Project No 213744

SECURE
Security of Energy Considering its Uncertainty, Risk and Economic implications

SP1 – Cooperation
Collaborative project
Small or medium-scale focused research project

DELIVERABLE No 5.2.7
Quantitative comparison of different risks, impact and mitigation possibilities

Due date of deliverable: March 2010
Actual submission date: May 2010 (revised version July 2010)

Start date of project: 1/1/2008 Duration: 36 months

Organisation name of lead contractor for this deliverable: Ramboll

Revision:

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Quantitative comparison of different risks, impact and mitigation possibilities

Ramboll

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Introduction

The issue of security of supply has been at the top of the agenda of the European energy debate for many years. Issues such as an increased import dependency due to decreasing indigenous production and increasing demand within the EU as well as the impact of the Russian-Ukrainian gas crisis of 2006 and 2009 and have instigated a number of discussions about the state of EU security of supply (SoS). Issues in the SoS debate span over a wide range of subjects.

In the public debate a number of different indicators have been quoted and used to illustrate a country's SoS status, such indicators include the import dependency and diversification indexes. The number of parameters used to describe the SoS status indicates the fact that SoS is a complex issue to quantify, because a number of issues are combined under the overall term of risk.

The concept of risk often covers the following three issues; firstly, what is the probability of an interruption (the actual risk), secondly what is the impact of an interruption and thirdly what options and tools are available in order to mitigate the effects of an interruption.

1. Risk - probability (of e.g. supply disruption, increasing import dependency, technical failure, geopolitical disruption etc.)[1]
    a. Long-term and short-term
2. Impact (vulnerability, affected countries etc.)
3. Mitigation (storage, demand reduction and legislative initiatives such as the proposal for a new regulation regarding security supply).

This report attempts to break these three issues down by first evaluating SoS in terms of risk by applying the Ramboll Security of Supply Index (RAMSOS) which is a combination of nine different parameters and indexes in one, then we evaluate the impact by assessing this risk in comparison of the overall share of natural gas in the energy mix of a country. The impact of different mitigation policies in terms of changes in the security of supply index is evaluated and compared to the costs associated with these policies.

The analysis will be based upon various scenarios which will be applied, as well as analysis of how SoS is going to develop in the future is also included by analysing SoS in 2020, 2030, and 2050.

Analysis will be made on a country individual level - as SoS is country specific it makes little sense to analyse SoS in the EU on an overall level, as individual countries differ in terms of gas supply, diversification, level of storage, dependency on imports, import sources, gas in the energy mix etc.

An overall evaluation of SoS in the EU is also provided, but the overall evaluation is merely a summation of individual scores and does thus not say anything about how individual countries perform.

[1] See deliverable 5.2.6 for an analysis of risk of natural gas disruption

Recommendations

The recommendations which have been made based on the analysis have been moved to the beginning of the report in order to ensure that they receive the full attention. The recommendations have been made and deduced based on the analysis and conclusions of this paper.

Main Conclusions

1. Improvement of SoS e.g. investments in the following six countries, Finland, Sweden, Estonia, Lithuania, Hungary and Bulgaria should be made right away.

2. Investments in Slovenia, Greece, Luxembourg, Ireland and Portugal are also essential.

3. The number of countries, subject to high risk and high dependency, is set to increase in the future. The following countries will face a reduction in SoS if no action is taken: Denmark, Bulgaria, Luxembourg, Austria, Slovenia, Finland, Greece, and Sweden.

4. Large economics of scale in infrastructure investments create a bias in SoS against smaller countries.

5. Markets invest in markets – not security of supply.

Policies and scenarios

6. Renewables only provide increased SoS in the long run, 2050.

7. Finland, Poland, Romania, and Ireland would benefit from investments in LNG - Market investments in LNG will however not solve SoS issues across the EU in general.

8. Slovenia, Hungary, Austria and Spain would benefit from investments in Storage - Market investments in storage will however not solve SoS issues across the EU in general.

9. N-1 regulation will improve SoS in many countries, but will not create an uniform distribution of SoS.

10. N-1 regulation will imply large costs for some countries and none for others.

11. If a policy such as the n-1 policy is adopted, then costs should be distributed evenly across the entire EU.

12. Storage capacity in the south-eastern part of Europe is limited.

National and regional implications

13. Focus on SoS in smaller markets is in general more urgent than focus on SoS in large markets.

14. Small countries and markets are correlated with lower SoS per unit of consumption i.e. small markets and countries have low SoS.

15. SoS investments should not be lumped together in a few countries but be spread across the entire EU.

16. A balanced provision of SoS using diversification, storage and interruptability is less risky e.g. UK's SoS is reduced because of very little storage capacity, despite being well diversified.

17. Regional focus in plans for development of SoS (Preventive action plans) and Emergency plans.

EU implications

18. Regulation and political intervention in the EU should be developed in order to ensure SoS across the member states, because Renewables will only improve SoS in the long run and markets mainly invest in relatively secure markets.

19. EU funding and financial aid is required in order to ensure the necessary investments in SoS.

20. EU should ensure easier implementation of cross-border projects.

21. Trans-European energy networks (TEN-E) guidelines should increase the importance of security of supply in the prioritisation of energy infrastructure investments.

22. The EU needs to analyse the fuel switching capabilities and potential of member states.

23. The EU should formulate a guide for joint regional SoS investments and planning.

24. The EU should increase transparency in terms of SoS prevention as well as emergency plans.

25. All measures for increasing SoS should be considered including financing, funding, regulation, market development and taxation.

Unconventional gas

26. Establish a dialogue with the gas industry, producers and consumers, in order to try to eliminate and reduce some of the uncertainties of EU unconventional gas utilisation.

27. Unconventional gas has already affected EU SoS by increasing LNG imports and diversification.

28. EU conventional gas could increase EU SoS and postpone decrease in EU natural gas import dependency.

29. Large uncertainties about unconventional gas in the EU compared to US.

30. Internal market integration, removal of bottlenecks and implementation of reverse flow remains a key issue for EU security of supply no matter what the prospect of unconventional gas is.

RAMSOS – Security of supply index

Initially we analyse the current overall level of SoS in the EU and the development of the various scenarios and mitigation policies thereafter. The level SoS is analysed by applying the Ramboll Security of Supply index (RAMSOS). Firstly the various different parameters and elements of the index will be described and then the results of the different parameters will be evaluated and subsequently their overall score.

The debate regarding security of natural gas supplies is often based on qualitative assessments of a few country specific indicators, such as import diversification and storage opportunities. However security of natural gas supply is affected by many other factors which are not known or considered, in this model. An attempt is made to give a more robust and visceral indication of the levels of security of supply in Europe.

RAMSOS is an attempt to bring a fresh perspective to the debate by quantifying the risks of supply disruptions and to combine these various measures into an overall index. There will always be a degree of subjectivity in the choosing indicators and measures. In the following we present the different indicators which describe a country's security of supply situation best. As mentioned, many factors affect a country's security of supply. However many of these variables are related and endogenously dependent. In order to ensure an optimal balance between transparency and simplicity on one hand and an authentic and detailed index, a total of nine parameters have been developed in accordance with the above mentioned conditions of transparency and detail.

Parameters

The parameters try to capture the essence of security of supply in the EU, today and in the future. Thus specific weight is placed on diversification, storage, development in consumption, production and reserves. The nine parameters are:

- **Capacity diversification** - This includes diversification in pipeline capacity entering the country, several connections are better in terms of diversification than a limited number of big connections. Firstly the import capacity for each import pipeline is counted. Secondly the LNG import capacity is calculated, the more LNG terminals the more diversified, each individual LNG terminal's capacity is included as a separate connection. Thirdly the production capacity is included, as possibilities for production enhances a country's ability to provide supplies and flexibility in times of supply shortages. The parameter is summarized using a Herfindahl index.

- **Volume diversification -** This parameter measures the actual diversification in terms of the physical import. The share of the import volume for each exporting country enters a Herfindahl concentration index. A country's indigenous production is included in the index, because being dependent on only indigenous production is also subject to risk.

- **Storage compared to household/services consumption -** Storage is typically regarded as one of the obvious measures to secure supply during periods of high demand and supply disruptions. The volumes in the storages are typically used for supplying those consumers that cannot shift to different energy sources, typically household consumers but also the service sector. Therefore we measure storage capacity relatively to household/services consumption[2].

- **Fuel switching possibilities** (replaceable gas) - is measured as the percentage of total demand which can shift to other fuels. Consumers with the ability to switch fuel are often large industrial consumers, such as cement factories and glass factories or dual fuelled power plants. The larger this ratio is, the easier it is for the country to manage the consequences of supply disruptions. Fuel switching is subject to a high level of uncertainty, both in terms of data quality but also due to the fact that fuel switching is often overstated as the incentives for many private companies are tempted to purchase gas on e.g. interruptible contracts, in order to receive a discount on the overall price. They often have difficultly assessing the costs of an interruption, and some do not even try.

- **Geopolitical risks -** Geopolitical risks have shown to be an important part of a country's security of supply. Events outside the sphere of influence of a country may imply that supplies are partially or completely disrupted. The latest example of this was the dispute between Russia and Ukraine in 2009. To quantify the geopolitical risk, import routes for a country are estimated, taking into account the exporting country and the associated transit countries.

- **Offshore risks** - Offshore pipes are more difficult to repair than onshore pipes – the average time of repair is around 60 days. Hence if a major part of a country's supply is transported via a single offshore pipe the consequences of disruptions may be significant. Thus even though the probability of a disruption is low it is relevant to include this indicator.

- **Reserves compared to total consumption** - Reserve estimates are measured relatively to total consumption of gas, and give an indication of which countries can remain producers in the future. Usually reserves are used in comparison to production, but the production is accounted for in the parameter "net export compared to production" and thus we focus on the potential of the reserves for indigenous consumption.

- **Import capacity compared to consumption** - This gives an indication of the possibility of increasing imports and the overall flexibility of the system.

- **Net export compared to production** - Large reserves strengthen a country's security of supply, but the distribution of reserves also matters. If a large share of

[2] This does not include services, however inclusion of services would have provided a better parameter as services like household consumption is not replaceable and consumers are dependent on the gas.

the production is committed to long term export contracts, it may be harmful to security of supply for the producing country.

For each country the parameters have been aggregated applying weights in the aggregation, weights have been generated based on expert assessment and evaluation and remain constant through-out the report. The weights have been chosen to achieve comparable values for each parameter - thus they only affect the absolute relationship between countries. For a more elaborate and technical presentation of the parameters we refer to the supplements of this report.

Data

In the below table the input data for each parameter is listed. The overall analysis is based on a variety of sources, which in itself highlights an important point – the availability of data for conducting thorough SoS analysis is scattered across many different sources and for some parameters no coherent and common source exists. The POLES SECURE scenarios and data have been used when applicable.

Table 1 shows the various data sources for each parameter used to calculate the level of SoS in RAMSOS.

Table 1 summary of parameters and data source

	SOURCE
CAPACITY DIVERSIFICATION	GIE, POLES, EIA, 2007, 2008
VOLUME DIVERSIFICATION	EUROSTAT 2006
STORAGE/HOUSEHOLD-SERVICES CONSUMPTION	UGS DATABASE, WGC 2009, POLES
REPLACEABLE GAS	EUROPEAN COMMISSION, CAMBRIDGE UNI, OWN ESTIMATES
GEOPOLITICAL RISK	FUNDFORPEACE AND SECURE DELIVERABLE 5.2.4
OFFSHORE RISK	GIE, IN-HOUSE KNOWLEDGE, 2009
RESERVES	OIL & GAS JOURNAL, BP, CEDIGAZ, 2008
IMPORT CAPACITY /CONSUMPTION	GIE, POLES
EXPORT / PRODUCTION	EUROSTAT 2007, POLES

This inconsistency in data availability between countries and sources of data allows us to draw the first conclusion and recommendation, even before the analysis is made, namely that a common source for data and information on Security of supply in the EU should be created, allowing industry, government, regulators, TSO, analysts and other stakeholders to attain relevant and good and timely data for assessing and evaluating issues of security of supply.

Results

Applying the data, the RAMSOS model calculates an index which allows for evaluation and comparison of the security of supply level amongst the different evaluated countries. The index does not define what a secure level of supplies is, but it allows for comparison of security levels among countries and allows for identification of specific issues that affect the security of supply score, e.g. a low score can be due to different parameters, such as lack of diversification or storage, or it may be caused by geopolitical threats.

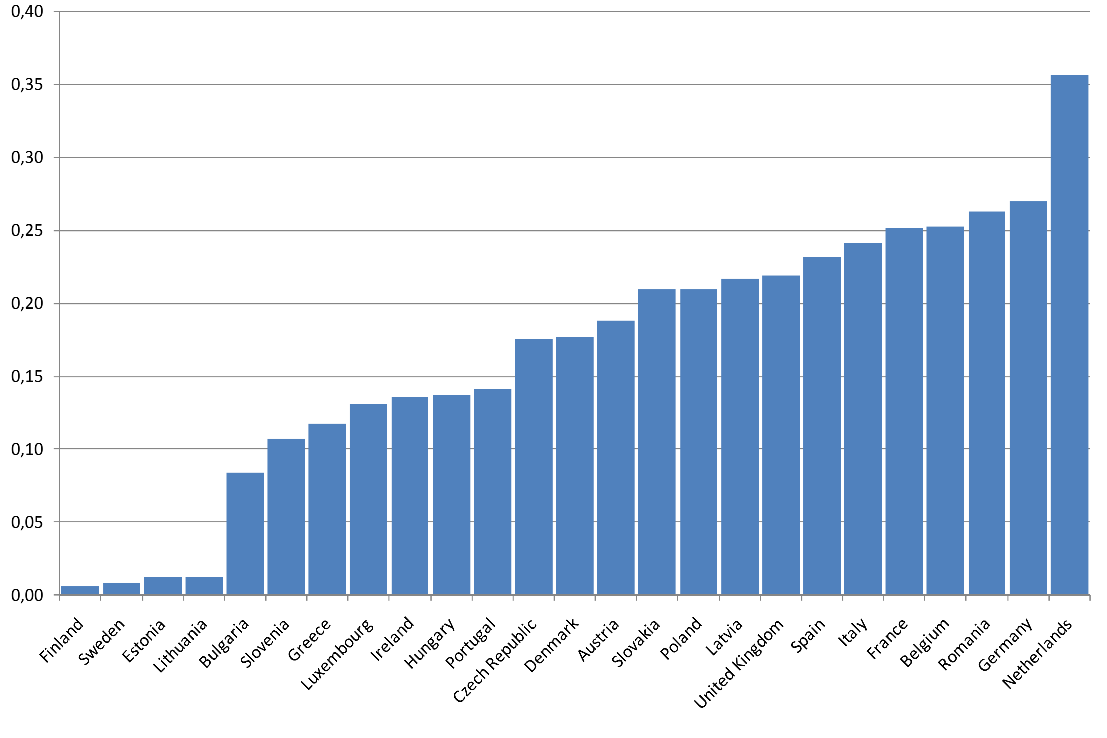
For the identification of specific SoS concerns, RAMSOS allows SoS results to be displayed in two different formats; disaggregated, where the contribution of each parameter can be identified and aggregated where only the total index score is displayed.

Baseline 2010, results

The current level of SoS in the EU has been assessed and serves as a baseline for comparison in the development of SoS in the EU and the affects of different mitigation measures. Figure 1 shows the result aggregated of SoS in 2010.

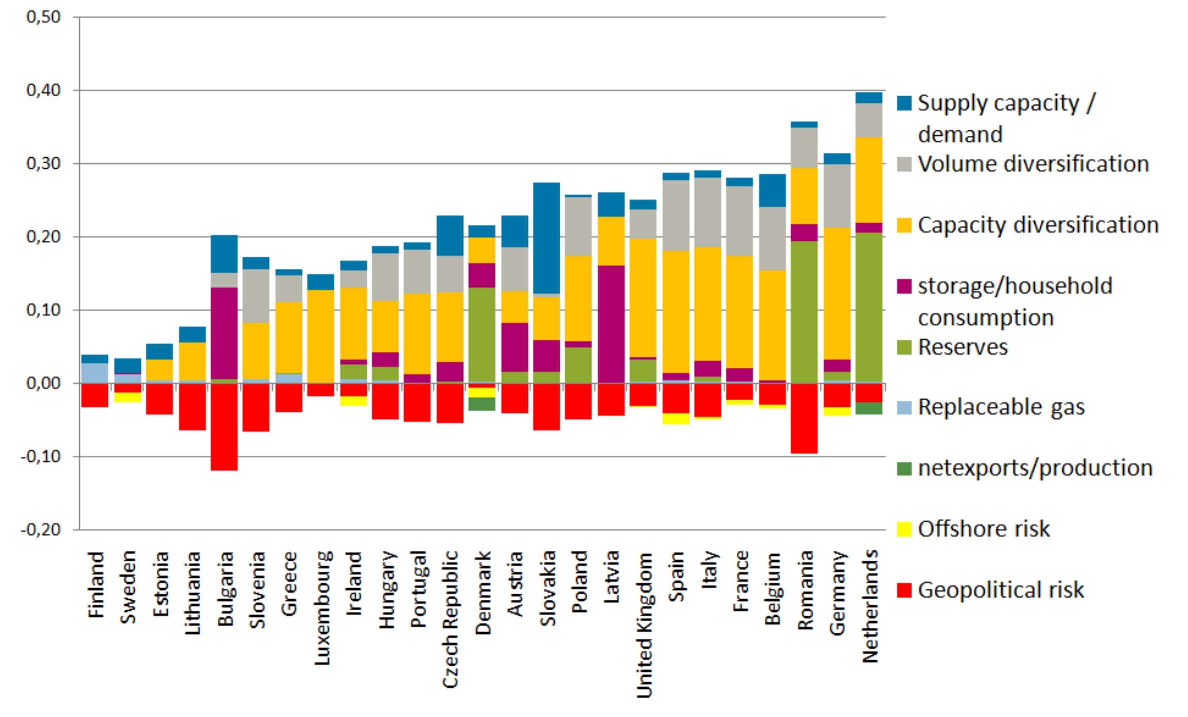
Figure 1 shows that the countries in the outskirts of the EU have the lowest security of supply, while the established countries in western and central parts of the EU score relatively well in the security of supply index.

Figure 1 Aggregated results, 2010



In Figure 2 the score of each country is disaggregated into different categories, allowing us to identify the different components which make up the overall score.

Figure 2 Disaggregated results



It is evident that the index can become negative for some countries if the parameters such as geopolitical risks and offshore risk increase or if the consumption increases without any additional investments in new infrastructure.

Conclusion Baseline results, 2010

A number of conclusions can be made from evaluating Figure 1 and Figure 2. It is seen that a country like the Netherlands benefits from being well diversified as well as having its own indigenous production, giving the country an overall high level of SoS.

Finland, Sweden, Estonia, and Lithuania, receive the lowest scores. This is due to a number of reasons but principally a very low or even non-existing level of diversification e.g. Finland, Estonia and Lithuania only receive gas from a single supplier i.e. Russia and for Finland only one route is available for imports. Furthermore none of the four countries have any storage facilities, but have to rely on neighbouring countries for storage. Moreover, Finland, Estonia and Lithuania also face a relatively large geopolitical risk triggered by their dependency on Russia[3] and with regard to Lithuania the dependence on Belarus for Transit.

A country like Bulgaria which has a relatively significant storage capacity is punished in terms of SoS, because Bulgaria is subject to a high level of political risk as Bulgaria receives all its gas via the Ukraine and thus is poorly diversified. This is a good example of the multilateral aspects of the concept of security of gas supply.

Countries with some mitigation possibilities such as Bulgaria in form of storage, Greece with a LNG terminal, and Luxembourg with the diversity in import possibilities for

[3] It should be noted that Finland has never experiences any disruptions in their gas supplies.

example, lie just above the bottom four countries. This illustrates the difference between having some mitigation measures available and not having anything at all. Some might argue that Finland should be placed higher due to the fact that Finland has a very high share of fuel switching. However mitigation measures on the demand side are much more uncertain than measures on the supply side. The actual "interruptability" or fuel switching potential may in many cases be lower than the official stated, as the "interruptability" in many countries never has thus far been tested.

Having indigenous reserves has a high value in terms of security of supply. This affects countries such as Denmark, Romania, and the Netherlands, where as countries like Poland and the UK also have considerable reserves, these are smaller compared to the level of consumption.

A country like Denmark is characterised by having a low level of diversification, but benefits from being self-sufficient because of indigenous production. However this will most likely change in the not so distant future as levels of indigenous production are decreasing and will thus leave Denmark in a very risky situation. Reducing the indigenous will, ceteris paribus, mean that Denmark will drop from a middle position to a very low position provided no action is taken to mitigate the implications of the decline in indigenous production.

Regarding the contribution of storage, relative to household/services consumption, it is important to notice that the storage score is the value of having storage within your own gas system borders and not the overall value of storage, because storage facilities increase SoS for all consumers in the vicinity of the storage and not only the consumers within the borders of the country holding the storage. The value of having access storage in another country is thus indirectly accounted for in the diversification index. This was exemplified during the Ukraine-Russia where storages were full in Western Europe but capacity was lacking. Some countries do however have a very high ratio of storage compared to household/services consumption and they receive a high score for this, countries include Latvia, Bulgaria, and to some degree Austria.

An almost complete absence of e.g. storage, as is the case in the UK, is also something that is worth examining further because although the UK is very well diversified, being too dependent on a single source of SoS is also risky. Countries should not only look at the level of SoS but also strive for a balanced provision of SoS, as this will reduce dependency and improve SoS. In the case of the UK capacity diversification is high but actual volume diversification is much lower, making the UK very dependent on a single gas supplier, Norway. This in essence does reduce the value of capacity diversification.

The geopolitical risks for gas supplies are especially pronounced in countries reliant on Russian gas supplies via the Ukraine. However also Portugal and Spain are subject to geopolitical risk because of e.g. LNG imports from African countries like Nigeria.

Diversification, both in terms of capacity and in terms of actual volumes received, is a major contributor to the index - here it is worth mentioning that countries with a significant extent of own production are typically less diversified, due to the fact that their own production counts as an import source.

The countries that receive a high SoS score are countries characterized by having a diversified portfolio such as Germany, France, Italy, Spain and Belgium. Furthermore the Netherlands and Romania also benefit from having diversified portfolios as well as considerable reserves.

The logical overall conclusion is that countries that are well diversified and have access to storage or indigenous production are in a better position to tackle possible supply disruption.

One should keep in mind that several of the countries with the lowest levels of SoS are characterized by the fact that natural gas only makes up a small share of the total primary energy consumption. Upon review of the previous point, it can be determined that to some extent SoS is covered by diversification of overall energy and one may ask 'why buy an expensive insurance if the impact of an accident is relatively small?' Thus we need to evaluate the risk identified in the above in relation to the impact of a gas supply disruption. This is done in following section.

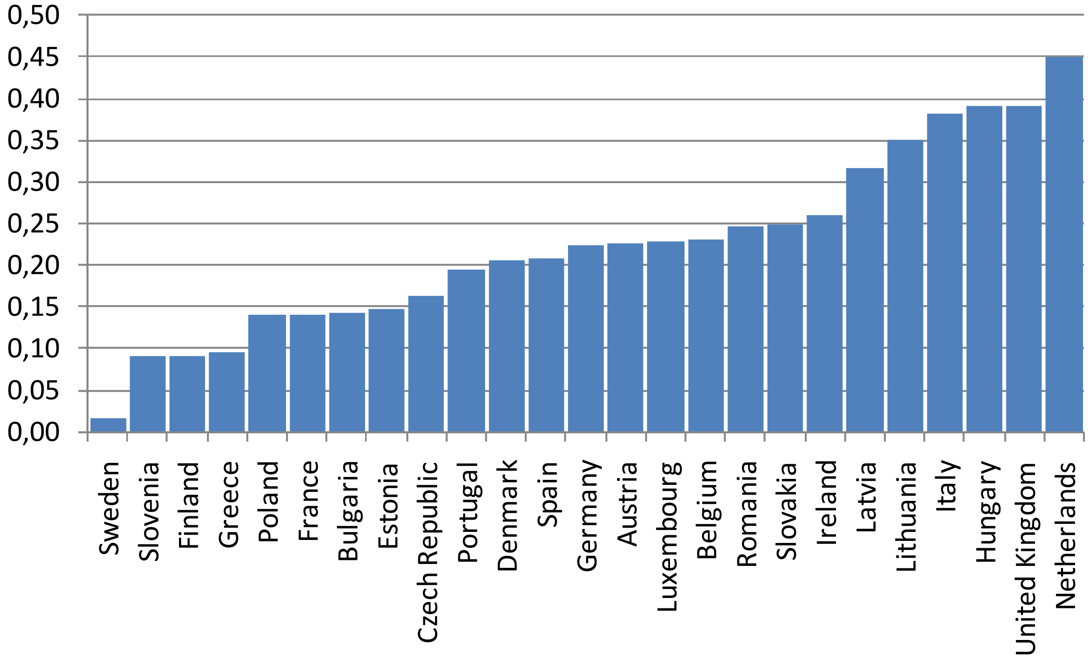
Impact

In this section we review the attained results from the SoS index by evaluating the results of the impact or vulnerability of individual countries in terms of a gas interruption. This is done by comparing the risk with the vulnerability. In this context the vulnerability is described by the share of natural gas in each country's primary energy consumption, i.e. we evaluate the vulnerability of each country in terms of overall energy consumption.

Share of natural gas in primary energy consumption

The second dimension enables us to assess both risk and impact. This implies that the countries which face a high risk *and* are vulnerable can be identified. These countries are important to identify as these are the countries which would benefit the most from taking mitigation measures against the SoS risk. Below natural gas share of total energy consumption is illustrated for all EU countries.

Figure 3 Share of natural gas in primary energy consumption, POLES 2010.



It is seen that many of the countries which scored low in the SoS index, such as Sweden, Finland, and Greece, have a rather low use of gas in their primary energy consumption. This implies that the incentive to increase the level SoS is relatively low, as the impact of an interruption would be relatively small.

Risk vs. impact

A more systematic comparison of the security of supply index and the gas market's share in total energy consumption will allow us to identify the countries that could benefit the most from taking action by e.g. implementing mitigation policies. This approach was also suggested in the SECURE deliverable 5.2.6 were possible disruptions to the supply of natural gas were described.

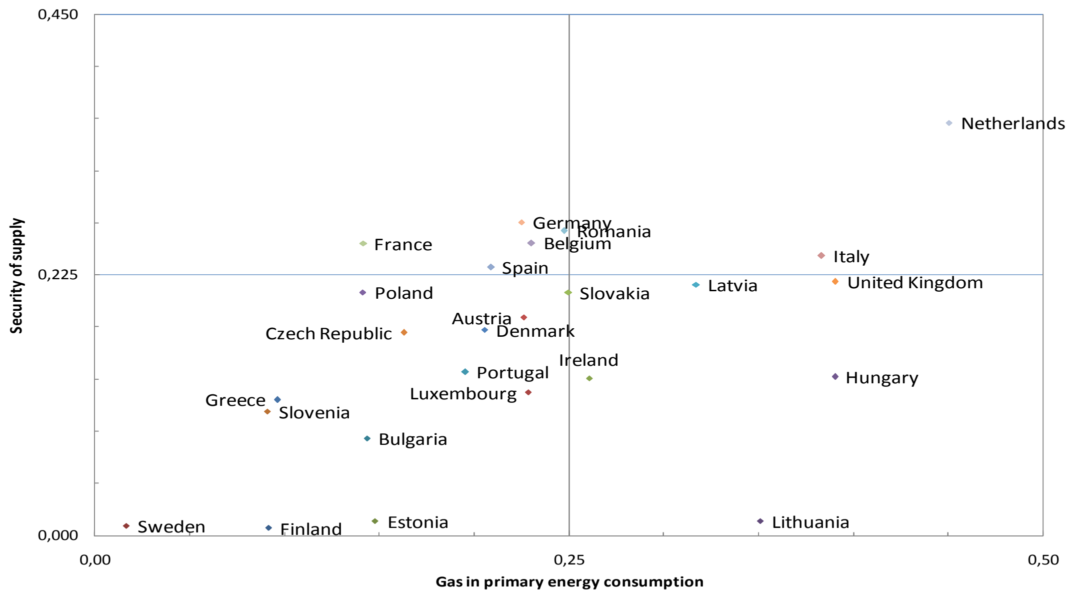
This relationship between risk and impact is shown for each EU country in the scatter plot in Figure 4 – The graph illustrates what overall seems to be a positive relation between scoring high in the security of supply index and having a high share of gas in primary energy consumption.

The below figure shows the share of gas in primary consumption on the horizontal axis from low to high and security of supply on the vertical axis from low to high. The figure is divided into four quadrants. Each quadrant may be interpreted the following way:

- Lower left-hand corner – countries which only use relatively little gas in their primary energy consumption and have a low (poor) level of SoS – low SoS (high risk) but low vulnerability, examples of countries in the quadrant are: Slovenia, Finland and Estonia.

- Upper left-hand corner – Countries in this quadrant are characterised by having relatively high SoS (low risk) and low vulnerability – these countries include e.g. France, Germany and Spain.
- Upper right-hand corner – are countries with high SoS (low risk) and high vulnerability i.e. countries which depend on gas for a large share of their primary energy consumption. Countries include Italy and the Netherlands.
- Lower right-hand corner – are countries with low SoS (high risk) and a high vulnerability. These countries are in a situation with the highest risk as they have relatively low SoS and at the same time they are very dependent on natural gas in the primary energy consumption. Countries include: Lithuania, Hungary, Latvia and the UK.

Figure 4 SoS index vs. gas share in primary energy consumption, 2010



Countries in the left upper-hand corner are countries characterised by a high level of SoS and a low level of vulnerability as they only use a low level of gas in their overall energy portfolio, therefore the impact of an interruption would be relatively small. Countries in this section are categorised by having a high level of SoS and low vulnerability - countries include France, Spain, Germany, Belgium and Romania.

Countries on the axis from the left low-hand corner to the right upper-hand corner, display a relationship where risk and impact correlate, which means that risk is low (SoS is high) for countries, which are relatively dependent on natural gas in their overall energy portfolio.

A number of countries are however subject to a relatively high level of risk as well as a large vulnerability, i.e. they have a high share of gas in primary energy consumption combined with a low level of security of supply. These countries are Lithuania, Ireland, Luxembourg, Slovakia, Latvia, United Kingdom, and Hungary. Based in the above it would be recommended that these countries review their security of supply situation and evaluate what can be done to improve their level of security of supply.

Further a number of countries are characterized by having a low level of security of supply, the countries being Sweden, Finland and Estonia. Although these countries do not depend on natural gas for a very large share of primary energy consumption, they are characterized by having a very low level of security of supply. These countries neither have storage nor indigenous production nor any diversification or only very little diversification. Further Finland and Estonia also face considerable geopolitical risk. Thus these countries would be advised to evaluate what measures could be taken in order to increase the level of SoS.

Future development

The level of SoS and the vulnerability or impact from a supply disruption, are dependent upon a number of parameters. One important parameter is consumption. As the role of natural gas in the overall energy consumption might change in the future, this will have an effect on the risk and vulnerability of the country, e.g. if a country reduces its gas consumption, the relative size of storage changes, further indigenous resources are set to decrease, further affecting the level of SoS.

In this section we evaluate the development of SoS based on the development of gas production and consumption in the EU until 2050.

We evaluate the development of security of supply by analysing the risk and impact for the years 2020 and 2050 in order to analyse any development, based purely on changes in consumption and production – everything else is kept constant. Thus any investments planned are not included. This is chosen in order to analyse the effects of consumption and production in isolation from other effects.

In doing so we apply the consumption and production forecasts from the POLES model Baseline scenario, described in the SECURE deliverable 4.1. This shows us how the level of SoS evolves if no mitigation measures are taken.

The results attained from using the POLES figures for 2020 and 2050 are illustrated in Figure 5 and Figure 6.

Figure 5 SoS index vs. gas share in primary energy consumption, 2020.

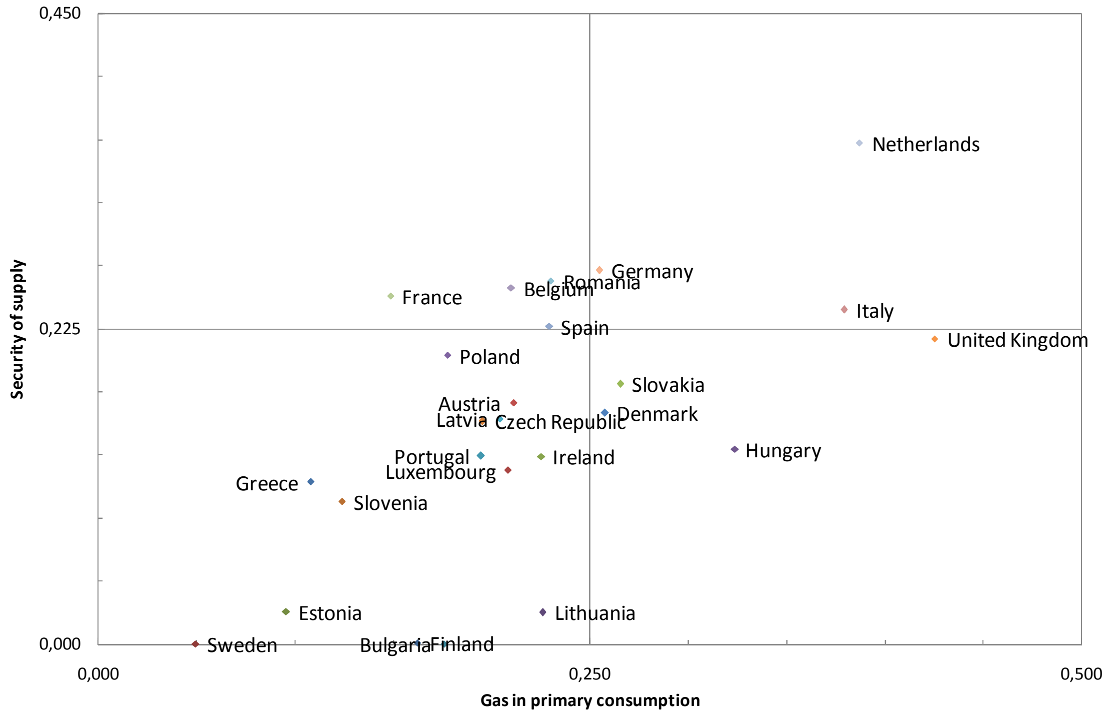
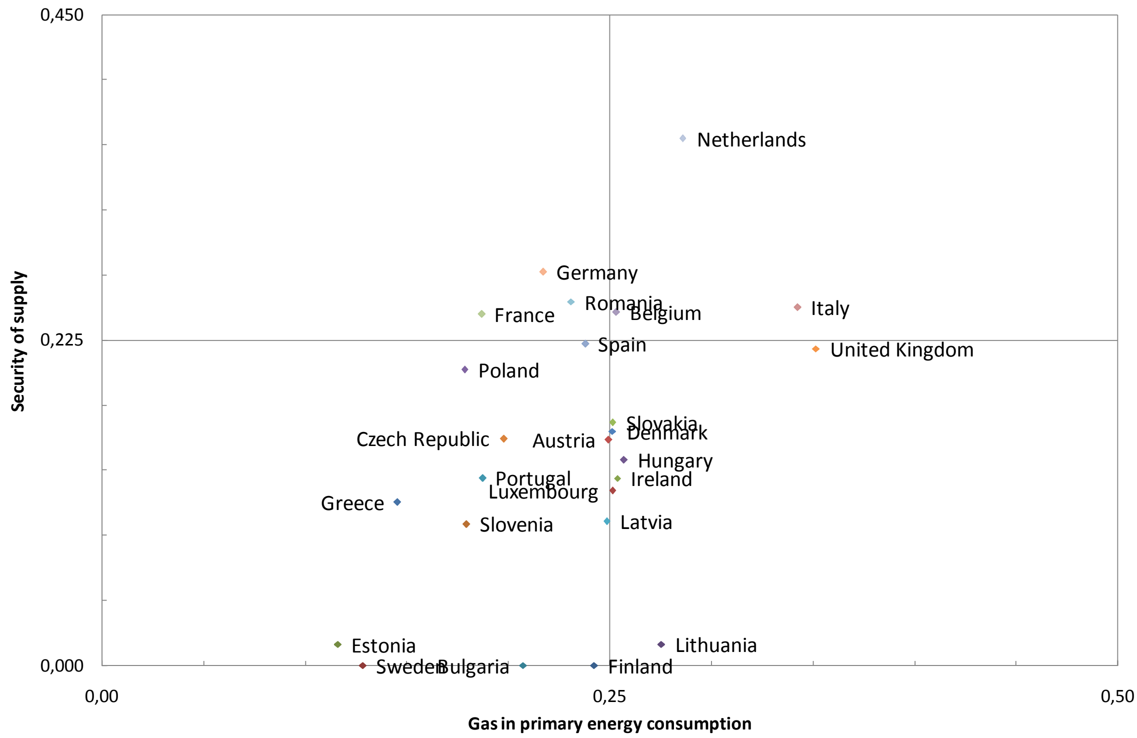


Figure 6 SoS index vs. gas share in primary energy consumption, 2050.



Conclusion - Development from 2010 - 2050

In the year 2050 it is seen how the number of countries, exposed to a high impact of disruption as well as having a high risk, increases from six in 2010 to nine in 2050 –

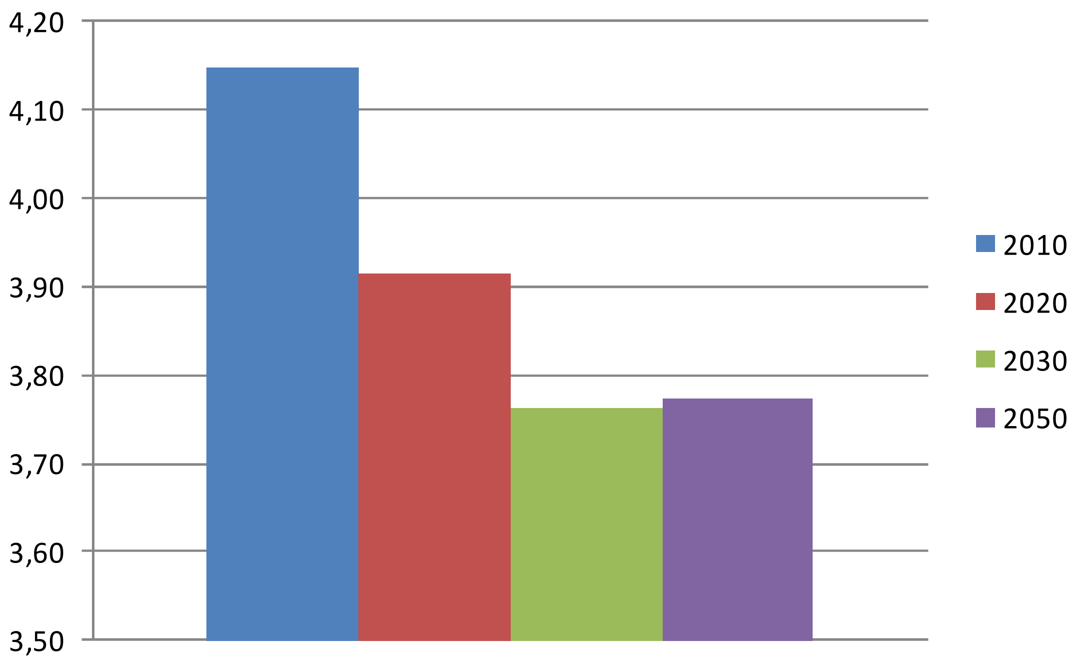
countries moving into or very close to the risky zone are: Denmark, Luxembourg and Austria. With regard to Denmark, this is due to decreasing indigenous production combined with a low level of diversification. For Austria and Luxembourg this increase is due to increasing gas consumption.

The largest relative increase in consumption is observed in Slovenia, Finland, Greece, and Sweden, whereas consumption in countries such as the Netherlands, Italy and Hungary decreases. Bulgaria drops significantly in terms of SOS, i.e. the situation in Bulgaria worsens from a SoS point of view in this scenario. This is due to an increase in gas consumption which is in turn not countered by an increase in for example storage investments. The SoS score for Sweden, Bulgaria, and Finland falls just below zero as consumption is increasing – for expositional purposes these countries have been truncated to zero.

Thus unless something is done, the level of security of supply will decrease for several countries within the EU.

To get an indication of how security of supply develops overall for the EU, we compare the aggregate of individual country scores. This is illustrated below in Figure 7.

Figure 7 Aggregate EU score for 2010, 2020, 2030, and 2050, POLES.



It is shown how security of supply will decrease in the EU if no further investments take place. The negative change is mainly driven by an increasing consumption of gas (17 % on EU level), in especially the household sector. A small positive change from 2030 to 2050 is observed – this is caused by the advancement of renewable technologies in some countries.

In summation we have that overall SoS in the EU varies considerably across the Union, with some countries being relatively secure and others being subject to considerable risk. Six of the countries with relatively high risk are also subject to a high impact or high level vulnerability against a disruption, as they are relatively dependent on natural gas in their overall energy consumption portfolio. The number of countries subject to high risk and high dependency is set to increase in the future.

Furthermore it can be concluded that if no mitigation policies and/or investments are made to increase the level of SoS then the overall level of security of supply in the EU is set to decrease.

Mitigation though is possible though both the investments which the market takes, and active mitigation and security of supply policies instigated by the EU-Commission and national regulators. Thus, several different types of mitigation policies are available. In the following section we illustrate the impacts of various selected policies with regard to security of supply.

The above results are referred to in the rest of the paper as the POLES Business as usual (BAU).

Mitigation

In order to assess possible mitigation measures the following section will analyse how different policies would affect the level of security of supply in individual countries as well as overall. The policies will also be assessed in terms of costs in order to allow for an assessment of which policies are the most cost effective.

Security of supply policies

The following four scenarios have been developed and the impact of each scenario will be assessed in the following, the scenarios are named:

- LNG
- Storage
- n-1
- Renewables

The mitigation scenarios have been developed in accordance with the two overall strategies, i.e. market provision of security of supply and public regulation of security of supply provision. The scenarios on LNG and Storage evaluate how market development will affect SoS, whereas the n-1 and the Renewables scenario assess how regulation of the energy market could impact SoS.

Alternatively the scenarios can be seen as an evaluation of:

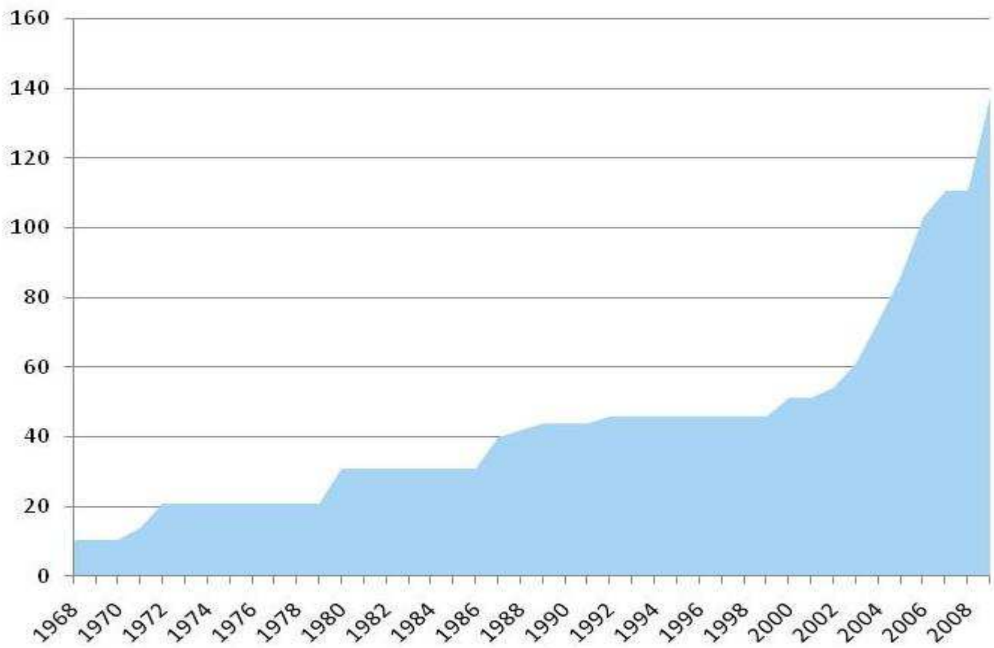
- Increasing long term gas supply (LNG scenario)
- Short-term gas supply (storage scenario)
- Increasing diversification (n-1 scenario)
- Decreasing dependency (Renewables scenario)

The intention of these different scenarios is to analyse and isolate affects of different individual policies. Any future for the EU would most likely be a combination of the above scenarios, but in order to isolate the effects of different policy instruments on overall SoS, as well as on specific geographic areas, we have chosen to analyse each scenario individually.

LNG scenario background

LNG has been a hot topic within the gas markets over the last 10 years. Traditionally in the EU, LNG has been used to provide gas for markets, which are not connected by pipeline to any major gas producers, and to provide peak capacity. Recently the focus of LNG has been on the fact that LNG is considered a good solution, in terms of increasing SoS, because LNG provides an option for increasing import diversification and thus reducing the dependency of gas imports from Russia, and other major import countries. Furthermore it has been seen as a potential replacement for the decreasing indigenous production in the EU. This is illustrated by the increase in LNG import capacity, which over the last 10 years or so, has almost tripled in the EU. Figure 8 shows the development of LNG import capacity development in the EU.

Figure 8 Capacity developments LNG in EU, BCM

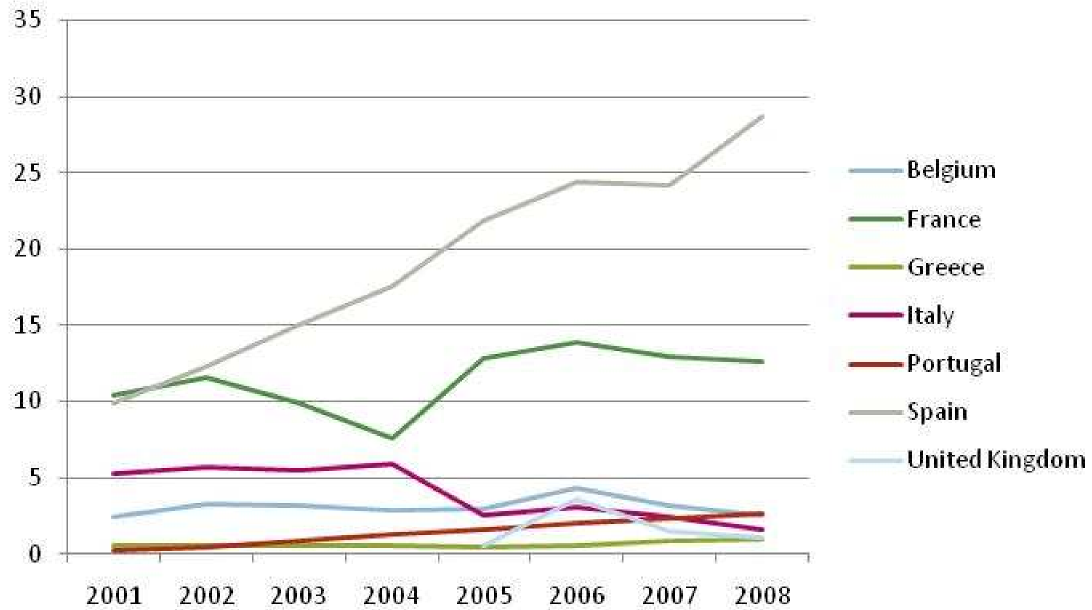


Source: Gas infrastructure Europe, Enagas, LNG in Europe King & Spalding, Ramboll

Although capacity has increased significantly the increase in actual imports is limited to mainly Spain.

Figure 9 shows the actual development of LNG imports in the EU.

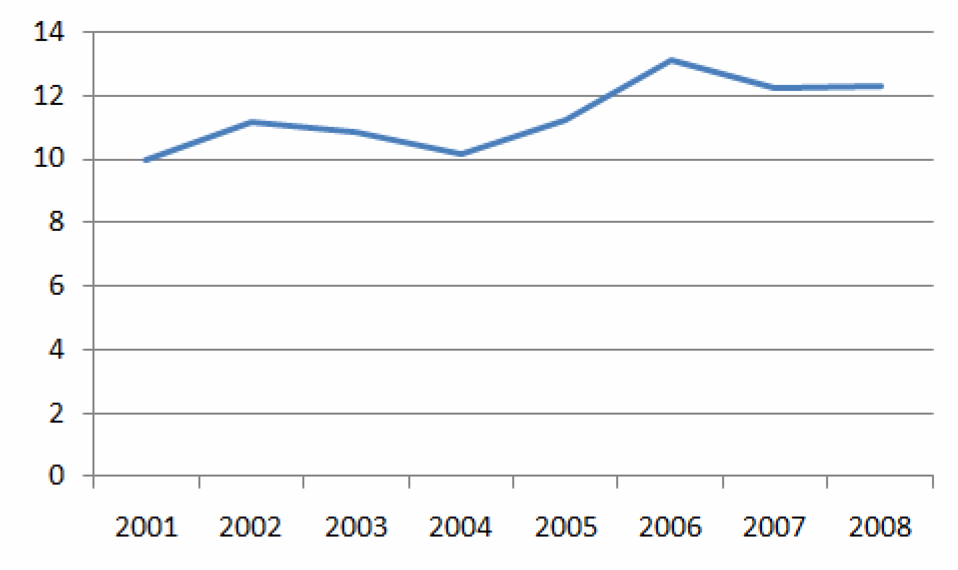
Figure 9 LNG imports in the EU, BCM



Source: BP statistical review

It is noticeable that except for France and Spain, LNG plays only a small role in terms of gas supply. This indicates that the purpose of LNG is not only securing the actual gas supplies, but also very much a question of providing peak capacity and SoS. The share of LNG out of the total EU imports over the last decade, is shown in the below graph.

Figure 10 Share of LNG in Total EU gas imports in pct.



Source: BP statistical review

When we evaluate the actual gas, imported as LNG in the EU over the last decade, we see that imports have remained relatively stable compared to the overall gas imports, despite the large increase in capacity.

It should be noted that investing in 1 BCM of LNG capacity does not imply increased imports of 1 BCM. In 2006 the utilisation rate of the total LNG capacity in the EU was around 50% and in 2008 this figure dropped to 45%.

The capacity increase which has led to a tripling of total capacity in the last decade, have taken place in a total of five countries, and has brought about investments in three new countries - Greece, Portugal and the UK.

Table 2 Investments in LNG capacity 2000-2009, BCM

Country	Capacity
Greece	5,3
Spain	43,6
Portugal	5,5
UK	41,5
France	8,3
Total	104,1

Source: Gas LNG Europe (GLE)

The above analysis has shown that although there has been a significant increase in terminal capacity, this capacity increase has been limited to only a few countries. This indicates that so far LNG may have led to diversification for only a small number of countries and it raises the question of what is the actual benefit in terms of SoS in the future in terms of the planned LNG investments – will they provide increased SoS for the countries which currently have a relatively low level of SoS or will the planned investments only increase the SoS in countries which already benefit from a high level of SoS? Are benefits spread across the EU? Or will only a small number of countries benefit?

Limitations to LNG

Further LNG terminals do not have unlimited options in terms of flexibility. A large share of the capacity of LNG terminals are based on long term contracts, which reduces the flexibility of imports overall. Further LNG terminals need onshore interconnections in order for them to be able to distribute the gas, e.g. Spain has a lot of LNG capacity but has only has relatively little capacity towards France, and even though this capacity is currently being increased, France has so far not been able to benefit from the LNG in Spain and will not be able to until this new capacity comes online likewise Spain has only had limited access to the Norwegian and Russian gas in France, due to the lack of cross-border capacity.

The question which remains unanswered is the effect of increased LNG import capacity and the associated diversification in volumes. Several new terminals have been proposed in a number of EU countries. In the following we incorporate these investments into the RAMSOS index.

LNG investment scenario

A series of LNG projects are listed as planned in the Gas Infrastructure Europe LNG investment database.[4] Although it seems unlikely that they would all be implemented, there seems to be evidence that LNG will play an increasing role in the EU gas market and European gas supply.

The question however is how this increased focus on LNG in the EU will affect security of supply? The LNG scenario evaluates this by implementing the following investments in the SoS index. As is shown in the below table, the diversification of the investment projects in the LNG scenario is somewhat higher compared to the diversification of LNG investments in the last ten years. New LNG countries are Germany, Poland, Ireland, Romania and Finland. However the bulk of capacity investments are still concentrated in a few countries, i.e. Spain, France, The Netherlands and the UK. The division between investments in new terminals and expansion of existing sites is approximately 50-50.

The scenario is created by using available GIE information in combination with Ramboll in-house data:

Table 3 LNG investment scenario, 2010-2017

	Name of facility	Investment type	Capacity (BCM)	Country total (BCM)
France	Montoir	Expansion	6,50	18,75
France	Fos Tonkin	Expansion	4,00	
France	Fos Cavaou	New facility	8,25	
Greece	Revithoussa	Expansion	2,00	2,00
Ireland	Shannon	New facility	6,20	6,20
Spain	Musel	New facility	10,50	33,80
Spain	Bilbao	Expansion	5,25	
Spain	Sagunto	Expansion	5,25	
Spain	Tenerife	New facility	1,30	
Spain	Gran Canaria	New facility	1,30	
Spain	El Ferrol	Expansion	3,60	
Spain	Cartagena	Expansion	2,70	
Spain	Huelva	Expansion	3,90	
Italy	Toscana Offshore	New facility	3,80	3,80
The Netherlands	Gate terminal	New facility	16,00	16,00
UK	Isle of Grain	Expansion	6,50	17,00
UK	South Hook	Expansion	10,50	
Germany	Wilhelmshaven	New facility	5,00	5,00
Poland	Swinoujscie	New facility	5,00	5,00
Portugal	Sines	Expansion	2,75	2,75
Romania[5]	Constanta	New facility	3,00	3,00
Finland[6]	-	New facility	3,00	3,00
Total			116,30	

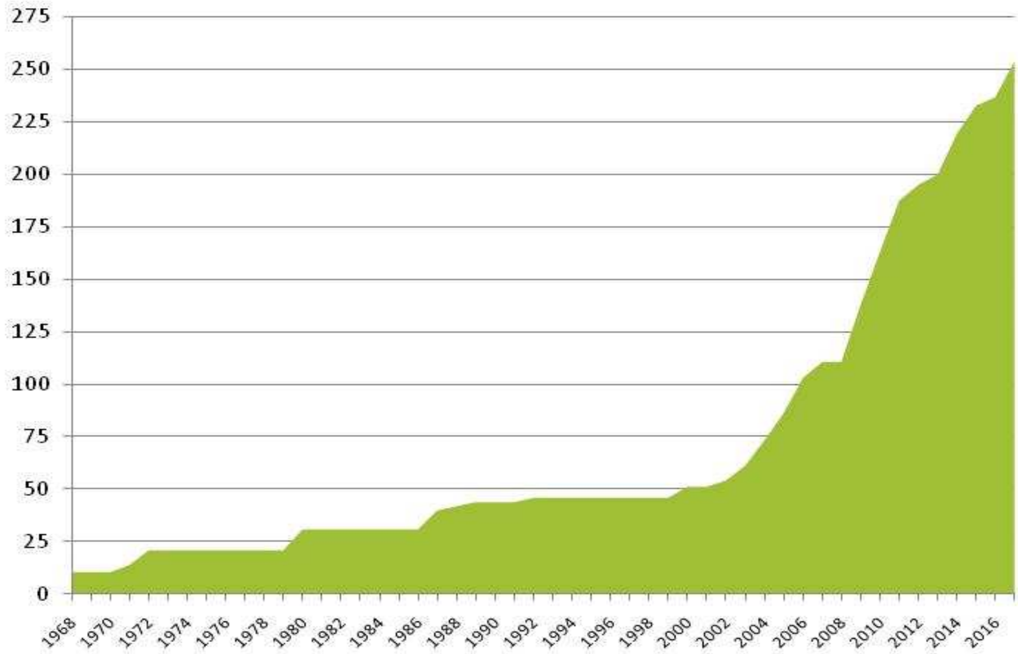
Given the above investment assumptions we have the following development in EU LNG capacity.

[4] Gas Infrastructure Europe (GIE) LNG investment database, December 2009, LNG terminals are also being evaluated in the Baltic countries and Finland. Some of the investments listed here have since the analysis begun already been implemented e.g. the UK capacity expansions.

[5] Ramboll in-house evaluation, 2016

[6] Ramboll in-house evaluation, BEMIP report

Figure 11 Development of LNG capacity in LNG scenario, BCM

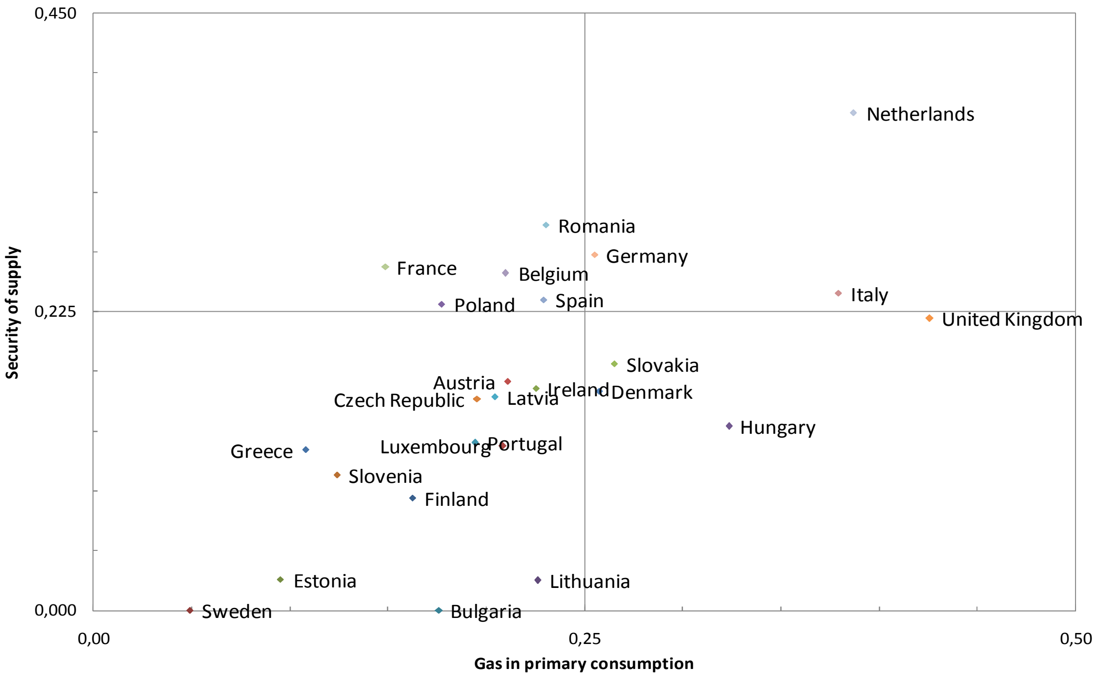


The results of the LNG scenario should evaluate what the value of LNG is for the EU in the future, and help determine whether LNG will help boost SoS in those countries where SoS is relatively low or whether LNG mainly helps bolster the SOS of countries with relatively strong SoS positions.

Results LNG Scenario

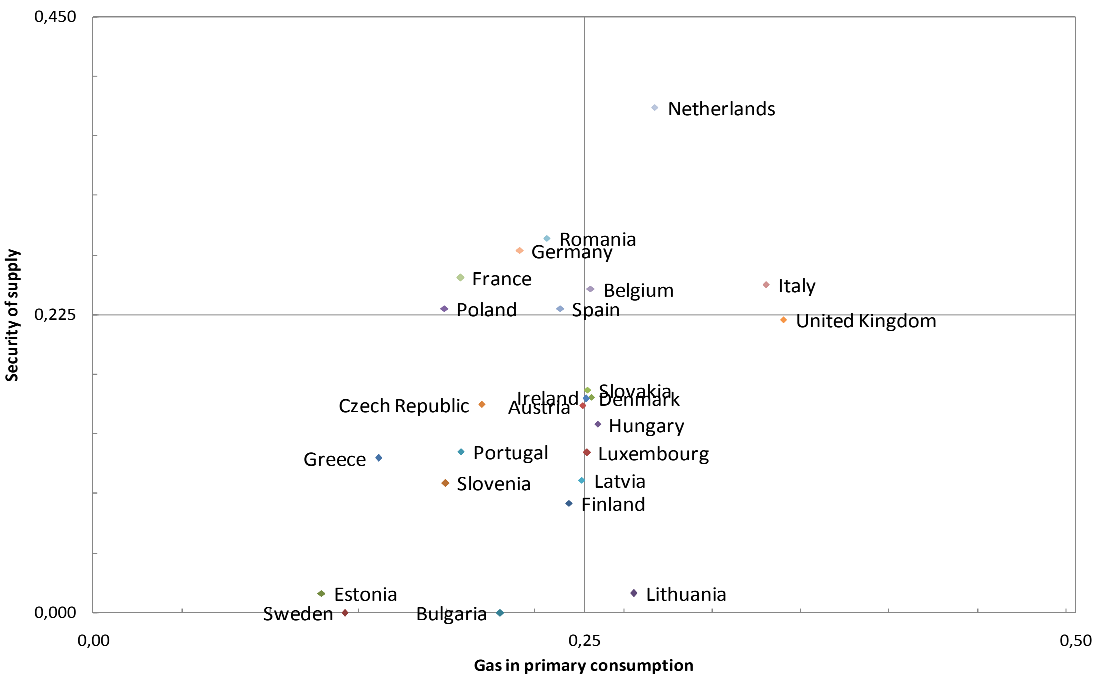
Incorporating the above mentioned investments in the security of supply index, while taking the demand and production modelled in POLES baseline scenario into account, yields the following results for 2020 and 2050.

Figure 12 LNG Scenario 2020 impact versus risk



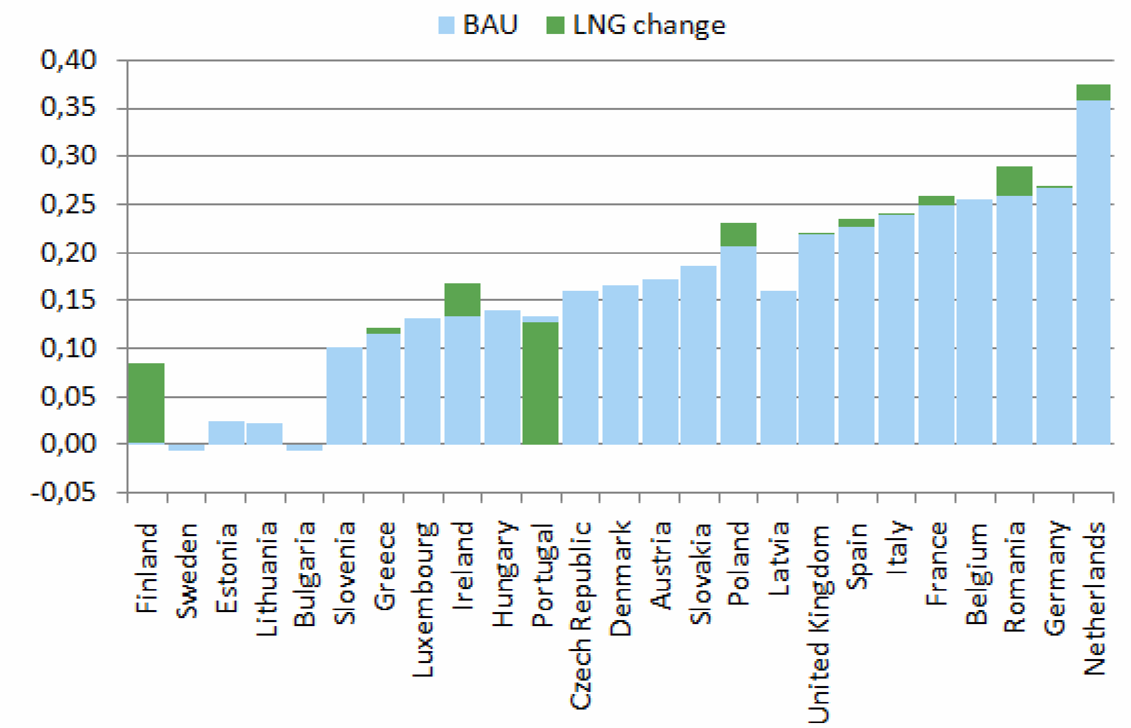
Compared to the BAU scenario countries such as Finland, Poland, Romania, and Ireland improve significantly in 2020. Looking further ahead to 2050, the increase in gas consumption increases the vulnerability of Finland and Ireland which implies a higher level of risk for those countries.

Figure 13 LNG Scenario 2050 impact versus risk



Thus comparing the results with the BAU scenario, it is seen that new terminals have a relatively large local effects in countries such as Ireland, Finland, Poland, and Romania, while the effects of expansions in UK and Spain are rather limited. This is also illustrated in Figure 14 below.

Figure 14 Changes in SoS, BAU vs. LNG 2020



It can be seen that in most countries security of supply is increasing, illustrated by the green bar. Only in Portugal a decrease is observed.

The conclusion is that the benefits of LNG terminals, with regard to security of supply, mainly lie in countries with little or no capacity diversification. The marginal effect of building terminals in large established LNG countries is relatively small. It should be noted that the volume diversification which the LNG terminals can provide, is not included in this score, as it is not possible to predict actual physical supplies until 2020. Thus the adverse security of supply effects of LNG terminals may be bigger, as countries, such as Ireland and Romania, get the possibility of volume diversification, while the larger LNG countries, such as Spain, are already diversified. Thus the effect of volume diversification will magnify the difference between the effect on new and old LNG countries.

It is noticeable that Portugal is actually reducing its SoS even though investments in a capacity expansion are made. There are two reasons for this; firstly all consumption in Portugal is set to increase considerably, reducing the positive impact of increased capacity. Secondly expansion of the Sines Terminal is a capacity extension and not a new source, thus it does not provide additional diversification for Portugal. The further diversification of supplies, which Portugal could benefit from, is not registered in the future scenarios. However if the terminal expansion would diversify import volumes then the overall effect of the expansion could be positive. The situation may be compared to a country, which is dependent on Russian gas import and decides to expand their Russian import pipeline - this would just simply increase the dependency on Russia or, in the case of Portugal, increase the dependency on LNG.

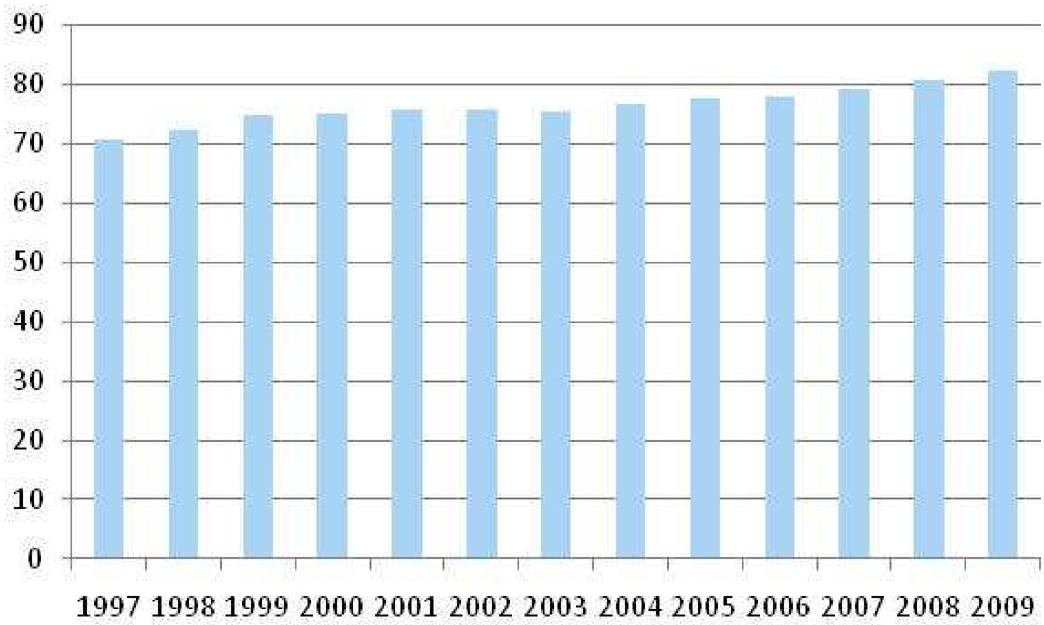
Thus from a security of supply perspective LNG investments should be undertaken in areas which are not endowed with LNG import facilities already, because although LNG imports are more flexible compared to pipelines, there is still a level of dependency, because just as LNG may be imported from many sources it can also be exported to many sources. Further the flexibility is not unlimited as LNG terminals also rely on long term contracts for gas supplies.

Storage scenario Background

Storage facilities provide security by providing access to gas during interruptions of supply and by increasing flexibility. In this scenario we evaluate the effects of increased storage investments on the EU. The declining indigenous production has increased demand for gas storage as an alternative flexibility tool. Furthermore the increase in renewable energy has put focus on natural gas in electricity generation because of the flexibility of gas fired electricity generation and low investments costs.

These factors have increased the demand for gas storage and will lead to a shift in the gas storage investment curve. Below is shown the development in gas storage capacity from 1997 to 2009 which only saw a minor development in gas storage capacity. However the changes in indigenous production and increased demand for flexibility had spurred a significant increase in storage investments. This increase in storage capacity will have impact on SoS in the EU, the question is how much and where?

Figure 15 Development of gas storage volume capacity in the EU, BCM

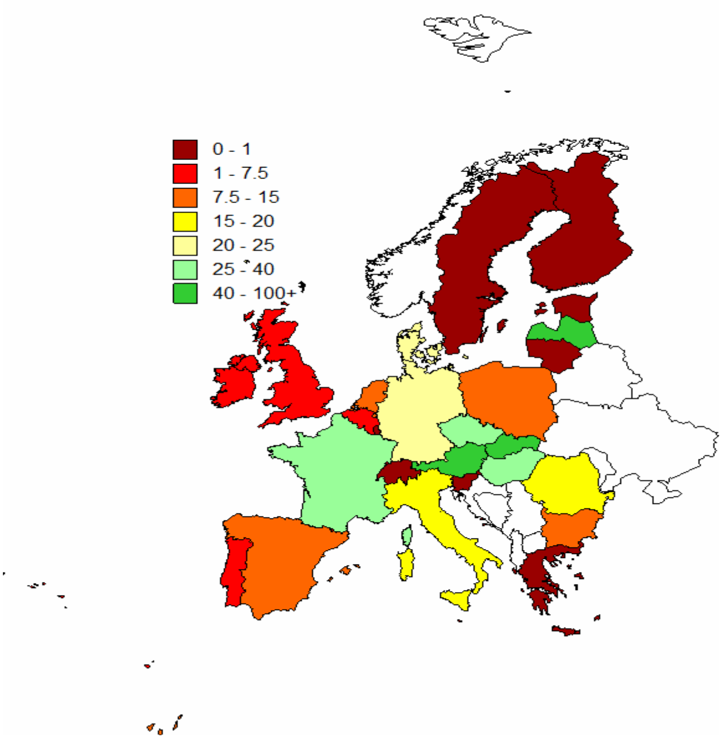


Source: EU study on natural gas storage in the EU 2008, GSE and Ramboll

If we take a look at how the EU member states are endowed with storage capacity, in comparison to their overall consumption, we have that especially the outer corners of the EU seem to be poorly endowed geologically in terms of storage capacity. The central member states, from Denmark in the North to Italy in the southern part of EU and from France in the west to Romania in the East, all have considerable storage capacity.

It is noticeable how differently endowed the different member states of the EU are, in terms of storage capacity. Countries like The UK which has a high level of consumption, only have very little storage available, whereas a country like Latvia have a lot of storage available. For the UK the reason is that they have been reliant on indigenous production for flexibility, where Latvia has a large storage facility, which provides gas storage services to their neighbouring countries of Estonia, Lithuania and Russia. Further Latvia is completely reliant on the gas storage for supplies during winter. The average storage capacity, compared to gas consumption, is 15 %. Latvia has more than 100% of storage capacity with regard to consumption. This is because the storage facility also supplies the neighbouring countries

Figure 16 Gas storage volume share of total gas consumption in pct. 2008



Source: Eurostat 2008 consumption data, 2009 storage data GIE and CER

Storage investment scenario

In the following we include investments from GSEs gas storage database, listed below in Table 4.

The storage investments which are included in this scenario are based on the GIE storage investment database and restricted to projects which have either been committed to or are already under construction. Only seasonal storage i.e. depleted fields, aquifers and salt caverns is included, as LNG storage only provides minimal security of supply.[7]

[7] Since the data collection some of the storage facilities listed as investments may already have been implemented.

Table 4 Gas storage investment scenario 2009-2020

BCM	Storage type	Investment	Capacity	Country total
Austria	Reservoir	New facility	1,20	1,20
Belgium	-		0,10	0,10
Denmark	-	Expansion	0,03	0,03
Czech Republic	-	Expansion	0,80	0,80
France	Aquifer	Expansion	0,06	0,64
France	Salt cavity	Expansion	0,20	
France	Salt cavity	New facility	0,10	
France	Aquifer	Expansion	0,20	
France	Reservoir	New facility	0,08	
Germany	Salt cavity	New facility	2,50	4,06
Germany	Salt cavity	Expansion	0,25	
Germany	Salt cavity	Expansion	0,27	
Germany	Salt cavity	Reparation	0,23	
Germany	Depleted field	Expansion	0,36	
Germany	Salt cavity	New facility	0,16	
Germany	Salt cavity	New facility	0,18	
Germany	Salt cavity	Expansion	0,11	
Hungary	Reservoir	New facility	1,90	2,30
Hungary	Reservoir	Expansion	0,40	
Italy	Reservoir	Expansion	0,55	5,27
Italy	Reservoir	New facility	0,92	
Italy	Reservoir	New facility	1,50	
Italy	Reservoir	New facility	0,45	
Italy	Reservoir	New facility	0,20	
Italy	Reservoir	New facility	0,35	
Italy	Reservoir	Expansion	0,20	
Italy	Reservoir	New facility	0,60	
Italy	Reservoir	Expansion	0,30	
Italy	Reservoir	Expansion	0,20	
Poland	Reservoir	New facility	0,20	1,71
Poland	Reservoir	New facility	0,03	
Poland	Salt cavity	New facility	0,25	
Poland	Salt cavity	Expansion	0,42	
Poland	Reservoir	Expansion	0,18	
Poland	Reservoir	Expansion	0,63	
Slovenia[8]	-	New facility	0,50	0,50
Spain	Reservoir	New facility	1,50	4,60
Spain	Reservoir	Expansion	0,58	
Spain	Reservoir	New facility	0,66	
Spain	Reservoir	New facility	0,30	
Spain	Aquifer	New facility	1,35	
Spain	Reservoir	New facility	0,09	
Spain	Reservoir	New facility	0,12	
UK	Salt cavity	Expansion	0,06	1,05
UK	Salt cavity	New facility	0,17	
UK	Salt cavity	New facility	0,40	
UK	Salt cavity	New facility	0,42	
Total	-	-	22,13	22,13

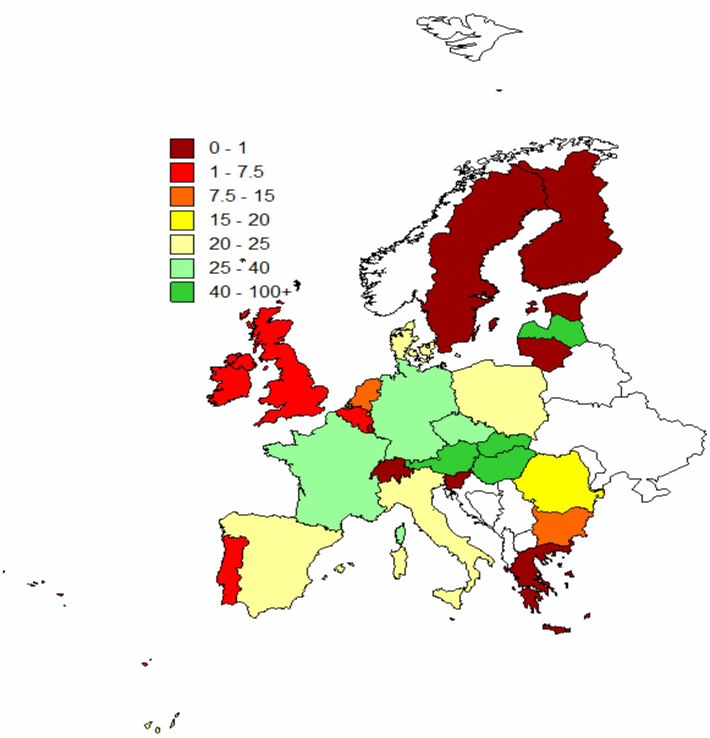
Source: Committed and under construction - Gas storage Europe (GSE), July 2009

[8] Ramboll in-house evaluation and http://www.ukom.gov.si/en/news/newsletter_slovenia_news/news/article/391/419/c6aad5c656/?tx_ttnews%5Bnewsletter%5D=19

The scenario assumes an increase in gas storage capacity of approximately 25% compared to the current total EU capacity of approximately 80 BCM.

Looking at how these storage investments affect the share of storage volume compared to household gas consumption shows that overall the SoS situation improves, but that the corners of the EU are still vulnerable e.g. in the UK. It should however be mentioned that there exists a large amount of planned investments in the UK, thus the situation may not be as bad for the UK as indicated below.

Figure 17 Gas storage volume share of total gas consumption in pct. 2008, incl. invest.



Source: Eurostat 2008 consumption data, 2009 storage and storage investment data GIE, storage capacity data is from 2009

Storage scenario results

Results indicate that even after a massive round of investments in storage in the EU, a number of countries are still subject to a very low level of security of supply. This goes for Sweden, Estonia, Bulgaria, Finland and Lithuania. Also a number of countries, represented in the lower right hand corner of Figure 18, are still represented in the category of being very vulnerable in terms of a gas disruption in comparison to the level of SoS.

The magnitude of the change becomes even more evident when comparing to the previous placement in the risk impact matrix, where no significant change appears in especially the lower right part where one could argue that change is needed the most.

Figure 18 Storage scenario impact versus risk. 2020.

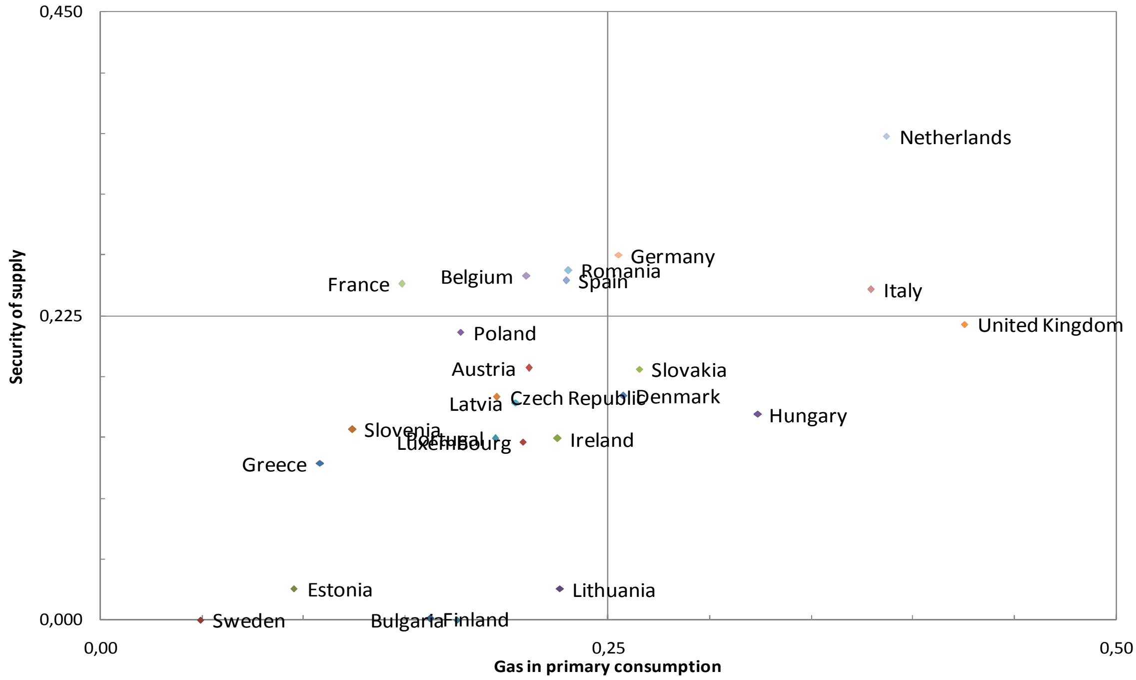
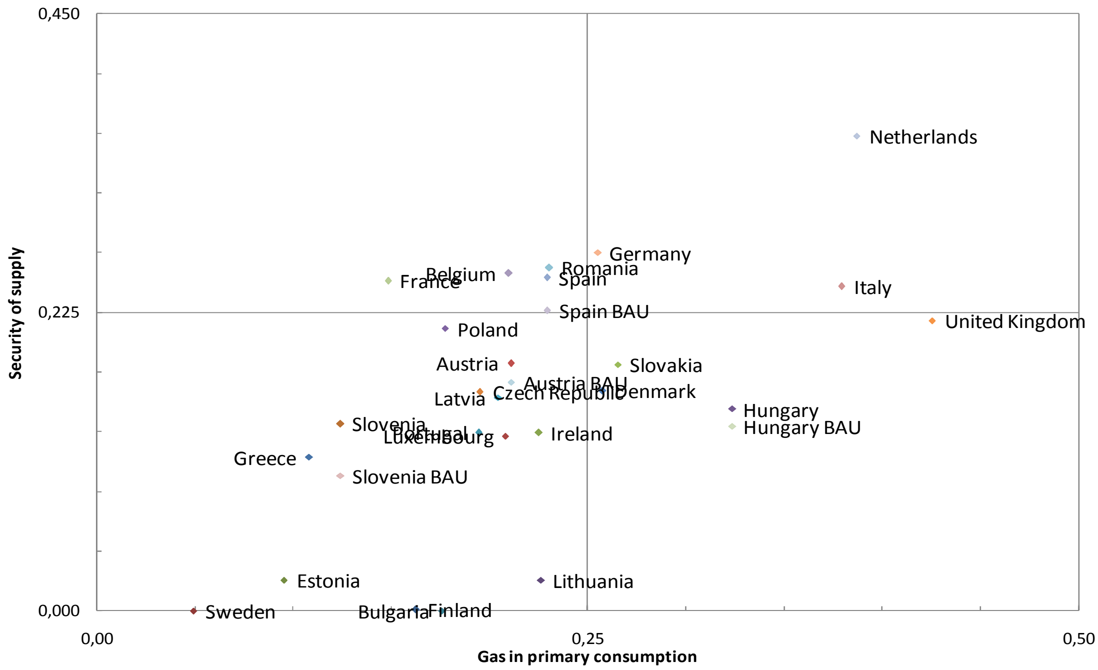


Figure 19 Storage scenario impact versus risk. 2050.



In order to highlight the impact of gas storage investments, Figure 20 shows the relative changes in security of supply for each country.

Figure 20 Relative changes in security of supply, Storage scenario 2020

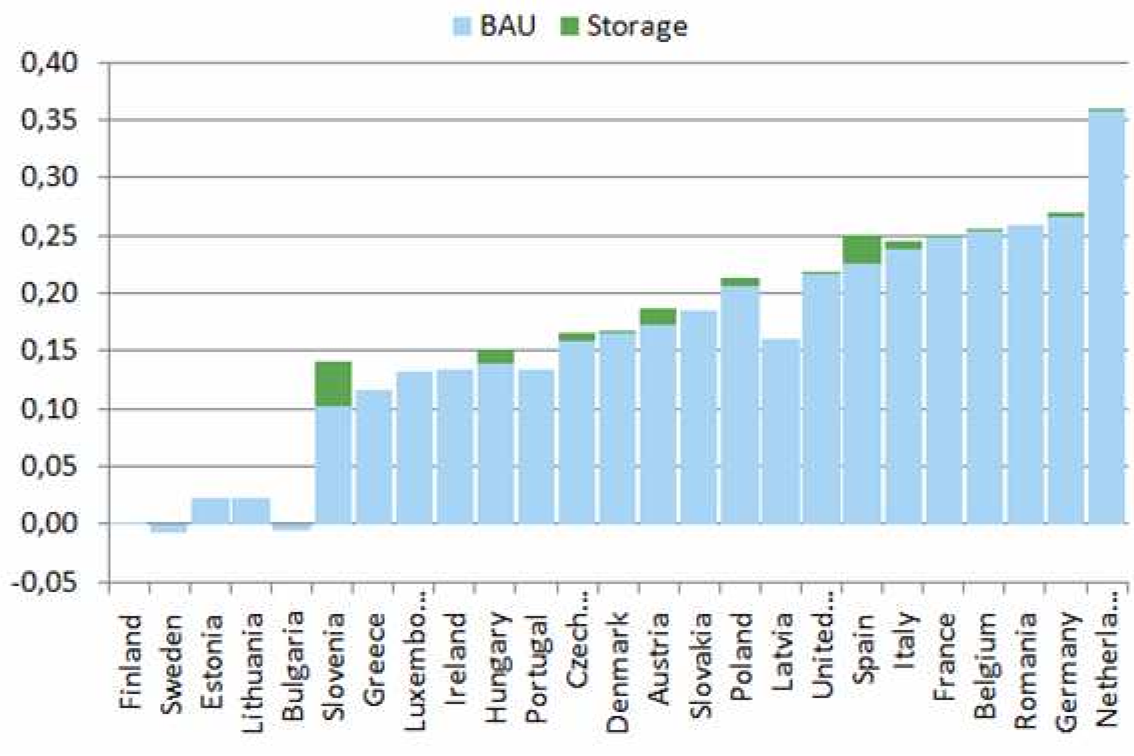


Figure 20 shows how storage investments mainly increase the security of supply in countries that already have a high level of security of supply. The effect of storage is also quite different across countries, the marginal effect of constructing a storage is larger in countries with little storage available, this is illustrated by the fact that although large investments are carried out in Germany and Italy, the effect on the security of supply index is below 5 %, while Slovenia, which does not have any storage capacity at present, will experience a large increase in security of supply.

Storage scenario conclusions

The conclusion of this analysis is that the overall level of security of supply in the EU is affected by new investments taken by the market. However, the direct effect is distributed unevenly across countries. Affects of storage investments on SoS in the storage scenario, are greater in countries which had low levels of storage capacity initially, thus the relative increase in storage capacity is the key.

Further storage investments seem to be less widespread in smaller markets as well as markets, which have a low level of security of supply. This could be due to:

- Less developed gas markets lack investment signals from e.g. prices.
- Storages are not built to provide security of supply, but mainly to provide flexibility.
- Less developed gas markets have low potential for arbitrage.

- High costs for the consumers, if storage investments are made mainly for security of supply purposes – thus the affordability may also be a restricting factor.
- Geological restrictions
- Storage development in the EU is mainly driven by the increased import dependency

It should however be noted that an overall increase in storage capacity, approximately 80 BCM to 100 BCM, will lead to an overall increase in SoS as increased storage capacity also benefits adjacent markets and neighbouring countries. This was illustrated during the 2009 Ukraine crisis where storages in Western Europe increased withdrawal in order to balance the decrease in Russian imports in the Eastern part of the EU.

However there is overall a low level of storage in the south-eastern European countries which does reduce the SoS in the region. If this problem is not addressed by the market, which the gas storage investment data does not suggest it will. Then the answer could be to build strategic storage in the region such as is being done in Hungary. However this could make the development of the gas markets in the region more difficult as strategic storages can crowd out commercial investments and thus become a hindrance to market development. Another way to solve the issue could be increasing funding support from the EU or to create incentives for cooperation in the region in terms of regional storage investments.

N-1 scenario Background

In the following we investigate the effects of implementing regulatory policies with regard to security of supply in the EU. This can give an indication of the difference between the security of supply that the markets provide and the security of supply that would be attained if all EU countries had to conform to the most recent EU directives on security of supply.

The new EU proposal for SoS regulation takes a somewhat different approach compared to the above two scenarios. The proposed regulation, set to replace the current directive 2004/67/EC, suggests using the n-1 rule for setting an overall EU requirement on a common security of supply standard. The scenario is created in order to evaluate the effect of the introduction of such a common standard in EU.

The n-1 rule implies that each country must be capable of withstanding a supply disruption from the single largest supply source, the n-1. This means that if a country has e.g. three importing pipelines and a small storage and a supply disruption occurs from the single largest source e.g. a pipeline, then the rest of the supply, the two other pipelines and the storage, must be able to supply the uninterruptible consumers for a given number of days. Thus the n-1 rule is a minimum standard intended to ensure that any country can deal with a disruption from their single largest supply source.

In this report we evaluate the effects of such a common standard by assuming that all countries would have to make investments, which would ensure that they would adhere to this requirement. The analysis is based on two cases 2009 and 2019. It is important to stress that this analysis evaluates the performance of the n-1 standard but is not an evaluation of the EU proposal for SoS regulation.

The analysis does not take into account where regional fulfilment of the n-1 criteria is appropriate, but is solely focussed on individual countries. This implies that the result attained may slightly overestimate the investments necessary to fulfil the n-1 requirement.

The 2009 case is based on the n-1 calculation prepared by the EU commission in their impact assessment concerning measures to safeguard security of gas supply and repealing Directive 2004/67/EC. The 2019 case is based on input from ENTSOG European Ten Year Network Development Plan Attachment A and B.

Investment required in order to adhere to the n-1 rule are identified based on capacity requirements and analysis of the overall gas system.

Calculation of the n-1 ratio is done based on the formula provided by the EU in the above mentioned impact assessment. However as the source of data differs minor differences in the results can occur. This is partly due to identification issues, e.g. the Dutch Groningen field, which provides indigenous production and storage and is in principle identified as one supplier. However in reality this site consists of many different production wells and a supply disruption will thus most likely not affect the entire facility. Further how storage and production capacity is divided may also cause for minor differences in the result.

N-1 investments in 2009

Based on the n-1 indicator, requirements for new investments as well as evaluation of the specific prerequisites of the markets in which they would be made, a number of investments have been implemented for the analysis. The investment decisions are based on the calculation on the requirement for new investments in order to fulfil the n-1 standard made in supplement 2 of this report.

Projects have been made in accordance with what have been judged as the most likely projects, based on actual projects, thus projects are based on real investment projects when possible.

Some countries invest even though they already fulfil the n-1 requirement. This is due to interconnector investments, which will increase capacity in more than one country e.g. the interconnectors in Poland/Lithuania and Bulgaria/Greece. The following investments and the expected costs have been identified as required in order to ensure that the n-1 rule is fulfilled.

Bulgaria:

- Increased storage capacity in Chiren to 500 MCM and increasing capacity by 4 MCM/day – cost Million Euro 250[9]
- Interconnector to Bulgaria from TGI in Greece 8 MCM/day – cost Million Euro 150[10]

Denmark:

[9] Source: http://www.economia.gr/en/index.php?option=com_content&task=view&id=862&Itemid=29
[10] Source: http://www.economia.gr/en/index.php?option=com_content&task=view&id=875&Itemid=29

- Strengthening of Germany-Denmark interconnector capacity by 10 MCM/day – Costs Million Euro 200 Million Euro[11] (this investment will not affect import capacity in Germany)

Estonia:
- BalticConnector, interconnector between Finland and Estonia 6 MCM/day – Million Euro 300

Finland:
- BalticConnector, interconnector between Finland and Estonia 6 MCM/day – Million Euro 300

Greece:
- Interconnector to Bulgaria from TGI in Greece 8 MCM/day – cost Million Euro 150[12]

Hungary:
- Gas storage investment increasing peak supply by 32 MCM/day (2,3 BCM volume capacity) – costs 900 Million Euro

Ireland:
- LNG terminal, 17 MCM/day total capacity (6,2 BCM annual capacity) – costs 600 Million Euro

Lithuania:
- Lithuania-Poland interconnector, 7 MCM/day (2,5 BCM per year) – costs 300 Million Euro[13]

Poland:
- Lithuania-Poland interconnector, 7 MCM/day (2,5 BCM per year) – costs 300 Million Euro[14]

Romania:
- LNG terminal in Constanta, 8 MCM/day (3 BCM per year) – costs 300 Million Euro

Sweden:
- Sweden faces a serious challenge in fulfilling the n-1 requirement, because storage is not an option due to geological reasons. A second pipeline from Denmark is proposed as well as utilisation of fuel switching which is already available. 4 MCM/day pipeline - costs 100 Million Euro.[15][16]

Slovenia:

[11] Source: Energinet.dk, BEMIP report
[12] Source: http://www.economia.gr/en/index.php?option=com_content&task=view&id=875&Itemid=29
[13] Source: BEMIP report
[14] Source: BEMIP report
[15] This pipeline does not increase the capacity in Denmark as this pipeline in effect is a one way pipeline due to Sweden only being supplied by Denmark
[16] In effect the emergency supply of Sweden would most likely fall under an regional evaluation which means that Swedish SoS could be increased by increased storage capacity in Denmark

- A gas storage facility with 5 MCM/day withdrawal capacity and 500 MCM volume capacity – costs 250 Million Euro

Total investment costs add up to 3350 Million Euro.

N-1 2019

As gas markets face large changes and challenges in the coming years, due to e.g. increasing import dependency, the development of the gas market will have an effect on the requirement for n-1 investments any n-1 indicator will be changing along with how the market develops.

In order to evaluate what the effects of changes in the gas markets are, an evaluation of the n-1 indicator in 2019 has been made. The 2019 scenario is not directly comparable to the 2009 because of two things. First of all, the EU calculations which the 2009 scenario is based on could not be recreated. Thus minor differences exist, due to issues such as interruptible consumers which are not included in the 2019 scenario. This will lead to slightly higher peak day consumption figures for some countries. The analysis for the 2019 scenario is based on the ENTSOG European Ten Year Network Development Plan.

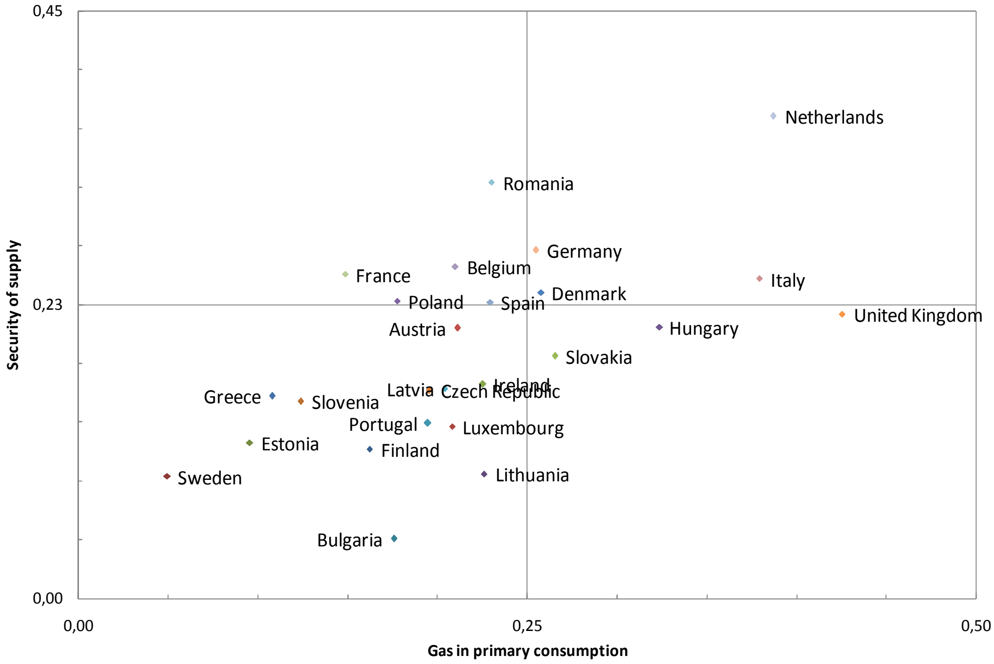
By evaluating the development of peak supply in the EU until 2019, we learn that total investments approximately will have to double, compared to the investments made, based on the 2009 evaluation. Another 131 MCM/day of total capacity would have to be made. See Supplement 3 for details.

Total additional investment costs in 2019 in the n-1 scenario are assessed to be around 3500 Million Euro. The capacities listed in the above, already include a number of investments planned by the market. The costs of those investments are not included as they are not SoS cost per se, but may be regarded as investments made or planned in accordance with market development.

N-1 impact on SoS

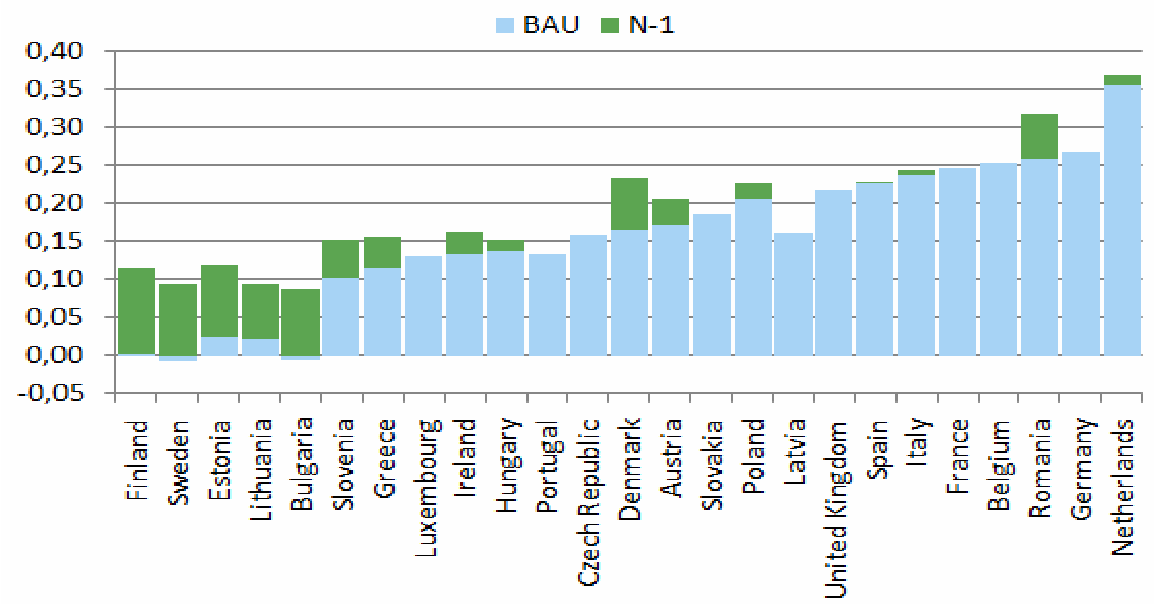
Including the investments required in order to fulfil the n-1 requirements in 2009 and 2019, it entails a clear improvement in the security of supply for the majority of the countries in the EU - this is illustrated in Figure 21 below.

Figure 21 n-1 2019 scenario, impact versus risk, 2020



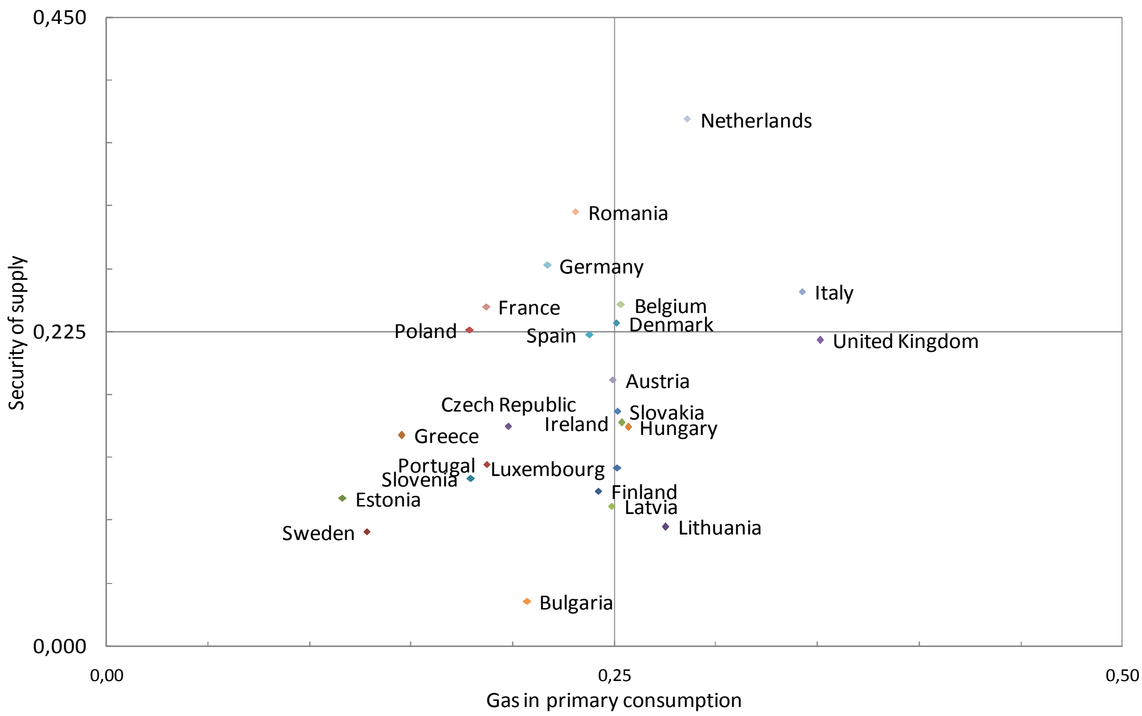
Compared to the BAU scenario the relative changes for some countries such as Finland, Sweden, Bulgaria, Lithuania and Estonia, is considerable. This is so because these countries had a very low level of security of supply before the investments.

Figure 22 Relative changes in security of supply, n-1 scenario 2020.



In 2050 some countries will increase their share of gas in primary energy consumption while others decrease. This will have the following impact on risk and impact. It should be noted that no new investments are made after 2020.

Figure 23 N-1, risk vs. impact 2050



In 2050 there is an increased concentration of countries, see Figure 23. Gas consumption increases in the countries having a low share of gas in primary consumption and is reduced in the countries, which consume relatively large amounts of gas e.g. UK, Italy and Hungary. The convergence of gas consumption is however not followed by a convergence in SoS.

Cost of n-1 investments

If we take a look at which countries will be affected the most, in terms of economics due to the costs of the required n-1 investments, we see that the average cost per inhabitant varies tremendously among member states.

Table 5 Cost of n-1 investment per inhabitant

COUNTRY	COSTS EUR PER INHABITANT	COUNTRY	COSTS EUR PER INHABITANT
AT	48	IT	17
BE	-	LT	176
BG	43	LUX	72
CY	-	LV	-
CZ	-	NL	61
DE	-	PL	4
DK	37	PT	-

EE	112	RO	71
ES	2	SE	11
FI	28	SI	124
FR	-	SK	-
GR	7	UK	-
HU	129	AVERAGE ALL COUNTRIES	14
IE	136	AVERAGE AFFECTED COUNTRIES	29

As can be seen from the above, the cost varies very much e.g. Lithuania will have to bear costs of around 176 EUR per inhabitant from investments in the Amber connection to Poland and an LNG terminal, whereas larger countries like Germany and France do not have any cost induced by the policy.

It is also noticeable that the UK is not affected by the n-1 indicator even though there is a notorious lack of gas storage in the country. This is because storage investments in the UK are already a part of the ENTSOG 10 year investment plan.

Because the n-1 indicator is a tool used to increase SoS in the EU in general, benefiting all countries. Even though a country may not be directly affected, if the neighbouring country is affected, then this will also be of benefit. Therefore it can be argued that costs should be shared more or less evenly across the EU. Thus ensuring solidarity is also implemented in relation to costs. A system where half of a SoS investment is paid by the country making the investment and the other half paid for by the EU could be a way to ensure implementations and financial solidarity.

N-1 conclusions

The n-1 regulation will lead to an increase in SoS in a number of countries. These are Finland, Sweden, Estonia, Lithuania, Bulgaria, Slovenia, Greece, Ireland, Hungary, Denmark, Austria, Poland, Spain, Italy, Romania and even the Netherlands.

The n-1 policy will increase the number of countries characterised by the lowest level of SoS today, and thus the n-1 policy seems to be able to put focus on the countries suffering from the lowest level of SoS. However this will also entail that the n-1 regulation will lead to huge costs in some countries and thus the financial burden of the policy is not evenly distributed.

The fact that the policy affects a number of countries and has a large financial impact for some, could question the viability of this policy unless some sort of financial support is offered along with the policy.

Further it is important to keep in mind that this analysis is only an analysis of the required investment based on this application of the n-1 standard. In relation to the specific application of this standard in the proposed SoS regulation, it should be noted that a number of uncertainties exist, how exactly to measure n-1, what about national SoS risk, such as national offshore pipelines connecting e.g. parts of Denmark, do we count import pipelines meaning do double lines count as one or two pipelines etc. The benefit of the n-1 standard is that it is able to address some of the SoS issues which are not dealt with by other measures.

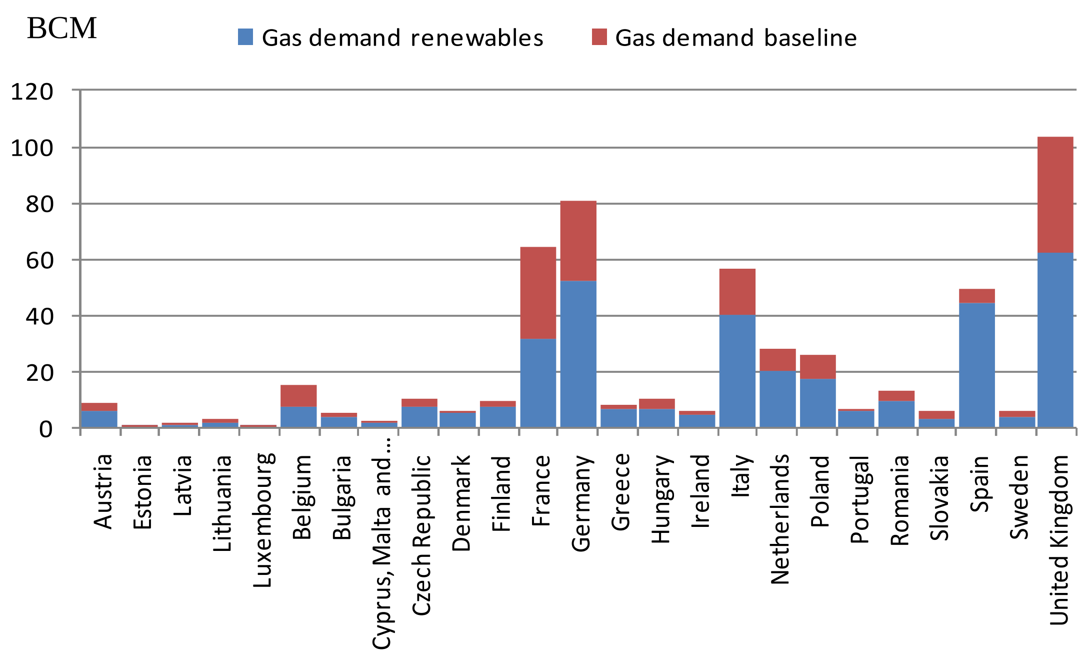
Renewables scenario

In recent years the focus on renewables in the EU has increased significantly. The focus on renewables has been partly fostered by the climate debate but also because renewables are seen as a means to increase European SoS. The argument being that wind, solar, biomass etc. are indigenous resources which would not have to be imported like oil or natural gas. This scenario tries to analyse the affects of increasing renewables in the EU energy mix, in order to evaluate what the effect is on natural gas security of supply.

The impact on natural gas SoS is two-fold. For one it is due to a decreased natural gas consumption[17], which will increase capacity in relation to natural gas consumption. Secondly because of reduced vulnerability, because countries become less dependent on natural gas in the energy mix.

In the following we use the forecasted gas and energy demand in the POLES scenario “EU Emission Constraint”. In this scenario the gas demand is set to decrease see Figure 24.

Figure 24 Gas demand in baseline versus renewables scenario 2050.



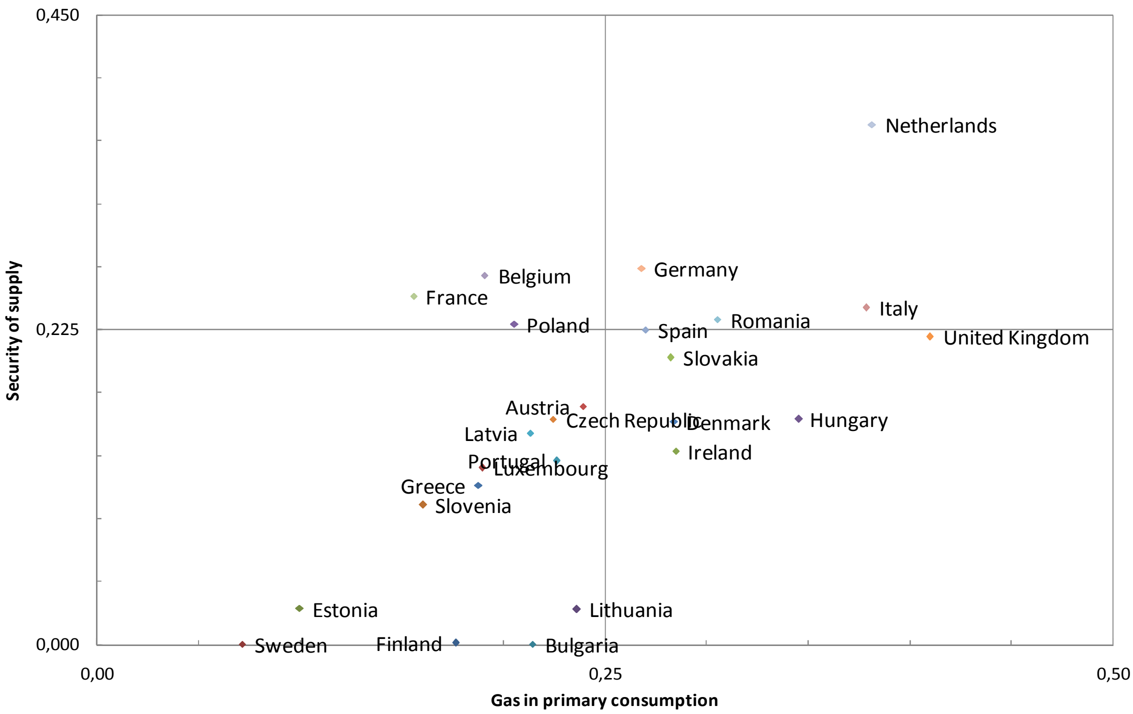
Results in the renewables scenario

Applying the forecasted gas demand in the renewables scenario to the RAMSOS index, enables us to infer the effect of decreased gas demand on security of supply. The impact and the risk after implementing this policy is illustrated in Figure 25 below Compared to the BAU scenario only a small change has occurred in 2020, indicating that the shift

[17] Consumption of natural gas could arguably increase in the renewable scenario as natural gas is the cleanest of the fossil fuels

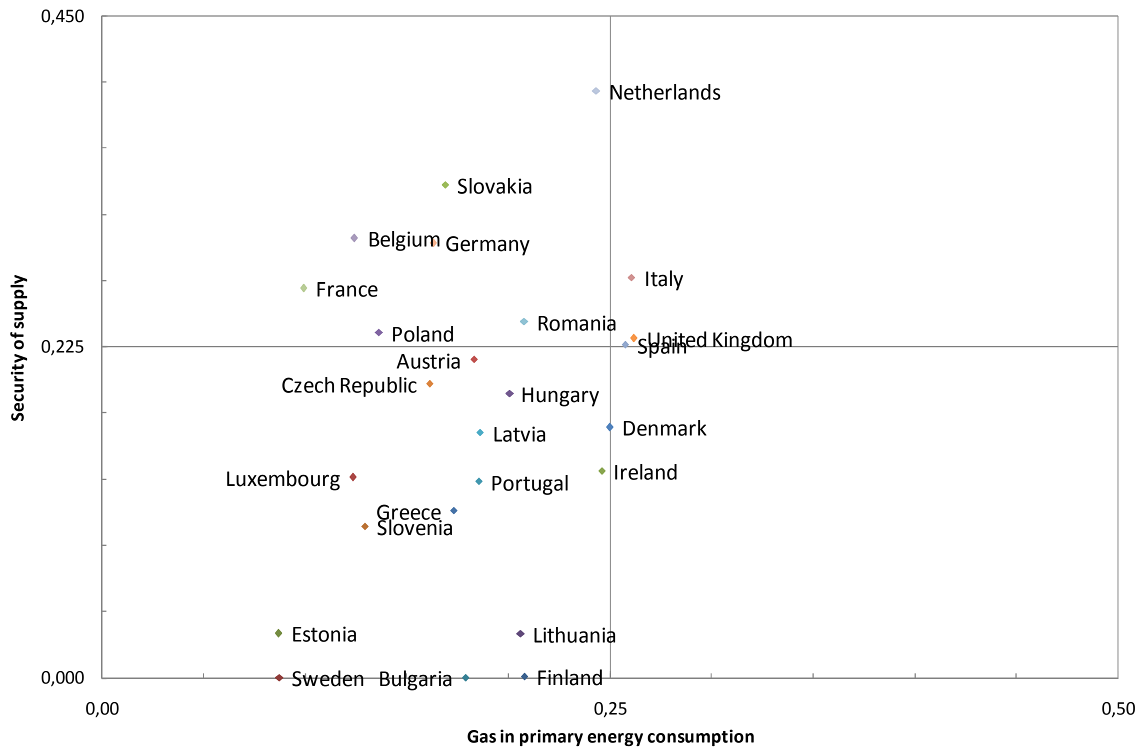
towards renewables takes a relatively slow start due to e.g. the long lead time of the investments in renewable energy.

Figure 25 Risk versus impact 2020- renewable scenario



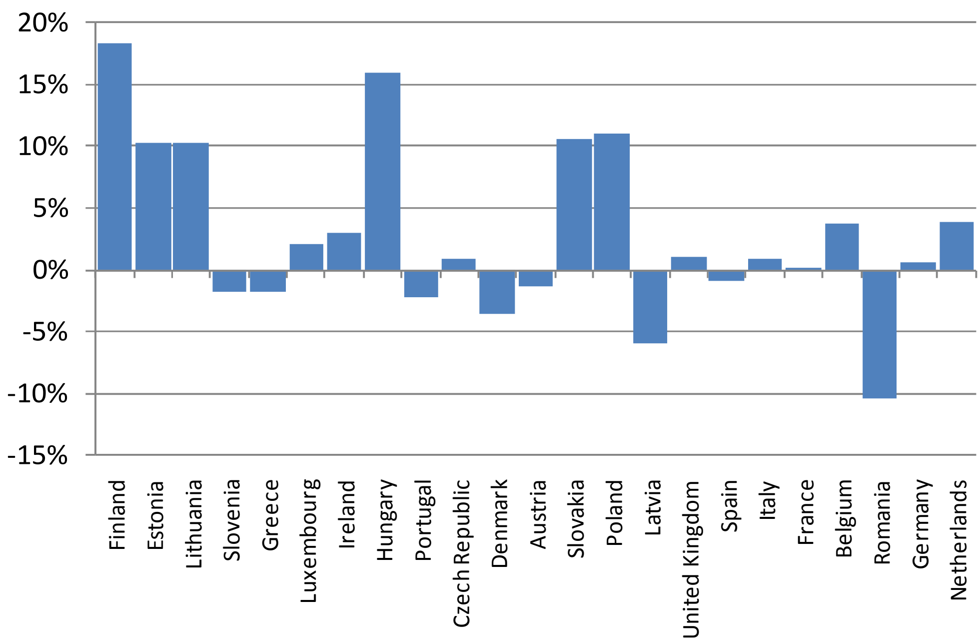
The effect of the renewable energy policy being implemented becomes much more pronounced in 2050 where it is seen that almost all countries decrease their share of gas in primary energy, as seen in Figure 26. It is seen how countries move from the right-hand side to the left and thus reducing their vulnerability, there is also a slight move upwards in the graph from the effect of having relatively more capacity available.

Figure 26 Risk versus impact 2050 – renewable scenario



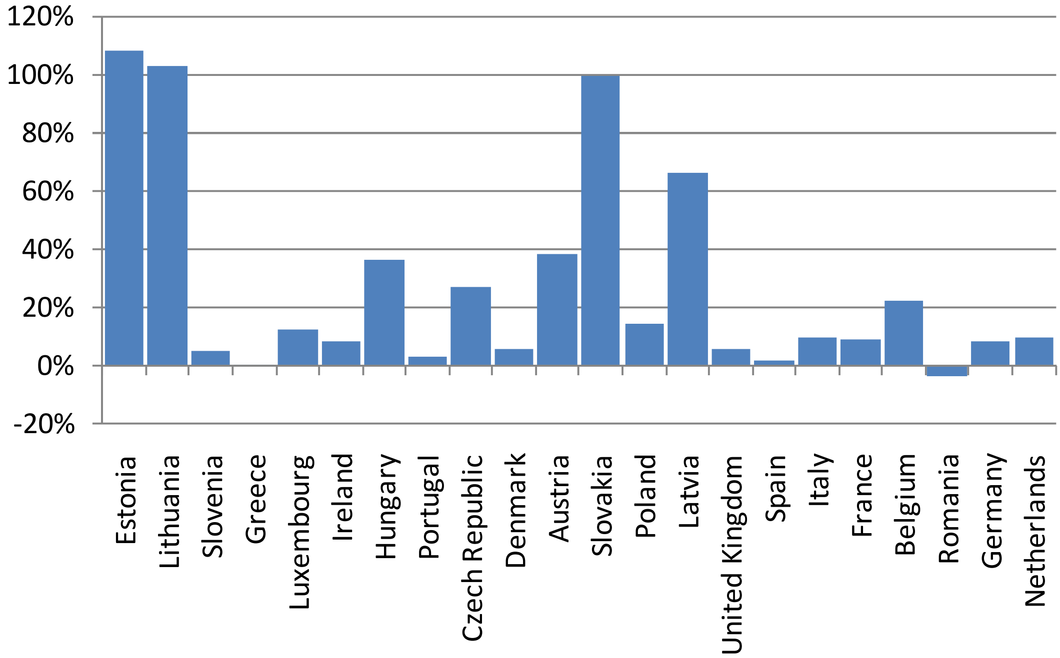
The relative effect in terms of security of supply in 2020 is depicted in Figure 27. It is noticeable that some countries increase their gas consumption in 2020, which implies that the overall effect on security of supply in 2020 from increasing renewables is not unambiguous, as some countries are affected positively, but others actually reduce their level of security, because of increased consumption.

Figure 27 relative changes in security of supply 2020.



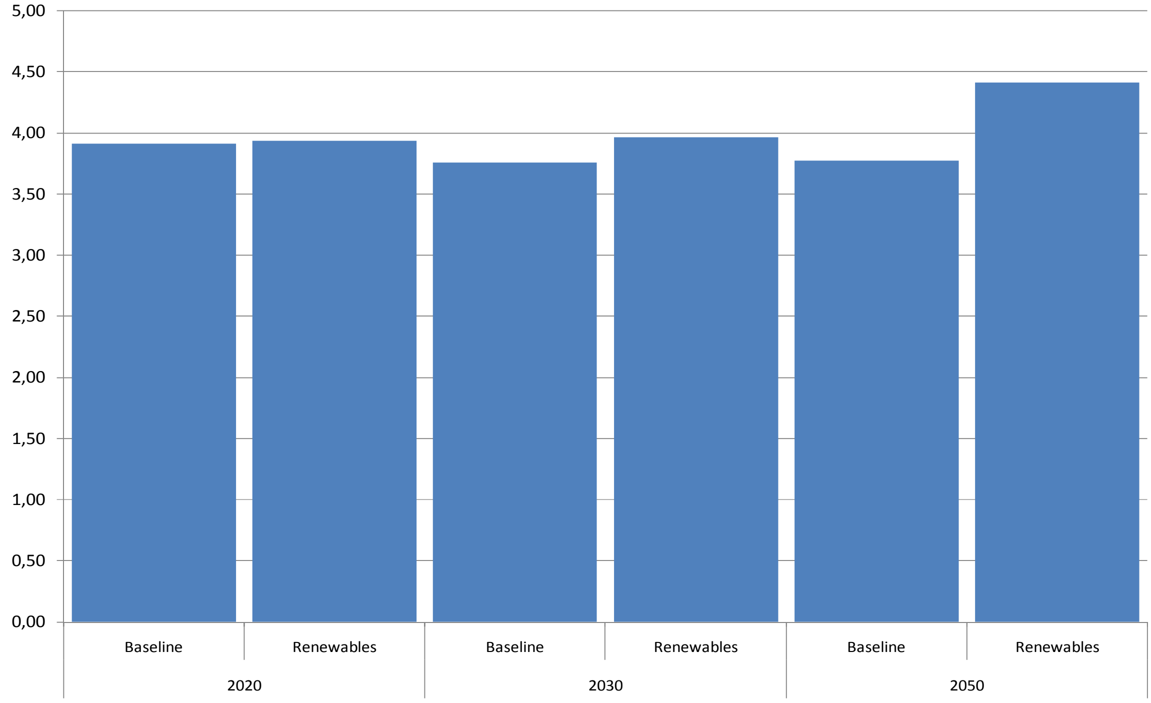
Thus in the medium run, the effects of the renewables policy are ambiguous – however in the long run almost all countries will increase their SoS because of the increased share of renewable energy in the primary energy consumption. This is illustrated in Figure 28.

Figure 28 Relative changes in the SoS index - Renewables vs. BAU, 2050.



The ambiguous medium run effects of the renewable policies on security of supply and the long run benefits are also illustrated in Figure 29, where it is seen that there is not much difference on an overall EU level between the BAU scenario and the renewable scenario in the medium run. Looking further ahead it can be seen that the effects of the renewable policy increases in 2050 where a relatively large increase in the RAMSOS index is observed.

Figure 29 Aggregated SoS index, absolute figures 2020.



Specifically it is seen that while the security of supply is decreasing in the baseline scenario, the decreased gas demand implies that security of supply in 2050 will increase compared to the baseline in 2020. What is moreover noticeable is the fact that there is a large time lag in the effects of the renewable policies, implying that the largest effect on security of supply is somewhere between 2030 and 2050. These signals indicate that gas in some countries could be used in the transition phase to renewable energy. It also emphasises the point that renewables may increase SoS but only in the very long run, in the short to medium run the effect of increased renewables are only able to counter the otherwise decline in SoS in the baseline scenario.

Comparison of mitigation scenarios

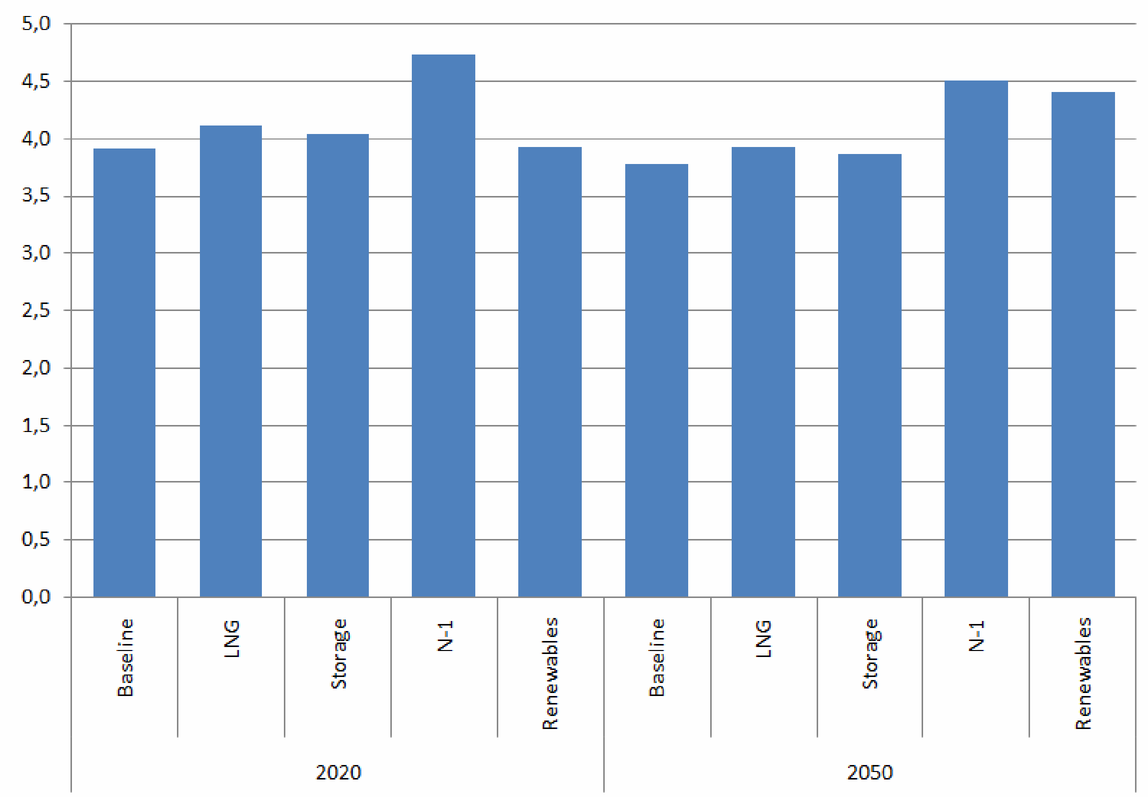
In Figure 30 the aggregated scores for the year 2020 for the four analysed scenarios have been indexed to the BAU scenario.

Figure 30 shows that in the medium run until 2020, the security of supply index increases with 5 % compared to the business as usual, due to the investments in new LNG facilities. The effect of additional storage capacity implies an overall increase in the security of supply index of approximately 3 %.

Both the storage and the LNG investments are to a certain degree driven by market decisions. When comparing with the choices that a social planner takes, the n-1 scenario, it is seen that in comparison to the effects of the market's choice of investments, the regulated approach gives a much higher level of security of supply. The index improves by almost 21 % compared to BAU.

However the LNG and the storage scenarios which remain market driven, are not security of supply scenarios per se as the investment decisions behind these scenarios are based on market demand. Thus these investments are made based on a business case rather than an obligation to provide SoS. Thus the two market scenarios could be interpreted as the SoS provision which is a by-product of the market mechanisms i.e. extra SoS value "for free".

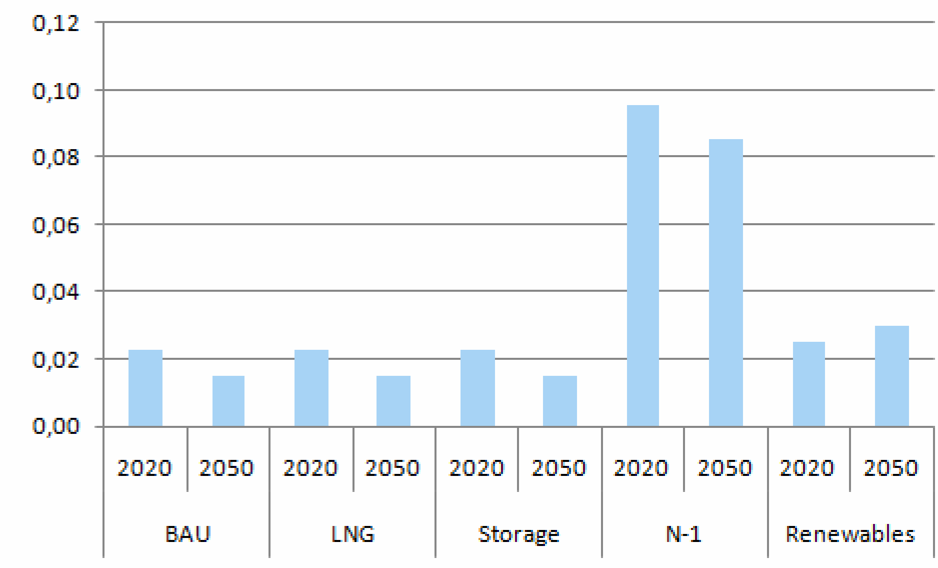
Figure 30 Indexed aggregated scores for 2020 and 2050



When looking into the future, it is seen that the effects of the renewables energy policies are almost as big as the n-1 in 2050. However as the costs are not known it is expected that the increase comes at a much higher price compared to the relatively small investments undertaken in the n-1 scenario. One should however remember that the primary objective with the renewable policy is not only to increase security of gas supply. After 2020 no further investments are undertaken in the n-1 scenario.

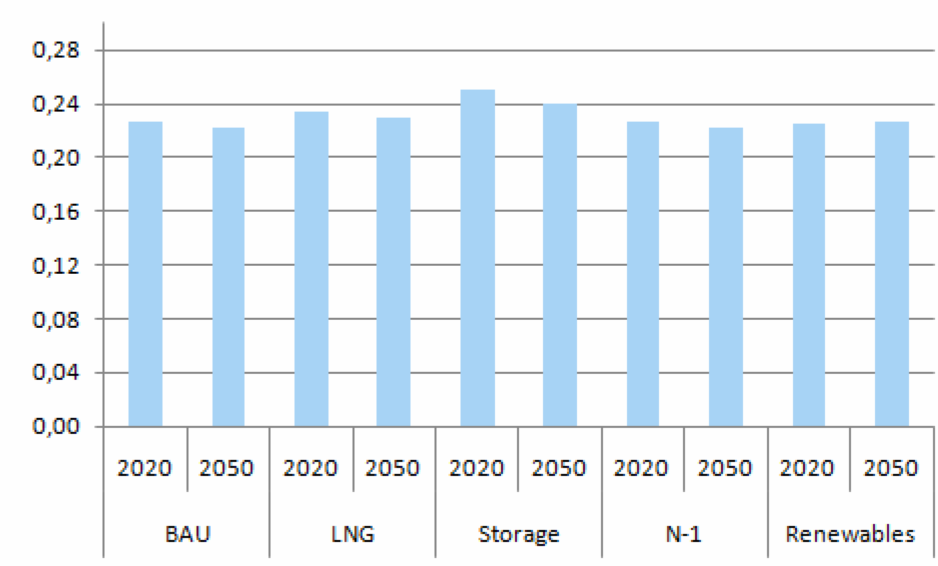
If we look at how the different scenarios affect individual countries, we see that the different policies differ largely in how they impact individual countries. In the below we look at two different countries, a small and a large country, Lithuania and Spain.

Figure 31 Scenario impact, Lithuania



In Spain the effects on the overall SoS do not differ very much, although the storage scenario seems to provide the highest level of SoS and the biggest improvement.

Figure 32 Scenario impact, Spain



It is moreover evident that each of these scenarios involves different types of investments and thus also different cost levels, both in terms of investment and socio-economic costs.

Comparison of SoS benefits and costs

When comparing the SoS benefits and costs, it has to be taken into account that only the SoS benefits are considered, thus the above stated non SoS benefits (like market development) are not included in the below.

Costs of the different scenarios have been based on some overall assumptions about investment costs. The following overall investment costs have been applied for calculation of costs, capacity in volume:

LNG costs per BCM:[18] 100 Million Euro per BCM

Storage cost per BCM:[19] Depleted field/reservoir 400 Million Euro per BCM
Aquifer 500 Million Euro per BCM
Salt Cavern 700 Million Euro per BCM

Pipeline costs per BCM:[20] 10 Million Euro per BCM per 100 km of piping

Naturally the costs of each investment vary according to the specifics of the investment. Moreover the cost estimates of a project typically vary over time. Thus the estimates in this section involve a great deal of uncertainty. Where available, specific project data and estimations have been applied for the cost estimation of the investments in the different scenarios as described previously in the report, when the above assumptions have not been applied to estimate costs of investments.

In Table 6 the costs of implementing the different scenarios are presented, as well as the relative changes in the overall SoS score. Furthermore the costs in billions Euro of increasing the SoS index by 1 % are presented.

Table 6 Benefits and costs

	Costs (Billion Euro)	Absolute level of SoS	Benefit (percentage change in SoS index)	Billion Euro per % increase in SoS index
LNG 2010-2017	11,6	4,03	5,19 %	2,23
Storage 2009-2020	11,0	4,12	3,11 %	3,53
n-1 2019 [21]	6,9	4,73	21,0 %	0,33
Renewables		3,93		

It is evident from Table 6 that costs vary significantly between scenarios and also the cost compared to impact. It is seen that the regulatory approach is by far the cheapest per percentage increase in the SoS index. It is important to remember that the reason why the n-1 scenario provides SoS in the cheapest way, is because this scenario is targeted at provision of SoS, whereas in the LNG and storage scenarios, SoS is a positive by-product, as these scenarios are based on a commercial market interest. Thus we only compare costs and not benefits. Alternatively you could argue that the market scenarios implied no costs from a SoS point of view.

[18] Ramboll: In-house LNG database
[19] Ramboll: Study on Natural gas storage in the EU, 2008
[20] Ramboll In-house experts
[21] The n-1 scenario includes a number of investments planned by TSOs and the markets within the next 10 years, the costs of those are not included, therefore the costs are slightly underestimated, in terms of comparing with the storage and LNG scenarios.

Comparing the n-1 policy to the renewable policy, it is seen that for this strategy to be cost competitive with the n-1 policy (they are approximately SoS competitive as they increase SoS by approximately the same on an overall EU level), the aggregate price of the renewable policy should be no more than 6-7 Billion Euro. A total investment in renewables of 6-7 Billion Euro would equal an investment in offshore wind parks of around 6.5 GW.[22] This equals approximately one quarter of wind power capacity installed in Germany alone and is only a small fraction of the total investment in the renewable scenario.

When comparing the n-1 and the renewable policies it should be noted that the positive security of supply effects of the renewable policies are realized at a much later time than the n-1 policy, i.e. the effects of the renewable scenario occur closer to 2050 whereas the n-1 policy already increases SoS in 2020.

Additional aspects

The above analyses all focus on the provision of security of supply. However as energy markets are complex and decisions are based on a number of parameters, such as market development and demand, sustainability, climate, regulation etc. There are a number of aspects which are not taken into account in the above analysis:

- Supply of “new” gas to Europe, especially LNG, i.e. supply diversification.

- LNG may also facilitate exploiting possible arbitrage possibilities that may occur due to oversupply on the global gas market.

- The overall market value of providing more flexibility for the gas market in the storage scenario is not included – as the storage investments included in this analysis are mainly market driven. This implies that the main rationale and benefits for storage investments are not included. Furthermore second-order benefits such as the increased flexibility could spur development of markets, which could allow for better price signals, which in turn could allow for more transparency and therefore would reduce uncertainty and improve the investment climate.

- Market benefits from SoS investments, such as new gas and new suppliers, increased capacity, increased access to markets and overall integration of the EU gas market etc. The increase in SoS, due to increased capacity, could lead to increased competition and thus lower prices.

- The effects on energy prices are also not included - if the different scenarios have adverse effects on energy prices, this will have an effect on the overall costs and benefits of the scenario.

- The value of the climate benefits are not accounted for in the renewables scenario.

[22] Based on the cost estimate of the biggest offshore wind park planned in Denmark, which will cost around 400 Million Euro and have a capacity of 400 MW

- The n-1 scenario includes a number of investments planned by TSOs and the markets within the next 10 years. The costs of those are not included.

- Political aspects of the various scenarios are not included- some scenarios could be more or less desirable from a political viewpoint.

Thus when comparing the different result, one should keep in mind that this study is limited in the respect that only SoS aspects are considered.

National and Regional considerations

Another aspect pointed out in the above analysis is that SoS is not uniformly distributed across the EU. Even taking into account the vulnerability of the different countries, only corrects for some of this disproportion and further the regional disparity is only partially corrected by some of the scenarios.

The fact that SoS is unevenly distributed on a regional basis as well as between individual countries, means that any policies trying to deal with the unevenness must be able to address the specific SoS situation of the individual member states. This uneven distribution of SOS also means that the incentives for addressing the problem, varies across the EU.

Looking at the overall distribution of SoS, it is seen that certain countries and regions are more subject to SoS risks. This applies for both the North-eastern and South-eastern part of EU. Especially the Baltic countries and Finland are in a very risky situation as well as countries like Hungary, Bulgaria, Greece and Slovenia are subject to relatively large risks.

Although the exposure of these two regions is lowered in the n-1 scenario, they remain at the lower end of the SoS index. Another trend which is evident from Figure 33 SoS BAU 2020 is that the biggest SoS threats are in the corners of the EU i.e. Portugal, Ireland, the Baltic countries and Finland, as well as Greece and Bulgaria.

Figure 33 SoS BAU 2020 – RAMSOS index

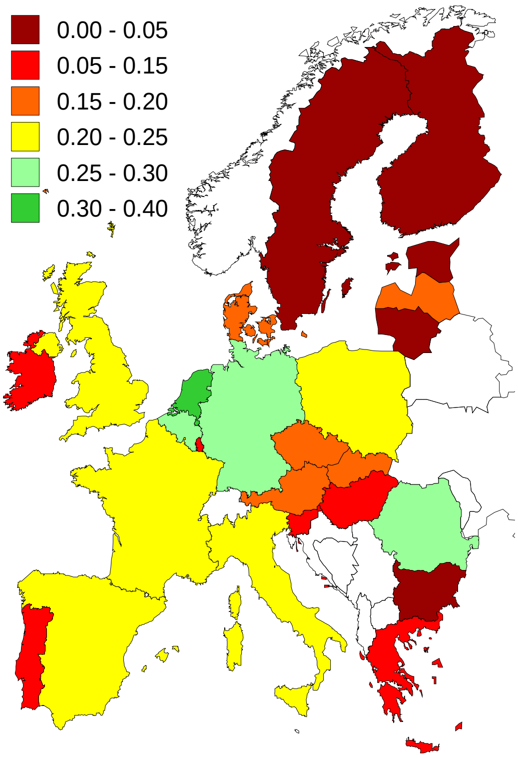
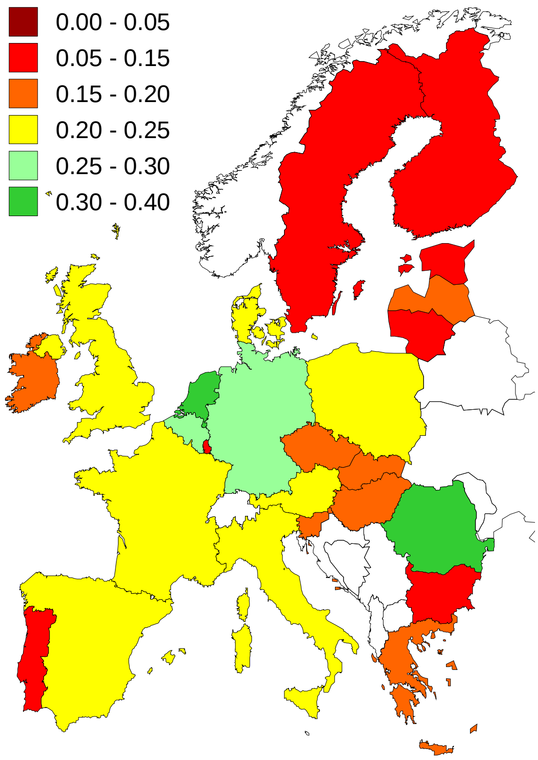


Figure 34 N-1 2020 RAMSOS index



In the high end of the SoS index we find countries such as Germany, Netherlands and France, i.e. there seems to be a tendency that the North western part of the EU has a relatively high level of SoS. Furthermore it seems that there is a tendency that large countries such as Germany, Spain and Italy have a higher level of SoS.

The fact that there could be a positive correlation between country size and level of SoS, could have a negative impact for smaller countries because they could have a harder time raising awareness to their problems if the problems are not shared amongst the larger member states.

Country specific initiatives

The above figures show that a number of countries struggle with low levels of SoS. Even if the n-1 policy is adopted, certain countries are still characterised by a relatively high level of risk.

Investments increasing SoS should be made in a number of countries. First and foremost investments are needed in Finland, Sweden, Estonia, Lithuania and Bulgaria. Investments are also required in Slovenia, Greece, Luxembourg, Ireland, Hungary and Portugal.

SoS economies of scale

Because of large economies of scale in gas investments, SoS investments are much more expensive for smaller countries, which are not able to take full advantage of economies of scale in their investments. This could be an explanation as to why we see that the larger countries in general have higher level of SoS. The high costs involved in raising SoS for smaller countries was also illustrated in the cost analysis, which showed that the n-1 regulation would entail large costs, especially for the smaller gas markets such as Slovenia, Ireland and Lithuania.

The reason for this is that a country like Spain needs six LNG terminals to service its customers, the dependency on each terminal decreases, whereas they only need one in Portugal and thus Portugal become very dependent on just one terminal.

Further investing in the large Northwest EU gas market is subject to lower risk as these markets are much not only larger but also much more transparent.

This speaks in favour of creating regional SoS investments, which are shared across country borders in order to allow investors to benefit from economies of scale and to share the costs between multiple markets. Increasing regional cooperation in relation to SoS could also increase the overall regional cooperation and thus improve the market development. It is however necessary to ensure that cross-border capacities are sufficient to support e.g. regional storages.

Regional projects

Taking this regional aspect into consideration provides another dimension to major import projects such as NordStream[23], Southstream and Nabucco. It should be considered how projects may benefit as many countries as possible, because raising overall SoS in the EU does not necessarily benefit all countries.

Forcing import projects to consider as many countries as possible is however at the expense of the "implementability" of the projects. Multilateral projects require numerous permissions and lengthy decision-making because many stakeholders have to agree – Thus institutions such as the ACER and the revision of the TEN plan should consider how the implementability of infrastructure projects may be improved from a legislative and political point of view, to ensure that as many countries as possible will benefit from the implemented projects.

The upcoming revision of the Trans European Network (TEN) policy could be expanded to include issues of "implementability" and base its support on whether projects consider the regional aspects of SoS or not, rather than overall aspects.

A project which has experienced this dichotomy of "implementability" on the hand and the SoS considerations on a regional point on the other is the NordStream pipeline. NordStream was initially, back when it was called the NEGP, planned to have branches to other countries in the Baltic Sea. These branches were however dropped, partly because each branch meant a number of new stakeholders and thus a decrease in the "implementability". Could these branches, which could have improved SoS in many countries around the Baltic Sea, have been possible if the necessary EU tools had been available?

There regional diversity could also call for regional initiatives in terms of SoS – e.g. a regional plan in Southeast Europe to deal with a disruption from Ukraine – this could be action plans or regionally shared investments in e.g. storage facilities, import pipelines etc.

[23] NordStream has already begun construction of the first pipeline in 2010

Regional aspects of a common regulation

The recent proposal for a new SoS regulation does take into account, at least to some extent, that the characteristics of the various countries are different. Still one common regulation with one common way to analyse and estimate SoS, can create difficulties and biases because the regulation does not take into account overall gas dependency and vulnerability. Furthermore the effectiveness of different tools may also vary between countries. Thus adding a regional dimension to the regulation could increase focus on vulnerable regions and ensure a better match between vulnerability, options and requirements.

Because the above analysis also showed that benefits and costs vary between policies, a common regulation may distribute costs unevenly.

Conclusion and recommendations

We have seen in the above analysis that SoS varies across the EU and that different regions are inconsistently exposed to SoS threats. The provision of SoS in the different scenarios also varies, as well as the overall costs of the different policies vary. However different policies are not directly comparable, as the benefits provided in each scenario only represent the benefits in terms of security of supply. Even so a number of interesting conclusions may be drawn from the above analysis. We divide them into conclusions and recommendations.

Conclusions

The above analysis has presented a number of interesting results both on SoS risk and vulnerability, as well as mitigation policies and costs. Although the different scenarios differ in their exact timeframe, the analysis has provided a close look into what some of the advantages and disadvantages are in connection to each policy.

Level of SoS - risk

The analysis and quantification of the security of supply for different European gas consumers showed that there were big differences within the EU regarding the risk profile and the level of security of supply. The distribution of SoS across the EU is not uniform. Some countries have a very low level of security of supply whilst other had relatively high security of supply. Countries with a high level are mainly located in the North-Eastern part of the EU, whereas the countries in the South-Eastern part of the EU were subject to a relatively low level of security of supply in general. This also goes for the eastern Baltic Sea region which was characterised by a very low level of SoS in general. In total 11 countries were in need of additional investments because of low security of supply.

Further it was shown that especially the smaller countries and gas markets are subject to larger SoS risk compared to the larger countries and gas markets, which in general have higher levels of SoS.

The countries with the highest risk were Finland, Sweden, Estonia, Lithuania and Bulgaria, but also Slovenia, Greece, Luxembourg, Ireland and Portugal need to improve their SoS.

Impact

The above analysis also showed that when evaluating SoS it is important to distinguish between risk and impact. Thus the risk may be high, the impact of a disruption or the vulnerability of a country may not necessarily be so.

Adjusting the SoS risk for the impact or vulnerability showed that in general it was found that the larger share of gas in primary energy consumption, the larger the level of security of supply. This was however not true for a group of countries that were especially exposed to SoS risk. These were countries with high risk as well as large vulnerability. Two countries were identified to have both high risk and high vulnerability- those countries were Lithuania and Hungary.

In terms of risk compared to vulnerability, no countries had a real “over supply” of SoS.

The most vulnerable countries due to a high share of gas in their primary energy demand were the Netherlands, Italy, UK, Hungary, Latvia and Lithuania.

Mitigation policies

A total of four different types of mitigation strategies for increasing SoS in the EU were analysed: LNG, Storage, n-1, and Renewables. The n-1 can be characterised as an active policy directly targeted at increasing security of supply, while the effects from the others are more or less positive externalities following market development, or implementation of the environmental targets set up in the EU.

When looking at changes in security of supply on a country level, it was seen that the effects of new infrastructure projects in countries which are already well off in terms of security of supply, were only marginal compared to the effects of gas infrastructure investment taking place in countries, which scored low in the security of supply index. Thus a clear decreasing marginal value of SoS investments was found, implying that making the wrong investments can be very costly because they will only provide very little additional SoS.

With respect to the overall mitigating effects, it was found that the n-1 scenario had the largest mitigating effects. This result favours the notion that markets are not adequate in terms of provision of SoS. SoS should be addressed at the political and regulatory level in terms of ensuring SoS in regions which are subject to a low level SoS. Regulation and policy work within the EU should take into account that in some regions market development is not sufficient. Thus SoS should be considered for EU support in vulnerable regions especially.

Analysis of the market policies shows that markets invest in markets and not in security of supply. This means that from a security point of view markets will not solve the current issues of low SoS in some countries, because in many member states markets are poorly developed, if at all, as in is the case in the Baltic countries markets. Thus increasing SoS is likely to be dependent on government intervention or EU regulation.

The positive effect on SoS in the renewables scenario can be labelled as a by-product or a positive externality, because increasing the share of renewables will in turn increase security of supply. This is however not an increase in security of supply, but a decrease in dependency. In the short term the effects of increasing renewables were ambiguous, as some countries actually increase the consumption of gas in the renewable scenario. This can be taken as an indication of the fact that a number of countries are using gas as a bridge towards more renewables. In the longer run, as increasing amounts of renewable energy are introduced, security of supply increases in most EU member states. However the absolute changes vary considerably from country to country.

In the medium run active policies, such as the n-1 indicator give the best results in terms of SoS. However functioning markets should still be supported as they do contribute to increasing SoS and do so at a low cost. In the long run increased focus on renewables could increase security of supply by cutting demand. However if a renewable future is built on natural gas as a back-up, then the value of this back-up is reduced as overall gas consumption is reduced in the EU.

The problem with the n-1 standard is however that it is very costly and does not necessarily ensure that the investments made are optimal from a market perspective or that they are cost-efficient. A number of difficulties also exist in relation to having the n-1 standard should be interpreted and to how exactly it should be calculated.

In order to ensure SoS in all EU countries the EU should employ a common policy such as some form of n-1 indicator, however it is also important to notice that this will entail an uneven distribution of costs where some countries will be affected much harder compared to others.

Costs of SoS in n-1

The cost of the different policies showed that increasing the provision of SoS in line with the n-1 indicator would imply total costs of approximately 6.9 Billion Euro in the EU, equivalent to approximately 14 EUR per EU citizen. However costs are not evenly distributed e.g. in Lithuania investments of around 176 EUR per inhabitant are required due to the n-1 policy whereas the amount required is 37 EUR in Denmark and “only” 17 EUR in Italy. Some countries like Portugal, Germany and Latvia are not affected at all by the n-1 policy. In Portugal’s case this is however only because additional investment are already planned by the “market” in the ENTSOG European Ten Year Network Development Plan.

Furthermore it was argued that smaller countries with relatively small gas markets are subject to low economics of scale, making SoS relatively costly compared to larger markets. This could raise incentives for creating a regional solution for SoS, which however will require increased cross-border capacities as well as joint investments set-ups.

It could also be that the EU should provide funding and subsidies for SoS investment in smaller countries/markets.

Unconventional gas in the EU

Unconventional has been one of the hottest topics in the gas industry in recent years. Unlike conventional gas is natural gas, which is gas that has been trapped in large polls by impermeable rock, unconventional gas can be divided into four different types:[24]

- Tight Sands Gas – formed in sandstone or carbonate
- Coalbed Methane (CBM) – formed in coal deposits
- Shale Gas – formed in fine-grained shale rock (called gas shales)
- Methane Hydrates – a crystalline combination of natural gas and water

The breakthrough of new technology in the US, which has led to massive increases in the production of unconventional gas, has already had significant impact on the EU gas market via world LNG trade flows and spot market prices for gas.

Having witnessed the dramatic effect of this increased production on the United States domestic gas production the question that should be posed from a security of supply point of view is: what is the potential of unconventional gas in the EU and how will it impact security of supply? This section briefly tries to analyse and evaluate the possible impact of unconventional gas on security of supply in the EU gas market. Though such conjectures upon the potential impact of unconventional gas are open to a significant degree of speculation it is still a worthwhile exercise given the ability of such production to revolutionise gas reserves.

Gas reserves

Europe currently has an estimated 5.4 TCM (trillion cubic meters) of proven reserves equivalent to approximately ten years of EU consumption.[25] When it comes to unconventional gas resources these reserves become significantly higher as total resources are estimated at approximately 35 TCM for Europe. Gas recovery rates[26] vary from around 8-30% but this could increase to approximately 40 % within a production cost of around 100 to 300 USD per 1000 m3 in the long run, the IEA estimates. At recovery rates of 40 % this would mean an increase in European gas reserves from 5,4 TCM to 19.4 TCM.

Assuming an annual indigenous European production (EU and Norway) of 300 BCM per year, we have that indigenous European production could be prolonged, at a production of 300 BCM per year, from 18 years to 65 years. Assuming a less optimistic recovery rate of 25 %, would increase European reserves by 8.75 BCM increasing current production levels from 18 years to 47 years.

The potential development of European unconventional gas in a manner similar to that of the USA has the ability to increase indigenous EU reserves considerably and thus to postpone the increasing import dependency in the EU[27]. This would have a considerable

[24] Sourrce: Cedigaz "A review of shale gas plays in Europe"
[25] IEA World Energy Outlook 2009
[26] Not all gas can be recovered from the ground i.e. only a fraction of the total resources can be produced. The share is called the recovery rate which may vary.
[27] Assuming that the utilisation of unconventional gas does not lead to increasing consumption due to to lower gas prices and increased security of supply.

effect on security of supply in the EU, but whether the production that has been witnessed in the USA can be replicated in the EU is subject to a number of uncertainties.

Large Uncertainties

In order to analyse and evaluate the unconventional gas and the possible effects on security of supply a number of issues must be taken into account. The first issue which should be raised is the issue of uncertainty that surrounds the potential production of unconventional gas in the EU. The potential impact of unconventional gas in terms of the level of resources, the potential production costs, environmental aspects, legislative issues etc. is far from clear and could push back the timeframe for large-scale production of shale gas in the EU and perhaps even be a complete showstopper. Although analysis has begun to assess the European potential for unconventional gas, actual production is still limited as well is analysis of environmental and legal uncertainties though limited production has started at sites in Poland.[28]

Environmental and legal issues may significantly impede the proposed production of shale gas in Europe. Europe differs from the US significantly on fundamental issues by having a more stringent legislation, a different geography and a much higher population density. All these factors contribute to making environmental obstacles more difficult to overcome, additionally such permitting procedures are also likely to result in longer permitting lead-times. There is also a relative lacuna in the existing law in the EU with no specific legislation dealing with unconventional gas production. In addition it would be expected that there may be widespread local opposition to unconventional production. Property ownership law is fundamentally different in the US and the EU. In the US the rights to the resources below the land belong to the individual who owns the land, this is rarely the case in the EU so as such it would be expected that there would be more opposition to potential development projects.

Further production, know-how and technology has so far been limited to the US and although a major consolidation, where international oil and gas companies have invested large amounts of money in unconventional gas firms, has taken place in recent years, the transfer of this know-how to the EU and the rest of Europe has yet to be implemented. This technology know-how includes horizontal drilling and hydraulic fracturing, which are key techniques to be mastered in order to make unconventional gas economically viable and to ensure that underground aquifers are not contaminated.[29]

Unconventional gas requires numerous wells in order to keep up production as gas production from single well peak quickly and the rapidly decline. The fact that unconventional gas requires more drilling and wells could be a showstopper in Europe where population density is much higher and the environmental and social costs of unconventional gas production thus would be higher compared to the US.

Further the connection of unconventional gas production to the EU gas grid is also an issue of uncertainty, how much investment will it require? And thus what are the total costs going to be?

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[28] Source: http://naturalgasforeurope.com/poland's-unconventional-gas-could-end-russian-stranglehold.htm

[29] Source: Cedigaz: " A review of shale gas plays in Europe"

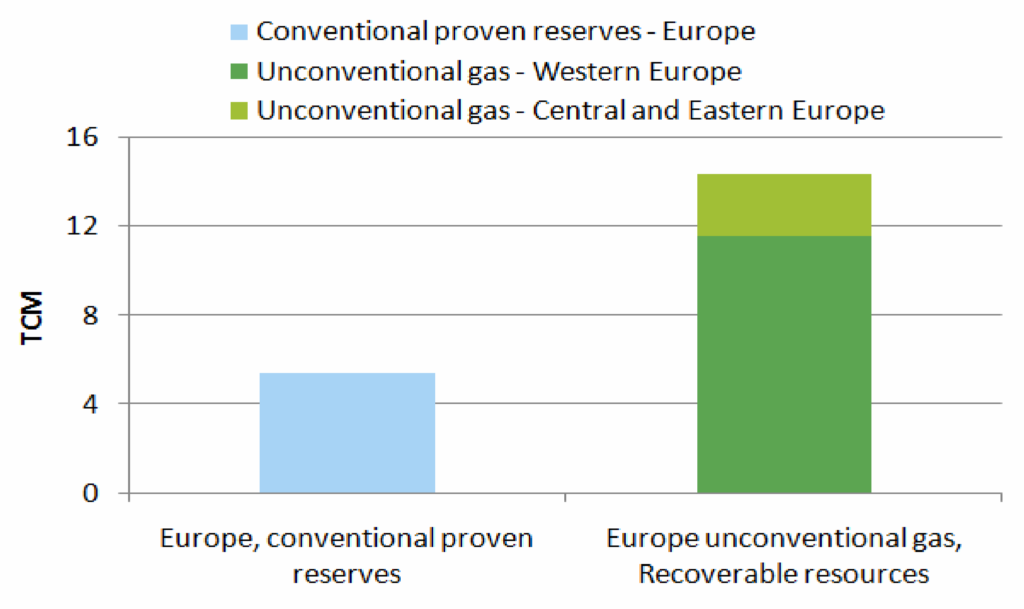
In light of these uncertainties and the current infancy of the European unconventional gas sector, the prospect of significantly utilising unconventional gas in the EU only seems realistic in the medium- to long-term.

EU availability of unconventional gas

As has been illustrated throughout this analysis security of supply differs from country to country and region to region. Significant differences exist between countries in a number of areas including the number of suppliers, diversification of routes and access to gas storage. .The fact that the EU gas market is lacking interconnections between some parts of the gas market, means that the EU is not a homogenous union in terms of security of gas supply.

The potential utilisation of unconventional gas is not certain to have the same effect on security of supply throughout the EU as unconventional resources are located mainly in Western Europe and thus the lack of reverse flow in the EU gas market from West to East could hamper the access to such resources for the southern-eastern and Baltic areas of the EU. Thus unconventional gas's impact may be limited on a European level unless existing bottlenecks and reverse flow issues are resolved first.

Figure 35 Gas reserves in the Europe - conventional and unconventional



Source: Cedigaz "A review of shale gas plays in Europe"

Even in the event that unconventional gas is fully utilised, it is still just as important that the gas infrastructure interconnections within the EU are improved, bottlenecks are removed and reverse flow is implemented. Furthermore although unconventional resources are large they are not of a size which will render the EU self-sufficient. The prospect of production of unconventional gas will only to postpone an inevitable increase in overall import dependency.

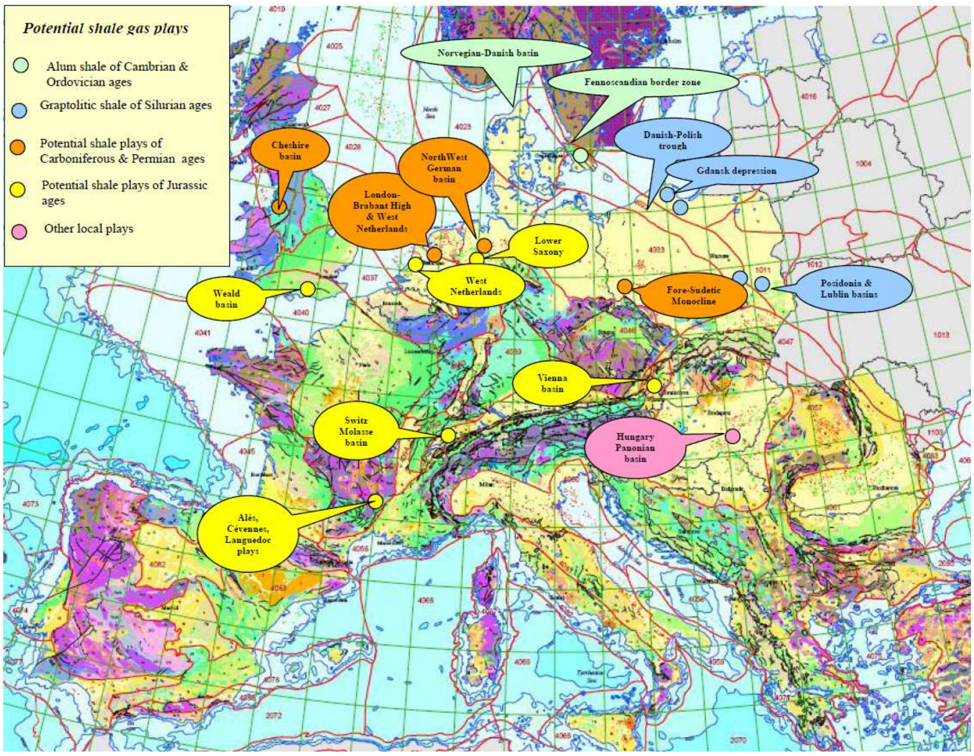
Thus the EU should continue to focus on opening of the south corridor allowing EU to import Caspian and Middle East gas in order to further diversify imports, which will become increasingly important when EU has to replace Norwegian and Algerian gas import after 2030, as production from the two countries is set to decline after 2030. Additionally the EU should think consider streamlining legislation in this area and ensure that more accurate estimates of the unconventional gas potential are produced. The EU should also look into establishing a dialogue with the gas industry, producers and consumers, in order to try to eliminate and reduce some of the uncertainties currently found.

List of uncertainties

To sum up the uncertainties affecting unconventional gas production in the EU are:

- No lack of potential resources in Europe, but unproven
- Requirement for connection unconventional gas resources to the EU gas grid
- Lack of knowledge and technology
- Lack of EU East-to-West interconnection
- High number of wells – higher costs per well in Europe compared to US
- High population density - not the same ’wide open plains’
- Stringent legislation
- EU has access 80% of world conventional gas reserves within pipeline distance
- Unconventional gas still in its infancy in the EU, thus only relevant for medium to long term.

Figure 36 Shale gas in Europe



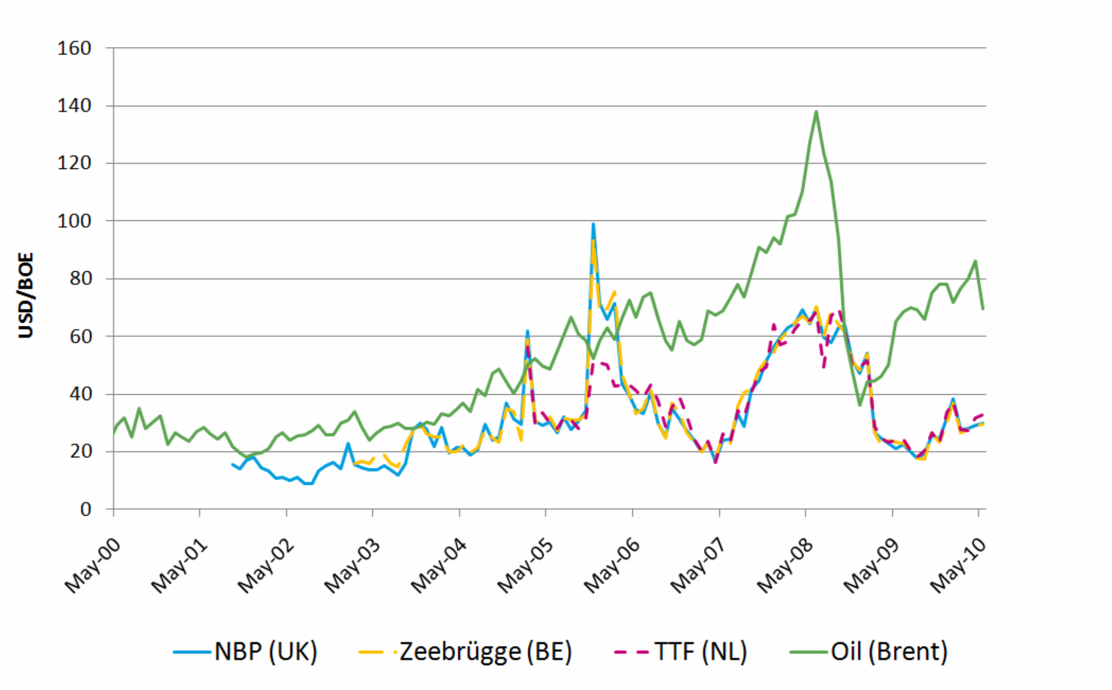
Source: Cedigaz “A review of shale gas plays in Europe”

US unconventional gas impact on EU security of supply

No matter what the future holds for EU unconventional gas, the discovery of new techniques and the high production rates of shale gas in the US already have made an impact on EU gas markets and security of supply in the EU.

The increase in US indigenous production has led to a change in worldwide LNG trade flows within the few last years. Looking at European gas spot market prices shows how there has been a decoupling of oil and gas prices.

Figure 37 Oil and gas spot prices



Sources: Reuters

Lower spot market prices in the EU has led to a temporary change of Russian long term contracts which have introduced a 15 % gas-to-gas price component in the long term contracts which is valid for three years. The decoupling of gas prices is not only due to changes in LNG flows, the economic and financial crisis and the decline in gas demand has also put pressure on gas prices.

With the decline in US LNG demand more LNG has found its way to the EU. The US decrease in demand for LNG in combination with the fact that more LNG liquefaction capacity has come online from sources such as Qatar in the same period, has led to a decrease in world gas prices allowing EU gas importers to import more LNG. This increase in LNG not only increases diversification of EU imports, as LNG can be imported from a number of countries, but it also increases flexibility for gas importers allowing them to replenish gas storage level after a very cold winter 09/10. These developments have prompted LNG imports in the EU to increase from around 50 BCM in 2008 to 63 BCM in 2009 equivalent of an increase of 26 %. This happened despite an overall decrease in natural gas demand of 6 % in the EU.

In short unconventional gas has increased world gas reserves and production and LNG has allowed any regional developments to reach across the world gas market.

Impact of unconventional gas and uncertainty

The potential impact of Unconventional gas in the EU could be significant and eventually it may postpone the increasing import dependency happening in the EU. However regardless of whether the EU will be able to replicate the production revolution as witnessed in the US unconventional gas has already had significant influence on the world gas market and thus on the EU where it has put a downward pressure on gas prices and increase world gas supply.

The considerable level of uncertainty connected to large scale production of unconventional gas in the EU, and the impact of unconventional gas on e.g. import requirements, may result in a potential risk for EU security of supply. Such increased uncertainty could affect the investment climate in the EU and, in particular, gas import infrastructure projects could be affected by this increased risk as large projects may be postponed due to the uncertainty of import requirements in the EU. If unconventional gas turns into a waiting game for overall gas investments then this could lead to a serious SoS threat if necessary investments are not undertaken in due time because of the long lead-times for gas infrastructure projects.

Recommendations

Recommendations have been moved to section in the beginning of the report.

Parameters

Capacity diversification

The more pipelines, LNG terminals, and larger indigenous production a country has access to, the better the security of supply. Moreover, many small pipelines may yield a higher security of supply than one single larger. To capture the diversity in the connections, both in terms of size and number, we calculate a concentration index for each country. The concentration index quantifies the level of diversification in terms of connection points into the country and consists of:

- Diversification in pipeline capacity entering the country, several connections are better than a few big. The import capacity from each import point enters as a connection.

- LNG import capacity, the more LNG terminals the more diversified, each LNG terminals capacity enters the index as a separate connection.

- Production capacity, possibilities for production enhances a country's ability to provide supplies and flexibility in times of supply shortages

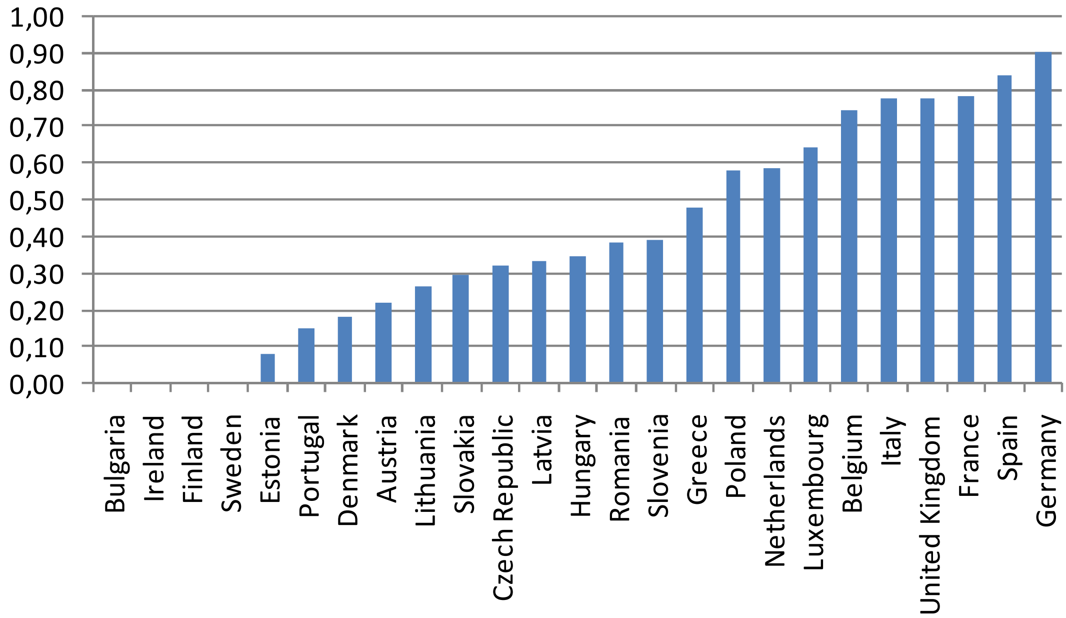
The parameter is summarized into a Herfindahl index calculated as follows:

$$H = \sum_{i=1}^{N} s_i^2$$

Where s_i is the capacity share of country i, and N is the number of connections.

This approach captures the importance of having more than one possibility of supply. The output is a number ranging from 0 to 1, with 1 implying no diversification while lower values indicating better diversified countries. The score has been deducted from 1 in order to maintain consistency in the overall ranking, thus large values indicate well diversified countries. This means that in the below graph a score close to 1 means a high level of diversification.

Figure 38 Capacity diversification 2007/08,



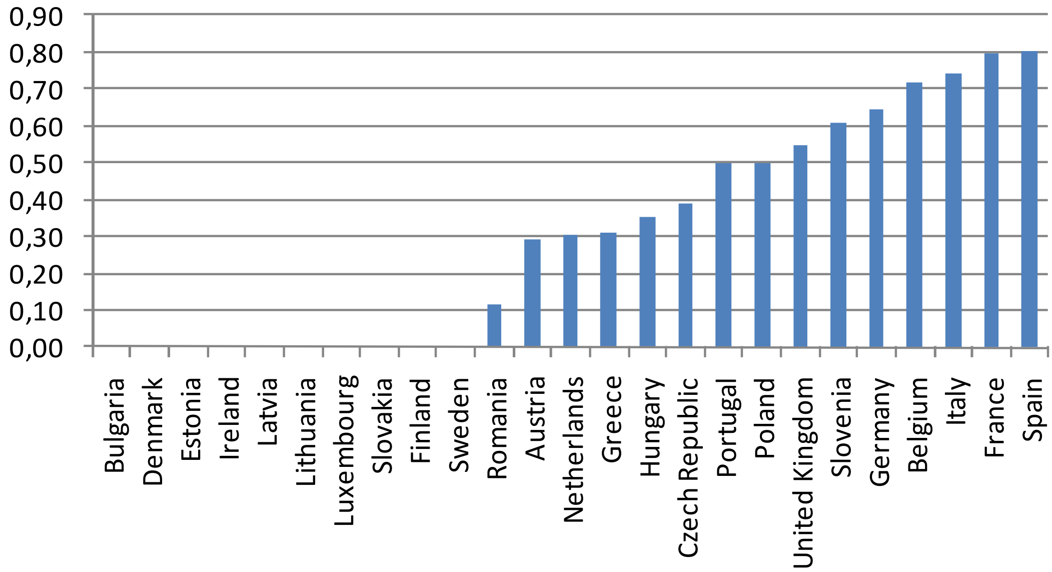
Source: GIE, Eurostat, EIA, 2007, 2008.

Naturally the general trend is that larger countries have more connections qua the size of the country.

Physical supply diversification

This measures the actual diversification in terms of physical import. The share of the import volume for each exporting country enters a concentration index constructed by the same principles as the capacity diversification index. A country's indigenous production is included in the index, as being dependent on only indigenous production and can be as risky as being dependent on only one import source. Thus Denmark scores low in this parameter. It is moreover seen that the countries with LNG import receives high scores due to multiple supply sources. Below the scores for each country is displayed.

Figure 39 Country diversification index, 2006

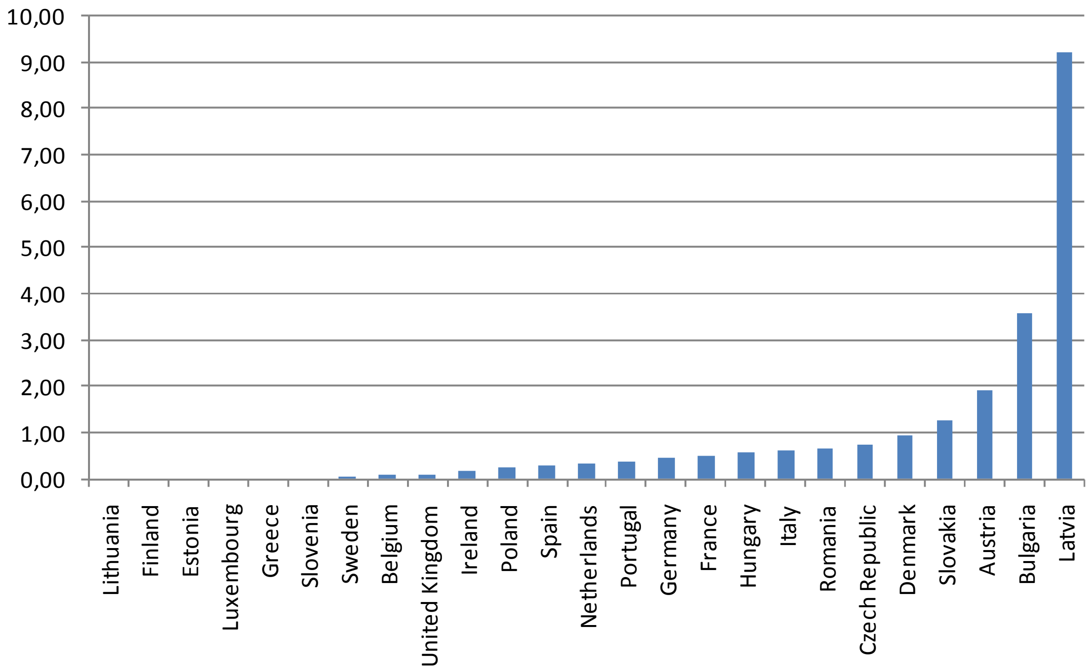


Source: Eurostat 2006

Storage/household consumption

Storage is typically regarded as one of the obvious measures to secure supplies in terms of high demand and supply disruptions. The volumes in the storages are typically used for supplying those consumers that cannot shift to different energy sources, typically household consumers. Therefore we measure storage capacity relative to household consumption. In principle there is no defined upper limit to this ratio as low household consumption increases the ratio.

Figure 40 Storage compared to household/services consumption, 2009



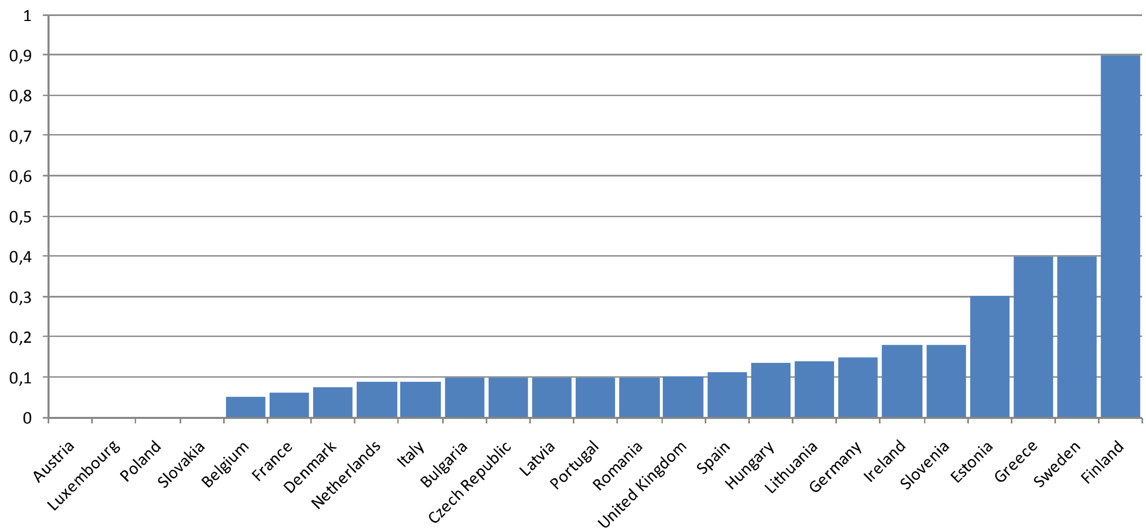
Source: Ramboll UGS database, WGC 2009, POLES

It should be noticed that Latvia may not dispose fully of the entire storage capacity – however, cross border ownerships in storages are quite common and do not directly prevent a country from benefiting from the storage.

Replaceable gas

Fuel switching possibilities are measured as the percentage of total demand which can shift to other fuels. Interruptible consumers are often large industrial consumers, such as cement factories and glass factories, or dual fuelled power plants. The larger this ratio is, the easier it is for the country to manage the consequences of supply disruptions, thus countries with limited possibilities for storage tend to have a relatively high share of interruptible consumers, this is the case in e.g. Finland and Sweden where both countries have no storage capacity and thus rely on imported storage or interruptible consumers for flexibility.

Figure 41 Fuel switching as share of total gas consumption, 2009



Source: EU Commission, own estimates

It is seen that Finland has the highest share of interruptible consumers. This reflects the security of supply policy of the Finnish state, where gas is not distributed to households, but only the industry to ensure consumption can be interrupted.

Geopolitical risks

Geopolitical risks have shown to be an important part of a country's security of supply. Events outside the sphere of influence of a country may imply that supplies are partially or completely disrupted. The latest example of this risk is the dispute between Russia and Ukraine in 2009.

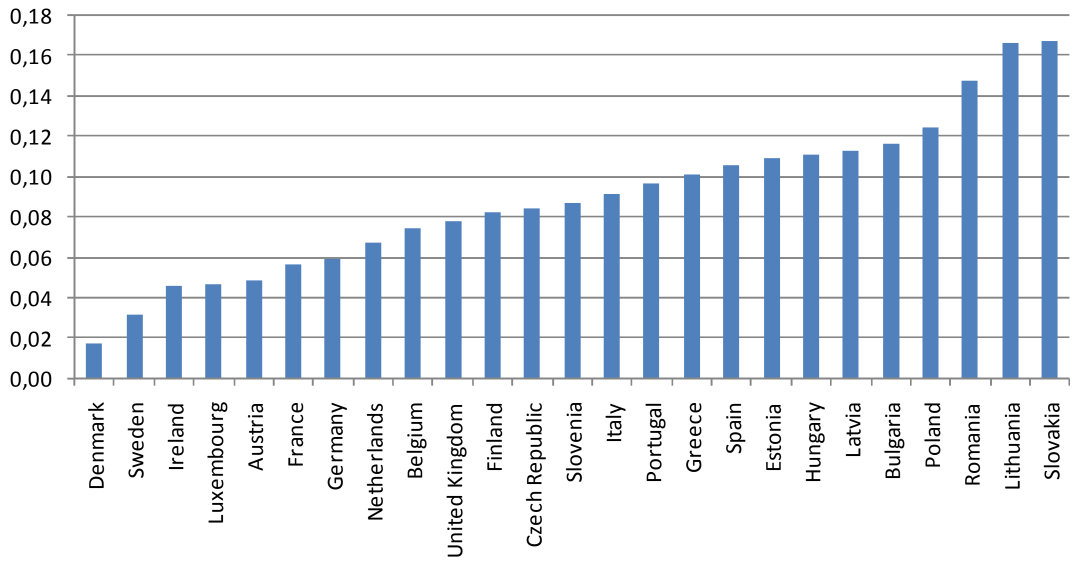
To quantify the geopolitical the risk of the import routes for a country are estimated, taking into account the exporting country and the associated transit countries. A risk is attached to each country, and specific import routes have been specified for each country. For each route the associated country risks are summed to form an aggregate risk for a route. If several routes exist, the final import risk consists of an average of the route risks.

The geopolitical risks may be higher if a country does not function as a transit country, thus some countries are isolated and can thus easier be disrupted. This has been taken into account by dividing the aggregate risk by the number of transit countries if there are more than 2 transit countries between the country and the exporting country.

To measure the political risk we have applied an independent, non-partisan research and educational organization Funforpeace.org which produces a risk index allowing for a ranking and scoring of geopolitical risks.

The overall risk score which ranges between 0 and 1, with 1 being the highest risk is withdrawn from 1, thus a high score below indicates a high level of risk. Risk included for both producer and transit countries.

Figure 42 Geopolitical risks



Source: Fundforpeace.org

The geopolitical risks enter the overall index negatively.

Offshore risk

Offshore pipes are more difficult to repair than onshore pipes – the average time of repair is around 60 days. Hence if a major part of a country's supplies is transported via a single offshore pipe, the consequences of disruptions may be significant, thus though the probability of a disruption is low it is relevant to include this indicator.

The identified offshore pipelines are detailed. The risk is calculated as follows:

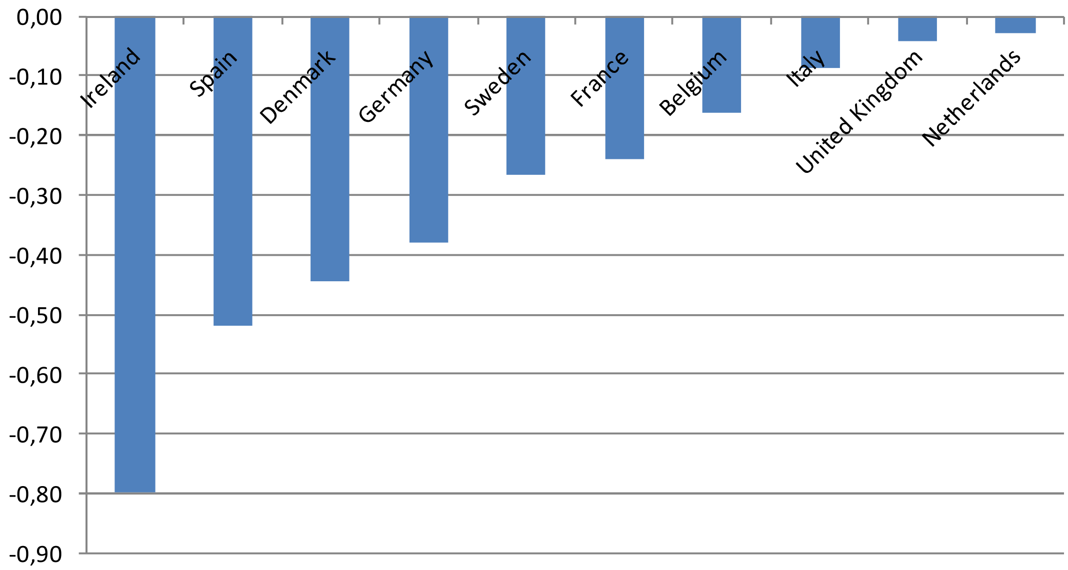
$OR = (L + D) / ((P+O)^2)$

Where,

L – Aggregate length

D – Aggregate depth
P – Number of offshore pipelines
O – Number of complementing onshore pipeline

Figure 43 Offshore risk index



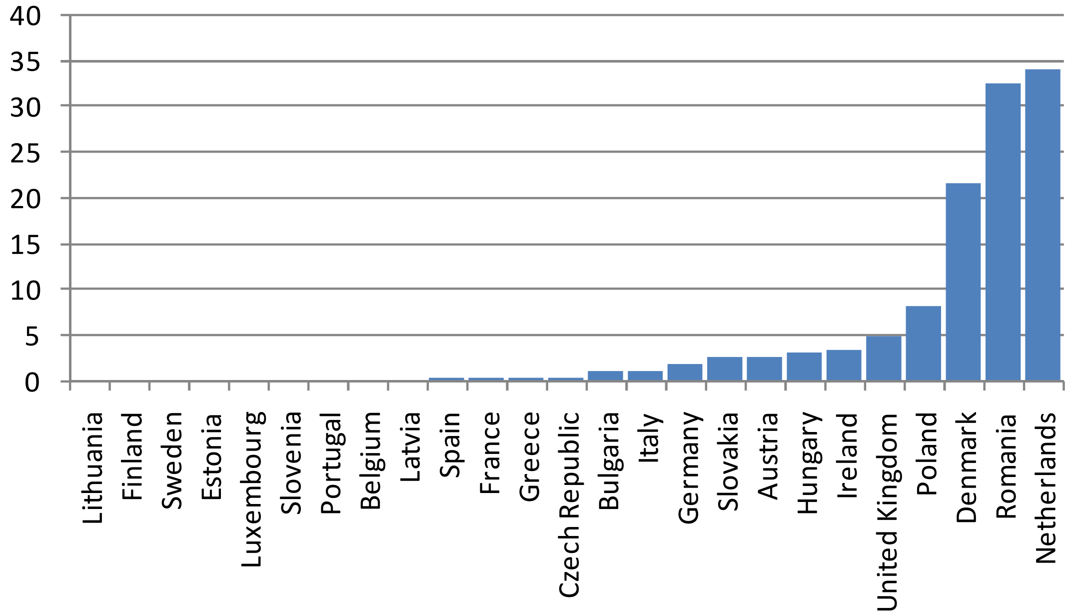
Source: GIE, in house knowledge, 2009

The above figure shows the risk associated with relying on onshore pipelines. It shows that a country like Ireland is subject to a relatively high offshore risk. This is because Ireland is a gas importer and an island, thus having to import all its gas via offshore pipelines. Other countries with a high offshore risk are Denmark and Spain.

Reserves

Reserve estimates are measured relative to the total consumption of gas and give an indication of which countries can remain producers in the future.

Figure 44 Reserves, TCM, 2008

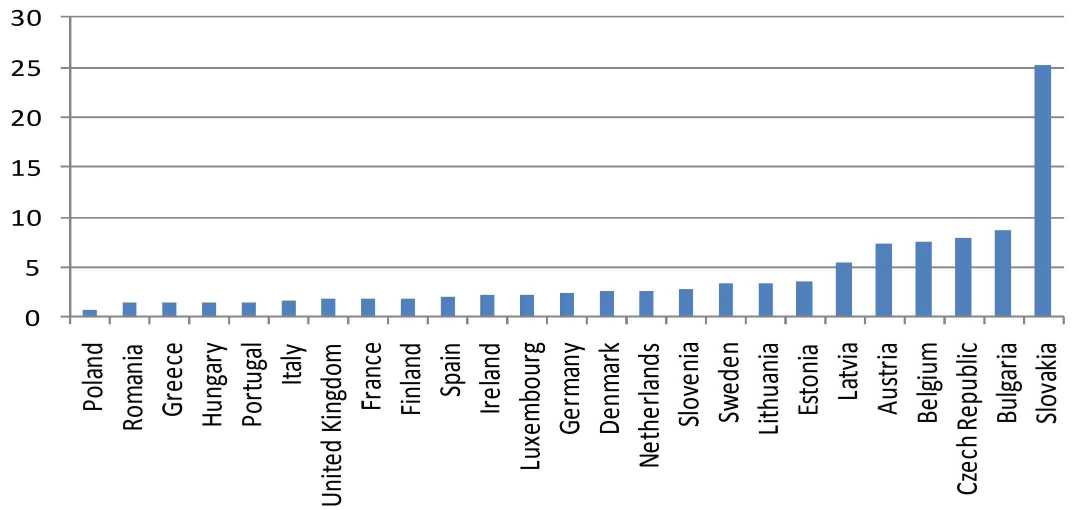


Source: Oil & Gas journal, BP, Cedigaz, 2008 POLES

Import capacity per day/ average consumption per day

The daily import capacities[30] for each country have been divided by the average daily consumption of gas. This gives an indication of the possibility of increasing imports compared to the total consumption i.e. how much importing capacity is available compared to how much is needed, not taking into account that a part of the capacity is used for transit.

Figure 45 Average import capacity/average consumption, 2007



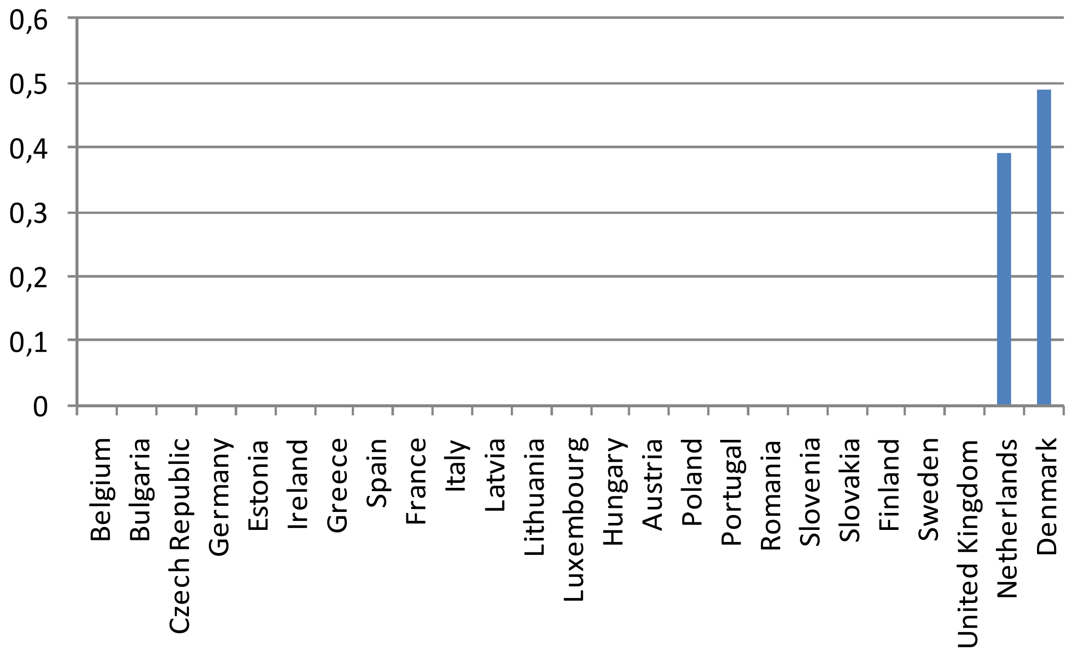
Source: GIE and Eurostat 2007

[30] Peak capacities adjusted with a load factor of 0.85.

The ratio is of course affected by own production and connection to large import pipes which are not necessarily destined for the country alone.

Net export vs. production
As seen above some countries have larger reserves than others, however though large reserves strengthen a country's security of supply, it also matters how the reserves are distributed. If a large share of the production is committed to long term export contracts, it may be harmful to security of supply for the producing country.

Figure 46 Net export/Production 2007



Aggregation and Weights
In comparing the different parameters, a challenging task is to compare on the right scale. To do this, it becomes necessary to rescale the variables, in such a way that they lie in the same range as the remaining parameters. In order to do this, subjective weights have been applied, this changes the absolute scale but leaves the relative relationship between the countries unchanged.

N-1 calculation

Analysis of how member states of the EU adhered to the n-1 rule was done as mentioned above in the 2009 impact assessment.

The different columns in the below table represent the following:

- Maximal consumption - peak consumption which should be covered, i.e. uninterruptible demand
- Production withdrawal capacity - supply from indigenous production
- Storage withdrawal capacity - supply from gas storages

- LNG send-out capacity - supply from LNG facilities
- Incoming pipeline capacity - supply from pipelines
- Single Largest Infrastructure - is the n-1 infrastructure which should be covered according to the SoS regulation
- n-1 2009 assessment EU (%) - is the percentage of coverage against a n-1 incident i.e. a score of 100 % means that the n-1 incident is just covered, is the score 80 % then 20 % of supplies will be missing in the event of a n-1 incident and 145 % means that there is excess capacity of 45 % in the gas supply system to cover against the n-1 incident.
- Additional capacity needed 2009 - shows the amount of investment required to fulfil the n-1 obligation
- n-1 2009 including investments - the percentage of coverage against a n-1 incident including new investments

Table 7 n-1 scenario,

	MCM/day						%	MCM/ day	%
	Maximal Consumption	Production withdrawal capacity	Storage withdrawal capacity	LNG send-out capacity	Incoming pipeline capacity	Single Largest Infrastructure	n-1 2009 coverage	Additional capacity 2009	n-1 2009 including investments
AT	49	12	48	0	138	126	145		**145**
BE	139	0	23	25	322	94	197		**197**
BG	16	0	4	0	72	72	29	**12**	**106**
CY	0	0	0	0	0	0	-		**-**
CZ	68	0	55	0	186	142	147		**147**
DE	400	45	463	0	579	106	245		**245**
DK	26	30	19	0	0	30	73	**10**	**112**
EE	4	0	0	0	23	17	144	**6**	**283**
ES	160	0	11	161	67	40	124		**124**
FI	1	0	0	0	21	21	0	**6**	**600**
FR	370	2	231	42	156	50	103		**103**
GR	14	0	0	14	38	19	235	**8**	**292**
HU	93	9	48	0	58	40	81	**32**	**115**
IE	20	1	3	0	30	30	18	**17**	**101**
IT	425	24	296	35	285	115	124		**124**
LT	16	0	0	0	39	30	57	**7**	**101**
LU	6	0	0	0	11	5	107		**107**
LV	9	0	15	0	25	25	163		**163**
MT	0	0	0	0	0	0	-		**-**
NL	235	440	153	0	96	300	165		**165**
PL	60	6	34	0	148	108	134	**7**	**146**
PT	19	0	7	14	13	14	105		**105**
RO	75	34	26	0	113	102	95	**8**	**105**
SE	6	0	1	0	8	8	10	**4**	**77**[31]
SI	6	0	0	0	15	10	76	5	162
SK	30	0	35	0	301	301	118		**118**
UK	536	231	127	85	241	74	114		**114**
Total	-	-	-	-	-	-	**-**	**122**	

The results, as shown in the third column from the right in Table 7 are, that countries which would require additional invests according to the n-1 rule are: Bulgaria, Denmark, Finland, Hungary, Ireland, Lithuania, Romania, Sweden and Slovenia.

Comparing this result to how countries were affected in the 2009 Ukraine Gas crisis, it is noticeable that Bulgaria and Hungary, who both were severely impacted by the crisis, are listed as in need of investments and thus time implementation of the n-1 indicator which could have helped Bulgaria and Hungary during the 2009 Ukraine crisis.

[31] Utilisation of Fuel switching will ensure fulfilment of the n-1 requirement

N-1 Additional investments in 2019, n-1 scenario

Table 8 n-1 scenario 2019

	MCM/day						%	MCM/day		%	
	Peak day Consumption	Production withdrawal capacity	Storage withdrawal capacity	LNG send-out capacity	Incoming pipeline capacity	Single Largest Infrastructure	n-1 2009 coverage	Additional capacity 2009	Additional capacity 2019	n-1 2019 coverage without any investments	n-1 2019 coverage including 2009 and 2019 investments
AT	86	5	32	0	166	137	145		**20**	77	**100**
BE	163	0	21	33	297	161	197			104	**104**
BG	13	0	7	0	58	58	29	**12**		47	**127**
CY		0	0	0	0	0	-			-	**-**
CZ	64	0	51	0	151	117	147			120	**120**
DE	425	36	228	0	763	181	245			169	**169**
DK	24	7	18	0	0	7	73	**10**		69	**108**
EE	1	0	0	0	23	17	144	**6**		144	**283**
ES	185	0	42	230	76	57	124			99	**99**
FI	2[32]	0	0	0	25	25	0	**6**		0	**250**
FR	396	0,4	317	126	190	56	103			137	**137**
GR	21	0	0	13	48	34	235	**8**		77	**100**
HU	88	3	59	0	80	68	81	**32**	**26**	56	**100**
IE	23	2	3	0	23	23	18	**17**	**6**	18	**100**
IT	394	16	150	52	283	101	124		**31**	92	**100**
LT	12	0	0	0	27	27	57	**7**	**7**	0	**100**
LUX	7	0	0	0	7	4	107		**4**	43	**100**
LV	9	0	15	0	25	25	163			163	**163**
MT	0	0	0	0	0	0	-			-	**-**
NL	394	300	189	33	188	300	165		**20**	95	**100**
PL	85	11	55	23	137	134	134	**7**		108	**116**
PT	32	0	10	27	27	14	105			156	**156**
RO	81	26	37	0	97	93	95	**8**	**16**	74	**101**
SE	5[33]	0	0,4	0	8	8	10	**4**		7	**81**
SI	7	0	0	0	14	10	76	**5**		44	**100**
SK	40	0,5	54	0	297	279	118			181	**181**
UK	380	96	243	153	230	75	114			134	**134**
Total	-	-	-	-	-	-	-	**122**	**131**	-	**-**

[32] Assuming interruptible consumers constitute 90 % of total consumption
[33] Assuming Sweden has 40 % interruptible consumers

Tables and figures