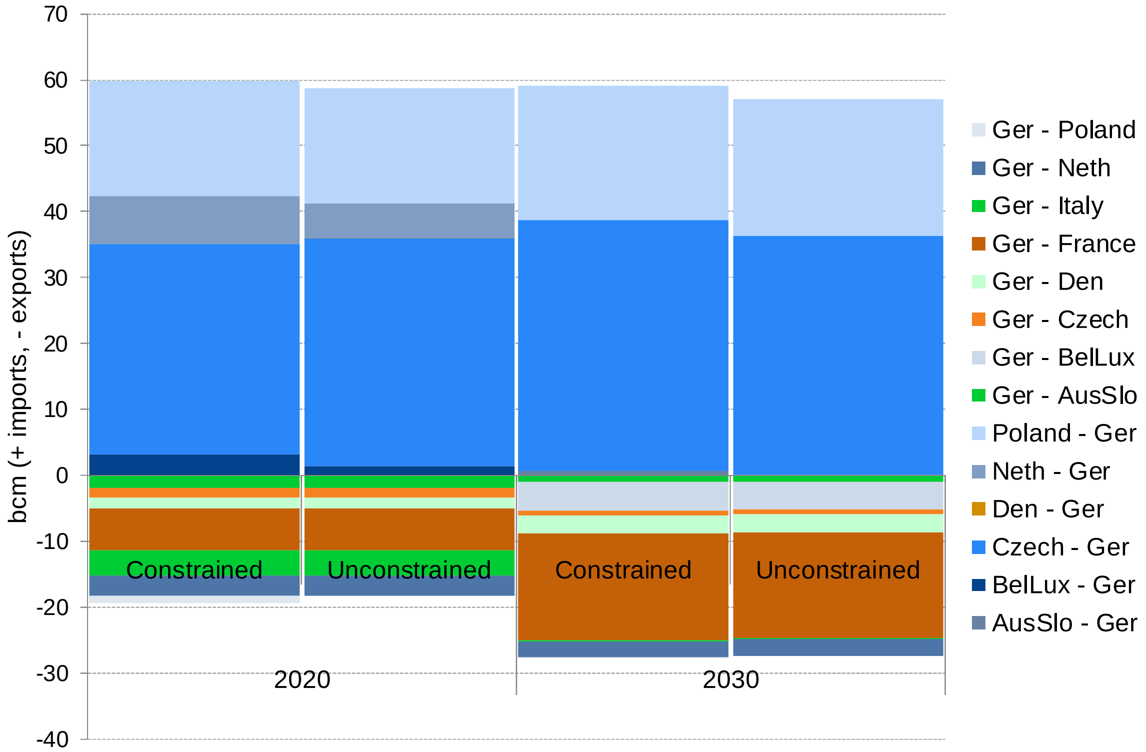
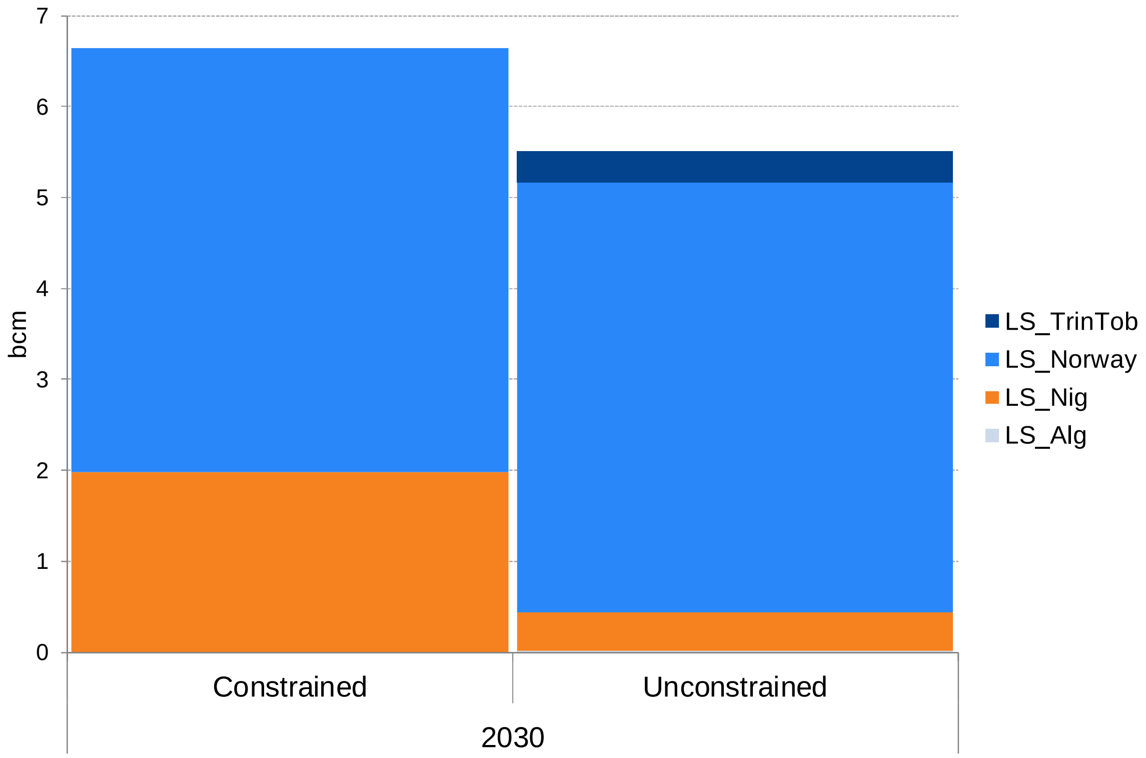


Figure 81 – LNG flows to Germany (bcm)



Italy

633. Total flows to and from Italy do not change considerably when gas is harmonised. In 2020, flow from AusSlo decreases slightly. LNG flows to Italy increases by approximately 6% in 2020. Increase in the LNG flow is mainly sourced from Yemen and Oman. In 2030, changes in flows are immaterial.

Figure 82 – Flows in Italy (bcm)

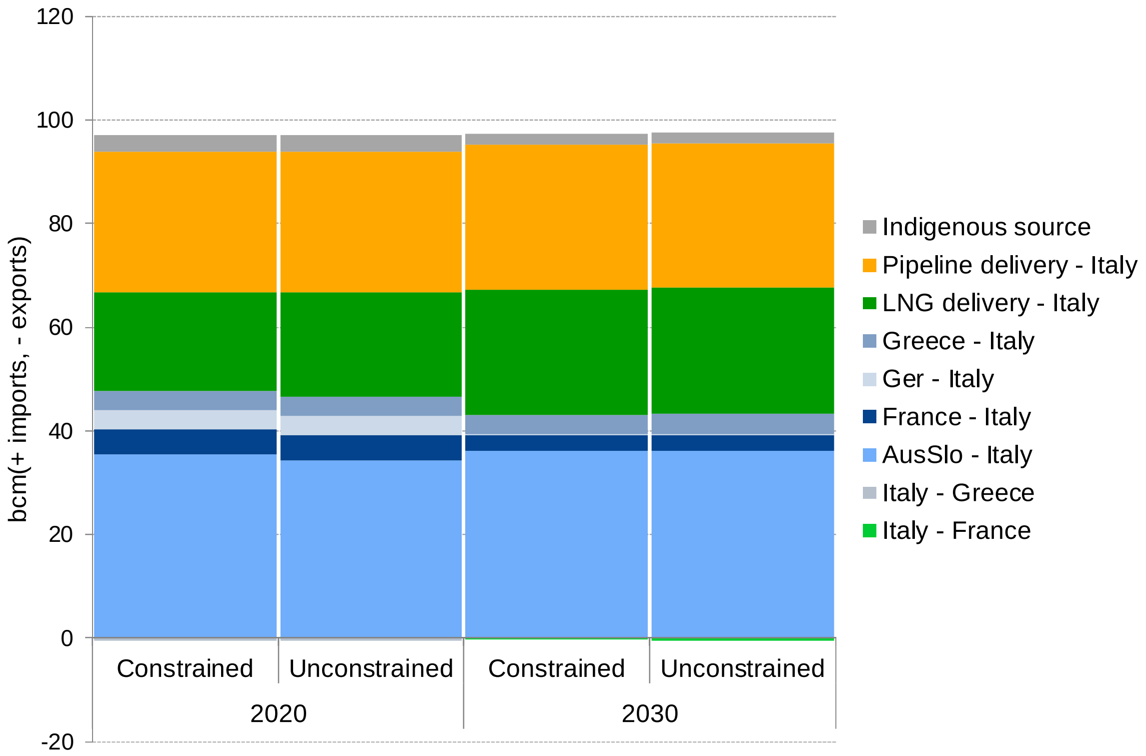


Figure 83 – Interconnection flows in Italy (bcm)

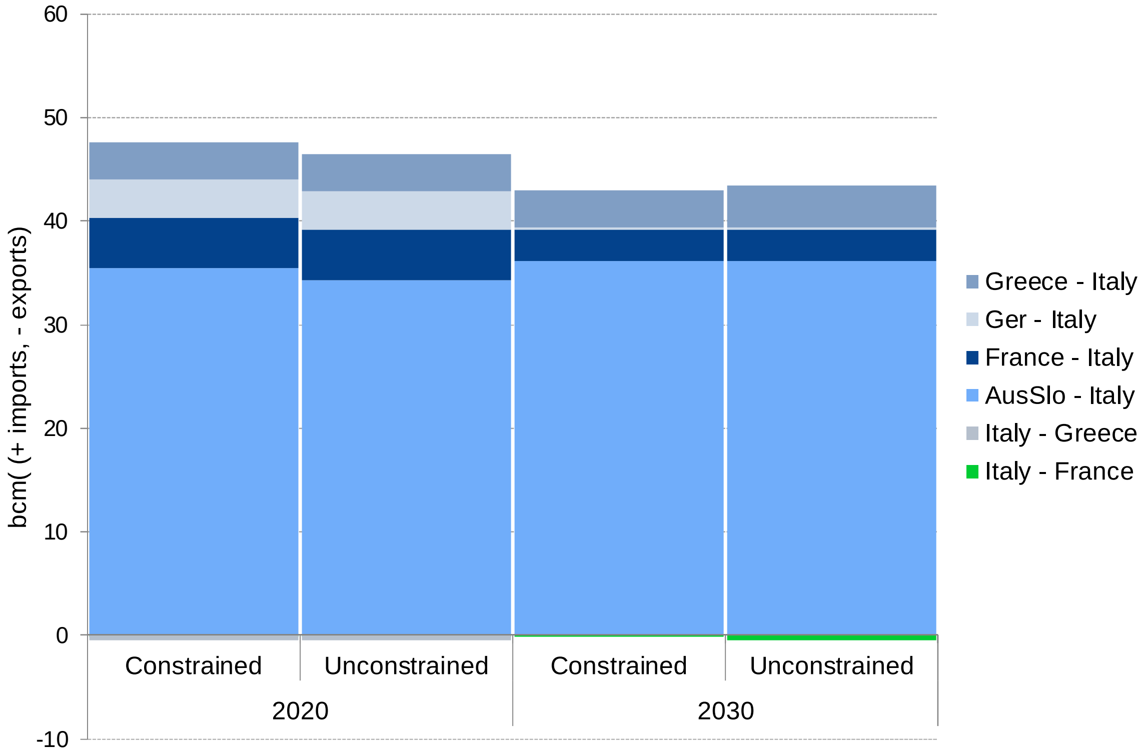
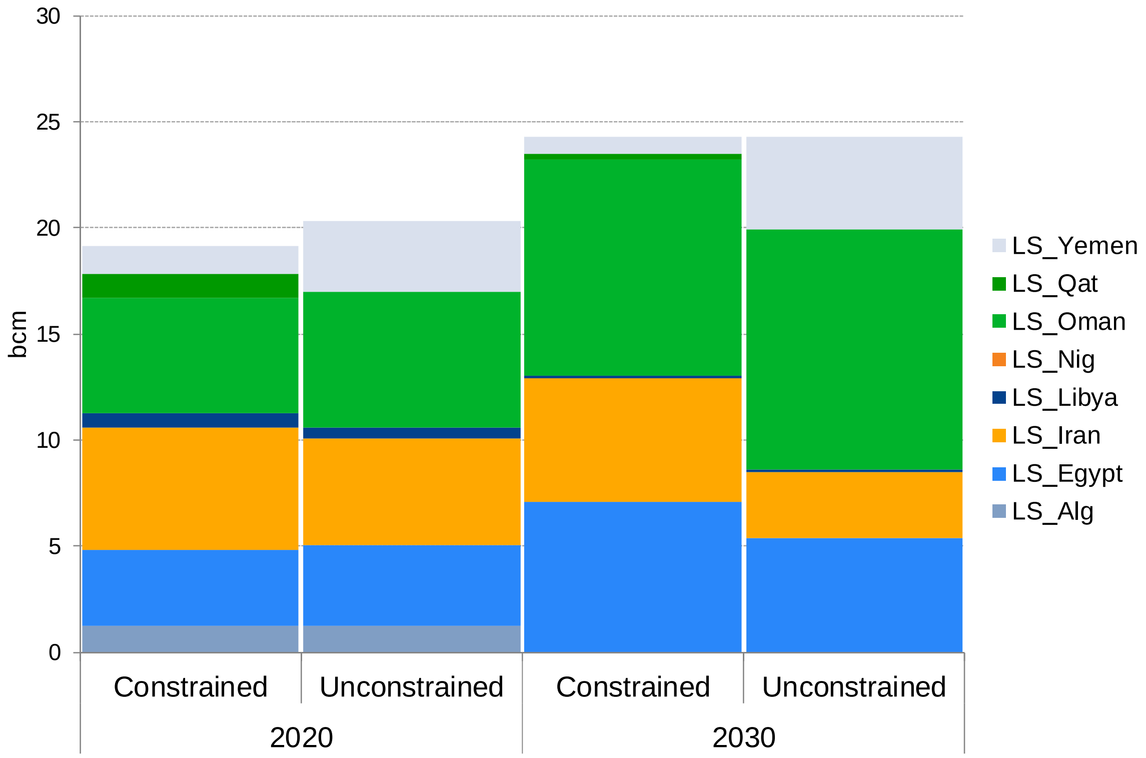


Figure 84 – LNG flows to Italy (bcm)



I.2.3.3 Accumulated flow changes

634. Total interconnection flow decreased by 6% (17262 mcm) in 2020 and by 6.6% (19385 mcm) in 2030 in the harmonised case compared to disharmonised case. Total LNG flows and pipeline flows remained the same when gas is harmonised.

LNG flow changes

635. Although the total LNG flow did not change between harmonised and disharmonised cases, LNG flows changed their routes in the harmonised scenario. In 2020, LNG flow to BelLux, Netherlands and France decreases, whereas LNG flow to Great Britain, Italy and Poland increases in the harmonised case compared to the disharmonised case. In 2030, changes in overall LNG flows are less significant.

636. More specifically, main LNG route changes can be summarised as follows:
   - Algerian gas diverted mainly from France to Netherlands, BelLux and Great Britain in both 2020 and 2030;
   - Nigerian gas diverted from BelLux and France to Great Britain in 2020; from US and Iberia to Great Britain, France and Netherlands in 2030;
   - Iranian gas diverted from, Italy and Netherlands Far East in 2020 and from Italy and Netherlands to Turkey, Croatia and Far East;
   - Norwegian gas diverted from Great Britain and US to BelLux and Netherlands in 2020.

Table 30 – Flows in 2020 (mcm)

From	To	Constrained	Unconstrained	Difference	Absolute difference
France	BelLux	156	2,909	2,754	2,754
Czech Rep.	Germany	31,918	34,561	2,643	2,643
Netherlands	Germany	7,181	5,234	-1,948	1,948
BelLux	Germany	3,192	1,379	-1,813	1,813
Netherlands	GB	404	1,611	1,207	1,207
AusSlo	Italy	35,482	34,316	-1,166	1,166
Iberia	France	2,921	2,609	-313	313
Netherlands	BelLux	12,420	12,463	43	43
Germany	Denmark	1,635	1,635	0	0
GB	BelLux	2,085	2,085	0	-
BelLux	France	12,420	12,420	0	-
Germany	BelLux	0	0	0	-
Germany	Netherlands	3,200	3,200	0	-
France	Italy	4,800	4,800	0	-
Italy	France	4	4	0	-
France	Iberia	1,536	1,536	0	-
Germany	France	6,400	6,400	0	-
Poland	Germany	17,600	17,600	0	-
Germany	Italy	3,760	3,760	0	-
Germany	AusSlo	1,921	1,921	0	-
Germany	Czech Rep.	1,400	1,400	0	-
Italy	Greece	489	489	0	-
Greece	Italy	3,600	3,600	0	-

Table 31 – Flows in 2030 (mcm)

From	To	Constrained	Unconstrained	Difference	Absolute difference
Czech Rep.	Germany	37,975	36,387	-1,588	1,588
Iberia	France	3,652	2,996	-656	656
Italy	France	126	511	385	385
Poland	Germany	20,410	20,774	364	364
Greece	Italy	3,654	4,000	346	346
Germany	France	16,243	16,053	-190	190
Netherlands	BelLux	1,683	1,754	71	71
BelLux	France	5,676	5,722	47	47
Germany	Italy	178	217	39	39
Germany	Netherlands	2,409	2,400	-9	9
Netherlands	GB	1,330	1,328	-2	2
Germany	Denmark	2,696	2,696	0	0
Germany	BelLux	4,230	4,230	0	-
GB	BelLux	0	0	0	-
France	BelLux	0	0	0	-
BelLux	Germany	0	0	0	-
Netherlands	Germany	0	0	0	-
France	Italy	3,000	3,000	0	-
France	Iberia	960	960	0	-
Germany	AusSlo	1,037	1,037	0	-
Germany	Czech Rep.	700	700	0	-
AusSlo	Italy	36,200	36,200	0	-
Italy	Greece	0	0	0	-

I.2.4 EASEE-gas specification

637. This section presents the results from the EASEE-gas Wobbe index specifications modelling. In this sensitivity, we used EASEE-gas specifications as gas quality constraints in all EU countries. The first section examines the high level results, with the following sections drilling down to examine more detailed results.

638. We have examined the impact of harmonising the Wobbe index ranges. This has considered an infinite harmonised quality, i.e. the analysis explores the benefit of removing all Wobbe index constraints.

I.2.4.1 High-level results

Table 32 – Objective function values

Gas year	Scenario	Objective function value (EUR)	Benefit of harmonisation
2020	Unconstrained	354,653,349,115	
2020	Constrained	354,657,020,465	**3,671,350**
2030	Unconstrained	402,931,504,050	
2030	Constrained	402,931,504,050	**0**

I.2.4.2 Flow changes

639. The flow changes experienced in this scenario are negligible.

I.2.4.3 Accumulated flow changes

640. Total interconnection flow decreased by 6% (17262 mcm) in 2020 and by 6.6% (19385 mcm) in 2030 in the harmonised case compared to disharmonised case. Total LNG flows and pipeline flows remained the same when gas is harmonised.

LNG flow changes

641. Although the total LNG flow did not change between harmonised and disharmonised cases, LNG flows changed their routes in the harmonised scenario. In 2020, LNG flow to BelLux, Netherlands and France decreases, whereas LNG flow to Great Britain, Italy and Poland increases in the harmonised case compared to the disharmonised case. In 2030, changes in overall LNG flows are less significant.

642. More specifically, main LNG route changes can be summarised as follows:
   - Algerian gas diverted mainly from France to Netherlands, BelLux and Great Britain in both 2020 and 2030;
   - Nigerian gas diverted from BelLux and France to Great Britain in 2020; from US and Iberia to Great Britain, France and Netherlands in 2030;
   - Iranian gas diverted from, Italy and Netherlands Far East in 2020 and from Italy and Netherlands to Turkey, Croatia and Far East;
   - Norwegian gas diverted from Great Britain and US to BelLux and Netherlands in 2020.

Table 33 – Flows in 2020 (mcm)

From	To	Constrained	Unconstrained	Difference	Absolute difference
France	BelLux	156	2,909	2,754	2,754
Czech Rep.	Germany	31,918	34,561	2,643	2,643
Netherlands	Germany	7,181	5,234	-1,948	1,948
BelLux	Germany	3,192	1,379	-1,813	1,813
Netherlands	GB	404	1,611	1,207	1,207
AusSlo	Italy	35,482	34,316	-1,166	1,166
Iberia	France	2,921	2,609	-313	313
Netherlands	BelLux	12,420	12,463	43	43
Germany	Denmark	1,635	1,635	0	0
GB	BelLux	2,085	2,085	0	-
BelLux	France	12,420	12,420	0	-
Germany	BelLux	0	0	0	-
Germany	Netherlands	3,200	3,200	0	-
France	Italy	4,800	4,800	0	-
Italy	France	4	4	0	-
France	Iberia	1,536	1,536	0	-
Germany	France	6,400	6,400	0	-
Poland	Germany	17,600	17,600	0	-
Germany	Italy	3,760	3,760	0	-
Germany	AusSlo	1,921	1,921	0	-
Germany	Czech Rep.	1,400	1,400	0	-
Italy	Greece	489	489	0	-
Greece	Italy	3,600	3,600	0	-

Table 34 – Flows in 2030 (mcm)

From	To	Constrained	Unconstrained	Difference	Absolute difference
Czech Rep.	Germany	37,975	36,387	-1,588	1,588
Iberia	France	3,652	2,996	-656	656
Italy	France	126	511	385	385
Poland	Germany	20,410	20,774	364	364
Greece	Italy	3,654	4,000	346	346
Germany	France	16,243	16,053	-190	190
Netherlands	BelLux	1,683	1,754	71	71
BelLux	France	5,676	5,722	47	47
Germany	Italy	178	217	39	39
Germany	Netherlands	2,409	2,400	-9	9
Netherlands	GB	1,330	1,328	-2	2
Germany	Denmark	2,696	2,696	0	0
Germany	BelLux	4,230	4,230	0	-
GB	BelLux	0	0	0	-
France	BelLux	0	0	0	-
BelLux	Germany	0	0	0	-
Netherlands	Germany	0	0	0	-
France	Italy	3,000	3,000	0	-
France	Iberia	960	960	0	-
Germany	AusSlo	1,037	1,037	0	-
Germany	Czech Rep.	700	700	0	-
AusSlo	Italy	36,200	36,200	0	-
Italy	Greece	0	0	0	-

I.2.5 Multi-property analysis

643. This section presents the results from the Multi-property modelling. The first section examines the high level results, with the following sections drilling down to examine more detailed results.

I.2.5.1 High-level results

644. The benefit of harmonisation is estimated by comparing the minimised objective function[15] values (total cost in Euros) of the two model runs. First, the model is run without any quality constraints, which represents a case where gas quality specifications are harmonised. Then, quality constraints were added to the model. All other things remain equal, so the difference in the objective function values should represent the costs of the gas quality constraints, which can then be used to estimate the benefits of harmonisation.

645. Benefit of harmonisation is only 0.013% of the objective function value in 2020. In 2030, benefits are estimated to be even lower and to make approximately 0.005% of the objective function value. These are relatively small changes; however they are significant enough in modelling terms to describe a benefit of harmonisation.

646. The term 'constrained scenario' below refers to the non-harmonised case, where gas flow is subject to gas quality constraints (which is closest to the real market), and

15 The precise formulation of the objective is commercially confidential, however it can be considered as the total cost of supplying all modelled demand after satisfying all of the appropriate constraints. Further description is given in section J.1.3.

'unconstrained scenario' refers to harmonised case, where gas quality constraints do not apply.

Table 35 – Objective function values (EUR)

Gas year	Scenario	Objective function value (EUR)	Benefit of harmonisation
2020	Unconstrained	354,653,349,115	
2020	Constrained	354,791,847,109	138,497,994
2030	Unconstrained	402,931,504,050	
2030	Constrained	402,951,469,335	19,965,285

I.2.5.2 Flow changes

Great Britain

647. Flows from and to Great Britain do not differ significantly between harmonised and disharmonised cases. Harmonisation of gas quality increases flow from the Netherlands to Great Britain by approximately 350%, however the volume of gas flowing from the Netherlands is significantly less than other flows. In the disharmonised case, Great Britain's narrower gas quality range prevents most of the gas from flowing from the Netherlands to Great Britain.

648. In addition to the interconnection flow change, LNG flows increase slightly and pipeline flows from Norway decrease. This is mainly because the gas quality of some LNG is a better match for Great Britain's quality constraints compared to some Norwegian gas.

649. LNG sourcing also shifts from Algeria, Iran and Trinidad Tobago to Nigeria in the harmonised scenario. Nigerian gas, having a high gas quality, cannot flow to Great Britain in the disharmonised case as its gas quality is too high compared to Great Britain's quality constraints. As a result of more high quality LNG flow, average gas quality in Great Britain is found to be higher in the harmonised case.

Figure 85 – Flows in Great Britain (bcm)

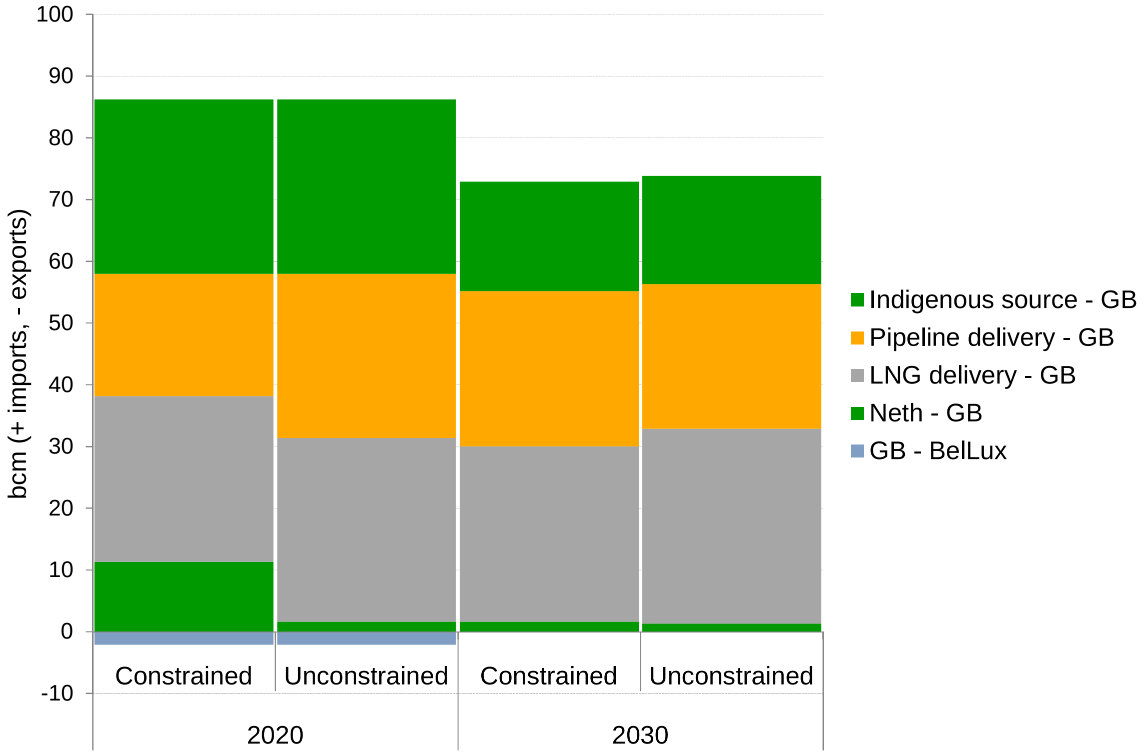


Figure 86 – Interconnection flows in Great Britain (bcm)

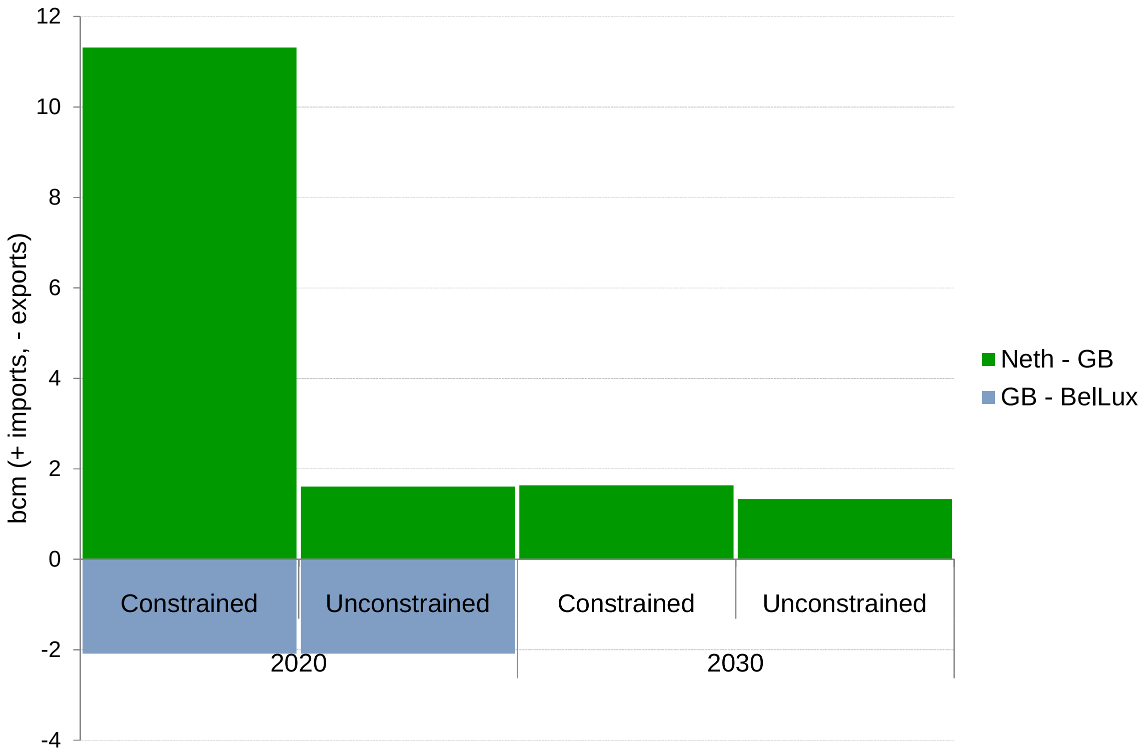
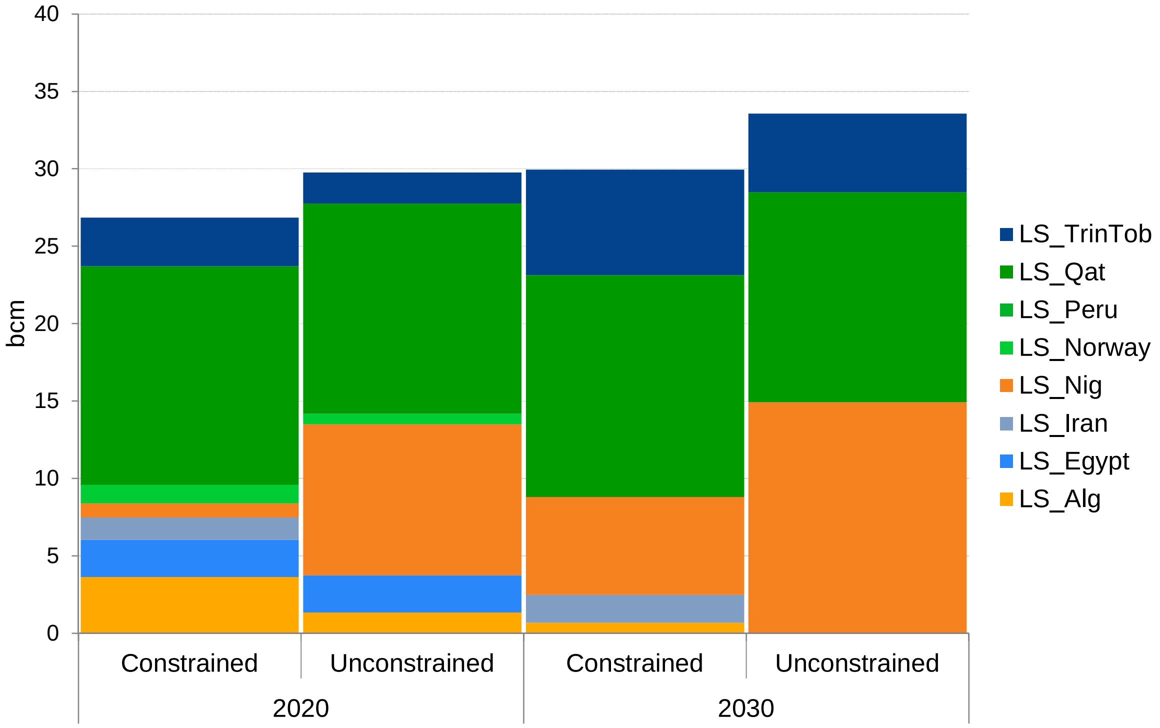


Figure 87 – LNG flows to Great Britain (bcm)



BelLux

650. Similar to flows to and from Great Britain, total flows to and from BelLux remains similar in the harmonised case. Flow mix shifts from LNG and interconnection flow to pipeline flow. More specifically, flows from France are replaced mainly by flows from Norway. Flows from BelLux to Germany also decrease slightly in 2020 in the harmonised case. Eliminated LNG flows mainly consist of Nigerian gas. Average gas quality is lower in the harmonised case as high quality LNG is replaced by lower quality Norwegian gas.

Figure 88 – Flows in BelLux (bcm)

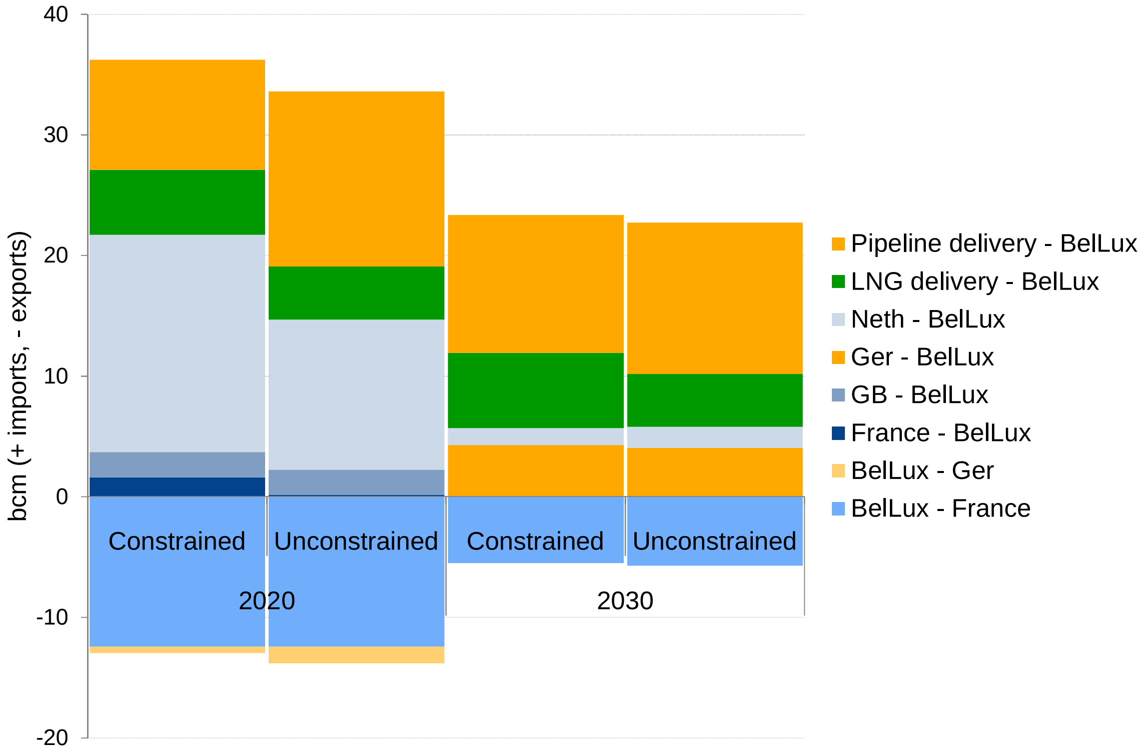


Figure 89 – Interconnection flows in BelLux (bcm)

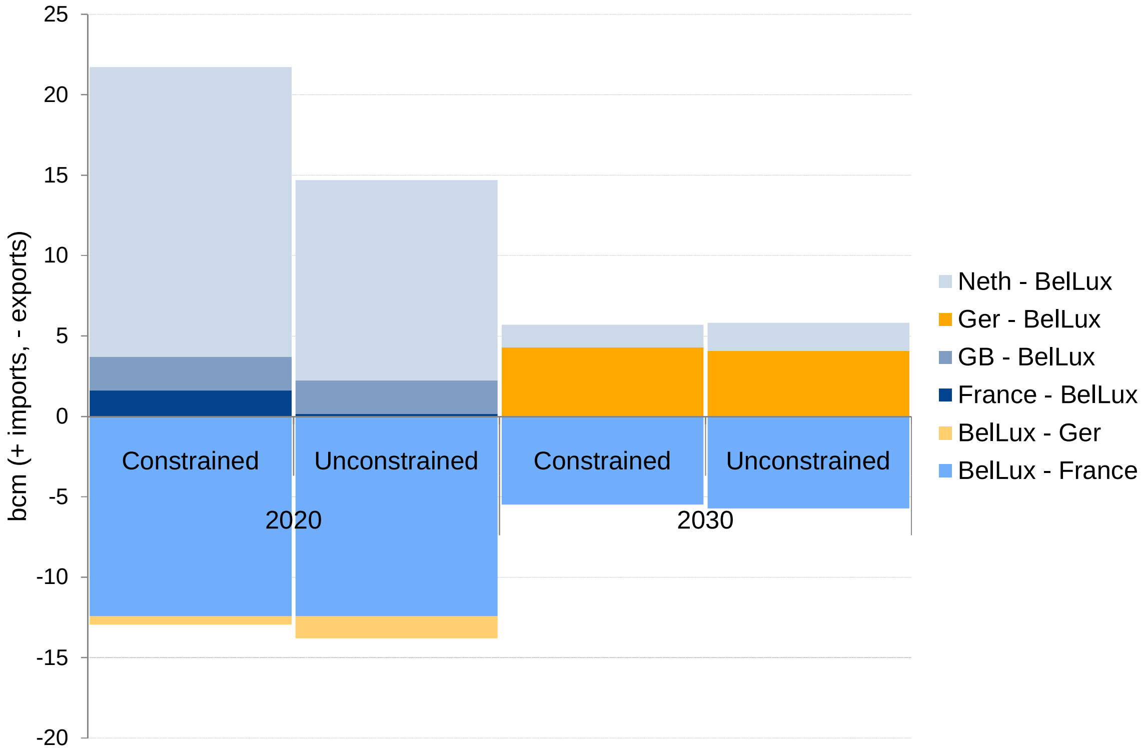
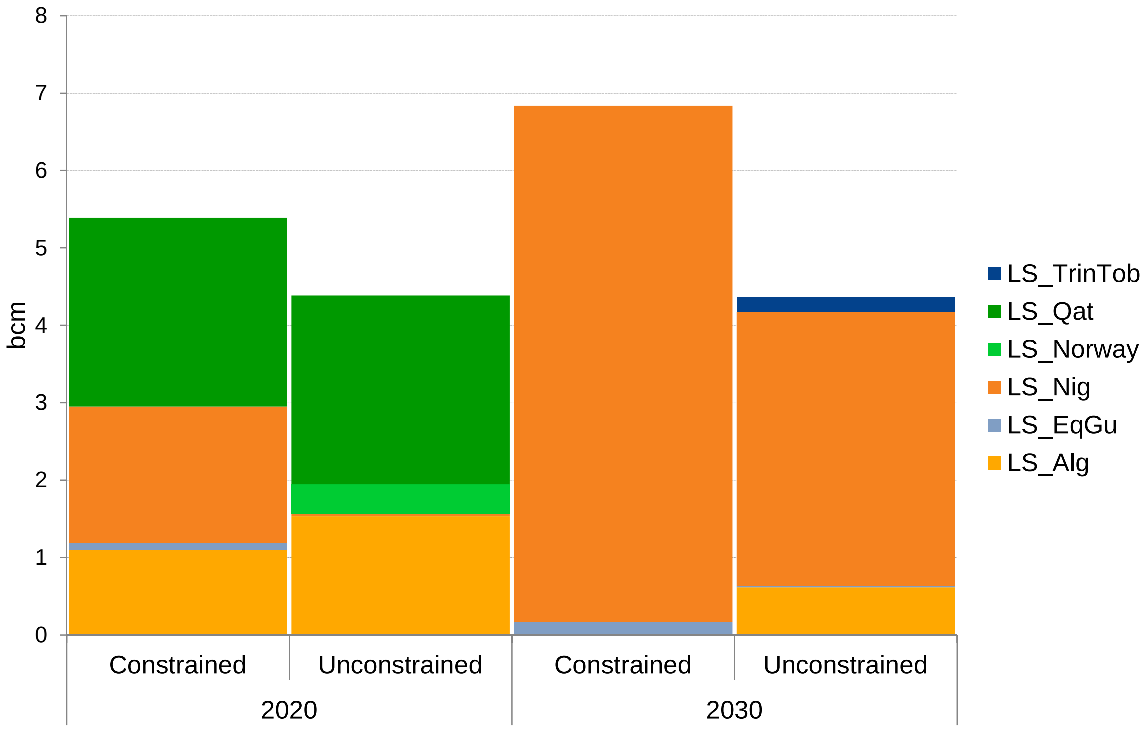


Figure 90 – LNG flows to BelLux (bcm)



The Netherlands

651. The total impact of harmonisation on the Dutch gas flow is limited. In 2020, gas flow mainly shifts from LNG to Norwegian gas. Majority of LNG from Iran and Trinidad Tobago divert from the Netherlands. Export to Great Britain increases, whereas export to Germany decreases in 2020. In 2030, changes in flows are immaterial.

Figure 91 – Flows in the Netherlands (bcm)

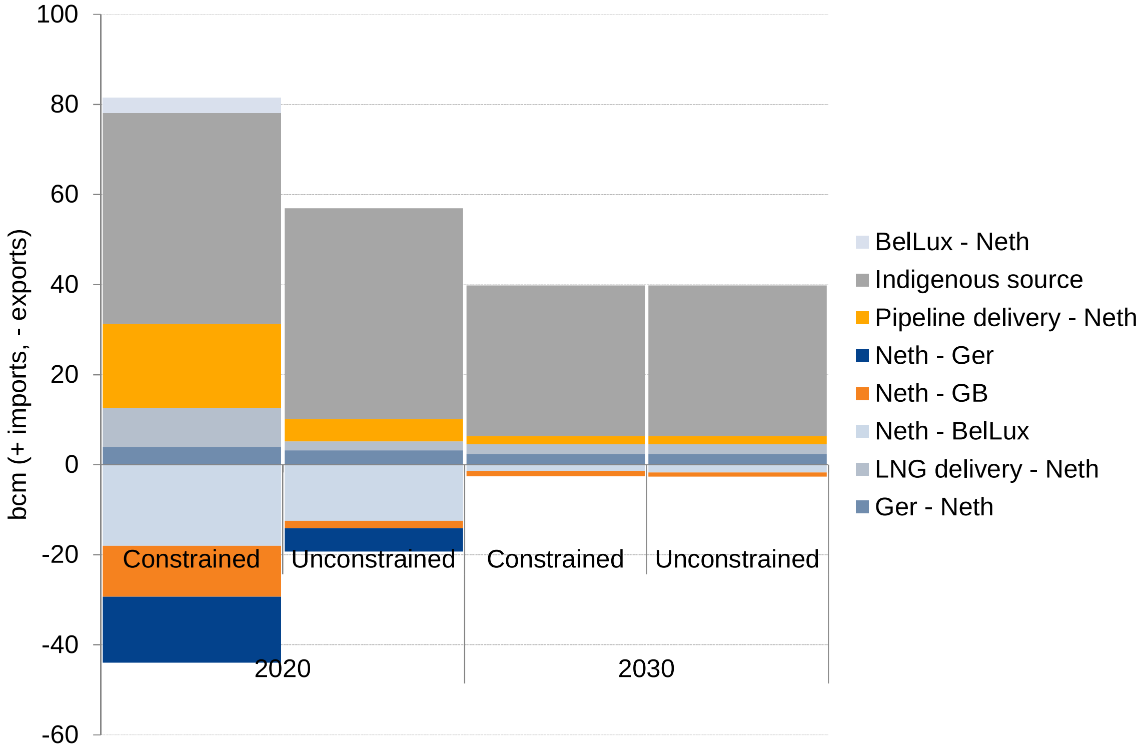


Figure 92 – Interconnection flows in the Netherlands (bcm)

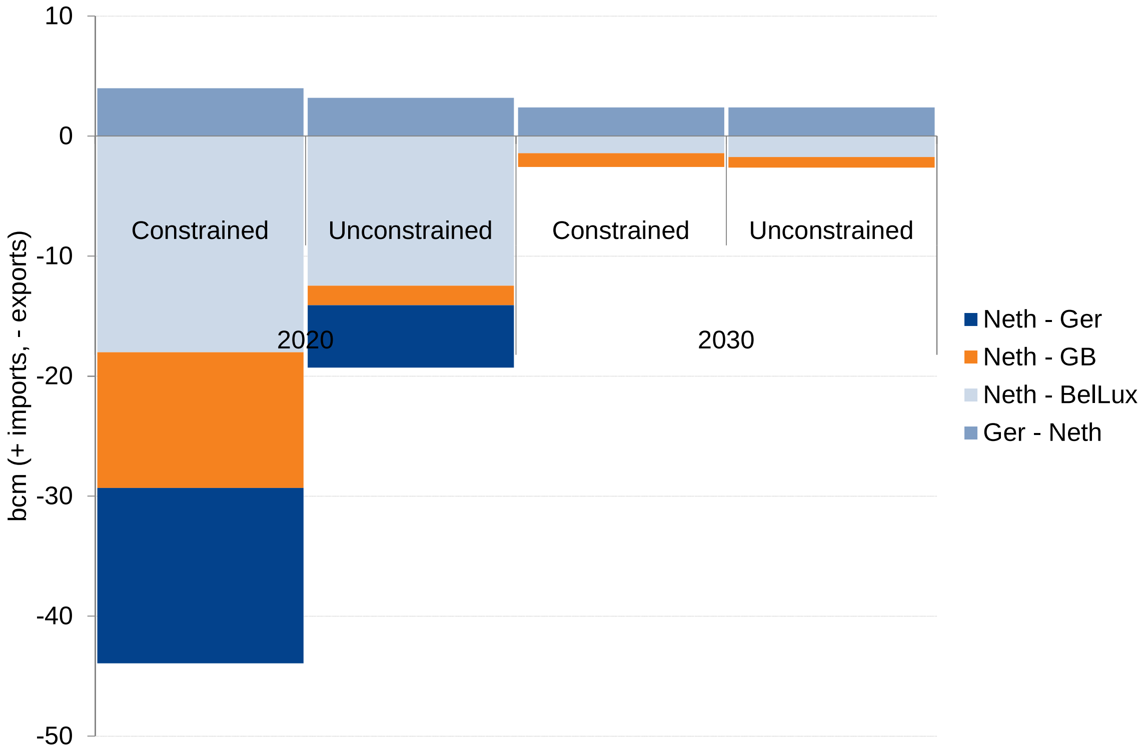
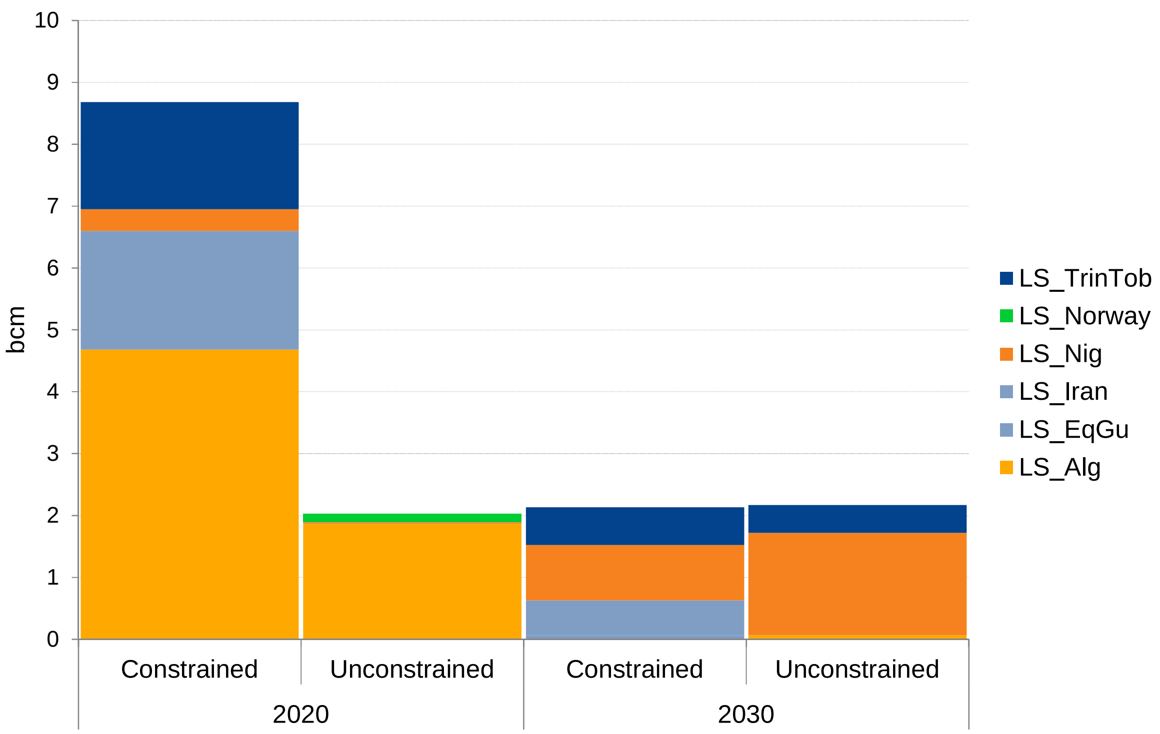


Figure 93 – LNG flows to the Netherlands (bcm)



France

652. Due to the decrease in the LNG flow to the country, total inflow decreases in 2020 in the harmonised case. Changes in the import flows are insignificant in both 2020 and 2030, whereas exports to BelLux stop in 2020 when quality constraints are removed. This is mainly because BelLux offsets gas flowing from France with Norwegian gas in the harmonised case. Due to lower flow of LNG, average gas quality decreases.

Figure 94 – Flows in France (bcm)

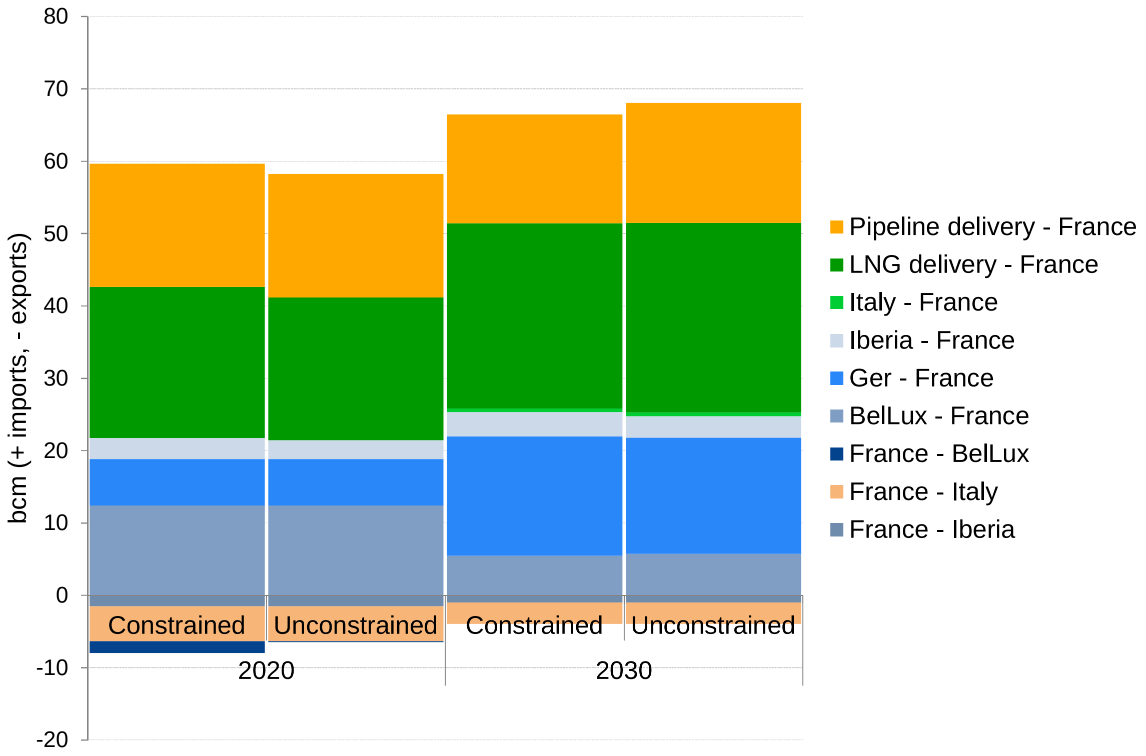


Figure 95 – Interconnection flows in France (bcm)

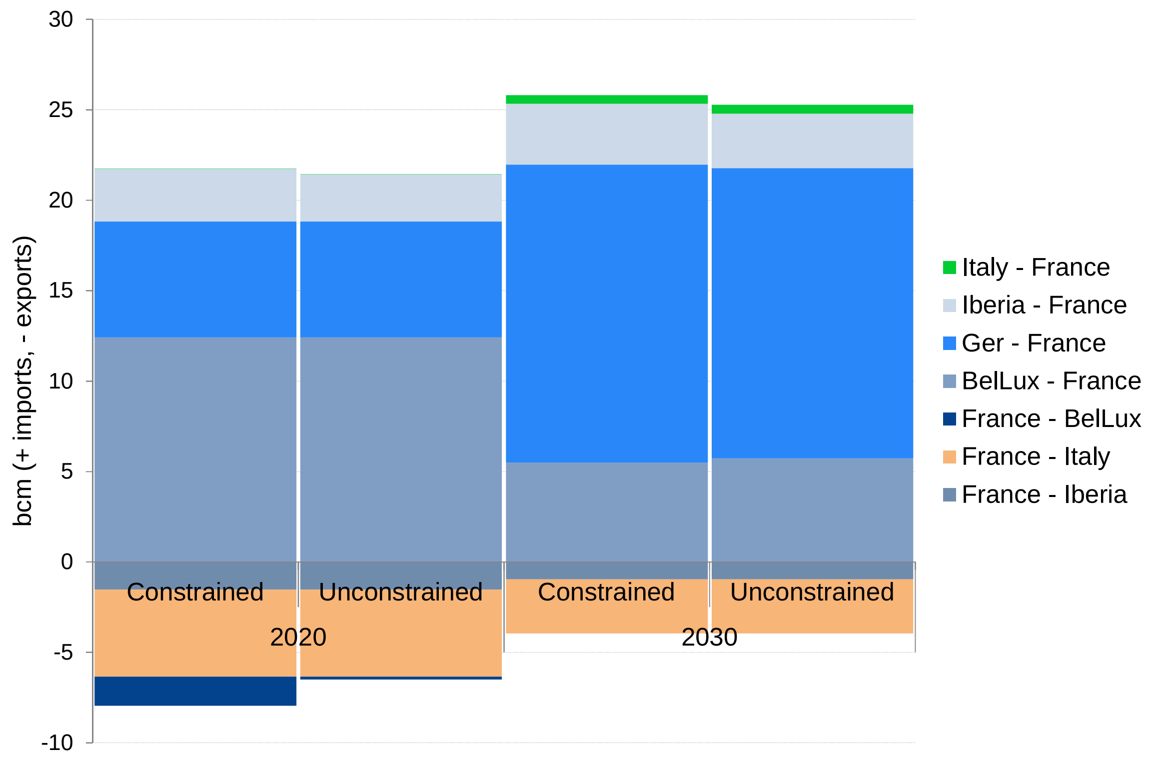
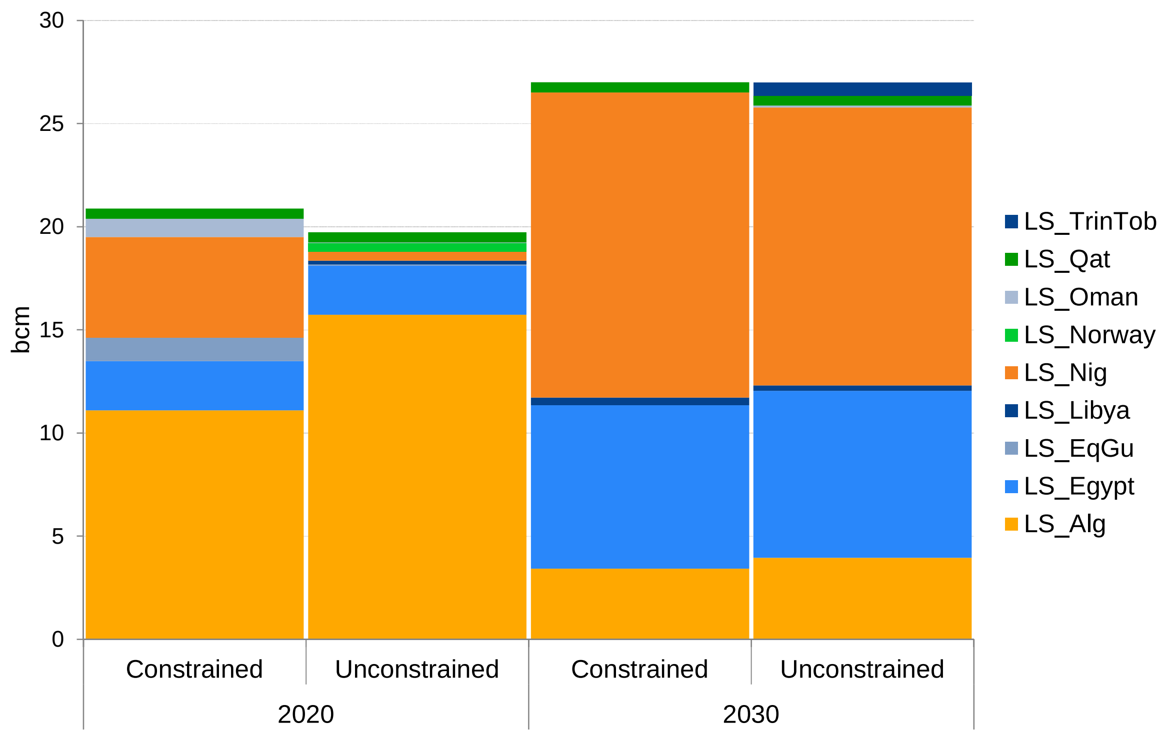


Figure 96 – LNG flows to France (bcm)



Germany

653. German gas flow does not change much when gas is harmonised. In 2020, Norwegian gas, which is delivered through pipeline, part of imports from the Netherlands and BelLux are replaced by imports from Czech Republic. On the other hand, export from Germany remains the same. In 2030, Germany receives limited LNG flows mainly from Norway and Nigeria.

Figure 97 – Flows in Germany (bcm)

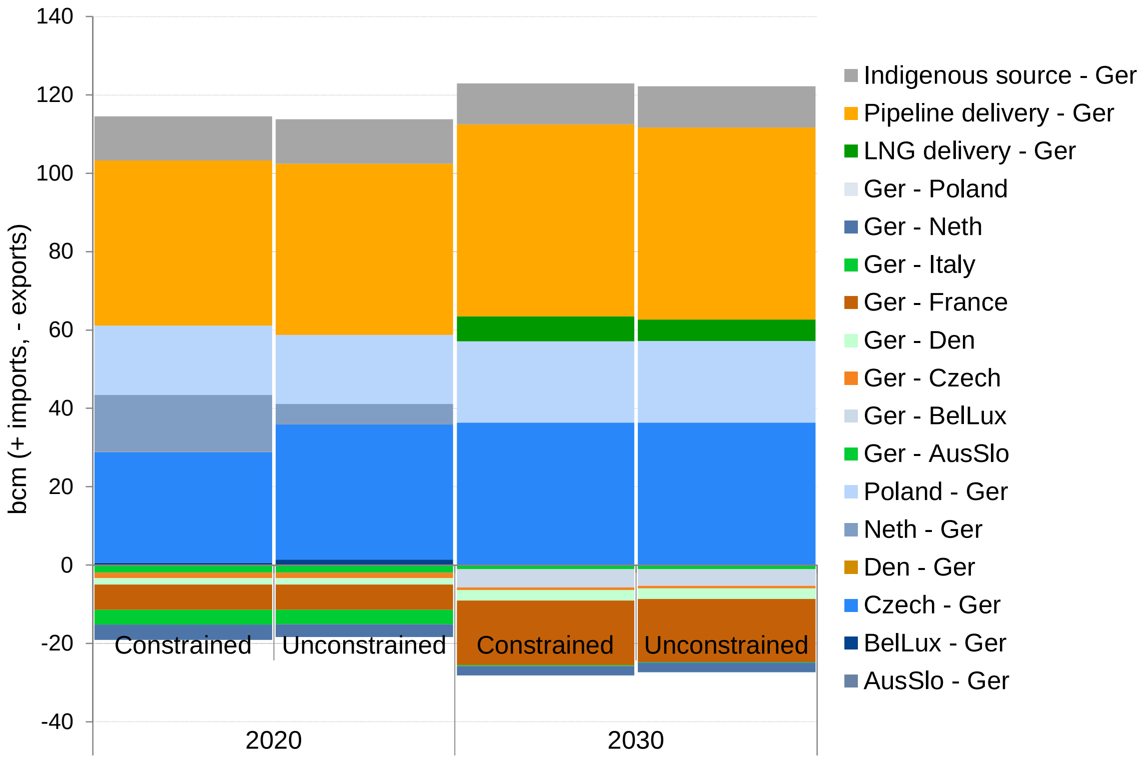


Figure 98 – Interconnection flows in Germany (bcm)

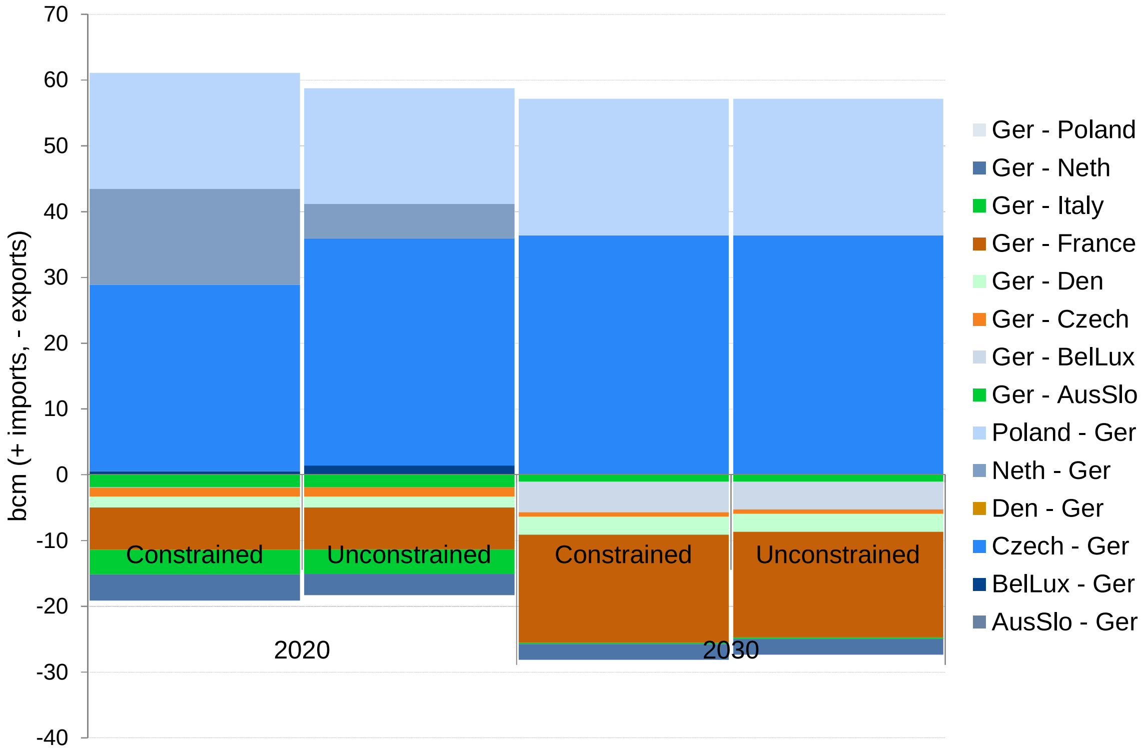
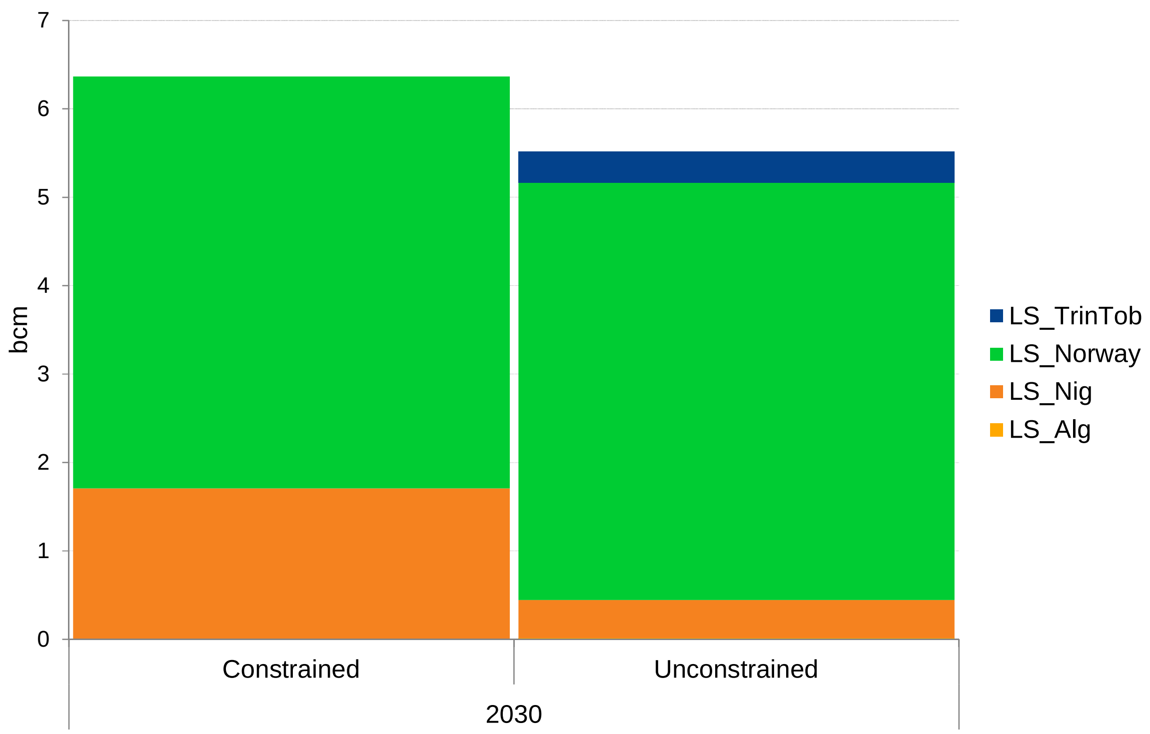


Figure 99 – LNG flows to Germany (bcm)



Italy

654. Similar to flows in Germany, flows in Italy do not change in 2030 in the harmonised case. LNG increases and imports from AusSlo decrease in 2020. Removing gas quality constraints allows Italy to benefit more from LNG sources, which have higher quality. As a result, average gas quality is increased in 2020. Additional LNG flows in the harmonised case mainly come from Iran, Yemen and Oman.

Figure 100 – Flows in Italy (bcm)

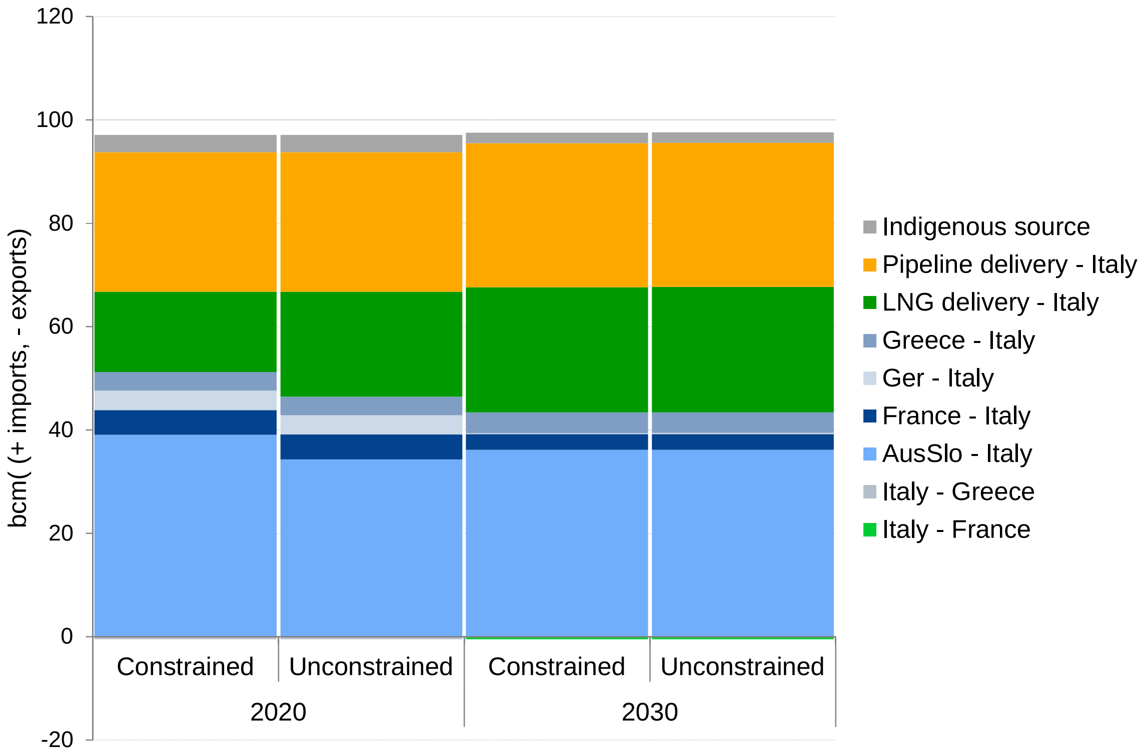


Figure 101 – Interconnection flows in Italy (bcm)

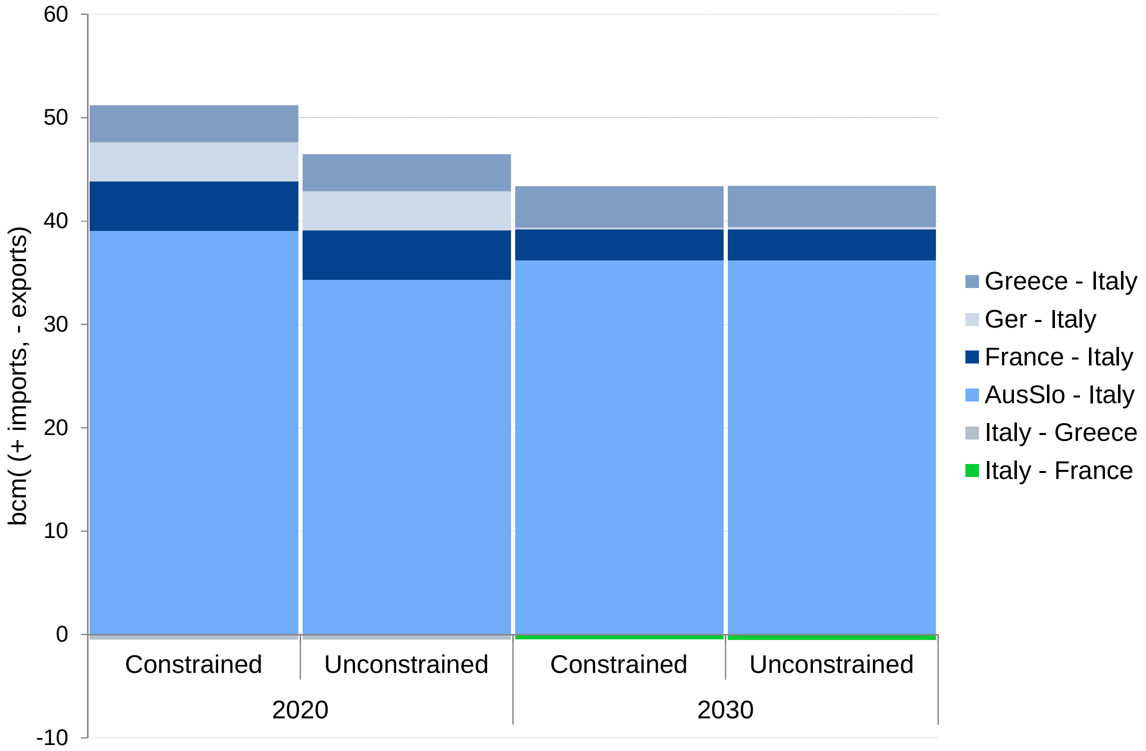
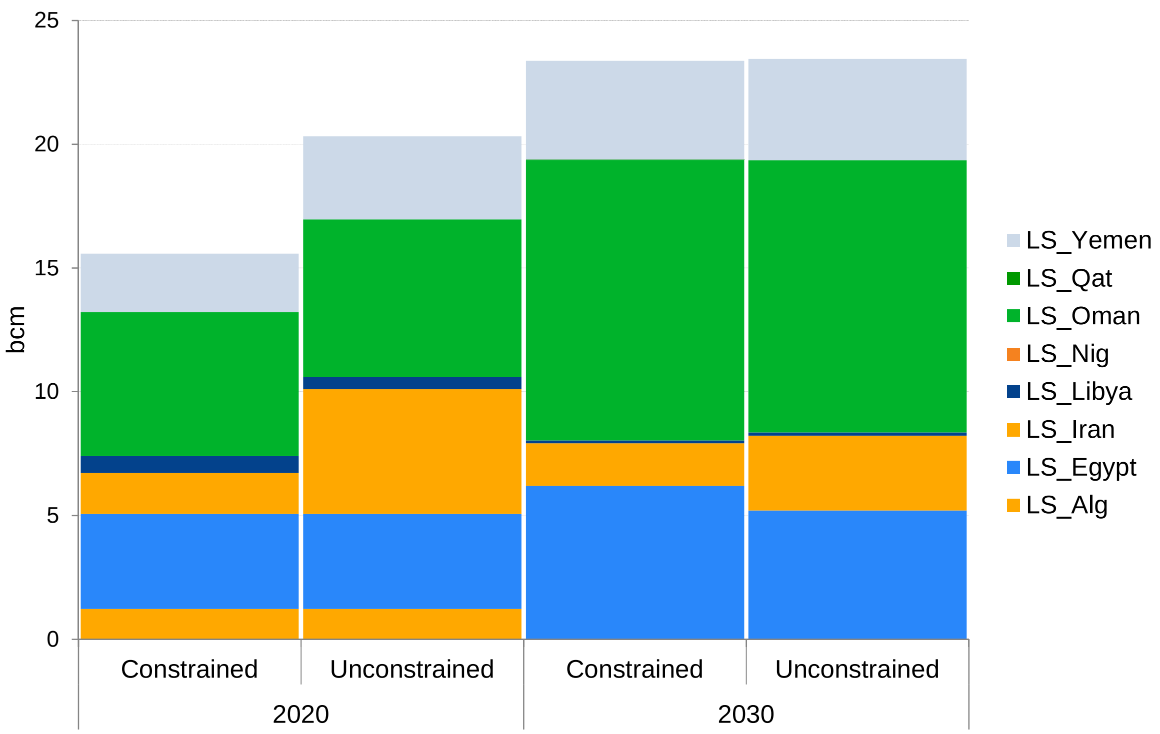


Figure 102 – LNG flows to Italy (bcm)



I.2.5.3 Accumulated flow changes

655. Total interconnection flow decreases by 0.9% (2540 mcm) in 2020 and by 0.3% (752 mcm) in 2030 in the harmonised case compared to disharmonised case. Total LNG flows and pipeline flows remain the same when gas is harmonised.

LNG flow changes

656. Although the total LNG flow does not change between harmonised and disharmonised cases, LNG flows change their routes in the harmonised scenario. LNG flow to BelLux, Netherlands and France decrease, whereas LNG flow to Great Britain, Italy and Poland increase in the harmonised case compared to the disharmonised case.

657. More specifically, main LNG route changes can be summarised as follows:

- Algerian gas diverts mainly from Great Britain to BelLux and France in both 2020 and 2030;
- Nigerian gas diverts from BelLux, France, US and BelLux to Great Britain and Netherlands in 2020 and to Netherlands only in 2030;
- Iranian gas diverts from Great Britain, Poland and Netherlands to Italy and Far East in both 2020 and 2030;;
- Norwegian gas diverts from Great Britain and US to Netherlands, France and BelLux in both 2020 and 2030.

Table 36 – Flows in 2020 (mcm)

From	To	Constrained	Unconstrained	Difference	Absolute difference
AusSlo	Italy	1,284	1,128	-156	156
BelLux	France	408	408	1	1
BelLux	Germany	17	45	28	28
BelLux	Netherlands	113		-113	113
Czech Rep.	Germany	932	1,136	204	204
Denmark	Germany	1	0	-1	1
France	BelLux	53	5	-48	48
France	Iberia	51	51	0	0
Germany	AusSlo	63	63	0	0
Germany	BelLux	0	0	0	0
Germany	Czech Rep.	46	46	0	0
Germany	Denmark	55	54	-1	1
Germany	France	211	211	0	0
Germany	Netherlands	130	105	-26	26
Greece	Italy	118	118	0	0
Iberia	France	97	86	-10	10
Netherlands	BelLux	591	410	-182	182
Netherlands	Germany	478	172	-307	307
Poland	Germany	578	577	-1	1
GB	BelLux	69	69	0	0
BelLux	GB	373	52	-321	321
Italy	Greece	16	16	0	0

Table 37 – Flows in 2030 (mcm)

From	To	Constrained	Unconstrained	Difference	Absolute difference
AusSlo	Germany	0		0	0
AusSlo	Italy	1,191	1,191	0	0
BelLux	France	190	182	7	7
Czech Rep.	Germany	1,195	1,195	-1	1
France	Iberia	32	32	0	0
Germany	AusSlo	34	34	0	0
Germany	BelLux	141	155	-14	14
Germany	Czech Rep.	23	23	0	0
Germany	Denmark	89	89	0	0
Germany	France	529	543	-14	14
Germany	Netherlands	79	79	0	0
Greece	Italy	132	132	0	0
Iberia	France	99	111	-12	12
Netherlands	BelLux	58	47	11	11
Poland	Germany	684	683	1	1
Netherlands	GB	43	54	-10	10

ANNEX J – GAS MARKET AND GAS QUALITY MODELLING WITH PEGASUS FOR THE PURPOSES OF ESTIMATING THE BENEFITS OF CHANGING GAS QUALITY SPECIFICATIONS

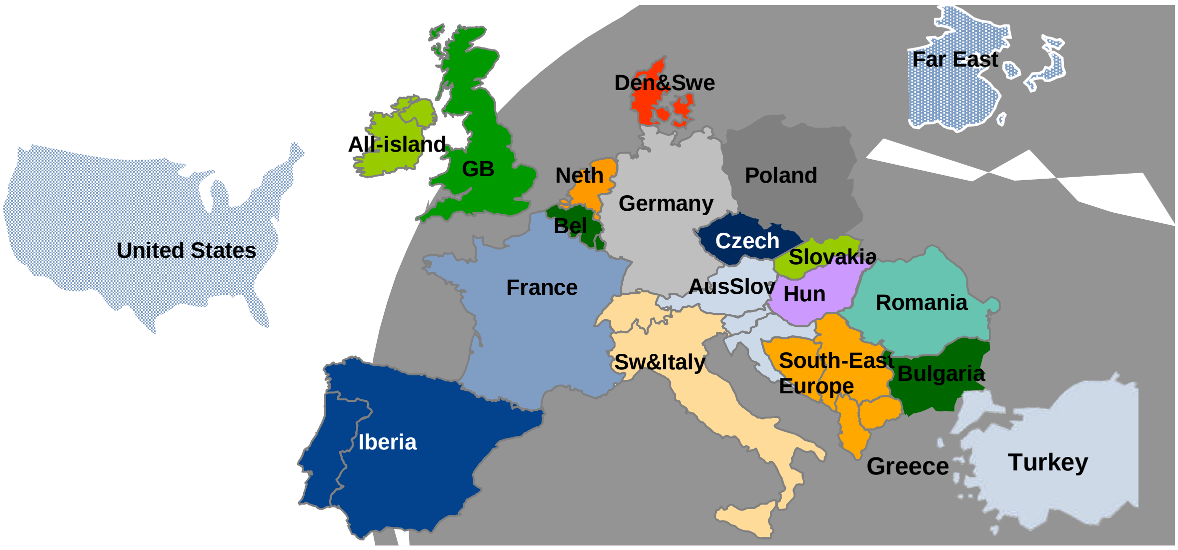
J.1 Modelling approach

J.1.1 Introduction

658. Pöyry models Europe's gas markets and projects the price of gas using its pan-European gas model, Pegasus. The model examines the interaction of supply and demand on a daily basis in 19 European countries/zones, the US, and the Far East, with a further demand for LNG to represent the rest of the world.

659. The underlying aim of Pegasus is to provide projections of wholesale market prices at a monthly resolution however, examining daily demand and supply in 22 worldwide zones gives a high degree of resolution, allowing the model to examine in detail weekday/weekend differences, flows of gas through interconnections between countries, and gas flows in and out of storage. Since the model comprises worldwide zones, it can examine the effect of LNG flows across the world, and how these impact differing markets.

Figure 103 – Gas market zones in Pegasus



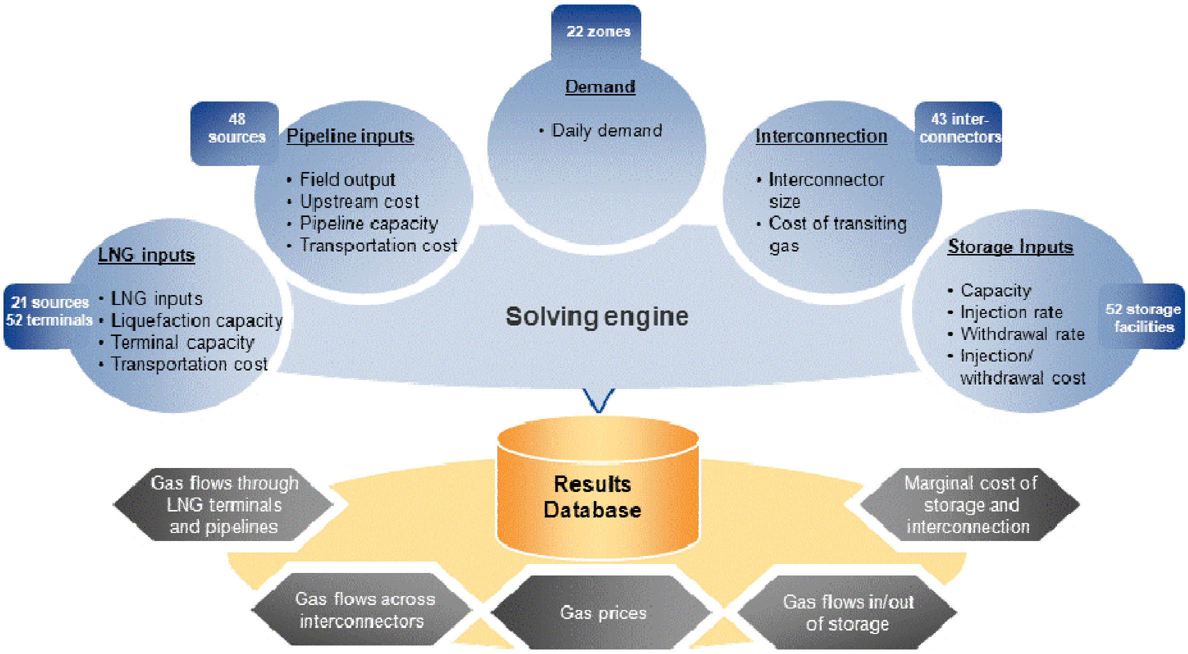
J.1.2 Structure

660. Pegasus itself is comprised of a series of modules. The main solving module is based in XPressMP, a powerful and widely used mathematical optimisation package, which optimises the objective - to find the least-cost solution to supply gas to Europe over a gas year. The solution is subject to a series of constraints, such as infrastructure capacities, storage injection/withdrawal restrictions, and requiring inflows to outflows on each day. The solving module takes input files held in a database, which allows scenarios and sensitivities to be created by changing variables such as supply, demand, costs, storage

and interconnectors. The outputs from the model, such as prices and flows of gas, are sent to a database to allow easy extraction of data at either a daily, monthly or annual resolution.

661. Pegasus allows detailed modelling of gas flows in and out of all European countries. This allows us to examine the effects that new infrastructure or policies will have on the flows and value of gas in Europe's markets.

Figure 104 – Structure of Pegasus



J.1.3 Theoretical underpinnings

662. The formulation of the objective function relies on the observation from economic theories that, in the long-run, the unit price of a commodity in a freely traded, liquid market with perfect competition, should out-turn to be the long-run marginal cost of supply to that market. However, given the strength of 'artificial' influences in the world's gas markets (most obviously the propensity of oil-indexed contracts) the formulisation of this theory into a practical model needs to take account of these.

663. The precise formulation of the objective function is proprietary knowledge, but it includes minimising the overall sum of the products of various fixed and variable elements. Crudely, the objective function is the sum of the product of unit costs and volumes, so it therefore produces an overall cost to serve all modelled demand. The elements included in the objective function include:

- the set of contracts, including:
  - ex-ante fixed contract prices (e.g. oil indexed prices);
  - ex-post fixed contract prices (e.g. hub-indexed prices);
  - variable flows;
- the set of fixed, per unit infrastructure costs (i.e. long-run marginal costs, augmented by oil-indexation considerations if necessary);

- the set of variable flows for infrastructure, including:
  - production;
  - LNG liquefaction;
  - LNG regasification;
  - LNG shipping;
  - pipeline transportation;
  - storage injection and withdrawal; and
- a series of internal variables to enable a graceful exit from mathematical infeasibilities.

664. The objective function is minimised subject to a series of constraints, including:

- requirements that the total flow into a zone/node equals the total flow out of the zone/node;
- that specified capacities are not breeched;
- that summed over a single gas year, gas storage facilities do not supply or demand gas;
- that minimum production levels and take-or-pay volumes at various resolutions are met; and
- that any requirements to shape the utilisation of particular infrastructure are met.

665. Pöyry's formulation of the objective function and its associated constraints is thought to be a unique representation of Europe's gas market, which provides clear insight into the most economically rational outcome of solving supply and demand. It is a simplification – all mathematical models are – and will only produce output with an accuracy reflecting both its simplifications but also the accuracy of its inputs.

J.1.4 Gas storage

666. Modelling storage is very important in understanding price formation in European and international markets, as it affects summer and winter prices, as well as weekday/weekend prices. Pegasus models each current and future UK gas storage field and groups of European and US fields, each with its own injection and withdrawal rates, total storage capacity and costs of injection/withdrawal. The optimisation algorithm used not only means that gas is injected into storage during the summer and withdrawn during the winter, as expected, but also that injection can happen during the winter weekends and Christmas periods due to lower demand, as can be seen in reality.

667. The primary focus of Pegasus is to produce long-run expected prices and flows at a monthly resolution. Within this context it is important to model the long-run influences of gas storage on price/flow seasonality, which is tackled in Pegasus by applying the long-run costs of storage investments within the gas year optimisation time-horizon.

J.1.5 Modelling LNG

668. Pegasus contains details of all worldwide liquefaction plants and regasification terminals, and can be used to understand the future changes that the LNG market may bring. LNG forms a vital part of Europe's future supply needs, so it is important to capture the influence on the European market from the global LNG market. This necessitates the inclusion, in a European-focussed model, of the other key LNG markets: the Atlantic basin market which includes the US, and the Asia-Pacific market which includes the Far East.

669. To avoid significantly complex mathematical formulation with a greater risk of producing indefinite results, Pegasus models LNG flows as a continuous variable. Cargoes of LNG are therefore infinitely divisible. Modelling individual cargoes would require the use of integer optimisation techniques with a significantly longer run times, a more complicated formulation, and a requirement to model specific, rather than generic, contracts.

670. Pegasus models the transportation costs of the LNG markets by ensuring that time and distance related costs are appropriately captured as LNG is delivered from liquefaction sources to regasification terminals. This includes consideration of distance related elements (e.g. fuel costs), time related elements (e.g. charter rates), and fixed elements (e.g. harbour fees). The actual dispatch of LNG from liquefaction terminal to regasification terminal is undertaken by the optimisation engine, subject to the contracts as specified in the contract model.

J.1.6 Contracts, prices and costs

671. Contracts with volume and price obligations will remain important into the future, as Gazprom has already renewed many of its contracts with its European customers to 2030 and beyond. Pegasus models the various European supply contracts, along both the traditional pipeline importation routes as well as newer flexible deliveries from LNG, including considerations of take-or-pay obligations and oil indexation.

672. The contract model that we deploy in Pegasus uses a hybrid of specific, known contracts, as well as generic contracts information which we have generated to substitute for unknown contracts. Ex-ante prices in these contracts can be specified based on a wide variety of indices – obviously these are predominantly oil based, but the model also allows for other indices such as coal. Gas volumes are specified at annual and/or monthly resolution, and can apply for minima (i.e. take-or-pay volumes) as well as maxima.

673. Contracts can also be set with ex-post pricing arrangements, which leave the costs of gas flowing under those contracts determined by the downstream hub's marginal prices.

674. The key output from Pegasus is an understanding of how future prices may develop. In addition to the marginal prices – arguably the true value of gas in those markets – Pegasus also produces the flow-weighted average costs that would be expected to be borne by a consumer, which takes account of the specified contract costs as well as marginal prices. This gives a clear understanding of the effects of long-term contracts within the market, showing how consumers might be paying too much or too little for their gas.

J.1.7 Exogenous assumptions

675. Pegasus allows the development of sophisticated future scenarios, and creates of price tracks which represent the underlying fundamentals. For any scenario, it is therefore possible to specify a wide variety of assumptions which encompasses:

- investments in infrastructure – pipelines, interconnectors, storage facilities, delivery terminals;
- production capacity and costs; and
- demand – annual consumption levels and growth rates, and optionally the severity winter, day-to-day variability and peak day demands.

676. Typically, Pöyry would run a series of different scenarios (each of which would be internally consistent), designed to represent a range of credible outcomes. Some of the

background to how we develop our main assumptions is discussed below. These considerations are integral to the specification of an input scenario.

J.1.7.1 Russian assumptions

677. Russia is a major gas supplier to Europe, and Pegasus uses the availability of gas from this source as a key input. Estimating the volume of gas that will be available to Europe from Russia is subject to several constraints, including:

- the depletion of existing gas-producing provinces in West Siberia;
- the ability of Gazprom to launch new fields on schedule and the impact of potential delays on the availability of gas;
- Russia's domestic gas consumption; and
- the volume of gas that Russia will be able to import from Central Asia.

J.1.7.2 Other upstream infrastructure

678. Pegasus is based on an extensive database of production capacity throughout Europe, as well as simplified, amalgamated upstream structures that take account of North American production (including unconventional production), and production feeding LNG liquefaction capacity.

J.1.7.3 Interconnection

679. Pegasus also allows detailed exploration of how interconnections between countries will flow into the future. This is key, as flows between interconnections determine the extent to which prices in nearby markets are linked. Pegasus allows detailed modelling of gas flows in and out of all modelled European zones. This allows effects such as the impact of new pipelines (such as Nordstream), or new LNG terminals, to be investigated.

J.1.7.4 Decisions based on imperfect or improved information

680. Many investments undertaken in the European market are not only driven by measurable economics (e.g. price capture), but by an assortment of other considerations.

681. Often, the economics presented to investment committees can be focussed on just local, micro-economic impacts. As competition grows within Europe, these investment practices might change and wider impacts, influences and risks might be considered. Political and semi-political influences also exert significant influence on investment decisions. Most are encompassed in security of supply concerns which seek to diversify away from reliance on particular sources, routes or technologies.

682. This means that many European gas market investments can appear to be economically irrational when measured against micro-economic indicators such as price. In fact they are based on imperfect information (e.g. incorrect analysis, or other incomplete information), or improved information (e.g. the value of security and/or diversity).

683. In a model designed to explore impacts on flows and prices, deciding which investments should be included in a forward looking market through endogenous methods (i.e. allowing the model to decide whether investments happen based on expected future returns), will therefore not reflect many of the real investment decisions made in the gas industry. The approach adopted in Pegasus – where the capacity outlook is determined exogenously – therefore allows us to capture the impacts of apparently irrational

investments, thus reflecting the imperfect or improved information used in making real decisions.

J.1.8 Features inappropriate for this project

684. Prior to executing this project and in its normal mode of operation, Pegasus assumes that all natural gas is fungible: where gas can flow from and to is only constrained by physical capacities of infrastructure and the economic objectives (cost minimisation) of the model. In normal practice where we are using Pegasus to project prices and flows of gas, this assumption possibly introduces small inaccuracies within the model; however these inaccuracies are insignificant when compared to inaccuracies introduced by other assumptions, e.g. demand growth or incomplete contract data.

685. In order to examine the possible benefits that arise from harmonising gas qualities, it has been necessary to develop Pegasus to restrict flows of gas to respect gas quality constraints. The larger inaccuracies that arise from imperfect information are handled by maintaining all other things equal in the model. For modelling gas quality harmonisation we have introduced new constraints to reflect the actuality of restrictions that apply in the real market. This is expanded upon below.

J.2 Modelling enhancements

686. For the purposes of this project, it has been necessary to develop the capability of Pegasus to allow the calculation of gas qualities throughout the model. This section of the report outlines the reasoning that was used to develop this capability.

J.2.1 Concept

687. Model development has been based on the simple concept that, as the objective function calculates the flows of gas between two adjacent nodes, we can trace the gas through the network and therefore know, for any given node, the proportions of different source gases flowing into the node. If we know how to calculate the resultant mix of a particular gas quality parameter, we can therefore trace gas quality parameters through the model.

688. It should therefore be possible to apply gas quality constraints and observe their effects on overall costs to serve, as well as flows along individual routes. Comparisons can then be drawn to unconstrained or less constrained results, providing an estimate of the benefits of harmonisation as well as the volumes and qualities of gas that need processing.

J.2.2 Issues and resolution

J.2.2.1 Iterative techniques

689. Investigation into the possibility of amalgamating the calculation of gas qualities within the objective function showed that the resultant formulation would be non-linear and non-quadratic. Pöyry considered simplifying the problem to that of a quadratic optimisation, however it was considered that the complexity of such an approach would:

- yield unacceptable calculation times;
- require re-specification of the objective function for each gas quality parameter that was to be modelled; and
- make it difficult or impossible to model coincident constraints on different parameters.

690. An alternative approach was developed that sought to calculate gas quality parameters by using a less elegant iterative technique. This approach calculates gas qualities for each day by using flow results for that day from an 'unconstrained' run (i.e. where gas quality constraints have not been applied) to calculate a resulting mix at immediately downstream nodes, and then iteratively reapplying the logic to downstream nodes.

J.2.2.2 Volumetric mixing

691. The major economic value of natural gas is its energy content (although sometimes it is the methane content, for example in ammonia production). As stated earlier, in normal operation Pegasus assumes natural gas is fungible; it therefore standardises the calorific value of gas to model energy flows across Europe. Pegasus also disregards other physical characteristics such as temperature and pressure, thereby instantaneously respecting physical laws of flow conservation.

692. As the Pegasus model only contains conserved-flow results, it is not possible to accurately represent the correct mixing characteristics of many gas quality parameters, including dewpoint temperatures, sooting index and importantly, Wobbe number. To characterise the Wobbe issue: two gases with different Wobbe numbers do not mix to form a single gas with a Wobbe number that is the volumetric average of the Wobbe numbers of the initial two gases. This formulation represented in Equation 1 below.

Equation 1 – Wobbe number calculations

$$\frac{\frac{\sum f_n c_n}{\sum f_n}}{\sqrt{\frac{\sum f_n d_n}{\sum f_n}}} \neq \frac{\sum f_n \frac{c_n}{\sqrt{d_n}}}{\sum f_n}$$

Where:

$d_n = density\ of\ gas\ n$

$f_n = flow\ of\ gas\ n$

$c_n = calorific\ value\ of\ gas\ n$

The left hand side of the inequality is a more correct calculation of Wobbe number than the right hand side.

693. The gas quality modelling that we have introduced in Pegasus is limited to considering volumetric mixing. To improve on this approach would require a full, non-linear, thermodynamic and hydraulic network analysis modelling which, if coupled to the existing supply/storage optimisation, contract model and global scope of Pegasus would yield unwieldy computation times using current technology.

J.2.2.3 Circular routes and inter-temporal constraints

694. The contract model included in Pegasus introduces the potential for loop flows within the model. Where loop flows exist, it is therefore impossible to compute volumetric averages within the loop. Where loop flows exist they are broken by using the previous day's computed gas quality (or a default if there is no prior day).

J.2.2.4 Gas quality iteration

695. An unconstrained run is used to set all gas quality parameters for each node within the model for a 'constrained' run (where gas quality constraints – specifications – are respected. The constrained run changes the upstream flows of gas to respect the downstream qualities; however the resulting downstream qualities are not recomputed for onward cascade. The resulting inaccuracies can be quantified by re-computing the gas qualities and repeating the application of quality constraints within the optimisation. We have tested this re-iteration approach in a number of cases and have not found significant differences in the results. We are therefore satisfied that a single-pass iteration is sufficient to provide results commensurate with the accuracy of input data.

J.3 Practical implementation of modelling concepts in a nodal model

J.3.1 Problems of mixing, requirements to disaggregate

696. If two disparate gas qualities, where one or both of which do not meet the local specification, are mixed into a single zone, the resultant single gas quality might be within the local specification. The viability of this situation would depend on the physical location of the delivery of the gases. If they can be co-mingled prior to consumption (e.g. different gases delivered to Bacton, GB; Barrow and St. Fergus gas co-mingled at Lupton, GB), then the situation might be viable. If however the co-mingling cannot physically occur (e.g. LNG deliveries to Milford Haven with other gas delivered to GB), the non-compliant gas would not be allowed to enter the local market.

697. In its usual configuration, Pegasus is designed to examine the flow and prices of 19 European zones, assuming that gas is fungible. The model therefore disregards the location of individual entry points, and the latter situation above would be considered a viable situation. It has therefore been necessary to have the capability to disaggregate the Pegasus model into more than 19 European zones.

698. As at the date of this report, we have produced a disaggregation to describe the Italian market (the original pilot study), and a disaggregation to describe the GB/Belgium/Dutch market interactions. To the extent that data could be made available for successful study, it might be worth considering other disaggregation – for example disaggregating Germany to capture interactions between traditional Russian gas via Austria/Czech Republic/Poland, new Russian gas via Nordstream, Norwegian gas, and Dutch gas, as well as considering the level of interconnection between German TSOs.

ANNEX K – ABOUT PÖYRY

699. Pöyry Management Consulting provides leading-edge consulting and advisory services covering the whole value chain in energy, forest and other process industries. Our energy practice is the leading provider of strategic, commercial, regulatory and policy advice to Europe's energy markets. Our energy team of 200 specialists, located across 14 European offices in 12 countries, offers unparalleled expertise in the rapidly changing energy sector.

700. Pöyry plc is a global consulting and engineering firm. Our in-depth expertise extends to the fields of energy, industry, urban & mobility and water & environment, with over 7,000 staff operating from offices in 50 countries.

701. Pöyry produces a series of standard reports to a variety of clients, providing detailed descriptions of European energy markets coupled with market-leading price projections for wholesale electricity, gas, carbon and green certificates. Pöyry's reports and price projections are currently available for the:

- electricity and/or gas markets including the following countries markets:
  - Belgium
  - Bulgaria
  - Cyprus
  - France
  - Germany
  - Great Britain
  - Greece
  - Ireland
  - Italy
  - the Netherlands
  - Poland
  - Romania
  - South East Europe
  - Spain
  - Switzerland
  - Turkey
- renewables markets in:
  - Italy
  - Poland
  - Romania
  - Spain
  - United Kingdom
- and the biofuels market in Europe.

702. Pöyry also produces a number of other reports, including electricity reports for Norway, Sweden and Finland, a renewables report for Sweden, and a report of the EU Emissions Trading Scheme with carbon price projections.

703. Underpinning these reports is a mass of in depth, up-to-date, and accurate analysis of the political, policy, economic, regulatory and commercial drivers that influence Europe's energy markets. The price projections are produced from a suite of highly sophisticated, computationally intensive, ground-breaking mathematical models, all designed and developed from first principles by Pöyry.

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ANNEX L – ABOUT GL

704. GL Industrial Services UK Ltd, trading as GL Noble Denton, is part of the Germanischer Lloyd (GL) group of companies. GL is a world class technical assurance and consulting company providing technical engineering services to the industrial (oil and gas, renewables and water) and maritime (ship classification society) business sectors.

705. Both business fields follow the same approach of technical competence, uncompromising quality and first-class services around the world. With its head office in Hamburg (Germany), GL employs more than 6,900 engineers, surveyors, experts and support staff in 80 countries. The global network consists of more than 200 offices around the globe.

706. GL Noble Denton is a global independent technical advisor to the oil & gas industry providing assurance, consulting, marine operations and project execution services across the complete asset lifecycle.

707. With over 3,000 employees based in 30 countries, GL Noble Denton combines advanced engineering and analytical skills with extensive operational experience of complex offshore and onshore oil & gas assets, enhanced by our leading-edge software portfolio.

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ANNEX M – CONSULTATION QUESTIONS

Invitation to respond

708. We welcome any feedback that interested parties may wish to make regarding this report. In particular we seek responses to the following questions:

- Do you agree with the high-level conclusions of this report?
- As a manufacturer do you maintain an inventory of installed appliances?
- Are there any specific gas quality related issues not recognised within this report?
- Do you manufacturer appliances that can operate over the full EASEE-gas specification without loss of efficiency or increased of emissions?
- Do you have evidence of damage or failures caused by appliance operating on gas that is not compliant with the local gas quality specification?
- Would you support the adoption of the proposed EUROMOT gas quality specification, (Appendix B)
- Are there any specific circumstances that should be assessed in detail?
- Do you consider that the data used to undertake this analysis is sufficient to support the conclusions presented in this report?
- Should significant effort be made to improve the data used in the analysis presented in this report?
- Do you have access to further data that could (if it were made available) improve the quality of the data used in the analysis presented in this report?
- Can you provide typical detailed gas composition at cross border points?
- If so, can this data be made available (respecting confidentiality, as required)?
- How should data be collected for such a study?

Timescales

709. GL Noble Denton and Pöyry Management Consulting have been asked to present this report, and a general update of the project, to the Madrid Forum in September. At the time of writing, we consider it unlikely that firmer conclusions will be discovered in the later phases of this project without significant improvements to the quality and volume of the data. It would be helpful to include an indication to the Madrid Forum as to whether such data might be made available.

710. We therefore require consultation responses to be provided **no later than 16th September 2011.**

ANNEX N – LIST OF RESPONDERS TO PRELIMINARY REPORT CONSULTATION

Table 38 – Consultation responders

No.	Organisation
1	Cogen Europe
2	Wartsilla
3	The Heating & Hotwater Industry Council (HHIC)
4	Tata Steel
5	Gaslink
6	Gas Terra B.V.
7	Council of European Regulators Gas Working Group (CEER GWG)
8	Centrica Energy
9	Gas Natural Fenosa
10	Danish Gas Technology Centre (DGC)
11	The British Ceramic Confederation (BCC)
12	Slovina Regulator
13	Galp Energia
14	ENSOG (European Network Transmission System Operators Gas)
15	Vaillant Group
16	European Association for the Streamlining of Energy Exchange-gas (EASEEgas)
17	ICOM Energy Association
18	Gas Infrastructure Europe (GIE)
19	Enagás
20	MARCOGAZ
21	GdF-SUEZ
22	Euro-Air and Elvhis
23	ExxonMobil
24	DVGW (German association of gas and water experts)
25	National Grid Transmission
26	Fluxys
27	AFG (Association Francaise du gas)
28	EUROMOT actually ifiec
29	CER (Trade Association for Decentralised Heating)
30	OVGW (Austrian Association for the Gas Grid Operators)

No.	Organisation
31	E.ON
32	NVGA (Natural Gas/Biomethane Vehicle Association Europe)
33	Energinet.dk
34	Shell U.K. Limited
35	COGEN Netherlands
36	RAG Austria Energie
37	WINGAS GmbH & Co. KG
38	Edison
39	EUROMOT (The European Association of Internal Combustion Engine Manufacturers)
40	HUNGAS
41	OCI Nitrogen
Madrid forum responses	
14	ENTSOG
18	GIE
20	MARCOGAZ
21	OGP
28	IFIEC (International Federation of Industrial Energy Consumers)
43	EFET (European Federation of Energy Traders)
44	ACER (Agency for the Cooperation of Energy Regulators)
45	CEN (European Committee for Standardization)

ANNEX O – SUMMARY OF STAKEHOLDER RESPONSES TO PRELIMINARY REPORT

Introduction

711. The initial cost-benefit analysis (CBA) was published in July 2011, and was accompanied with a set of consultation questions that were primarily focussed on improving data quality. The consultation period was set such that a report could be made to the XX Madrid Forum.

712. 45 responses were received which included answers to all the consultation questions or in many cases just to those questions that were relevant to the stakeholder. In some cases stakeholders submitted a letter outlining specific concerns or opinions. A list of contributors is provided in Annex N.

713. In addition to the written responses, eight responses were provided at the Madrid Forum held in September 2011.

714. This document provides a summary of the questions and points raised collated under appropriate headings together with a response or explanation. The respondents that made the key contribution to each question are indicated below. In some cases the same or similar comments were made in response to several questions.

715. The consultation responses have provided an important contribution to the final CBA. Where errors in the report were identified the text in the body of the report has been corrected. In addition, several key concepts have precipitated from the consultation responses, such as the concept of 'de facto specifications' and that the temporal nature of appliance replacement might lower costs.

O.1 Q1. Do you agree with the high-level conclusions of this report?

716. 17 responses supported the finding of the report [1, 2, 3, 4, 5. 9, 11, 12, 13, 15, 17, 22, 25, 28, 29, 35, 42] whilst 14 disagreed [14, 19, 20, 24, 26, 30, 31, 33, 37, 18, 41, 43, 44, 45]. It is notable that the majority of support of the report findings came from appliance manufacturers.

O.1.1 Cost, benefits and the model [6, 16, 20, 30, 31, 33, 34, 20, 44]

717. Several responses commented that the cost consequences appear to be based on worst-case scenarios and may need to be validated further. Several responses considered that the assumptions were extreme. Many responses considered that the estimated costs for various elements would be significantly lower in reality.

718. Several responses stated the benefits determined by the model were not clear. Some specific questions were raised, for example, whether physical bottlenecks been properly considered. More transparency was requested to allow a clearer understanding of how the assumptions have produced the conclusion.

719. It was questioned if different gas quality specifications affect trade, for example H-gas and L-gas is traded in Germany and Netherlands but there are no plans to harmonise specifications.

720. One response observed that whilst at first sight the findings of the study seem to present a clear case that the costs far exceed the benefits, this can be questioned as benefits are being presented on a per-annum basis (0.61€ bn per annum) whereas costs are presented as one-off (10.6 € bn) which would suggests a 17-year payback. The response went on to consider a sensitivity to this pay-back period based on only 50% of the costs being appropriate.

O.1.1.1 Response

In the absence of reliable data on the percentage of appliances or other combustion equipment that would be effected or rendered inoperable by the change in gas quality range, it was decided that in all cases a 'worst-case scenario' would be modelled for costs. This was to ensure that all risks – both commercial risks and safety risks – were fully mitigated. The most significant omission in the data was the results of the GASQUAL project that undertook a physical assessment of domestic appliances. The results of that work have been used to reassess the cost of domestic appliance upgrade/adjustment or replacement. Other work to ascertain de facto (i.e. as per practice) specifications will be undertaken to gauge the risk that could be absorbed by TSOs by not applying the legally applicable specifications and thus examine a perceptively plausible scenario for processing costs.

The design and operating mode of the model is described in Section 4 and Appendix G. Additional descriptive text will be included in the final report to clarify the extent to which physical bottlenecks are included within the model, however the model contains commercially sensitive proprietary information and will therefore ultimately remain non-transparent.

Whilst the contractual scope of the CBA excluded specific consideration of L-gas, we have examined some of the practices to try and gain an understanding of commercial harmonisation options (where insufficient physical conversion capacity is supported through commercial action by the relevant TSO). The H-gas and L-gas systems in Europe are primarily operated as different networks, and at present there is only limited capacity to physically exchange gases (utilising nitrogen blending to enable H-gas to flow to L-gas systems, and commingling to enable L-gas to be blended into H-gas networks). The H-gas and L-gas networks are harmonised only in respect of commercial operation within these physical capacities ('conversion capacity'). It appears as is there are different approaches to handling the risk that conversion capacity is insufficient: sometimes it is explicit that shippers bear risk, sometimes otherwise, although in some of these cases it is not clear that extreme risks have been contemplated (i.e. there might be assumptions regarding shippers' ability to respond to a TSO's commercial signals, and a disregard of the potential inability to respond).

The capex was reported as a one-off figure, estimated at €10.66bn, with an annual opex of €0.81bn against a projected annual benefit of only €0.2bn. The figures have been misinterpreted in the response: the benefits as presented in the report are not sufficient to enable any payback. We note that, assuming a 5% post-tax real discount rate over 20 years, breakeven is only achieved if costs are less than 12% of those presented in the report. The executive summary and conclusions presented in the final report will be improved for clarity.

O.1.2 Gas quality specification [1, 2, 28, 29, 31, 37, 38, 40]

721. It was questioned in some responses weather a single gas quality specification could fit all the gas equipment manufacturers and users across Europe. Others recommended that a

narrow gas composition range should be adopted, referring to the US interim guidelines issued by FERC in which a Wobbe index range of 1.5 MJ/m^3 is proposed. One response proposed that a gas quality range within the proven limits of safety should be adopted recommending a maximum range from 47.87 MJ/m^3 to 52.09 MJ/m^3, a range of 4.22 MJ/m^3. Concerns were raised that a harmonised gas quality specification may constrain indigenous production as access to the transportation network would be prevented. It was also suggested that, where correction services (typically nitrogen ballasting) are not currently available at the import LNG facility, a wider specification may make a wider range of LNG sources available.

722. Many responses commented that the EASEE-gas specification was designed for cross-border flows only and was not intended to be applied within the distribution or domestic environments. Some responses appeared to misunderstand how the EASEE-gas specification had been applied.

723. Several responses noted that the EASEE-gas specification does not include methane number which, they stated, is crucial for industrial consumers using natural gas as feedstock and for furnaces as well as for CHP. Others highlighted that it was rate of change in gas quality that has a significant impact on end users.

724. It was also proposed that harmonisation could be achieved through Wobbe index alone.

725. One response stated that the report did not take into account that almost all of the gas transported to Europe is virtually free of sulphur and oxygen and also has very low water and hydrocarbon dew points.

O.1.2.1 Response

The disparity of comments concerning what parameters any single gas quality specification should contain highlight the particular difficulty the project has had in attempting to identify an appropriate common standard. There were different approaches used in the initial analysis: benefits were computed by examining particular parameters; appliance replacement costs assumed the EASEE-gas specification; processing costs did not assume any single specification but sought to work with existing national specifications. The final report will clarify what specifications have been assumed and why they have so been assumed.

It is clear that there are very different views about what should be included in a gas quality specification. A common theme appears to be that the specification should ensure that gas in household environments arrives and burns safely. Beyond this, gas quality specifications might provide additional characteristics to ensure the integrity of the transportation networks, or ensure the operability and/or efficiency of particular appliances.

We note that the option to harmonise on Wobbe index alone would not satisfy the requirement to ensure safe burning in the household environment, as a second parameter is required to prevent transmission of gases containing a significant quantity of higher hydrocarbons that would give rise to poor combustion. To avoid this scenario it has been proposed that density is used, but in the UK a study of CO emissions and soot production resulted in Sooting Index (SI) and Incomplete Combustion Factor (ICF) as additional gas specification control factors linked to gas quality.

In addition, it might be necessary to specify limits for some sulphur compounds because of the interaction with copper and lead-based low pressure pipeline systems that might be present in household settings. It should be noted the costs of processing the gas to meet the EASEE-gas Wobbe index alone are reported in section 5.1 (as capex €3.3bn with an annual opex of €0.21bn) which, given annual benefits of €0.2bn, would not be recovered.

The EASEE-gas specification was used in the report to assess the costs of appliance replacement. It is acknowledged that it was not designed or intended for this purpose; however it was used in absence of any other suitable pan-European specification. When the GASQUAL project publishes their findings, if the recommended Wobbe index range proposed differs significantly from the EASEE-gas specification, the appliance replacement assessment will be recalculated accordingly. We note that whilst a narrower specification may be beneficial to some end users it may also restrict supplies (both indigenous and imported) which would increase wholesale market prices and may cause security of supply concerns.

We note that whilst natural gas does not naturally contain molecular oxygen when it is extracted, it can be introduced – for example where air is used to ballast high Wobbe index gas to a lower Wobbe index. We are also aware that there are gases extracted and used locally that do contain significant sulphur content. We have not been provided with any data regarding the volumes of gas with particular dew points. Whilst we recognise that the gases containing significant quantities of oxygen or sulphur or having problematic dew points are perhaps negligible on a wider European scale, we note that many national specifications contain particular threshold limit parameters for these components. It is this latter fact that has led to identification of the processing costs.

It was assumed that gas transported within each country could have properties and composition at the extreme of that country's specification. This is appropriate because, in absence of a body of actual gas quality data, (historic or future), confidence (as measured by statistical significance or robust forecasting) and therefore risks remain unknown. The approach adopted provides a fully risk-free solution where the full costs are identified – these costs protect the full amount of existing cross-border capacity under all situations, currently permissible, where disparate specifications might present an issue.

It should also be noted that historic data may not be assumed to be indicative of future supplies as new gas supplies may be sourced from different regions and be significantly different to existing supplies.

O.1.3 Regional Harmonisation [2, 8, 9, 18, 20, 24, 26, 27, 28, 34, 36, 41]

Responses reported that gas is transferred across several European countries without issue, including Spain to France, and to Portugal. It was also noted that the EASEE-gas specification for Wobbe index (46.45 – 53.99 MJ/m^3) is narrower than 'H' (45.7 – 54.7 MJ/m3) for which existing gas appliances are certified under standard EN 437. This wider range has been adopted in Spain. It is also very close to the Wobbe index ranges in Belgium, France and Germany. Accordingly it was proposed in several responses that whilst full harmonisation may not be practicable it could be possible that some borders would benefit from regional harmonisation, even if on a restricted number of parameters.

O.1.3.1 Response

It has been recognised that some form of regional harmonisation may present benefits without incurring significant costs. Work will be undertaken to examine the potential for cost-effective regional harmonisation, the results of which will be included in the final report.

O.1.4 Appliance Replacement [4, 13, 14, 26, 33]

726. Several responses questioned why appliance replacement had not been assumed to be over a large period of time allowing natural replacement of old appliances. It was observed that experience suggested that regular maintenance and inspection programs could, in many cases, obviate the need for replacement of appliances. Others suggested that adjustment or modification of appliances would be satisfactory and preferable to replacement – an example was provided that showed that adjustment of appliances has been carried out in Denmark in response to changing gas quality of supplied gas.

727. One response questioned the high level of appliance replacement proposed because post-GAD appliances currently burn gases within the H and E range of EN 437, and that the EASEE-gas range is narrower than these ranges. Other responses supported the replacement of appliances to minimise the risk to public safety but added that products and production facilities are not currently available so that such a replacement could not be achieved within a reasonable period of time.

O.1.4.1 Response

The focus of the study was 2020 and 2030 and it was assumed that rapid replacement of appliances would be necessary to achieve harmonisation within the stated timeframe. The full benefits of harmonisation would not materialise until the replacement requirements were achieved. We recognise that it would not be credible to embark on a 'big-bang' appliance replacement programme, and that if rolled out over time efficiencies would be found through the replacement of fully depreciated assets. However, we also note that Europe's increased use of inherently flexible LNG into the future means that, in real terms, benefits realised in the longer-term will not be as large as benefits realised in the nearer-term – this effect is noted in the initial report.

We further recognise that a phased regional roll-out of appliance replacement might mean that many of the benefits could begin to accrue whilst delaying many of the costs. We expect to include consideration of this within the final report after exploring potential regional harmonisation and receiving the results of the GASQUAL project.

In the absence of alternative recommendations the project assumed full replacement and partial replacement based on at-risk appliances as characterised in the initial stages of the GASQUAL project. The costs associated with appliance replacement and adjustment will be revised once the findings of the GASQUAL have been published.

Whilst replacement of appliances may be recommended it has been highlighted by several appliance manufacturers that they do not have available products that can operate across a wide gas quality range, and in the limited cases where they do, operation of the appliance may be compromised in terms of efficiency and emissions. The GASQUAL project has tested domestic appliances and whilst some parallels may be drawn to commercial products very little performance information is known about appliances in the industrial and commercial sector. The experience and costings incurred by individual countries when responding to changes in gas quality will be used to validate the cost assumptions.

GAD appliances may be demonstrated to operate over a relatively wide range, however the limit gases, that represent gases at the extremes of the specification are only used to demonstrate that the appliance can operate safely, for a short time. It is possible that long term operation on these extreme gases will result in damage to the appliance and compromise its safe operation.

O.1.5 Additional Impacts [25]

728. One response noted that the EASEE-gas specification does not take into account any potential impact on the transmission and distribution pipeline networks of adopting a wider specification.

O.1.5.1 Response

We recognise that we did not specifically include costs of this within the appliance replacement option, however for the purposes of the cost-benefit analysis we considered them negligible given the other costs identified. We expect that each network operator will need to review their safety practices to ensure that any harmonised gas quality specification does not compromise the safety and integrity of their network, and may also need to agree appropriate levels of efficient additional expenditure with their relevant NRA.

O.2 Q2. As a manufacturer do you maintain an inventory of installed appliances? [1, 2, 12, 13, 17]

Few appliance manufacturers were able to provide an inventory of supplied equipment. The exception being Wärtsilä who are aware of the location of the large majority of delivered installations. Some end users may have an asset inventory of their appliances. For example, TATA Steel is establishing the status of its 8500 burners in advance of gas quality changes in the Netherlands.

O.2.1.1 Response

There is limited information on installed appliances. To collect this information to generate an inventory or as the initial survey to establish the type and condition of appliances as part of the replacement or upgrade process is a significant commitment requiring the support of trained engineers. It is unlikely there are sufficient engineers available.

O.3 Q3. Are there any specific gas quality related issues not recognised within this report?

O.3.1 Gas specification [5, 33, 9, 21,28]

729. EASEE-gas specification would be the common specification, but the merits or otherwise of this specification are not examined. Several responses proposed additional parameters that they considered should be included with a harmonised gas specification, these included:

- propane equivalent (PE) number;
- change rate of the Wobbe index (kWh/m3/min);
- methane number; and
- hydrogen content.

730. In addition IFIEC proposed that there should be an explanation, comment and recommendations regarding the Methane number and the Propane Equivalent number.

731. ENTSOG stated that it would welcome a clear decision on which parameters are to be covered under a gas quality specification, and note that the report identifies treatment facilities to reduce some substances (sulphur and oxygen) are not required in most cases.

732. Biogas and odourisation were highlighted as issues which should be addressed within the report.

733. In addition, there were some issues raised in this part of the consultation that were also raised under question 1.

O.3.1.1 Response

It was not the intention of the initial report to examine the various merits of the parameters within a proposed gas quality specification, only the costs or benefits of adopting it. In addition there are no common, established practices for calculating methane number. Further, it is recognised that across Europe different units and reference conditions are used and as a first step these should be harmonised.

Typically gas quality specifications include parameters that protect the integrity of the network and ensure safe combustion of the gas by the domestic user. In harmonising the gas quality specification it might be important to maintain these principles without unnecessarily restricting the range of gases that can be accepted into the network.

Consideration of biogas and biomethane are excluded from the scope of this study and, as these are not a specification *per se,* it would not be appropriate to consider it. Biogas and biomethane specifications are the subject of other work being undertaken at a European level. Biomethane looks likely to have an influence on particular parameters, such as oxygen, which are included within the study.

Whilst odourisation was excluded from the scope of the study, it does present the potential for inhibiting cross borer flows. We have included commentary on odourisation in the final report.

The majority of Europe's gas is transported in the transmission systems in an unodourised state. It is our understanding that, where odourisation occurs within the transmission system it does so because of the relevant economics of the system; there is a simple choice between odourisation at offtake or deodourisation at export points. Key influencing factors in this decision will be the number of offtakes and the appetite for export. Specifically in France, we understand that studies undertaken to date suggest deodourisation would be the most cost effective way of delivering an obligation to export unodourised gas.

O.3.2 Unconventional gases [1, 12, 18, 20, 21, 24, 26, 27, 32, 33, 35. 36, 37]

734. A significant number of respondents proposed that gases originating from renewable or waste sources (particularly biomethane) should be considered. Whilst many of the consultation responses acknowledged that at present these gases are normally injected into the distribution network, it was thought significant amounts could be compressed and injected into the transmission system at some point in the future. It was further proposed that the EC should thoroughly monitor, and take action if needed, in the event of an increased level of impurities (based on their associated impact).

735. It was noted that odorisation and L-gas were excluded from the study.

736. Another response requested that the specification should address the use of natural gas and biomethane as a transport fuel.

737. One response commented that it can be easily calculated that inaccuracies of +/- 12% in energy measurement can occur if the EASEE-gas quality range is adopted.

O.3.2.1 Response

Biomethane, L-gas and odourisation are discussed above. The possibility of a European shale gas facility supplying gas into the transmission network was considered in the modelling.

We recognise that we have excluded specific costs that might be imposed on what are currently relatively small applications, such as the transport sector. Whilst we acknowledge that some of those applications (especially transport) will present a greater share of the gas market by 2030, the shares are still low in comparison to traditional applications such as space heating and power generation. Given the scale of the costs identified for mitigating the impact of full physical harmonisation in traditional appliances, the costs imposed on these niche applications was considered negligible in the study period. We acknowledge that as Europe pursues full decarbonisation by 2050, the market share of, in particular, the transport sector, will continue to grow.

The impact of a wider gas quality specification may impact on installed monitoring and metering systems. It would be the responsibility of the facility operator to implement the necessary changes to ensure the facility meets operational and legal requirements.

O.3.3 Impact on appliances [4, 6]

738. One response stated that the full Wobbe index band which will be valid in the Netherlands as from the year 2014 (48.3 – 55.7 MJ/m^3 at 0 ºC) is not fully supported (yet) by manufacturers of comfort appliances.

739. Another response considered that no end-user or equipment related requirements should be included.

O.3.3.1 Response

Several appliance manufacturers have raised the possibility that current appliances will not operate over a wide Wobbe index range, or if they do, then energy efficiency and emissions may be compromised. This is particularly topical as Denmark and the Netherlands have historically received gas within a tight range and appliances have been optimised to that range but future gas supplies will be over a wider range. Appliances are being re-set to operate over the revised range.

Any specification should at the very least consider domestic appliances which in general are not automatically adjusted for variable gas quality, and should incorporate sufficient gas quality parameters to protect the general public.

O.3.4 Other [25]

740. Gas blending could be used to supplement to gas processing, thereby lowering the costs of processing.

O.3.4.1 Response

Gas blending is carried out in some networks typically on a best endeavours basis, sometimes also including commercial inducement to the relevant shippers. However, because a vertically separated gas market requires that TSO has no direct control over the supply gases (particularly the compliant gas used to blend non-compliant gases), it is difficult to offer this as a physically firm service. We have explored the concept of commercial harmonisation within the final report.

O.4 Q4. Do you manufacturer appliances that can operate over the full EASEE-gas specification without loss of efficiency or increased of emissions? [1, 2, 4, 15, 17, 20, 22, 32, 35]

741. All of these responses highlighted issues that related to appliances being operated outside of the optimised range. In addition one response reported that in general the gas quality delivered has a much narrower quality range than the specification would allow and this provides for good operating results. A narrow Wobbe index range supply gas enables appliances to be optimised for efficiency and emissions.

742. The issue of availability of appliances that can operate over a wide range was raised with the following examples provided:

- The majority of the latest mass-produced boiler cannot operate safely over the full EASEE-gas Wobbe index range. There will be an increase of the emissions and in some applications a loss of efficiency. New technical solutions are available but they aren't suitable for mass-produced boilers. A considerable reduction of the EASEE-gas Wobbe index range could solve the problems.
- ICOM members have indicated that their appliances will not operate over the full EASEE-gas specification without loss of efficiency or increased of emissions
- MARCOGAZ have been informed of problems with appliances subjected to gas quality changes in Denmark but the reason seems to be linked to the resetting of domestic gas appliances on site to optimise the appliance performance to the supplied gas quality.
- The test results of the "FIGAWA working group GASQUAL" on warm air heaters, radiant luminous heaters and radiant tube heaters [being representative for the predominant population of heating appliances of these technologies in the European market] have proven that free variation of gas quality across a wide range is unacceptable for safe operation.
- Natural Gas Vehicle manufacturers optimise their engines according to a reference gas quality specification. While some engine types might only experience a lower efficiency when using natural gas of lower quality, in some cases they may experience problems that could harm the engines and reduce their expected life.
- Experience in the Netherlands has shown that, even within the current Dutch gas specifications, failures in equipment have occurred due to abrupt gas quality fluctuations.

O.4.1.1 Response

Whilst this is a limited number of responses, representing a vast number of appliances, it does raise the issue that many appliance manufacturers do not believe that their appliances will work efficiently, with low emissions and, of even more concern, safely, across a wide gas quality specification.

Recent experiences in Denmark and the Netherlands provide valuable information regarding the impact of changes in gas quality and the cost of remedial action. This information will be used to validate and verify the costing proposed in this report.

O.5 Q5. Do you have evidence of damage or failures caused by appliance operating on gas that is not compliant with the local gas quality specification?

O.5.1 No evidence [4, 32, 33]

743. Reference is made to the recent developments in Denmark. Most appliances in Demark were originally installed while the allowed Wobbe index range was smaller than today. The widening of the specification has not resulted in any damage or malfunctioning.

744. NVGA advised that there was no record of impact of gas quality changes being reported on Natural Gas Vehicles.

O.5.1.1 Response

Consistent with the assumptions used in the initial report, there appear to be few instances where changes in gas quality have not impacted on appliance performance. The changes in specification in Denmark were relatively small and consequently of minimal impact on appliances.

O.5.2 Evidence available [1, 2, 21, 24 31]

745. Several responses stated they had evidence available and/or provided anecdotal evidence of damage to, failure of, and inefficient operation of a range of different appliances, including turbines, reciprocating engines, fuel cells and chemical feedstock equipment.

746. There was scant quantification; however an operator of ammonia plants in the Netherlands has estimated the cost of modifications to operate with a wider gas quality range in the future. Capex has been estimated at €20m to €30m with annual efficiency losses equivalent to €7m to €10m.

O.5.2.1 Response

The respondents have indicated that changes in gas quality will cause a loss of efficiency, increase in emissions, and cause damage to the appliance. This is consistent with the assumptions used in the initial report.

Stakeholders that use natural gas as a feedstock, particularly where it has historically been supplied over a narrow range, may incur significant costs in installing additional plant and higher operating costs.

O.6 Q6. Would you support the adoption of the proposed EUROMOT gas quality specification

747. Four responses [2,15, 30, 32, 39] supported the gas quality proposed by EUROMOT, one [35] considered it preferable to the EASEE-gas specification whilst fifteen considered it unacceptable [6, 13, 17, 18, 19, 20, 21, 23, 24, 25, 26 , 27, 31, 33, 35. 36]

O.6.1 Acceptable

748. The EUROMOT proposal was supported by several appliance manufacturers who prefer a narrow Wobbe index range although several also considered that the EUROMOT range would be still too wide. Such a narrow specification could help to establish mass

production in micro-CHP appliances. Two respondents proposed adoption of USA standard proposed by the Federal Energy Regulatory Committee (FERC), that includes a Wobbe index range of ±1½%. One respondent suggested that a rate of variation of the Wobbe index was required.

O.6.2 Unacceptable

749. Several respondents stated that an overly narrow specification for all of Europe (such as the EUROMOT specification), would not allow the acceptance of gas from some supply sources without treatment thereby restricting supplies and increasing prices for consumers. A wider specification would support gas exchange, and increase available flexibility and security of supply. One respondent questioned a specification of zero for RSH parameter.

750. Several challenged the need for a narrow Wobbe index range based on the observation that several countries have a wide specification range over which appliances apparently operate safely. This view was supported with reference to the fact that some appliance manufacturers claim their appliances can operate over a Wobbe index range of ± 5% around test gas G20.

751. The certification of appliances according to EN 437 was cited as evidence for safe operation of appliances over a wide range. Another stated that he believed that there would still be a requirement for regional differences in specification.

O.6.2.1 Response

In general there is strong opposition to the EUROMOT proposal as it proposes a more restrictive gas quality specification and as such is restrictive to many gas supplies, would result in a reduction in security of supplies and require increased processing of gas supplies. Many believed that a wider gas specification could be introduced but may require a regional approach to be adopted, see response to Question 1.

We note an incompatibility between the observations noted by some respondents of appliances apparently operating over a wide range, and responses from appliance manufacturers that current appliances cannot operate over a wide range.

O.7 Q7 Are there any specific circumstances that should be assessed in detail?

O.7.1 Appliances [3, 10, 28, 30]

752. One respondent questioned the need to replace all appliances, referring to unpublished information from the GASQUAL study indicating that a gas quality specification change will only have a small impact and as a result it would not require the replacement of those appliances as suggested in the initial CBA. Also, where there are appliances that have been tuned during installation that subsequently exhibit issues, the problem could be solved by readjusting those back to the appropriate specification. The respondent highlighted that this has been the approach in Denmark. The respondent further stated that in many cases impacts are due to the combination of Wobbe index variation and variation of other parameters such as gas pressure. Consequently, for some appliances it may be possible to reduce the impact of gas quality variations with other technical solutions, for example pressure regulators or combustion controls.

753. Other respondents suggested other parameters should be considered: excessive variations of gas quality; any and all circumstances that can violate appliance safety;

effects on equipment that do not have continuous measurement of air/fuel ratio and/or control; and any that impact on performance of CNG driven motors.

754. One respondent questioned the availability of installers and engineers to implement the changes that would be required.

O.7.1.1 Response

Findings of the GASQUAL study have been made available for the final report, and they will be used to revise the appliance replacement costs. We note that retrofitting and retuning are other appliance remedies which may offer some cost reduction, however we also note that the industry must continue to ensure the safe operation of appliances. The complexity of factors affecting appliance performance has been included within the scope of work of the GASQUAL study.

Given the poor quality of the data available it has not been possible to examine many of the more complicated parameters that could be used to described gas quality, especially those measured over a time differential (such as rates of change). Whilst we acknowledge that there is no consensus as to what ‘harmonisation’ should entail or precisely what should be included in a ‘specification’, it could be argued that the introduction of parameters not included in existing specifications is not ‘harmonisation’.

The need for, and availability of a suitably trained workforce has been highlighted in the questionnaires returned by appliance manufacturers returned during 2010, and has been identified as a risk within the final report.

O.7.2 Gas Quality Specification [12, 13, 14, 23, 32]

755. One respondent stated there is a need for mixing rules, agreed tolerances and financial penalties.

756. Whilst some believed the conclusions drawn from the existing set of data would remain valid even if additional data was made available others felt a more ‘tailor made’ study focusing on regional gas quality issues, different timelines for implementation and taking into account a broader range of issues would have been more appropriate.

757. One respondent observed that replacement of very old appliances by new efficient appliances contributed to emission and energy efficiency goals, and that the installation of control systems that dynamically adjust the set point of equipment in response to gas quality may also provide similar benefits.

758. Other respondents believed selection of specified parameters within the EASEE-gas specification would enable harmonisation at minimal cost impact. They recommended the report should identify the key cost drivers and provide a breakdown.

759. One respondent recommend inclusion of unconventional gas to grid injection.

O.7.2.1 Response

Mixing is generally not offered on a commercial basis and will be dependent on availability of compliant gases over which the relevant TSO may have no control. We recognise that a commercial route to harmonisation – where the TSO contracts for, inter alia, flow management services to ensure sufficient compliant gases – may offer a similar structure to that suggested. This has been included in the final report. Detailed rules, penalty and other charging regimes are however not within the scope of this project.

Regional harmonisation is addressed in Question 1. Temporal and breadth considerations are also discussed in the final report.

We agree that the replacement of very old appliances would contribute to wider policy objectives and we have included qualitative consideration of this in the final report. We have also ensured that other options such as retrofitting and readjustment have also been considered in the revised costs.

Unconventional gas issues are considered in Question 3

O.7.3 Cost and Benefits [2, 4, 18, 19, 20, 24, 31, 36, 37]

760. One respondent suggested that for pipeline gas the most cost-efficient solution may be gas processing upstream at source but acknowledged this would be difficult at present and not feasible for LNG producers. The respondent proposed that it is more likely that gas would be treated in the EU (entry points, cross-border interconnection points) and therefore that it was necessary to define responsibilities to deliver gas to an agreed specification and to carry out gas processing as necessary.

761. Several respondents believed that the installation of gas processing facilities should not be an obligation for infrastructures operators. The location and responsibility of gas processing was raised by several respondents.

762. One respondent claimed EASEE-gas had ignored the benefits of stripping the higher hydrocarbons from the imported gases and using these as feedstock for refineries or for vehicle fuel directly (LPG).

763. Several respondents believed a regional approach should be adopted modelling real scenarios using existing national situations. One wanted the impact on underground storage to be assessed while others wanted greater detail of the gas processing required, notably for Wobbe index and including the location of the plant.

O.7.3.1 Response

We note that gas only requires processing where it is not compliant with a stated specification. Any requirement for upstream processing (i.e. outside the EU) would therefore stem from the application of a set specification at the EU border. This concept has been included within the modelling and is therefore implicitly included in the benefits identification. Cost allocation (who should pay for costs, e.g. LNG producers, importing or TSOs), is predominantly a regulatory matter and is not within the scope of the project. The location of the investment may impact on the costs, but only to a limited extent.

We note that existing practices already remove a significant volume of valuable heavy hydrocarbons to the extent that it is economic under prevailing market conditions. This can be observed at liquefaction facilities such as the Qatargas facilities in Qatar, as well as beach terminals such as St. Fergus in Scotland.

A regional approach has been discussed in response to Question 1.

O.8 Q8. Do you consider that the data used to undertake this analysis is sufficient to support the conclusions presented in this report?

764. Of the fifteen responses seven [2, 3, 4, 5, 17, 25, 35] considered the data sufficient whilst eight did not [20, 21, 24, 26, 30, 31, 33 37].

765. Many acknowledged the fact that may assumptions had been made, and that generally there was a lack of data and that some of it was of poor quality.

O.8.1 General [1, 13, 17, 18, 37]

766. Though some poor quality data has been used together with a large number of assumptions, the discrepancy between costs and benefits is so great that several considered it unlikely that even more data would yield a different overall conclusion. Others supported the conclusions made upon the existing data. However several suspected that the value developed for the costs and the benefits would differ significantly if better data were available and the errors could be corrected.

767. One response believed that the conclusions drawn from the existing set of data will remain valid; therefore no more data is required.

768. One response was concerned that the volatility of LNG market could have a significant on future gas supplies.

O.8.1.1 Response

The report highlighted the limited data and the assumptions made. The final report will be revised to incorporate any additional information that is made available to the project team.

The commercial nature of the LNG market and the influence of Far Eastern and North American markets were fully incorporated in the modelling. We acknowledge that this does not include volatility of gas quality which might arise from the volatility of the price of liquids, however we feel it is unlikely that such changes would significantly alter the benefits calculated.

O.8.2 Processing [2, 30, 31]

769. One respondent suggest the study should consider stripping. One respondent stated that the report did not clarify how far capex and opex are influenced by the differences of specified gas compositions and actual gas compositions.

O.8.2.1 Response

Stripping has been addressed in response to Question 7.

We acknowledge that the sensitivity of gas processing capex and opex to specification or composition had not been examined. We have considered sensitivities of specification within the final report, but note that the capex figures are largely insensitive to actual composition.

O.8.3 Appliances [10, 12, 20, 24, 26]

770. One respondent suggested that the replacement scenarios should be revised taking into account the most recent results from GASQUAL.

771. The regulator from Slovenia questioned the lack of data relating to Slovenia.

772. Several proposed that a long term implementation scheme could reduce the costs near to nil if the replacement of appliances, if required, would be near the average lifetime of such appliances only by marketing adapted appliances only once the standard is issued.

O.8.3.1 Response

The results of the GASQUAL study have been used to update the costing within this report before issue of the final version.

Only limited data for Slovenia was sourced.

Long term replacement of appliances is addressed in Question 1

O.9 Q9. Should significant effort be made to improve the data used in the analysis presented in this report?

773. Eight responses [4, 20, 21, 24, 28, 31, 33, 37] believed additional effort should be made to improve the data whilst six did not [2, 5, 17, 25, 26, 35].

O.9.1 Available data

774. One response considered that collecting sufficiently improved data would be a large task, and implied this should not be undertaken if there were no obvious (net) benefits. Another response highlighted the impossibility of TSOs to provide data that is considered confidential, and implied that such data could only be provided on a formal, legal basis.

775. One response suggested that the data should be compared on all interconnection points and that data should be tracked or monitored by the TSO. To improve transparency it was further suggested that information could be included in the annual TSO's reporting to the state regulator.

776. One response suggested that a full overhaul of the report is necessary, however, it is not just the quality of the data that should be improved, but also the scenarios studied and the aspects taken into account.

777. Several respondents considered that the final report should include the results of the GASQUAL project.

778. Energinet.dk advised that they have a detailed mapping of the total environmental effects and efficiencies of all installed appliances in Denmark as a function of the expected gas qualities, together with a well-functioning cost-benefit model.

O.9.1.1 Response

The final report has included information supplied as a result of the responses made to the preliminary report and further work. This has included using the results from the GASQUAL project to update the appliance replacement costs, and data from TSOs to construct ‘de facto specifications’.

We note the comments regarding the difficulty of collecting better quality data, and agree that substantially better data would enable the construction of much more detailed analyses. The final report will put forward recommendations for further study, which should afford the opportunity to collect better quality data.

Information made available by Energinet will be used to verify and validate the cost assumptions used in the final report.

O.9.2 Gas quality specification [19, 28, 36, 42]

779. One response suggested that further analysis could be carried out to determine which gas specification could be acceptable to the largest number of Member States with the lowest replacement cost of gas appliances across the EU.

780. Several respondents expressed the opinion that the introduction of a harmonised gas quality specification could have higher cost implications in addition to those detailed in the report.

O.9.2.1 Response

Regional harmonisation is considered in question 1. The CBA has not sought to produce a specification that minimises the costs of its imposition across the EU, as the lowest cost appears to be obtained by **not** imposing harmonisation – it is therefore impossible to know which parameters should or should not be included in a single specification.

The impact on users of natural gas as a feedstock has focussed on modification of burners and plant equipment. We note that there may be additional costs in the form of loss of efficiency and financial penalties for increased emissions. Discussion of these is included in the final report.

O.9.3 Model [20,24,26}

781. Greater transparency on the modelling tool should be given in order to allow a clearer assessment of the way the data have been integrated towards the conclusion. Several responses recommended that efforts should be taken to collect additional information and accurate data in order to better define measures to be proposed. Regional harmonisation was also suggested in several responses.

782. One response questioned why Italy had not been modelled as stated in the original scope.

O.9.3.1 Response

Regional harmonisation is considered in question 1.

Once the model was developed and validated it proved impossible to run the model with the gas quality constraints impacting on a selected region (for the pilot, Italy), without also properly considered the pan–European impact. Consequently it has not been possible to run the model for individual countries. The results presented within the report reflect the levels of disaggregation used within the model.

As stated in the initial report, the model contains proprietary information, intellectual property and commercial intelligence, so it is not possible to make it fully transparent.

O.10 Q10 – do you have access to further data that could (if it were made available) improve the quality of the data used in the analysis presented in this report? Q11 - can you provide typical detailed gas composition at cross border points? Q12 - if so, can this data be made available (respecting confidentiality, as required)?

783. Several responses [6, 12, 18, 20, 24, 37, 43] proposed that gas quality data was the responsibility of TSO's and could be obtained directly from them or their websites. There

were very few offers to provide data [5, 26, 21] and some respondents suggested using public domain reports.

784. Four responses [5, 19, 26, 30] offered to provide gas quality data however several cautioned the use of this data as past gas quality data may not be representative of future supplies [19, 25].

785. Respondents referred to the ENTSOG Transparency Platform (http://www.gas-roads.eu/) that includes information on gas specifications at cross border points can be obtained. [14, 18].

786. Generally it was agreed that information about current and future gas qualities should be obtained from the large producers supplying gas to the European market together with ENTSOG's TYNDP. It was noted that the quality of gas expected to come to the European market from new gas sources should be considered.

O.10.1.1Response

Following a specific request from the EC, better data has been provided by some TSOs via ENTSOG, which has been used to improve the analysis in the final report. We note though that this is not a geographically complete data set, relates primarily only to Wobbe index, provides limited temporal scope (a few years), and is usually recorded as averages thereby destroying extremity data. To develop any meaningful statistics, it seems quite likely that a sufficiently complete historical data set does not exist.

We note the cautions on using historical data. As the historical data has been insufficient to develop meaningful descriptive statistics for risk analyses, the historical data provided has only been used to understand the difference between the written specifications and practice.

We consider that there might be various mechanisms to improve visibility of forward looking data.

O.11 Q11. See A.10.

O.12 Q12. See A.10.

O.13 Q13. How should data be collected for such a study?

787. It was agreed that information should be sought from all stakeholders, TSO's, shippers, suppliers, producers, LNG operators and end users. In addition it was felt that pan-European organisations, for example Eurogas and Marcogaz, could support and facilitate data collection.

788. It was thought that the use of clear and unambiguous questionnaires hosted on-line or issued to all relevant stakeholders might be helpful. Stakeholders should be made aware of the importance of responding. This process should be supported by bilateral meetings with different stakeholders and organisation of workshops.

O.13.1.1Response

The project had already adopted many of the data collection methods proposed by the consultation respondents (the project was initiated at a kick off meeting during the Flame Conference in January 2010,an initial questionnaire was issued to Stakeholders during the summer of 2010, and meetings held with interested stakeholders). To further understand the issues another workshop was arranged in December 2011.

O.14 Selected other comments

A.14.1 In the view of the CEER GWG, the most essential improvement of interoperability in the European gas markets could be realized through harmonizing of commercial standards and units at cross border points. [7]

O.14.1.1 Response: this will be one of the recommendations to be made by this report

A.14.2 Where security of supply considerations or specific problems related to market integration require it, conversion and processing facilities could be put in place at border points. [7]

O.14.1.2 Response: It was always EASEE-gas intention that countries would process gas to meet the requirements of the domestic market. We also note that the aggregate commercial value of security of gas supply to commercial enties trading in a liquid and competitive market is different to the political value of security of a nation's gas supply.

A.14.3 Portugal is receiving natural gas and LNG with very close specifications, in a narrow range close to the upper limit of the Portuguese specification (NG ≈ 53.3 and LNG ≈ 55.4 MJ/m^3). During 8 years of LNG imports from various sources and natural gas from Algeria) through Spain, no utilisation problems have been experienced. The Portuguese specification is very close to that of EASEE, but the sudden utilization of the full scale of variation could be disruptive. [13]

O.14.1.3 Response: we note that a wide gas quality specification for a country cannot be used as evidence that appliances will operate safely across that range as the range of the supplied gas is often narrower.

A.14.4 The conclusion of the study that "a net benefit would not materialise from harmonisation of Europe's gas quality specifications" is much too general and is as such not supported by the findings in the study, which only addresses a specific case under a specific scenario. This is an important shortcoming of the study. [14]

O.14.1.4 Response: The report details the data and the assumptions made in determining the costs and benefits and provides conclusion drawn upon those findings. The study has considered a variety of different scenarios for both the costs and the benefits of harmonisation and failed, in every combination of costs and benefits, to show any net benefit. We therefore disagree that the findings of the study do not support the conclusion.

A.14.5 The preliminary report presented by GL/Pöyry makes some assumptions which are not based on realistic facts and assessed data. Its overall conclusions are highly questionable and do not reflect the reality of the existing situation in some EU Countries. It seems that the study always considers the worst scenario in EU. [xx]

O.14.1.5 Response: See comment 4 above. The study assumes the safest scenario unless data has supported an alternative approach, to ensure the continued safe operation of gas networks and appliances. The study has also examined *sensitivities which would introduce unknown safety risks however these less safe approaches also fail to show any net benefit. conclusion.*

A.14.6 GIE wants to outline that the issue of paramount importance regarding any proposal to change gas quality is safety. Changes to gas quality specifications may lead to unintended consequences that have an impact on safety standards.[18, 36]. The safety risk in the context of an appliance replacement or adaption programme is the possibility that a number of appliances might be overlooked. [25]

O.14.1.6Response: The safety of end users is paramount in recommending any harmonisation of a gas quality specification.

A.14.7 Gas quality is sufficiently controlled in Germany by DVGW code of practice G 260, which means that Germany wouldn't need any European standard in this field [24]

O.14.1.7Response. The cost benefit project has sought to ascertain if the EU would benefit from harmonisation throughout EU, based on meeting the needs of all Member States.

A.14.8 Any proposal to introduce wider gas specifications must also take account of the ability of pipeline networks to safely transport wider specification gas. For example, gas with a higher Wobbe index would contain a greater proportion of higher hydrocarbons which some pipelines may not be designed to transport whilst retaining an appropriate level of integrity over the longer term. Accommodating increased levels of higher hydrocarbons has the potential to increase the likelihood and impact of a pipeline failure event and would require NGG, and potentially other TSOs, to revisit their risk assessments in this area, possibly leading to pipeline replacement or modification requirements and the associated additional costs and lead-times to achieve compliance. If measurement of a wider compositional range were required, the current measurement equipment would need to be tested and failure to perform to the required standards of accuracy would, again, lead to additional costs associated with replacement or adjustment of these assets [25]

O.14.1.8Response. Network operators would need to consider the impact of a wider gas quality specification on the integrity of their networks and all metering and gas quality measurement systems. We acknowledge that there might be additional costs in the appliance replacement options pertaining to the need to modify transmission systems.

A.14.9 Fluxys is convinced that the cost benefit analysis would show benefits at least for the harmonisation of some parameters at a regional approach: the Wobbe index issue is for instance essentially located in the UK/BE/NL/DE countries, and an appropriate regional solution would alleviate the problem for the whole of Europe, in that the benefits might in that case exceed the costs by far. [26]

O.14.1.9Response. Regional harmonisation has been addressed in response to question 1.

A.14.10 Chemical companies using natural gas as feedstock need clear specifications and means of short-term correction in case of high variations, and to be able to anticipate the long-term gas quality in order to be able to make necessary investments, [28].

O.14.1.10 Response: Once a harmonised gas quality specification has been defined it may be necessary for stakeholders to be given sufficient time to assess the potential impact and undertake corrective action as necessary.

A.14.11 EASEE-gas does wish to clarify two points: firstly the W.I. range as specified in the EASEE-gas CBP was agreed by the members of EASEE-gas as being the broadest range possible whilst it was known that in some areas of the EU natural gas enters the grid which does not fall within this W.I. range, thereby indicating that the adopted W.I. range is not extreme. Secondly EASEE-gas wish to make the point that the report is not clear on the fact that the EASEE-gas specifications as presented in our CBP is only applicable at cross border points and it was never the intention to use these specifications throughout Europe (i.e. within the Member States). The actual physical hardware changes either by changing out appliances or installation of processing equipment would only have to be done at the time when Member States would actually be confronted with gas flows within the CBP specification but outside the national specification. Furthermore each Member State could decide at its own discretion which measures to take and when providing the most cost efficient solution whilst ensuring trading of gas is possible throughout Europe. Therefore adopting the EASEE-gas specification for gas quality within countries was never the intention. [16]

O.14.1.11 Response. We note that the EASEE-gas specification was never intended for full physical harmonisation; however it was used because of the absence of any other generally broad pan-European specification. We note that as the application of EASEE-gas is voluntary, where existing contractual arrangements are different to the EASEE-gas specification and renegotiation would impose costs that cannot be recovered by a party, affected entities (i.e. either contractual parties or NRAs regulating the allowed costs of one of the entities) can disregard the EASEE-gas specification. We consider that without placing obligations on particular entities, any attempt at imposing any form of harmonisation will be frustrated.

A.14.12 It has been suggested that a TSO could accommodate out of specification gas into its network on a risk assessed basis by blending with another compliant source. In NGG's view, given that a TSO has no control over the availability of the compliant stream and that its unavailability would also render the non-compliant stream unavailable, this method, if employed at all, could only act to supplement a processing solution rather than serve as a solution in its own right. [25]

O.14.1.12 Response. We note that the vertical separation of transmission and shipping activities, coupled with competition in shipping/supply and liquid traded gas markets, means that TSOs are not necessarily in control of the availability of any particular stream of gas. We therefore agree that 'blending' or 'fortuitous commingling' can only be undertaken where there are either specific commercial arrangements between the TSO and relevant shipper(s) or on a reasonable endeavours basis. We have therefore not assumed any reduction in processing costs within the study.

ANNEX P – DETAILED ANALYSES OF PHYSICAL SOLUTIONS

P.1 Appliance replacement requirements

789. The following section considers the costs that could potentially arise if the current population of residential appliances and non-domestic equipment were to be adjusted, modified or replaced. It assumes a short intervention period and so does not take account of the natural replacement cycle which may significantly reduce these costs.

790. We have examined the costs of replacing and possibly adjusting:

- domestic appliances, comprising:
  - boilers and jet burners;
  - cookers;
  - water heaters; and
  - space heaters;
- commercial appliances, comprising:
  - commercial boilers with outputs greater than 70kW and jet burners;
  - storage water heaters;
  - catering – non-domestic cooking; and
  - commercial heating;
- industrial appliances;
- gas engines; and
- gas turbines.

791. These appliance populations and performance characteristics under a wide gas quality specification are discussed below.

P.2 Introduction – issues affecting domestic appliances

792. There are a number of possible ways to consider how a changeover to a more flexible population of natural gas burning appliances and equipment might occur. These relate to the outcome of the previously mentioned GASQUAL study and breakdown as follows:

I) some equipment will continue to operate safely without the need for any intervention such as replacement, adjustment or modification;

II) some equipment might be able to be modified or adjusted; and

III) some equipment will need to be replaced with re-designed appliances capable of operating safely over a broader gas quality band.

793. This breakdown can be described further:

- No Intervention - The GASQUAL study concluded that when tested over the full Wobbe index range of their test gases (46 to 54.7 MJ/m^3) over 70 million domestic appliances (42%) would be unaffected by gas quality variations. These less sensitive appliance groups would still need to be identified and inspected but, if found in good working order, would not attract any remedial costs.

- Adjustment – The GASQUAL study concluded that gas appliance and equipment designs vary considerably throughout Europe and it is only a very few that would be capable of simply being adjusted to operate over a wide gas quality range. The appliance type that might be most capable of safe adjustment are the high efficiency condensing boilers which incorporate a gas/air ratio controller that could be re-tuned to allow emissions to remain within limit over a wider range of natural gas quality, however the boiler efficiency might be adversely affected. This group represent only 6% of the domestic appliance market with 3% being installed in the UK. If the outcome of the GASQUAL study is validated across the full range of current condensing boiler designs then the cost of adjusting these appliances is significantly reduced down to the cost of a number of visits by qualified and competent engineers.
- Modification – On more main stream gas appliances such as cookers, fires and water heaters the gas controls tend to be simpler and as such modifications to allow them to operate safely over a wider gas quality range would be more fundamental such as reducing its heat input rating and burner changes. A modification to an installed appliance would require a number of visits by a competent engineer to ensure continual correct and safe operation and it does raise the issue of its condition, maintenance history and the age. It is worth noting that significant field modifications to installed equipment and adjusting the gas setting pressure will affect their CE status under GAD and will raise issues relating to the manufacturer's responsibility for ongoing product liability. Modification costs have been estimated as part of a UK Government public consultation document[16] and vary from just 4% of the replacement cost for a boiler to up to 36-40% of the replacement cost for cookers and water heaters. This does not include the cost of survey and post-modifications visits which will vary considerably from country to country. There is potential to reduce replacement costs but effort and costs would need to be spent and then factored in to develop the modification kits needed to ensure the continued safe operation of installed appliances.
- Replacement – At this stage and without detailed survey information on specific appliance designs and input from manufacturers there is uncertainty about the number that can be safely adjusted or modified. Further work would need to be carried out by MSs to verify the precise extent to which appliances might be safely adjusted or modified, however it is clear that a requirement for the full replacement of all 'at risk domestic appliances is going to be very unlikely. We have assumed that 67% of the identified 'at risk' domestic appliances might require replacement and that the remainder could be adjusted or modified at 25% of the estimated cost of replacement.

P.2.1.1 Natural replacement rates for domestic appliances

794. Precise information about the rate at which domestic gas appliances are replaced is difficult to obtain as it is unlikely to be recorded and varies considerably between appliance types and may be initiated for a range of reasons. A UK Government funded study in 2005[17] did consider this topic and concluded that the number of appliances replaced each year is a complex mix of the following:

- a distress purchase of an irreparable appliance;
- unreliability, genuine or perceived;

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[16] Future Arrangements For Great Britain's Gas Quality Specifications, DTI, December 2005

[17] Assessment of the size and composition of the UK gas appliance population produced for the DTI and Gas Quality Project Steering Group , November 2005

- the promise of likely future fuel savings; and
- fashion and style, particularly for cookers and room heaters.

795. In addition the report states that a further factor is the availability of functional spare parts. The general view is that manufacturers maintain stocks of these for at least ten years and possibly longer for popular appliances, although most manufacturers would claim a fifteen year expected life span which does not seem unrealistic.

796. If considering an appliance replacement programme it would be reasonable to assume that within a fifteen year period the majority of the existing installed equipment would have been replaced. However it can never be guaranteed as there will always be some that continue to operate safely and reliably for much longer. This view is confirmed by data contained in one of the supporting GASQUAL reports[18] that shows that from a population of European boilers of sixty six million in 2007 over seven million were installed prior to 1993, some 11% of the total.

797. Another important factor if natural replacement is to be considered as a possible way of reducing appliance replacement costs is the availability of suitable 'new generation' appliances capable of operating safely if gas quality varies over a wider band. For a number of years it will be the case that equipment will have to be replaced by appliances that are only designed for the existing gas quality operational range. The development of appliances that will accept a broader range of gas qualities might take several years of development and in some cases might never be technically possible or could lead to gas-fired equipment being too costly leading to a shift towards appliances using other fuels such as electricity. Appliance manufacturers would need to be encouraged to develop equipment whose design goes beyond the current requirements of GAD.

P.2.1.2 Further discussion on whether to replace, modify or adjust domestic appliances facing gas quality variations

798. Tuning costs are small in relation to overall installation and maintenance costs. This project has concentrated on the potential costs of a partial replacement programme for appliances as a way of ensuring safe operation in the event of gas quality variations, subject to the availability of suitable appliance designs. Modification or adjustment might be a solution for some appliance types in some countries. One of the outcomes of the GASQUAL study is that further assessment is needed at a national level to understand the way domestic appliances are set-up or adjusted to be safe with current gas qualities and the impact of other variables such as gas supply pressure and electricity voltage.

799. If modifying or adjusting appliances is technically feasible and results in a unit operating safely over a wider gas quality range then the appliance replacement costs based upon the GASQUAL results would be significantly reduced.

800. Both an adjustment and a modification programme would need to involve an initial detailed appliance survey exercise in addition to the upgrade visit by a competent gas engineer. A UK Government study from 2005[19] and a more recent report by energinet.dk[20] covering the Danish situation suggest typical costs to either modify or adjust boilers at between €60 and €160 per appliance. This compared with a boiler replacement cost of €1450 used in this study.

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[18] GASQUAL Work Package 1 Report 1.2 Market Study, November 2009

[19] Future Arrangements for Great Britain's Gas Quality Specifications, DTI, December 2005

[20] Nye Gaskvaliteter (New Gas Qualities), Energinet.dk, ref 29-000 GR-5003, October 2011

801. It can be assumed that there is inherently more safety risk associated with carrying out adjustments or modifications compared to the replacement of existing used equipment with a new appliance. Consideration would need to be given to mitigate the potential hazards relating to making field changes to an installed appliance with little prior knowledge of its history, condition or age.

802. Appendix G 'Historic Experience of Changing Gas Quality', gives further details of relevant case studies including more information on the recent Danish gas quality situation which did involve a successful limited boiler adjustment programme but over a much smaller Wobbe index range.

803. If an appliance change programme is to be initiated, consideration would need to be given to the issue of the availability of sufficient numbers of competent gas engineers to carry out the necessary survey, inspection and installation work. Although recognising the logistical problem of suitable skilled labour, for the cost assessment exercise that follows it has been assumed that this workforce will be available.

804. With over 165 million domestic appliances and over 15 million commercial / industrial units the biggest risk when considering a survey and change programme is the possibility of the number that might be overlooked. There is a potential safety risk from such equipment due to the likelihood of higher emissions and premature materials failure. This could be mitigated, at a cost, by a robust project management system and stringent quality control of the process.

P.2.2 Domestic appliance populations and potential replacement costs – performance based replacement

805. This section has been developed using the data and the conclusions that has been presented as part of the previously referenced EC funded GASQUAL study.

806. The residential appliance population data used in the GASQUAL study relates to the period 1993 to 2007 and covers sixteen of the EU countries. It is estimated that at the time this population data was collated these sixteen countries represented 91% of the EUs gas users

807. At a high level domestic appliances have been grouped into four main categories:

- boilers and jet burners;
- cooking appliances;
- water heaters; and
- space heaters

P.2.2.1 European appliance populations

808. Table 39 details the appliance population by category in each of the sixteen EU countries.

Table 39 – European appliance populations

Appliance Type	Appliance Population by Country (000s)							
	Austria	Belgium	Czech Republic	Denmark	France	Germany	Greece	Hungary
Boilers & Jet Burners	633	1,583	1,460	325	7,700	6,479	115	1,361
Cooking	539	600	2,451	96	12,866	2,168	30	2,600
Water Heaters	169	1,347	344	9	2,694	1,856	12	669
Space Heaters	ND	625	ND	ND	625	1,253	ND	3,903
Totals	1341	4,155	4,255	430	23,885	11,756	157	8,533
	Ireland	Italy	Poland	Portugal	Romania	Slovenia	Spain	UK
Boilers & Jet Burners	594	12,268	1,401	197	1,519	626	4332	18,455
Cooking	ND	24,445	7,191	ND	ND	1,290	3980	10,842
Water Heaters	348	2,718	2046	2661	212	118	6896	989
Space Heaters	624	ND	ND	ND	ND	ND	ND	8,770
Totals	1566	39,431	10,638	2858	1,731	2,034	15208	39,056

Note: ND means 'no data available'.

809. This gives a total figure of 167,034,000 domestic appliances broken as summarised in Table 40.

Table 40 – European appliance population (millions)

Boilers & jet burners	Cooking appliances	Water heaters	Space heaters
59.0	69.1	23.1	15.8

810. This total appliance population compares with a figure of 65 million domestic meter points based upon the data submitted by 17 of the European Gas Regulators, see Table 27 Appendix E. This figure would rise if contributions from the remaining five Regulators could be included.

811. This comparison between meter points and appliances indicates approximately two appliances per household which does not seem to be unrealistic.

P.2.2.2 Partial residential appliance replacement costs

812. Looking at the four main domestic appliance types the following assumptions have been used to calculate replacement costs. It should be noted that the estimated equipment hardware cost does not include any additional costs that might be applied relating to the development and production of new appliance designs.

- A labour cost of € 300 per day.
- Boilers & Jet Burners: €1450 per replacement, comprising:
  - equipment cost €1000; and
  - labour €450.
- Cookers (ovens, hobs and cookers): €400 per replacement, comprising:
  - equipment cost €300; and

  - labour €100.
- Water heaters: €550 per replacement, comprising:
  - equipment cost €400; and
  - labour €150.
- Space heaters: € 400 per replacement, comprising:
  - equipment cost €300; and
  - labour €100.

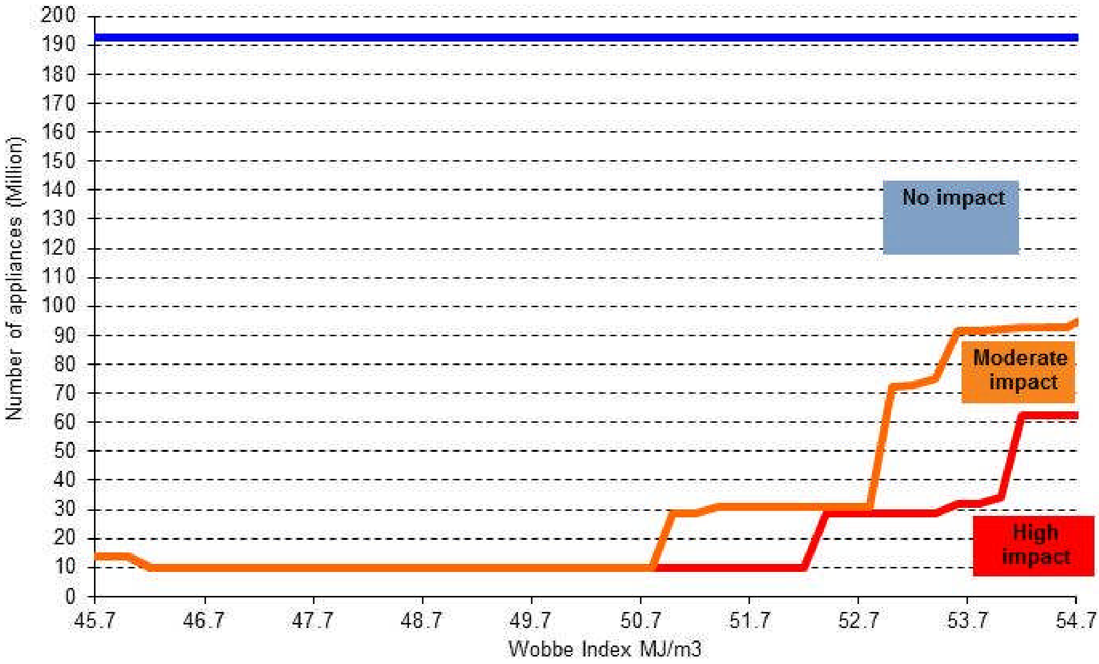
813. A previously discussed, we have assumed that 67% of the identified ‘at risk’ appliances (i.e. those appliances that are highly or moderately impacted by changes to gas quality) would need to be replaced, and that the remainder could be adjusted or retrofitted at 25% of the cost of replacement.

P.2.2.3 GASQUAL results

814. The GASQUAL study looked at the effect of varying gas quality on GAD compliant appliances, both residential and commercial. For domestic appliances, practical testing was carried out using a range of gas compositions recording any impact on their behaviour including safe operation, efficiency and environmental emissions. Non-domestic commercial equipment was also considered across the same range of varying gas quality using a theoretical approach based upon extrapolations from the residential data and supporting gas industry knowledge.

815. Using a risk ranking developed for each appliance type about a hundred mainly new domestic appliances were tested using an agreed range of gas compositions representing natural gas covering a Wobbe index spread of between 45.7 to 54.7 MJ/m^3. The results obtained from this test programme allowed the sample appliances that represented the twenty nine appliance types to be grouped by the severity of the gas quality variation impact over a defined Wobbe index range. Figure 105 below illustrates the increasing impact of gas quality change as the Wobbe index range rises.

Figure 105 – GASQUAL number of impacted appliances



Note: The reason that the total number of appliances in this diagram is over 192 million compared to the value of 167 million given in this paper is explained by the GASQUAL group deciding to count free-standing cookers as two units.

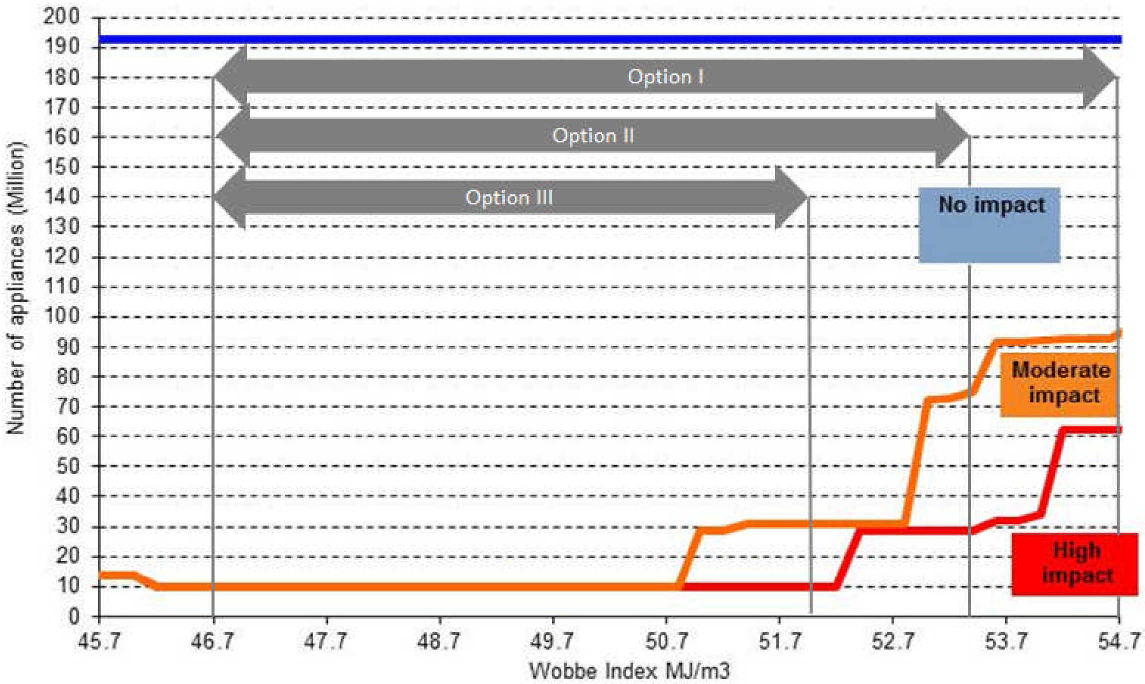
P.2.2.4 Options for single pan-EU specifications

816. Using the outcome of the GASQUAL study it is possible to consider the impact of this over a range of options. We have selected the following options as representing a good variety of possible specifications:

- Option I – appliances with high or moderate impact to gas quality variation over a Wobbe index range from 46.7 to 54.7 MJ/m^3;
- Option II – appliances with high or moderate impact to gas quality variation over a Wobbe index range from 46.7 to 53.4 MJ/m^3; and
- Option III – appliances with high or moderate impact to gas quality variation over a Wobbe index range from 46.7 to 52.0 MJ/m^3.

817. We have overlaid these options on the GASQUAL chart, shown in Figure 106.

Figure 106 – Examined appliance replacement options



818. Using the assumed unit replacement costs and the country appliance populations the following Table 7 has been produced showing the replacement/modification/adjustment costs for domestic appliances over the range 46.7 to 54.7 MJ/m^3.

Table 41 - Appliance replacement costs by country, Option I

Country	Upper Wobbe limit	Number of appliances requiring activity (000s)				Cost of action (€m)				Total (€bn)	Cost attributable to harmonisation (€bn)
		Boilers & Jet burners	Cookers	Water heaters	Space heaters	Boilers & Jet burners	Cookers	Water heaters	Space heaters		
Austria	2	566	60	168	N/A	618	18	70	0	0.71	0.71
Belgium	2	1529	66	1341	0	1668	20	555	0	2.24	2.24
Czech Republic	3	1434	273	336	N/A	1565	82	139	0	1.79	1.79
Denmark	3	315	11	9	N/A	344	3	4	0	0.35	0.35
France	2	7535	2160	2675	0	8222	650	1107	0	9.98	9.98
Germany	2	5231	686	1821	500	5708	206	754	151	6.82	6.82
Greece	1	115	4	12	N/A	125	1	5	0	0.13	0.00
Hungary	2	1353	289	658	0	1476	87	272	0	1.84	1.84
Ireland	4	573	N/A	331	0	625	0	137	0	0.76	0.76
Italy	3	11383	5372	2717	N/A	12420	1617	1124	0	15.16	15.16
Poland	4	1391	798	2036	N/A	1518	240	843	0	2.60	2.60
Portugal	1	197	N/A	2660	N/A	215	0	1101	0	1.32	0.00
Romania	4	1492	N/A	212	N/A	1628	0	88	0	1.72	1.72
Slovenia	4	623	143	115	N/A	680	43	48	0	0.77	0.77
Spain	1	4023	756	6894	N/A	4390	228	2853	0	7.47	0.00
UK	4	18089	3531	981	3240	19737	1063	406	975	22.18	22.18

Upper Wobbe limits: 1is >=54.7 MJ/m^3 , i.e. excluded in all options; 2 is >53.4, i.e. excluded in options II and III; 3 is >52.0, i.e. excluded in option III only, and 4 is <52.0, i.e. requires action in all options.

819. The number of appliances adversely impacted by gas quality variations across the Wobbe index range 46.7 to 54.7 MJ/m^3 is approximately 97 million with an estimated replacement/modification/adjustment cost of close to €75.8bn. As some MS already have

specifications consistent with Option I, the total costs of replacement associated with harmonisation would total €66.9bn.

820. Using the assumed unit replacement costs and the country appliance populations the following Table 8 has been produced showing the replacement/modification/adjustment costs for domestic appliances over the range 46.7 to 53.4 MJ/m^3.

Table 42 - Appliance replacement costs by country, Option II

Country	Upper Wobbe limit	Number of appliances requiring activity (000s)				Cost of replacement (€m)				Total (€bn)	Cost attributable to harmonisation (€bn)
		Boilers & Jet burners	Cookers	Water heaters	Space heaters	Boilers & Jet burners	Cookers	Water heaters	Space heaters		
Austria	2	446	60	150	N/A	647	24	83	0	0.75	0.00
Belgium	2	738	66	1225	0	1070	26	674	0	1.77	0.00
Czech Republic	3	545	273	190	N/A	790	109	105	0	1.00	1.00
Denmark	3	285	11	6	N/A	413	4	3	0	0.42	0.42
France	2	3528	2160	2313	0	5116	864	1272	0	7.25	0.00
Germany	2	2099	686	1158	500	3044	274	637	200	4.15	0.00
Greece	1	98	4	12	N/A	142	2	7	0	0.15	0.00
Hungary	2	263	289	443	0	381	116	244	0	0.74	0.00
Ireland	4	551	N/A	7	0	799	0	4	0	0.80	0.80
Italy	3	7806	5372	2697	N/A	11319	2149	1483	0	14.95	14.95
Poland	4	382	798	1840	N/A	554	319	1012	0	1.89	1.89
Portugal	1	66	N/A	2650	N/A	96	0	1458	0	1.55	0.00
Romania	4	1406	N/A	211	N/A	2039	0	116	0	2.15	2.15
Slovenia	4	182	143	58	N/A	264	57	32	0	0.35	0.35
Spain	1	2614	756	6853	N/A	3790	302	3769	0	7.86	0.00
UK	4	16649	3531	834	2270	24141	1412	459	908	26.92	26.92

Upper Wobbe limits: 1is >=54.7 MJ/m^3 , i.e. excluded in all options; 2 is >53.4, i.e. excluded in options II and III; 3 is >52.0, i.e. excluded in option III only, and 4 is <52.0, i.e. requires action in all options.

821. The number of appliances adversely impacted by gas quality variations across the Wobbe index range 46.7 to 53.4 MJ/m^3 is approximately 75 million with an estimated replacement/modification/adjustment cost of close to €54.7bn. As some MS already have specifications consistent with Option II, the total costs of replacement associated with harmonisation would total €36.5bn.

822. Using the assumed unit replacement costs and the country appliance populations the following Table 9 has been produced showing the replacement/modification/adjustment costs for domestic appliances over the range 46.7 to 52.0 MJ/m^3.

Table 43 - Appliance replacement costs by country, Option III

Country	Upper Wobbe limit	Number of appliances requiring activity (000s)				Cost of replacement (€m)				Total (€bn)	Cost attributable to harmonisation (€bn)
		Boilers & Jet burners	Cookers	Water heaters	Space heaters	Boilers & Jet burners	Cookers	Water heaters	Space heaters		
Austria	2	260	0	135	N/A	377	0	74	0	0.45	0.00
Belgium	2	282	0	1225	0	409	0	674	0	1.08	0.00
Czech Republic	3	84	1	177	N/A	122	0	97	0	0.22	0.00
Denmark	3	170	0	5	N/A	247	0	3	0	0.25	0.00
France	2	483	0	2082	0	700	0	1145	0	1.85	0.00
Germany	2	1773	0	1042	500	2571	0	573	200	3.34	0.00
Greece	1	3	1	11	N/A	4	0	6	0	0.01	0.00
Hungary	2	32	0	399	0	46	0	219	0	0.27	0.00
Ireland	4	33	N/A	6	0	48	0	3	0	0.05	0.05
Italy	3	891	0	2427	N/A	1292	0	1335	0	2.63	0.00
Poland	4	113	0	1656	N/A	164	0	911	0	1.07	1.07
Portugal	1	1	N/A	2385	N/A	1	0	1312	0	1.31	0.00
Romania	4	32	N/A	190	N/A	46	0	105	0	0.15	0.15
Slovenia	4	56	0	52	N/A	81	0	29	0	0.11	0.11
Spain	1	26	0	6168	N/A	38	0	3392	0	3.43	0.00
UK	4	5296	0	751	2270	7679	0	413	908	9.00	9.00

Upper Wobbe limits: 1is >=54.7 MJ/m^3 , i.e. excluded in all options; 2 is >53.4, i.e. excluded in options II and III; 3 is >52.0, i.e. excluded in option III only, and 4 is <52.0, i.e. requires action in all options.

823. The number of appliances adversely impacted by gas quality variations across the Wobbe index range 46.7 to 52.0 MJ/m^3 is approximately 31 million with an estimated replacement/modification/adjustment cost of close to €19.0bn. As some MS already have specifications consistent with Option III, the total costs of replacement associated with harmonisation would total €7.82bn.

824. The three appliance replacement cost options based upon the GASQUAL data and detailed in Tables Table 41Table 43 are summarised in Table 44 below.

Table 44 – Appliance costs summary

Option	I	II	III
Scenario	GASQUAL based results showing high and moderate impact		
Wobbe index range (MJ/m^3)	46.7 to 54.7	46.7 to 53.4	46.7 to 52.0
Number of appliances replaced/modified/adjusted (millions)	96.7	75.2	31.0
Capex of harmonisation driven appliance activity (€bn)	66.9	36.5	7.82
Capex of harmonisation driven appliance activity (€bn) (excluding Great Britain and Italy)	29.6	5.0	1.0

825. In summary the GASQUAL results show that at the full Wobbe index range of gas quality variation in the study's test programme 97 million appliances could be adversely affected. The total affected appliances reduce significantly to around 31 million if the gas quality variation is reduced to a Wobbe index range of between 46 and 52 MJ/m^3. Conversely this indicates that between 70 and 136 million appliances are unaffected at all by gas quality variations over the same Wobbe index variation ranges. Due to the type of appliance installed the UK and Italy account for typically 50% of the estimated replacement costs. Table 44 above gives indicative figures for the reduced costs based upon this scenario.

826. A significant factor that comes out of a review of the breakdown by country of the appliance replacement costs is that it is disproportionate across the sixteen main gas using countries in the EU. The UK leads this group by far with between 29 and 37% of the total cost for the three options considered. This is due to the requirement in the UK legislation for high efficiency boilers to be mandatory for new and replacement installations. This type of boiler has been identified by the GASQUAL study as having the highest safety risk factor when operated over a wide gas quality range giving rise to potential safety issues. Evidence supplied by the SBGI[21] indicates that this high cost implication is already far worse as the condensing boiler population in the UK since the 2007 GASQUAL data has increased rapidly from the reported 5.3 million and is predicted to be 10 million by 2015.

[21] Data provided by appliance manufacturers and collated by the Heating and Hot water Industry Council (HHIC) a division of the SBGI

827. Table 39, which gives the European appliance populations, shows that the UK and Italy have the highest number of appliances particularly those that fall into the 'at risk' category as defined by the GASQUAL project. If these two countries were to be excluded from the gas quality harmonisation process possibly by applying a derogation period before introducing wider gas quality limits, then replacement / adjustment costs reduce significantly. The last line in Table 44 accommodates this adjustment.

P.2.2.5 Additional processing requirements

828. It should be noted that appliance replacement Option II and III developed from the GASQUAL test results reduces the original Wobbe range in some countries, so it would be necessary to install gas processing facilities to maintain this narrower Wobbe index range. The one-off capital costs and on-going opex costs to process gas flowing to the EU from non-EU states, based purely on Wobbe index adjustment, is shown below for the two narrower ranges. Note that no processing would be required if Option I, (46.45 to 54.7 MJ/m^3) is adopted as all gas supplies Wobbe index are within this range. The additional costs are show in Table 45 and Table 46, below.

Table 45 – Additional processing costs, Option II

	50% Capacity	100% Capacity
Capex (€m)	695	1,060
Opex (€m per annum)	2.4	5.1

Table 46 – Additional processing costs, Option III

	50% Capacity	100% Capacity
Capex (€m)	2,989	3,673
Opex (€m per annum)	4.0	13.0

829. The estimated cost of appliance replacement should for Option 2 and 3 be adjusted to account for the associated processing costs, assuming 50% design capacity, is shown in Table 47.

Table 47 – Post-GASQUAL domestic appliance costs, summary

	Appliance Replacement Cost (€bn)	**Processing capex** (50% capacity) (€bn)	**Total capex** (€bn)	**Processing opex** (€m per annum)
Option I	66.9	-	66.9	-
Option II	36.5	0.695	37.2	2.4
Option III	7.82	2.99	10.01	4.0

Total costs assume the maximum NPV of the opex assuming a discount rate of 5%

P.2.3 Commercial appliance populations and potential replacement costs

830. This section has been developed using data that has been presented as part of the GASQUAL study set up to investigate acceptable EU limits for gas quality influence on the performance of new and installed gas appliances. The commercial appliance population data used in the GASQUAL study relates to the period 1993 to 2007 and covers sixteen of the EU countries. It is estimated that at the time this population data was collated these sixteen countries represented 91% of the EUs gas users.

831. The final report issued by CEN[22] covering the work of GASQUAL states that '*more work should be done to achieve a common understanding with the non-domestic appliances industry'*. This statement relates to the lack of consensus within the industry over the ability of their equipment to be either adjusted or modified to accept gas quality variations. For this reason and from feedback provided by manufacturers (included in Annex D), it has been decided to base the following cost estimates upon a full replacement programme. However consideration has been given to the situation where it will not be necessary to replace equipment when existing country gas quality specifications match the proposed harmonised gas quality specifications. This approach reduces the replacement costs and is detailed in Options I, II and III in the following tables. The same discussion regarding natural replacement and the availability of suitable new generation equipment as outlined in Section P.2.1.1 above can be applied to the non-domestic market although development costs will be significantly higher.

832. We have grouped commercial appliances into four main categories:

- commercial boilers with outputs greater than 70kW and jet burners;
- storage water heaters;
- catering – non-domestic cooking; and
- commercial heating.

P.2.3.1 Commercial boilers and jet burners

833. The GASQUAL project provided information that estimated the total number of commercial boilers, some with integral burners and some with bolt-on jet burners, as being 863,010 across the major gas using countries in Europe. Adjustment to accept a wider gas quality specification is unlikely to be possible with existing installed designs and accordingly a full replacement programme needs to be considered. The following typical costs have been used to assess the cost of replacement:

- a labour cost of €300 per day and an appliance cost of € 100 per kW of boiler output;
- an average boiler rating of 100kW;
- replacement would take two days to complete.

This implies an average cost of €10.6k per installation.

834. Table 48 below has been developed using these assumptions and a commercial boiler and jet burner population breakdown for sixteen EU countries.

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22 CEN/AFNOR/BT/WG/197 Doc N310 Standardisation in the field of gas qualities Mandate CE M400, Phase 1 Final report dated 12.03.2012

Table 48 – Boiler and jet burner population and replacement costs

Country	Boiler & Jet Burner Population	Full Replacement Cost €m	Option I replacement cost €m	Option II replacement cost €m	Option III replacement cost €m
Austria	37,225	395	395	0	0
Belgium	38,880	412	412	0	0
Czech Republic	13,200	140	140	140	0
Denmark	6,108	65	65	65	0
France	73,130	775	775	0	0
Germany	243,127	2,577	2,577	0	0
Greece	5,200	55	0	0	0
Hungary	4,831	51	51	0	0
Ireland	2,382	25	25	25	25
Italy	104,727	1,110	1,110	1,110	0
Poland	63,725	675	675	675	675
Portugal	1,333	14	0	0	0
Romania	17,123	182	182	182	182
Slovenia	7,363	78	78	78	78
Spain	31,831	337	0	0	0
UK	212,825	2,256	2,256	2,256	2,256
Totals	**863,010**	**9,148**	**8,741**	**4,531**	**3,216**

P.2.3.2 Storage water heaters

835. The GASQUAL project provided information that estimated the total number of commercial gas-fired storage water heaters as being 241,147 across the major gas using countries in Europe. Adjustment to accept a wider gas quality specification is unlikely to be possible with existing installed designs and accordingly a full replacement programme needs to be considered.   The following typical costs have been used to assess the cost of replacement:

- a labour cost of € 300 per day and an appliance cost of € 100 per kW of useful heat;
- an average storage-type water heater is rated at 50 kW; and
- replacement would take one day to complete.

This implies an average cost of €5.3k per installation.

Table 49 has been developed using these assumptions and a storage water heater population breakdown for sixteen EU countries.

Table 49 – Storage water heater population and replacement costs

Country	Storage Water Heater Population	Full Replacement Cost €m	Option I replacement cost €m	Option II replacement cost €m	Option III replacement cost €m
Austria	1,550	8	8	0	0
Belgium	6,200	33	33	0	0
Czech Republic	2,606	14	14	14	0
Denmark	98	1	1	1	0
France	80,844	428	428	0	0
Germany	15,564	82	82	0	0
Greece	811	4	0	0	0
Hungary	4,625	25	25	0	0
Ireland	9,089	48	48	48	48
Italy	66,446	352	352	352	0
Poland	1,921	10	10	10	10
Portugal	1,158	6	0	0	0
Romania	582	3	3	3	3
Slovenia	1,895	10	10	10	10
Spain	2,985	16	0	0	0
UK	44,773	237	237	237	237
Totals	**241,147**	**1,278**	**1,252**	**675**	**309**

P.2.3.3 Catering – non-domestic cooking

836. The GASQUAL project provided information that estimated the total number of commercial catering establishments covering hotels, restaurants, canteens and fast food outlets. The total number given is 1,880,336 across the major gas using countries in Europe. Adjustment to accept a wider gas quality specification is unlikely to be possible with existing installed designs and accordingly a full replacement programme needs to be considered. The following typical costs have been used to assess the cost of replacement:

- a labour cost of €300 per day and appliance cost of €100 per kW of appliance rating;
- the 'average' commercial kitchen would have a range of equipment including grills, ovens, fryers and hob burners possibly totalling up to 25 kW; and
- replacement would take up to three days.

This implies an average cost of € 3,400 per installation.

837. Table 50 have been developed using these figures and a catering establishment breakdown for sixteen EU countries

Table 50 – Catering replacement costs

Country	Number of Catering Establishments	Full Replacement Cost €m	Option I replacement cost €m	Option II replacement cost €m	Option III replacement cost €m
Austria	43,821	149	149	0	0
Belgium	57,259	195	195	0	0
Czech Republic	43,785	149	149	149	0
Denmark	22,616	77	77	77	0
France	254,672	866	866	0	0
Germany	311,610	1,059	1,059	0	0
Greece	35,608	121	0	0	0
Hungary	34,474	117	117	0	0
Ireland	22,183	75	75	75	75
Italy	239,653	815	815	815	0
Poland	120,017	408	408	408	408
Portugal	96,843	329	0	0	0
Romania	38,581	131	131	131	131
Slovenia	23,774	81	81	81	81
Spain	255,623	869	0	0	0
UK	279,817	951	951	951	951
Totals	**1,880,336**	**6,393**	**5,074**	**2,687**	**1,647**

P.2.3.4 Commercial heating

838. The GASQUAL project provided information that estimated the total number of commercial heating systems covering warm air heaters, radiant luminous heaters and radiant tube heaters. Firm information is very difficult to obtain and an extrapolated figure of between 2.5 and 3.5 million units is provided based upon numbers obtained for the UK and France. A breakdown by country has not been made available.

839. As before adjustment to accept a wider gas quality specification is unlikely to be possible with existing designs, so a full replacement programme needs to be considered. To estimate the costs of this we have made the following assumptions:

- a labour cost of € 300 per day and appliance cost of € 100 per kW of appliance rating;
- an average warm air heater would be rated at 70 kW;
- an average radiant luminous heater would be rated at 35 kW;
- an average radiant tube heater would be rated at 15 kW; and
- replacement of these types of appliances would take up to two days.

This gives the following cost per installation for each type of commercial heater:

- warm air heater, €7.6k;
- radiant luminous heater, €4.1k; and
- radiant tube heater, €2.1k.

840. We have assumed a population of:

- 1.5 million warm air heaters;
- 0.75 million radiant luminous heaters; and
- 0.75 radiant tube heaters;

distributed through member states pro-rata to the distribution of other commercial appliances.

841. Table 51 has been developed using these assumptions and a commercial heater population breakdown for sixteen EU countries.

Table 51 – Commercial heating systems replacement cost

Type	No. appliances (million)	Full replacement cost (€m)	Option I replacement cost €m	Option II replacement cost €m	Option III replacement cost €m
Warm air heaters	2	11,100	9,983	4,685	1,441
Radiant luminous heater	1	3,080	2,770	1,300	400
Radiant tube heater	1	1,508	1,356	637	196
Total	**3**	**15,688**	**14,109**	**6,622**	**2,036**

P.2.3.5 Commercial appliance replacement summary

842. Further to the conclusions in the GASQUAL study only a full replacement programme has been considered for commercial equipment and the estimated costs for this are summarised in Table 52.

Table 52 – Commercial appliance replacement costs

Commercial Appliance Type	Full Replacement Cost €m	Option I replacement cost €m	Option II replacement cost €m	Option III replacement cost €m
Boilers & Jet Burners	9,148	8,741	4,531	3,216
Storage Water Heaters	1,278	1,252	675	309
Commercial Cooking	6,393	5,074	2,687	1,647
Commercial Heaters	15,750	14,109	6,622	2,036
Total	**32,569**	**29,176**	**14,516**	**7,208**
Total Excluding GB and IT	**26,848**	**23,453**	**8,794**	**3,762**

843. As with the domestic appliances, commercial equipment populations are higher in the UK and in Italy. If these two countries were to be excluded from the gas quality harmonisation process possibly by applying a derogation period before introducing wider gas quality limits, then replacement / adjustment costs reduce significantly. The last line in Table 53 above provides the costs based upon this assumption.

P.2.4 Other applications

P.2.4.1 Industrial gas utilisation equipment population and potential replacement cost

844. The industrial gas utilisation market sector is not well documented, and although some data has been obtained on meter connections the overall sector size is uncertain, and covers a very wide range of applications. The total number of meter connections (110k) appears reasonable but the number of burners or combustion equipment associated with each meter point is unknown. Therefore we assume this to be a minimum value for the number of burners.

845. Marcogaz has evaluated the potential impact of gas quality changes on equipment[23] and provided a summary in Table 53.

Table 53 – Impact on appliances (Marcogaz)

Main category	Sub categories		Comment	Sensitivity	Possible solution
Low temperature (<200°C) industrial applications	Big boilers / large scale hot water & steam			Low for efficiency. May be high for NOx emissions	Air gas control via measurement of the oxygen in combustion products.
	Food industry	Green houses	NO_2 is a problem when combustion products are in contact with food. NO_2 is a plant hormone, and can damage crops. NO_2 emissions can also increase with gases having higher hydrocarbons (which facilitate the conversion of NO → NO_2).	High to NO_2 emissions	Adjustment of burners for reduced unburned fuel slippage (source of NO_2 production). New burners or air/gas ratio control
		Drying process		High to NO_2 emissions	
	Infra red	Drying	Low temp. combustion with potential presence of solvents. Radiant power/efficiency dependent on burning velocity.	High to burning velocity	In premixed radiant tiles, air/gas ratio and thermal input controls can minimize this effect.
		Heating			
High temperature (>200°C) industrial applications	Ceramic/Glass	Bulk (melting feeders)	Sensitive to flame temperature and radiative power. Finished product is also sensitive to flame geometry. Finished glass products sensitive to flame length (burning velocity). Soot formation (composition) and increased NO_x emissions (Wobbe/calorific value) possible. Control of under-/overstoichiometric firing essential in ceramics.	Soot formation often desired in bulk glass (heat transfer). Sensitivity to NO_x ? (temperature is already very high)	Gas quality (Wobbe Index) and air flow control. Air ratio and thermal input control should minimize effects. Air ratio control solves stoichiometry.
		Finished product (bulbs, etc.)		High sensitivity to burning velocity	
		Ceramic roofing tiles, bricks, etc.		High sensitivity to air ratio (over/under stoichiometry). High sensitivity to NO_x. High sensitivity to soot.	
	Metal oven		General for metal industry. Air factor, soot formation and NO_x important issues	High to soot and NO_x and oxygen in the oven atmosphere.	Solutions may be very specific according to the application

846. To accommodate the potential impacts from changing gas quality, full burner or appliance replacement may be necessary, although some more sophisticated equipment may be modified through careful air/fuel ratio control or oxygen exhaust concentration feedback. However, each individual installation will need to be assessed to ensure that optimum performance in terms of efficiency and emissions are obtainable when the equipment is modified.

847. For the purposes of this study we have estimated that full replacement with new equipment would result in a cost of €100 per kW. This together with an estimate of the average load of 1MW, would lead to a cost of €100k per installation. This results in a sector cost of around €11 billion.

[23] "Main Effects of Gas Quality Variations on Applications", Marcogaz, UTIL-GQ-05-04, September 2008.

P.2.4.2 Gas engine population and potential replacement cost

848. The number, size and operation of gas engines around Europe are not well defined. Equipment delivered to suppliers is often not traceable as sales to third parties and unit replacements are not well understood. EUROMOT estimate[24] that the total installed gas engine capacity in Europe is 9GW, equivalent to a €7 billion investment.

849. Based on some detailed information from The Netherlands, their engine population of around 4500 provides a power generation capacity of 3.7 GW. If this is used to provide average capacities of installation then each installation would be of the order of 800 kW. Of these installation 40% are not equipped with controls that could accept wide ranging gas quality changes and, if this factor is applied to all Europe, it is expected that replacement costs for gas engines alone could be of the order of €3 billion.

850. The EUROMOT study also highlights the skill shortage for mechanics and engineers to undertake any substantial conversion programme and estimates the manpower requirements for adapting all the engines to be equivalent to 1100 man-years of effort. If the man-year cost is €40,000, then this produces a cost of €44 million, assuming that sufficient man-power resources could be mobilised to undertake the work around Europe.

P.2.4.3 Gas turbine population and potential replacement cost

851. Gas turbine power plants are installed throughout Europe. Data on total numbers are difficult to establish but an estimate of 2500 based on information from GE and Siemens regarding their installations.

852. Gas turbines are very sensitive to variations in natural gas composition and the rate of change of composition may also be important.

853. The European Turbine Network has produced a position paper related to the impact of natural gas quality on gas turbine performance[25] where they state that:

"There is a common misconception that gas turbines can burn almost any combustible gas and that gas fuel variability is not a significant issue. There are gas turbines firing a very wide range of gases including: natural gas (including gas with high inerts and high non-methane hydrocarbons); syngas (from coal, biomass and wastes); steelworks gases (coke oven gas and blast furnace gas); and gases with very high hydrogen content (such as refinery gases); but each individual gas turbine can only tolerate limited changes in gas composition and properties, depending on the gas turbine design and the set-up of the gas turbine hardware and controls."

854. Here, it is assumed that to balance low emissions regulation and unit operating performance additional control systems will be required. This has been estimated as €300,000 per installation, and results in a potential adjustment cost of €750 million. This cost will be significantly higher if complete replacement of the gas turbine combustors is required.

855. The existing knowledge base on the impact of gas specification change is not sufficient to fully support the EASEE-gas range. Most gas turbine manufacturers support a ±5%

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[24] Euromot Position Paper 'Gas Quality Aspects for Reciprocating Gas Engines' 30th May 2011

[25] European Turbine Network – Position Paper 'Impact of Natural Gas Quality on Gas Turbine Performance' February 2009

Wobbe index variation (which is a range of about 5 MJ/m^3, not the 7.5 MJ/m^3 from EASEE-gas. It has not been possible to establish costs to fully meet this wider range.

P.2.4.4 Other applications – summary

856. Table 3Table 54 below summarises the full replacement costs we have identified for the other applications. To generate costs applicable to the three options, we have assumed a geographical distribution of appliances similar to the distribution of commercial appliances. This has allowed us to estimate the costs under each of the options I, II and III.

Table 54 – Other applications' replacement costs

Commercial Appliance Type		Full Replacement Cost €m	Option I replacement cost €m	Option II replacement cost €m	Option III replacement cost €m
Industrial		11,000	9,854	4,392	972
Gas engines		3,000	2,687	1,198	265
Gas turbines		750	672	299	66
	Total	**14,750**	**13,213**	**5,889**	**1,303**

P.2.5 The influence of gas quality on emissions and efficiencies

857. Although the main focus of this cost/benefit analysis study is on the gas interchangeability aspect with regard to harmonisation of Wobbe index around Europe, there are additional points that can lead to secondary costs over-and-above those relating to equipment costs. The impact of gas quality on emissions and efficiency will also create a potential cost for the harmonisation process as a result of changes to the operational performance of the combustion equipment. A decrease in efficiency will result in increased gas usage and an increase in the carbon dioxide emission across the gas utilisation sector, having a negative effect on the aims to reduce carbon dioxide emissions.

858. The potential increase in pollutant emissions, for example NOx and CO, may result in impacts on the local atmosphere and as a consequence on the health of the population around Europe. The Industrial Emissions Directive (Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)) provides information on emission limits from industrial gas utilisation and these may be breached if the plant has to accommodate significant gas quality variations. It is not possible to assess the potential cost of this without further study but it is clear that some combustion equipment will be difficult to control to maintain good emissions performance.

859. There is insufficient data to fully quantify the impact of gas quality on efficiency or emissions, but the general view is that pollutant emission levels will increase and efficiencies will decrease.

P.3 Gas processing requirements

860. The extreme investment presented in section 4.6.2 assumes the unlikely situation that commercial solutions are not available to TSOs and that they therefore invest in gas processing. In absence of any useful data to understand the reasonable level of these costs, an upper limit can be estimated by assuming the maximum gas quality specification difference at the cross-border point covering the full amount of the prevailing pipeline capacity. This section describes the analysis of these options.

861. To achieve a specified Wobbe index the gas requires derichment, to reduce, or enrichment to raise the Wobbe index. Various gas processing options are available and the preferred method is normally selected after a detailed technical and financial assessment. An outline of the various processes together with estimates for both one-off capital costs, and on-going opex costs are provided in Annex H.

862. For plant selection and optimum sizing to achieve clean-up of the other parameters, it is necessary to have a detailed gas composition. In the absence of this it is only possible to estimate the cost of such plants assuming gas flow, the clean-up technology selected, the number of plants in the clean-up train and the scaled-up costs based on a single unit.

863. It has been assumed that two types of gas processing plant will be required to perform the additional processing requirements:

- acid gas removal based on liquid absorption technology is assumed for removal of sulphur, hydrogen sulphide, carbonyl sulphur, mercaptan and carbon dioxide; and
- solid bed technology for the removal of oxygen.

864. As the cross border pipeline capacities are very large in many cases, it has been assumed that multiple gas treatment trains will be required depending on the flow. We have restricted the capacity of individual trains based on commercial plant sizes for acid gas removal and solid bed technologies. It should be noted however that there is no precedence for natural gas oxygen removal plants at anywhere near this scale of operation. It is therefore possible that a range of other technologies might be considered to perform this gas processing.

865. Where acid gas removal plants are required, it has been assumed that 8 acid gas removal trains will be required for a high flow (>100mcm/d) cross border transfer, 5 trains for a medium flow (50 to 100 mcm/d) and 2 trains for a low flow (< 50 mcm/d). The capex for a single acid gas removal train is assumed at €63m. This is based on budgetary costs for similar units in the natural gas industry at a capacity of 15mcm/d. The flow rates assigned to each border crossing are provided in ANNEX I.

866. Where oxygen removal plants are required, it has been assumed that 3 solid bed trains will be required for a high flow cross border transfer, 2 trains for a medium flow and a single train for a low flow. The capex for a single solid bed train is assumed at €50 million. This is based on budgetary costs for similar units in the natural gas industry at a capacity of 37.5 mcm/d.

867. For gas quality control the costs have been estimated based on the envisaged flowrates, generated by the Pöyry model, and assumed gas properties thereby enable an initial indication of the capex and opex required for suitable gas processing facilities to perform gas quality adjustment. The processing costs have been assessed based on the requirements of processing gas to meet local gas quality specification as the gas flows into and across the EU. The costs develop represent the worst case scenario of harmonising gas quality.

868. The assumptions used in the determination of the processing costs are provided in ANNEX I.

869. Table 55 indicates where, according to existing gas quality specifications, additional processing may be required. The number in a cell in the matrix indicates which substances may need to be removed to meet the local gas specification of the country along the horizontal axis when gas is sent to it from the country on vertical axis. For example, to send gas from Germany to Austria there is a possibility that oxygen and carbon dioxide will need to be removed.

Table 55 – Additional processing matrix

From \ To	Austria	Belgium	Bulgaria	Czech republic	Denmark	France	Germany	Greece	Hungary	Netherlands	Poland	Romania	Slovakia
Austria				1,2,3			1,3,5		3				1,2,3,4
Belgium						1,4	1			1			
Bulgaria								3				4	
Czech republic	5												1,4
Denmark													
Estonia													
France		3, 5											
Germany	4, 5	3, 4		2,3,4	4	4				4	4		
Greece			1,2,4,5										
Hungary	2,4,5											2,4	1,2,4
Ireland													
Italy	1,2,3,4,5							1,2,3,4					
Latvia													
Luxembourg													
Netherlands		3					1,3						
Poland					1,2,3,4,5		1,2,3						
Portugal													
Romania			1,2,3,5						3				
Slovakia	5			3					3				
Slovenia													
Spain						1,2,3							
Sweden													
UK										1			

1 = Sulphur; 2 = H_2S & COS; 3 = Mercaptans; 4 = Oxygen; 5 = CO_2. Source: GL Noble Denton analysis

P.3.1.1 Estimation of Processing Costs

870. The estimated costs are given in Table 56 and Table 57. Assuming 100% design capacity the capex would be in the region of €11bn with opex costs in 2020 estimated at €814m.

Table 56 – Capex costs for full processing

Parameter	Capacity type	50% capacity (€bn)	100% capacity (€bn)
Wobbe index	Interconnection	1.36	2.40
	EU entry	0.538	0.863
Others	Interconnection	4.65	7.40
Total		**6.54**	**10.7**

Table 57 – Opex costs for full processing

Parameter	Capacity type	50% capacity (€m per annum)	100% capacity (€m per annum)
Wobbe index	Interconnection	144	206
	EU entry	7	10
Others	Interconnection	359	598
Total		**510**	**814**

P.3.2 Analysis of de facto specifications

871. Data provided via ENTSOG, indicates that:

- Fluxys may have allowed exceptions to their minimum Wobbe index limit;
- Snam Rete Gas may have allowed exception to their maximum Wobbe index limit; and
- Enagas may have allowed exception to their maximum and minimum Wobbe index limits.

872. We note that as the Spanish (and Portuguese) limits are already both higher and lower than the French limits so the last point has no effect in the cross-border analysis.

873. National Grid (NG) provided data that suggested several excursions from the written specifications. NG has clarified that the apparent minimum Wobbe index exceptions are facilitated through a 'reasonable endeavours' approach that has the sanction of the relevant safety authority. The endeavour has historically relied on a stream of high Wobbe index gas from UKCS, but decline in the UKCS gas that they can no longer reasonably meet the endeavour. The particular non-compliant gas is sometimes curtailed as a result. We have therefore not included a ‘de facto specification’ for GB.

874. The application of the de facto specifications means that the processing capex comes down from €10.7bn to €10.4bn. Assuming that we harmonise Germany, France, Denmark, Spain, and Belgium (by disregarding their processing costs), the cost comes down to €9.97bn. Opex costs come down from €814m per annum to €801m per annum.

P.3.2.1 Other de facto specifications

875. The ENTSOG data suggests that Gas-System might have allowed exception to the H2S limit, though we suspect this is a data error as the figure is not reasonable. As including this figure in a 'de facto specification' would significantly increase the processing requirements and costs, we have not included it.

876. Data from NG suggests that the carbon dioxide limits are sometimes disregarded. NG has clarified that there are some legacy contracts (contracts struck before the vertical separation of British Gas) which have different specifications, so it seems likely that this could be made available to other imports and so represents a 'de facto specification'.

877. Otherwise no evidence has been provided to suggest that other gas quality specification parameters have been disregarded and enjoy a liberal status. However we note that the dataset provided by ENTSOG was limited: it might be the case that non-Wobbe 'de facto specifications' apply but there is no way of estimating what they might be. Given the additional uncertainties regarding whether deviations form 'de facto specifications' or are reflective of reasonable endeavours (i.e. whether they are always available, or only under specific circumstances), it does not seem appropriate to conclude that costs would be significantly lower.

P.3.2.2 Regional harmonisation

878. Following feedback that the Wobbe index specification is very similar for Germany, France, Belgium, Spain and Denmark, we have also removed the costs of Wobbe index processing between these Member States. Note we have not removed costs associated with non-Wobbe parameters (e.g. O2, CO2, H2S).

P.3.2.3 Conclusions

879. The data provided by ENSTOG is limited and not consistent across TSOs. Most data relates only to density, Wobbe index and/or calorific value. A very limited set of data for H2S and total Sulphur has been provided, with a similarly limited set of data for dewpoints. Length of history and the time granularity of data are also not consistent, and in some cases average values have been provided thereby losing information about the extremes of the data –information which is crucial in understanding gas quality specifications.

880. The results of the 'de facto specification' based physical transmission harmonisation costs are presented in Table 58 below.

Table 58 – De-facto specification based processing costs

Geography	EU	EU *less* DE, FR, BE, ES & DK	EU	EU *less* DE, FR, BE, ES & DK
Capacity	100%	100%	50%	50%
Capex (€bn)	10.4	9.97	6.32	6.06
Opex (€m/annum)	814	801	510	502

ANNEX Q – DESCRIPTION OF THE PROJECT

Q.1 Original scope

881. The original scope for this project was to provide a series of inventories, costs and measures to examine the potential for gas quality harmonisation and to provide '*a recommendation to CEN for a definition of gas quality standards that are the broadest possible within reasonable costs.*'

882. It was envisaged that a pilot study would be undertaken prior to the main study. Italy was chosen.

Q.2 Revised approach

883. It proved impossible to model the impact on Italy in isolation from the rest of Europe, because of the interconnection of the wholesale markets and co-dependency of supply sources. (For example, Italy relies on gas from Russia which also supplies other EU markets – decisions to route specific Russian gases to Italy are co-dependent on decisions to not route that gas to other EU markets.)

884. The data available for the analysis envisaged was also significantly deficient. An alternative approach was therefore designed where it was agreed that Pöyry and GL would make a series of assumptions regarding the missing data, and to examine the sensitivity of the analysis to variations in these assumptions.

Q.3 Initial analysis

885. The initial analysis focussed on three areas:
   - quantifying the impact that future gas quality issues might present assuming the continuation of existing gas quality specifications;
   - estimating the costs of replacing the appliance fleet to meet the requirements of a single EU gas quality specification; and
   - estimating the costs of complete physical harmonisation of the transmission system to meet the requirements of a single EU gas quality specification.

886. The project constructed a new modelling approach to quantify the impacts that might be expected under normal circumstances of future potential gas quality constraints on the European wholesale market. This allowed the identification of the costs that would be borne by consumers under a 'do nothing' approach.

887. The work to estimate the costs of replacing the appliance fleet was based on initial findings from the work of CEN under the M400 mandate. This approach assumed a movement to a single pan-European gas quality specification which required the complete replacement of the appliance fleet. In the initial analysis, a 'big-bang' implementation was assumed where appliance replacement happens everywhere instantaneously.

888. The concept of complete physical harmonisation of Europe's transmission system was used to estimate the costs of obliging TSOs to invest in physical equipment to fully mitigate any potential of cross-border gas quality differences. This approach assumes that the full amount of cross-border capacity is protected for the largest difference between the applicable gas quality specifications.

889. The initial analysis culminated in the publication of a preliminary report, which was published alongside a consultation.

Q.4 Consultation and workshop

890. A public consultation was held between 29th July 2011 and 16th September 2011. This generated a series of responses which are summarised in Annex O. The preliminary report was presented at the XX Madrid Forum.

891. The consultation responses were crucial in identifying alternative options that might be considered. A workshop was held for interested parties on the 5th December 2011, where various stakeholders were invited to speak. Two key considerations materialised from this workshop:

- the possibility that moving to a uniform Wobbe specification in a limited regional area should not be too difficult to achieve; and
- that behaviours will only change where there are obligations to do so and that parties will not unreasonably act to their own detriment.

892. The consultation responses and the workshop have highlighted the vast array of issues and interests in the field of gas quality specifications, and it is obvious that there is no consensus opinion on how harmonisation should be achieved, or even if it should Within the project the feedback has led to:

- investigations of L-gas and H-gas mergers in the German market which has led to the investigation of the potential for commercial transmission system harmonisation;
- consideration of a regional approach to harmonisation;
- an understanding that the written specifications are sometimes, in practice, not strictly applied by TSOs;
- a discussion of cost recovery issues; and
- the identification of ‘quick wins’ and recommendations for further actions.

Q.5 Further analysis

893. Further information was sought from stakeholders to examine whether ‘de facto specifications’ existed (i.e. whether there was an established practice of accepting gas that did not comply with written specifications). Again, the quality, breadth and extent of the data provided was lower than hoped for, however it did provide some evidence written specifications are not rigidly adhered to.

894. In addition, during this period, the results of Phase I of the GASQUAL’ study have been made available and have enabled the refinement of the household appliance replacement costs.

895. Following reconsideration of the previous work to accommodate the observation that much of the investments previously identified would not, in fact be required immediately as a consequence of harmonisation, we have restructured the analysis to consider the immediate impacts of applying a new specification, and to clearly set out the range of risks that might materialise.

QUALITY AND DOCUMENT CONTROL

Quality control

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Document control

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