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Supply Security Dutch Gas Market

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PREFACE AND ACKNOWLEGDEMENTS

Writing this thesis made me aware how small the attention for supply security of gas is compared to mainstream economical science about for example stock markets. Much of what has been written is somewhat outdated and usually qualitative data. Some additional research in this area therefore seems to be appropriate. Before I started writing this thesis I did not know much about the gas market. I followed some classes in gas price modelling. This interested me enough to dive into this subject. In addition a positive factor in writing this thesis was the recent gas crisis caused by Russia and the Ukraine. Because energy is the fuel for every economy, I simply was interested whether gas supply could threaten the continuity of the economy. Since I live in The Netherlands I bounded my research to this country. Looking back I have learned a lot about the gas market and even got interested to maybe start working in the energy industry.

ABSTRACT

As the third world most used fossil fuel and still demand is growing investments need to be made to keep up. Gas is a scarce and ending commodity. To facilitate trade in gas, large infrastructures like pipelines and storage facilities have been build in the past and needs to be build in the future. The EU mainly imports gas to meet demand. To improve trade they are liberalising the gas market as we speak.
The Dutch own large gas reserve, which can still produce gas for up to twenty years.
Due to supply disruptions like the Russian-Ukrainian gas crisis, questions rise whether supply securities of EU countries, and in this case in special The Netherlands, are sufficient. The Dutch have been self-sufficient since 1963 due to the discovery of a large gas field in Groningen. In the present The Netherlands is aiming at being *the* gas hub of north-west Europe in the future. To do this they invest in infrastructure and storage facilities.
Due to the liberalisation, scarcity and the possibility of gas emergencies/disruptions this research tried to find out whether The Netherlands its long-term gas supply security worsened or not in past decade. To do this a model from the Energy research Centre of the Netherlands is used (ECN). This model was used to indicate the supply security of all primary energy sources. The model looks at import dependence, social and political stability and depletion rates to measure supply security.
When looked at their home depletion rates concluded is that the supply security worsened over the past decade. Taking a closer look at the input variables, shown is that variety and balance of the imports for The Netherlands improved over the past decade. This was mainly due to the change in gas supplying countries. Due to this change the depletion rates of imports did improve significant.
Although the model did not cover all aspects of supply security, it does give a good indication for the long-term supply security. Nevertheless it is still important to look to other information besides a certain model to fully capture the essence of supply security. In Chapter one an introduction is given about the gas market with respect to supply security. Chapter two covers the problems concerning long-term gas supply security. The next chapter state the research question and hypothesis. In chapter five the methodology is discussed followed by the results in Chapter six. Chapter seven there is some discussion about the used model. Chapter eight summarized the thesis and its conclusion.

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CHAPTER 1 Introduction

1.1 World

Energy is the “fuel” for the world economy. Without energy our society, as we know it, would not be able to exist. Gas in the future will compete with oil as “the” dominant energy source. The consumption of gas in the year 2008 accounted for 24.1% of the worlds total energy consumption. Compared to oil and coal, which accounted for respectively 34.8% and 29.2%, gas is the third main consumed energy source[1]. The choice for gas is a logical one because it is the cleanest fossil fuel.

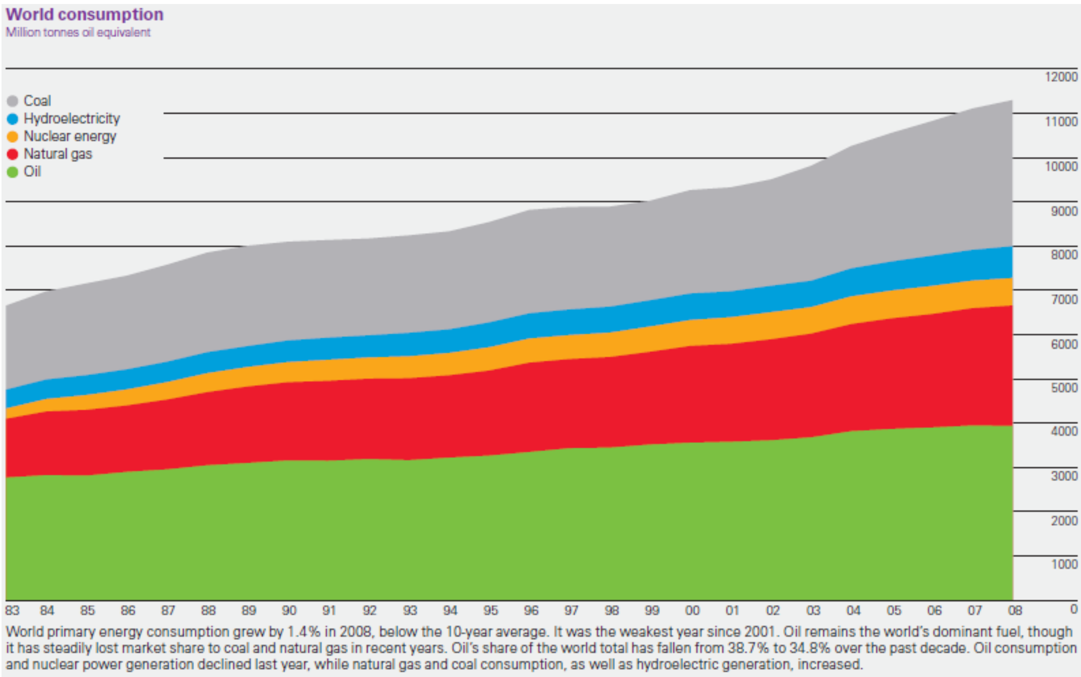

Figure 1 BP statistical review of world energy report June 2009

In the generation of electricity gas plays a vital role. Unavoidable these two sources of energy are heavily interrelated. Therefore disruption in gas supply effects the supply of electricity as well. A supply disruption in gas has a large influence on the costs of individual participants in the gas market, due to price spikes. In the future there will be a lot of demand with too few sources, therefore creating a lack of options in choosing a supplier, making countries which are net importers vulnerable to disruptions and as a result put individual participants to expenses. (Weisser 2005)

World gas consumption is projected to more than double over the next three decades. Most of this gas is transported through pipelines. LNG[2] is a more flexible way of transportation. LNG transport invokes the benefit of avoiding problems with transit countries and not being fixed

[1] BP statistical review of world energy report June 2009

[2] Liquefied Natural Gas

to destinations as with pipelines. LNG accounts for 27.8% of the total exported amount of gas in the world in the year 2008[3].
The world moves to a more integrated gas market due to scarce resources, efficiency opportunities and liberalisation of markets. With the rapidly growing demand for gas, construction of new infrastructures will be essential for the future. Not only new infrastructures are needed, also maintenance and replacements is important. The older the pipeline-infrastructures are, which is built mostly in 1970s and 1980s, the larger the risk of technical failure will be for the future. (Stern 2002)
The role of governments in gas trade will change dramatically in the future, if not changed already, from ownerships in energy companies to a more facilitating role of the energy markets. There will be a rising importance for supply security in the future, due to rising demand and the scarcity of resources. According to Baker (2005) the shift to a more global gas market will only occur if the right financial and intellectual investments are made.
A more global and integrated gas market also in a political context has important consequences. The Dutch Minister of Economic Affairs Verhoeven states that relationships with governments of foreign suppliers are very important and therefore should be maintained carefully.[4](Dutch Economic Affairs 2009)

1.2 European Union

In 2007 only three countries out of the EU-27 were net exporting gas. The EU structurally depends on the gas from Norway, Netherlands and UK and most of all depends on imported gas from Russia and Algeria. With the breakdown of the Soviet Union the numbers of transit countries increased, therefore increasing the risk on supply security. The Middle East as an alternative withholds a lot of obstacles, therefore not being a better alternative. (Correlje 2006) The past 20 years very few supply security incidents have occurred, except from the Russian-Ukrainian gas crisis in beginning 2006[5]. To cope with such gas shortages, reserves can offer a good but temporary solution. Shortages can have a large social and economic impact, hence the inevitable dependence of gas importing countries.
Due to liberalisation of gas markets and accordingly the need for more flexibility, long-term contracts are expected to change into more short-term contracts. The European Union in fact is moving to a more liberalized gas market. Liberalized gas markets are especially vulnerable to supply shortages due to lower reserves. European governments should make risk and cost judgements of possible supply disruptions and create a more transparent supply security framework of standards and obligations. The European investment climate needs stability to attract long term investments and commitments. European standards should also be set in order to protect countries from others free-riding on their safety nets. Raymond (2007) agrees and also suggests that governments could have a minority stake in energy firms to keep an influence.

[3] BP statistical review of world energy report June 2009
[4] http://www.ez.nl
[5] http://www.businessweek.com/globalbiz/blog/europeinsight/archives/2009/01/russia-ukraine.html

Figure 2 Gas Pipeline Routes to Europe[6]

The EU should anticipate and invest in a good infrastructure for the supply of gas. It should regulate to take away insecurities and improve the perception on the rising dependency. Also it should not exaggerate problems, this could harm the market. Start dialogue with exporting countries to emphasize mutual interests. (Tönjes 2006)
Importing and exporting countries can both have positive welfare effects due to trade in gas, creating a mutual dependency for supply and demand. This mutual dependency mainly occurs due to the inflexible infrastructures for transport. Pipelines simply cannot be moved. The supplier cannot easy reroute their supplies to another client without building a new infrastructure, which is costly and time consuming. Vice versa demanding countries cannot go to another supplier due to the same infrastructural limitations. This goes for the short term supply. Long term the EU should provide a gas market with an attractive environment otherwise suppliers might allocate their resources to other markets. Like for instance the Chinese market.[7]

1.3 The Netherlands

With the discovery of the Groningen gas field in the year 1959 (production started in 1963) the Dutch instantly became self-sufficient in the supply of gas and became a large potential player in supplying gas in Europe. The Dutch use gas for one third of their total energy consumption.[8] Before 1965 the Dutch state earned super normal profit through its monopolist power as a gas supplier. Only recently the Dutch gas market and other European gas markets[9] became more liberal and more suppliers gained access to these markets, due to EU regulation. The Groningen gas field is highly competitive compared to foreign fields due to its low cost production. Due to constraints and regulation by the Dutch government in past the Groningen

[6] http://www.economist.com.hk/displayStory.cfm?story_id=14041672
[7] http://www.nuzakelijk.nl/algemeen/2101047/china-en-rusland-sluiten-gasdeal.html
[8] International Energy Agency 2006 Standard Review of the Netherlands
[9] UK most liberalized gas market

gas field lost its pivotal role in the gas supply system of Europe. The Dutch have been educated for many years about the strategic importance of the Groningen gas field, but in the late nineties due to liberalization slowly this strategic position was compromised. This created an adverse reaction from the Dutch public which has been brought up for decades with the idea that Groningen gas is a scarce asset and that it should be reserved primarily to Dutch[10]. (Correlje, Odell 1999)

Is this anxiety concerning the changed strategy valid? Is the supply security of gas in the Netherlands really worse or is it just a case of perception. In this research is tried to answer that question.

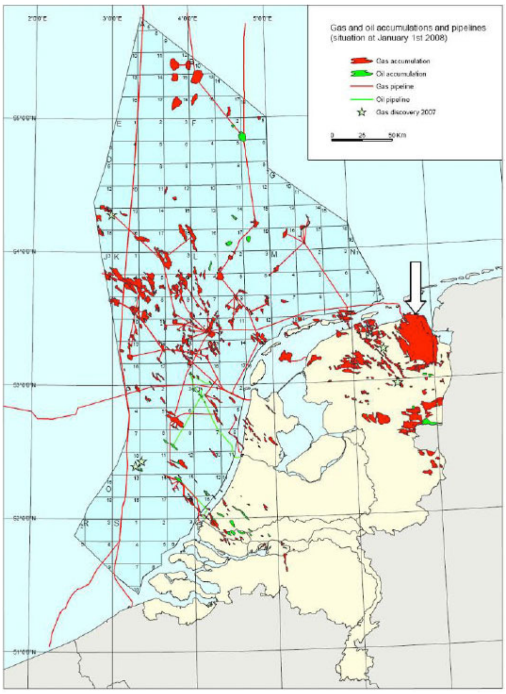

Figure 3 Dutch Gas and Oil Accumulation[11]

Nowadays the Dutch government is aiming at being "the" gas hub of Western Europe. This should benefit the Dutch in a financial and security perspective. Due to protective behaviour in the past the Dutch gas market has been avoided with respect to the construction of gas infrastructures, which ended up being built around The Netherlands, weakening their potential hub position for the future. Recently Gasunie[12] started to improve their position by for example exchanging shares in pipeline projects, like the Nord Stream and Balgzand Bacton Line with Gazprom. With the building of the North Stream Pipeline the Russians can avoid transit countries, like for instance the Ukraine, and connect directly to the German and following the Dutch and UK gas markets.

The Dutch due to its monopoly on gas in the past had a major interest in high gas prices. Today they follow a more market orientated approach. The "small fields" policy is implemented to keep the Dutch gas market flexible and able to cope with demand peaks and secure supply further into the future. Smaller expensive gas fields are used to cope with

[10] Four decades of Groningen production and pricing policies and a view to the future, A.F. Correlje, P.R. Odell, 18 July 1999

[11] http://www.aapg.org/europe/newsletters/2008/12dec/neth1.jpg

[12] Gasunie is a 100% state owned gas infrastructure and transmission company from the Netherlands

regular gas demand and natural gas storage facilities are used to cope with seasonality of gas demand. The Groningen gas field is also used for extreme demand peaks. In this way the small fields are guaranteed for demand and the Groningen gas field is preserved for extreme situations and in this way indigenous supply is guaranteed for a longer period.

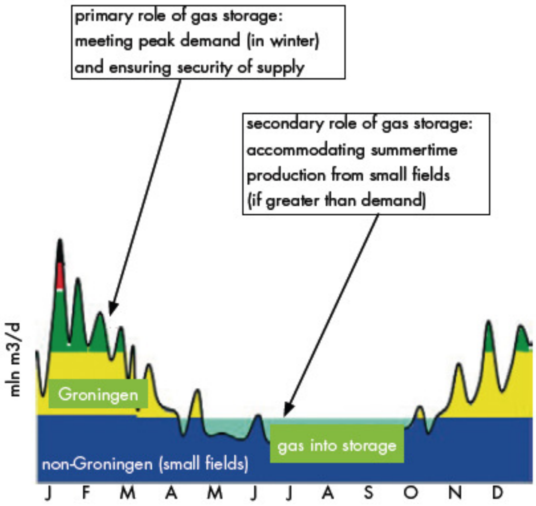

Figure 4 Seasonality of gas production[13]

In case of peak demand Gas Transport Services is by law [14]obligated to deliver to the small end-users when temperature is between -9 and -17 degrees Celsius. The Dutch Gas market in more global perspective is very competitive due to its large storage capacity and internal gas infrastructure. When they realize the building of LNG terminals and keep their market attractive they could do well in the future. The first step in this process has already been taken. As we speak the Maasvlakte II is being constructed near the Rotterdam Harbour. An agreement has been made to build the first Dutch LNG terminal on the Maasvlakte II by Vopak, improving the position of The Netherlands in being a gas hub.[15] (Lomme 2008)

Figure 4 gives an illustration of the structure of the Dutch gas market. First gas is produced in one of the many gas field located in The Netherlands or gas is imported. This gas is pumped into the national gas transport network. This network is managed by the Gasunie. In the past there was 100% control by the Gasunie. Currently also so called "shippers" are active on this transport network. These shippers also manage gas transport flows though or within The Netherlands, this due to the liberalisation of the market. Gasunie and the shippers make sure that gas is delivered to energy distribution companies, which supplies both to small and large end-users. Sometimes large end-users are directly connected to Gasunie. To make sure no cartels are made and to assure a free market the *Nederlandse Mededingens autoriteit* (NMa) is supervising. They created the *Dienst uitvoering & Toezicht energie* (DTe) to give guidelines to the Dutch gas market. They do so by setting tariffs and conditions. The Dutch government also has an influence. If needed, they can advice the DTe with their policies.

[13] NAM: Source of Energy, Groningen Gas Field "Slochteren"
[14] Besluit Leveringszekerheid Gaswet (Staatsblad 2004, nr. 170)
[15] http://www.schuttevaer.nl/nieuws/techniek/nid9054-lng-terminal-versterkt-gasrotonde-nederland.html
http://www.vopak.nl/press/137_1243.php, Gate LNG terminal tekent overeenkomst met E.ON Ruhrgas

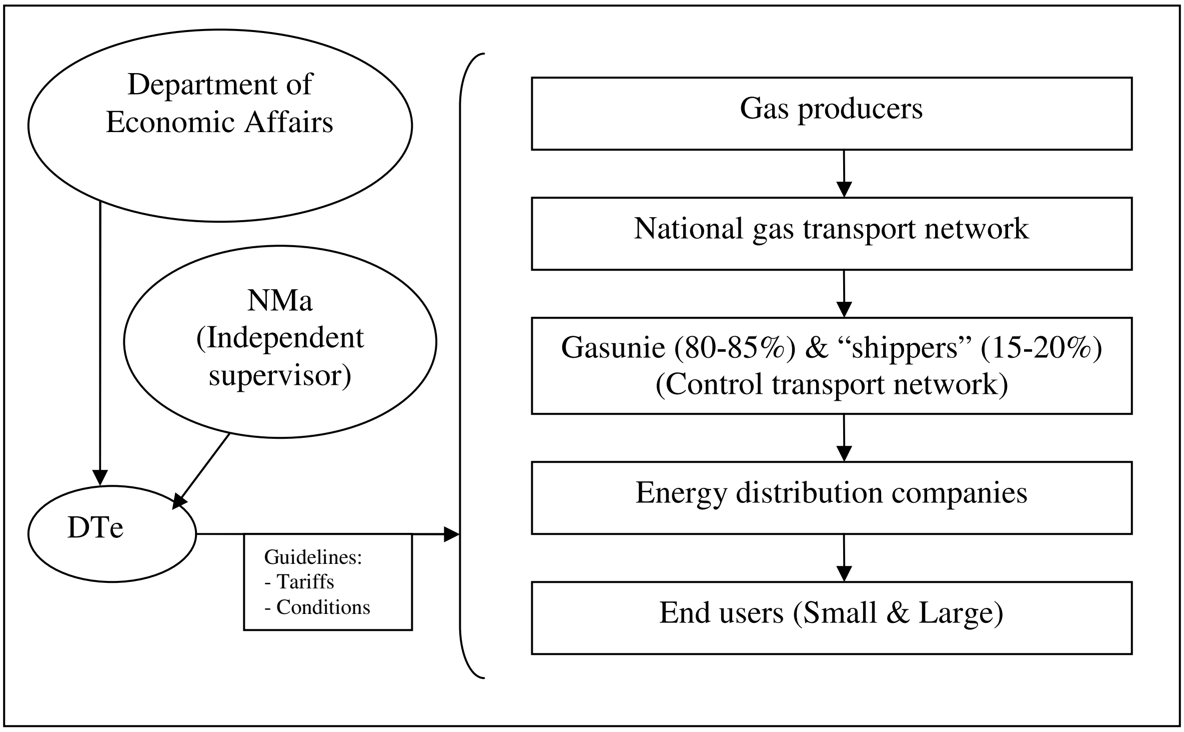

Figure 5 Structure Dutch Gas Market

CHAPTER 2: The Problems

2.1 Dependence

A country is dependent for gas through the share of net gas imports with respect to the total consumption of gas. The larger the amount of imports compared to the total energy consumption, the larger the dependency. Dependency can affect the supply security. This dependence can be divided in three subcategories.

First, *source dependence*, when a country imports gas from a certain country it is logical to state that its source dependence is proportional to the share on the total imports. An important aspect is that dependence is not necessarily always problematic. One source country is more reliable than the other. When a country becomes *vulnerable* this poses a bigger problem. For example, take two countries with the same amount of dependency on gas imports, but both have different suppliers. The first country imports 100% of its consumption from one source with a lot of political instability, this makes them vulnerable. In the contrary the other country imports 100% of from another source, but this source is considered politically stable, this makes the second importing country dependent on imports, but not necessarily equally vulnerable.[16]

Second, *transit dependence*, occurs when imported gas needs to travel through other than the source country's territory. This could pose similar problems as with source dependence. The more transit countries, the higher the risk and dependence on foreign social and economic stability will be.

And last, *facility dependence*, gas is transported through pipelines or with ships (LNG), it needs to be stored and processed. The quality and security of these facilities are very important. If a facility breaks down, this could disrupt the gas supply. (Stern 2002)

According to Correlje (2006) energy disruption can occur in three ways, as stated below:

- Sudden disruptions due to political decisions or military conflict
- Slow emerging energy gaps, lagging investments in production/transport
- Or gaps arising due to ideological choices or producer governments

According to Joode (2008) the depletion of the Groningen gas reserve and the rising dependence on foreign gas (outside EU) is making the Dutch gas market more vulnerable. The rising EU demand for gas and the uncertain future of Dutch demand for gas even worsens this problem. Capacity is important for flexibility with short and long term demand peaks.
Is The Netherlands really becoming more vulnerable or is it only more dependent on the supply of foreign gas? One might think that The Netherlands is becoming more vulnerable. In this research is looked at the *validation* of this argument.

2.2 Strengths, Weaknesses, Opportunities and Threats

Energy policy in general consists of three main pivots in which are cost-price, environment and supply security. The three main risks in energy trade are technical, economical and political risks. The main goal of this paper is to look at the supply security concerning gas. Previous mentioned dependences are important factors which can make your supply security less controllable and subjected to certain risks. When a country is self-sufficient in supplying

[16] This is a simplified example. 100% dependence from one foreign source is not recommended and also makes a country more vulnerable.

gas it can control source and facility dependence and transit dependence does not exist. One of the most important risks taken into account is the political risk with respect to gas imports, which will be specified later. (Tönjes, Perlot 2006)

This research focuses on the supply security. High dependence and vulnerability can increase the risk for gas supply disruptions. In the following table is summarized most of the strengths, weaknesses, opportunities and threats for the supply security of Dutch gas.

Strength	Technical	- Domestic infrastructure - Rotterdam Harbor - Geographic of The Netherlands - Natural storage capacity - Natural gas reserves - Location with respect to the hinterland
	Economical	- Low cost production fields
	Political	- Stable domestic government - Leverage of size EU in negotiations (importing gas)
Weakness	Technical	- Past monopolist gas policy (negative influence on infrastructure surrounding the Netherlands)
	Economical	- Dependency on income from export for funding domestic projects (domestic supply versus income)
	Political	- European Union policy (have to take into account EU regulation)
Opportunity	Technical	- Construction of Maasvlakte II - Construction of LNG terminals - Becoming European Gas Hub (natural storage) - More efficient gas usage - New salvation methods
	Economical	- Discovery of gas fields - Decreasing export (prices in the future will be high due to scarcity)
	Political	- Maintenance foreign relations - European Union (less *transit* countries)
Threat	Technical	- Ageing infrastructure - Depletion rate domestic reserves
	Economical	- Increasing export (prices in the future will be high due to scarcity)
	Political	- Foreign regime change, conflict or war - Liberalization gas market (low prices, low gas reserves) - The end of Soviet Union (more transit countries) - Terrorism on infrastructure (LNG terminals, pipelines) - Foreign demand (e.g. China, India)

Table 1 SWOT supply security Dutch gas

CHAPTER 3: Research Question & Hypothesis

3.1 Research question

Supply security in gas is very important, especially for the Dutch. After the discovery of the Groningen gas field almost every household in The Netherlands started using gas for cooking and heating, therefore making them more dependent on gas, in fulfilling some basic human needs, compared to other countries. The big advantage off course is that the Dutch have a large gas reserve to fulfil these needs. These reserves are large enough to even export gas and boost the economy. Recently, due to events like the Russian-Ukrainian gas crisis, people are starting to question the supply security in gas. Due to "negative" media attention, perspective on supply security maybe lost? Therefore an independent measurement for this supply security would be appropriate. After extensive research, no such framework yet exists. The Energy research Centre of the Netherlands did make a framework to measure the supply security for all primary energy sources collectively. In order to measure the supply security gas separate, this framework will be adjusted appropriately.

Leading to the following research question:
Did the supply security of The Netherlands worsen over the past decade?

3.2 Hypothesis

H0: The supply security of gas in The Netherlands worsened over the past decade.
H1: The supply security of gas in The Netherlands stayed the same or improved over the last decade.

Prediction outcome answer: *Rejecting the Null-hypotheses*

CHAPTER 4 Literature on methodology

4.1 ECN & Stirling[17]

In Stirling (1994) three types of incertitude [18]are distinguished, also stated in the figure below:

Risk
A probability density function may be defined for a range of possible outcomes

Uncertainty
No basis for the assignment of probabilities exists

Ignorance
No basis for the assignment of probabilities to neither outcomes, nor knowledge about many of the possible outcomes themselves exists.

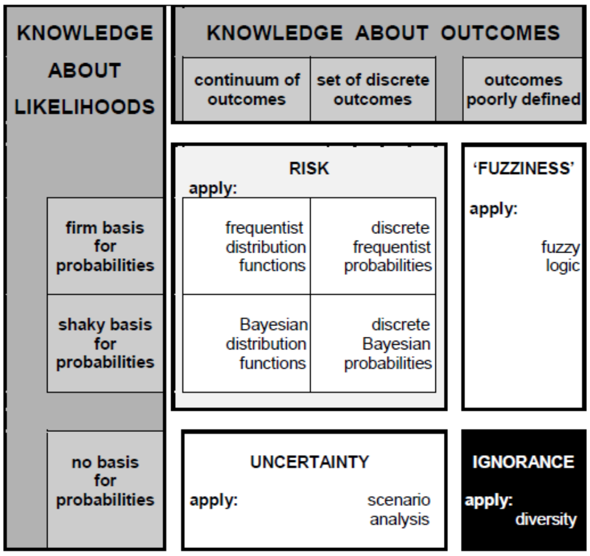

Figure 6 Andrew Stirling's scheme for the definition of risk, uncertainty and ignorance (Stirling 1998)

4.1.1 Probabilistic approaches

Risk - Financial analysts for instance look at the downside risk of exposure and chance of negative events (default). When risk develops along patterns predictable from the past these probabilistic approaches lend themselves in addressing these same risks. For instance insurance businesses use this to estimate fair insurance premiums. The insured is prepared to accept a premium from which the insurer can cover its cost and even make a reasonable profit. Risk in this case is reduced through pooling under the prevalence of "the law of large numbers".

Another approach to cope with risk is the Value-at-Risk (VaR) approach, used by banks, asset and liability managements. It can be used with any asset or liability portfolio. In general, one

[17] This part lends its information from Stirling 1999 and the ECN article
[18] Stirling (1994) uses this term to both address risk and uncertainty at the same time

needs market values to be available on a periodic basis. Depending on the complexity of the portfolio this approach usually uses volatility, correlation matrixes and market values changes to estimate the VaR. Using for instance a 5% probability means that, for example the company, in 95% of the cases will not be exposed to a loss greater than the calculated value. VaR is used to set trading limits or to force banks to hold a certain amount of cash (Basel II).

Another approach is the Markowitz's Modern Portfolio Theory. The main idea in this application is to determine an efficient frontier. This frontier visualises the set of optimal portfolios. Optimality refers to Pareto optimality in the trade-off between portfolio risk and return.

Uncertainty - But even in the case of using approaches to assign probabilities to certain events these probabilities are sometimes subjected to Delphi-like methods and so called: "weighted expert opinions". Friedrich Hayek also called this "the pretence of knowledge". Therefore these assigning methods might not always give a good view on probabilities of risk.

Ignorance - This condition which plays an important role in defining the ECN article as well as this research. Crucially, ignorance is neither the simple inverse of knowledge nor the linear 'zero-sum' complement of what is 'known'. Rather than being thought of as the 'residual' remaining after all that is known has been accounted for, ignorance may instead be seen partly as an independent condition in its own right. Indeed, there is an important sense in which ignorance may actually be seen to increase with the accumulation of knowledge.[19] Ignorance emerges especially in complex and dynamic environments where agents may themselves influence (in indeterminate ways) supposedly exogenous "events" and where the very identification of particular courses of action can exert a reflexive influence on the appraisal of alternatives.

4.1.2 Diversity approach

In a state of ignorance diversity provides resilience to systems exposed to incertitude. In natural sciences diversity is widely known. Darwin for instance stated that diversification through evolution facilitates creation and survival of the fittest species and by implication the biodiversity system. Also when looking at technical innovations, R&D expenditure is usually diversified through different projects to mitigate the impact of technical lock-in.

In order to determine the optimal diversity strategy in the face of ignorance diversity needs to be characterised. Stirling has done this is in three subcategories.

Variety
This refers to the number of categories into which the quantity in question is partitioned. For example, in the case of this research the quantity may be defined in share of import on total gas supply and the categories may be denoted in country of origin. Variety is a positive factor to diversity. All else being equal, the greater the variety of a system, the greater the diversity will be.

Balance
This refers to the pattern in the apportionment also known as spread of that quantity across relevant categories. Given the number of categories, the more even the spread, the greater is

[19] Ravetz, 1986; Wynne, 1992.

diversity. For example, when gas is imported from certain countries, you need to balance the portion of import per country. In the case of three import countries, the optimal situation would then be when you import 33% of total imports from each country.

Disparity
This refers to the nature and degree to which the categories themselves are different from each other. For example, when countries are compared to each other, some are from the EU and therefore show more similarity than they would do with non-EU countries. Also some countries are subjected to other social and economical events than others,.

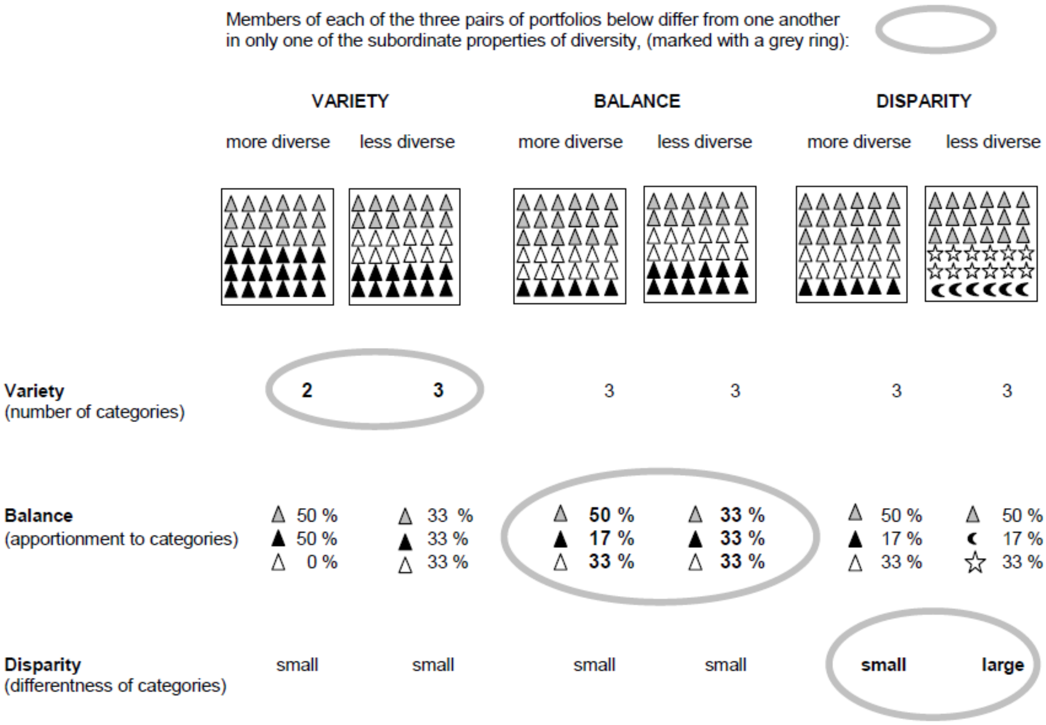

Figure 7 The separate contributions to diversity made by variety, balance and disparity (Stirling 1998)

Stirling has addressed the question as to whether and how diversity can be captured in a simple and robust quantitative index. The threefold variety-balance-disparity concept of diversity is non-parametric in the sense that the system is not ex ante stylised by a structural model, for example a normal distribution or theoretical framework. Based on a review of non-parametric measures of ecological diversity, Stirling could not identify a measurement that addresses the complex and fundamentally concept of disparity.

The Shannon index obtained by hill by setting a=1 for the general form stated below, indicates both variety and balance, also called “an index of dual concept”. The higher this index, the better diversity will be.

General form

$$\Delta_a = \sum_i \left(p_i{}^a\right)^{1/(1-a)} \qquad (1)$$

Shannon-Wiener function

$$\Delta_1 = -\sum_i p_i \ln p_i \qquad (2)$$

Stirling prefers the Shannon Index as the dual concept diversity index. This is due to the sensitivity of final ordering and the additivity property in case of refining taxonomy.

Sensitivity of final ordering
Changes on base of logarithms used in Shannon (Stirling uses natural logarithm by default) do not change the rank orderings of different systems; therefore do not lead to relative sensitivities to variety and balance. But this is in the case of a=1. When using a=2 as Simpson does this would lead to different orderings. There is no real clear reason why this is.

Additivity property in case of refining the taxonomy
Due to the subjectivity of the classifications a diversity index should hold the following property to be more robust. The value of a system of options, disaggregated according a combined taxonomy, should be equal to the sum of the index values obtained for the same system classified under taxonomy individually. The Shannon index withholds this property.

4.2 Original article ECN

The original article published in January 2004 was written to fulfil the need to estimate the degree of supply security of in this case the primary energy supply. Therefore Jansen, Arkel and Boots wrote *Designing indicators of long-term energy supply security*. In this article the Shannon Index was used to address diversification, based on the work from Andrew Stirling. This index is distinguished into four indicators of long-term energy supply security. These are introduced stepwise as followed in predicting supply security for different scenarios in the future.

4.2.1 Model

Indicators:

I_1 - Diversification of energy sources in energy supply

$$I_1 = -\sum_i \left(c_i^1 p_i \ln p_i\right) \quad (3)$$

I_2 - Diversification of imports with respect to imported energy sources

$$I_2 = -\sum_i \left(c_i^2 p_i \ln p_i\right) \quad (4)$$

I_3 - Long-term political stability in regions of origin

$$I_3 = -\sum_i \left(c_i^3 p_i \ln p_i\right) \quad (5)$$

I_4 – Depletion rate of the resource base in regions of origin, including the home region itself

$$I_4 = -\sum_i \left(c_i^4 p_i \ln p_i\right) \quad (6)$$

i	= [1,M]: primary energy source
M	= number of primary energy sources
j	= [1,N]: region of origin
N	= number of regions of origin
k	= home region
p_i	= share of primary energy source i in the total primary energy supply (TPES)
c_i^{1-4}	= correction factor(s) for the security of supply per share of energy source i on TPES
m_i	= share of net import in PES of source i
m_{ij}	= share of imports of energy source i from region j in total import of source i
$S_i^{m\,[*,**]}$	= Shannon index of import flows of source i
$S_i^{m,max\,[*,**]}$	= maximum value of Shannon index of import flows of gas (equal to …. For …regions
h_{ij}	= extent of political stability in region j [0,1], according to the HDI index
$r_{ij(k)}$	= depletion index for source i in import region j

The closer the indicator I_{1-4} will be to 100% the better the supply security will be. Differences between the indicators (stepwise) indicate for the change of the added effect. To show the effects of each indicator, a simplified example is shown in every step.

Step 1:
I_1 - Diversification of energy sources in energy supply

$$I_1 = -\sum_i \left(c_i^1 p_i \ln p_i\right) \qquad (3)$$
$$Max(diversity) = -\ln\left(1/M\right) \qquad (7)$$

Indicator 1 views the diversity throughout variety and balance in energy sources. The higher this diversity, the better the energy supply security will be. This indicator will be better when shares between different sources are more balanced or when more different sources are used. The correction factor c_i^1 in this case will be equal to unity because no corrections are necessary at this step.

Example one[20]:
4 sources – Oil, Gas, Coal, Nuclear

Source	Case 1 (share on TPES)	Case 2 (share on TPES)
Oil	20%	25%
Gas	5%	30%
Coal	50%	20%
Nuclear	25%	25%

Table 2 Example one

Example case 2 is better balanced and therefore will have a higher I_1. Assumed in this example is that both countries use the same energy-sources and therefore variety is equal in both cases. When for instance Case 2 doesn't use nuclear energy this would have a large negative effect on the diversity.

Step 2:
I_2 - Diversification of imports with respect to imported energy sources

$$I_2 = -\sum_i \left(c_i^2 p_i \ln p_i\right) \qquad (4)$$
$$c_i^2 = 1 - m_i\left(1 - S_i^m / S_i^{m,\max}\right) \qquad (9)$$
$$S_i^m = -\sum_j \left(m_{ij} \ln m_{ij}\right) \qquad (10)$$
$$S_i^{m,\max} = -\ln\left(1/N\right) \qquad (11)$$

Indicator 2 views the diversity, corrected for import dependence. The lower the share of net imports on the PES of source i, the lower the correction will be for import dependence of source i. All sources together will influence indicator 2 according to their share on TPES. The larger the share on the TPES, the larger the impact of its import dependence will be.

[20] Examples consist of fictional numbers to illustrate the effect of the model

Example two:
4 sources – Oil, Gas, Coals, Nuclear

Source	Share on TPES	Case 1 (import)	Case 2 (import)
Oil	25%	80%	20%
Gas	30%	60%	10%
Coal	20%	80%	0%
Nuclear	25%	40%	0%

Table 3 Example two

Example case 2 consists of a lower import share and therefore the correction compared to indicator 1 will be less than made in Case 1. Therefore the energy supply security will be considered better in Case 2. In this example two extremes are taken. Also the share per energy source will be of influence on the power of the correction made with indicator 2, in this example equal shares per source are used.
If for instance the share of oil on TPES is 2% with an import share of 100% this will be of a low influence on the indicator.

Step 3:
I_3 - Long-term political stability in regions of origin

$$I_3 = -\sum_i \left(c_i^3 p_i \ln p_i \right) \quad (5)$$
$$c_i^3 = 1 - m_i \left(1 - S_i^{m*} / S_i^{m*,\max} \right) \quad (12)$$
$$S_i^{m*} = -\sum_j \left(h_j m_{ij} \ln m_{ij} \right) \quad (13)$$
$$S_i^{m*,\max} = -\ln(1/N) \quad (14)$$

Indicator 3 views the diversity, corrected for import dependence and political stability. The higher the political stability of the region/country j of origin of source i, the lower the correction and accordingly the vulnerability will be for importing this source.

Example three[21]:
Source - Oil

Region	Share on total imports	Human Development Index
Russia	25%	0.785
Brazil	30%	0.852
Iran	20%	0.342
Venezuela	25%	0.695

Table 4 Example three: Case one

[21] Used HDI numbers are fictive and for illustration only

Region	Share on total imports	Human Development Index
Canada	25%	0.965
Australia	30%	0.910
Europe	20%	0.920
Mexico	25%	0.755

Table 5 Example three: Case two

Example case 2 consists of import regions with higher HDI's, assuming this indicates a higher political stability, therefore making Case 2 its energy supply security less vulnerable for disruptions based on socio-political stability.

Step4:

I_4 - Depletion rate of the resource base in regions of origin, including the home region itself

$$I_4 = -\sum_i \left(c_i^4 p_i \ln p_i\right) \qquad (6)$$

$$c_i^4 = \left[1-(1-r_k)(1-m_i)\right] * \left[1-m_i\left(1-S_i^{m**}/S_i^{m**,\max}\right)\right] \qquad (15)$$

$$S_i^{m**} = -\sum_j \left(r_{ij} h_j m_{ij} \ln m_{ij}\right) \qquad (16)$$

$$S_i^{m**,\max} = -\ln(1/N) \qquad (17)$$

$$r_{ij} = Min\left[\left(\frac{(R/P)_{ij}}{50}\right)^a ;1\right] \qquad (a \geq 1) \qquad (18)$$

Indicator 4 views the diversity, corrected for import dependence, political stability and depletion rate of energy sources. Reserves divided by production indicate the years to depletion. The higher this value, the lower the correction for the indicator on supply security for depletion will be. This correction is separated in import source depletion and the depletion of reserves in the home region. Only when the years to depletion are lower than fifty years there will be a correction for this source. Of course the share on TPES share and its share in imports are of important for the amount influence this depletion will have.

Example four:
The variable r_{ij} will be between 0 and 1 and therefore look similar as example three.

Concluding:

$$I_1 > I_2 > I_3 > I_4 \qquad (19)$$

The higher the change between the indicators, the bigger the impact of the new added correction variable is.

CHAPTER 5 Methodology

5.1 Implemented model

The following methodology has been based on the previous explained model *Designing indicators of long-term energy supply security, 2004*. It has been adjusted to the characteristics of this research. The difference in methodology from the original article is in the focus of energy source. This research in comparison to the original article solely focuses on gas as the energy source in stead of all the primary energy sources.

In the next part the indicators used for this research will be explained. The indicators are based on the Shannon Diversity Index. In a step-by-step process variables are added to the formula, including those for *import diversity, political stability of source countries and depletion rate*. (LNG).

c = [0,1], ranging from 0 (fully dependent) and 1 (fully independent)

In the article from ECN the indicators were designed to look at the total long-term energy supply security. In order to combine all energy sources. They were all observed separately and corrected for the share of the specific energy source on the total primary energy supply.

In this research is only looked at the gas supply security and in special the long-term gas supply security. Therefore no correction needs to be made for the share on total primary energy supply. Therefore the first step in the original articles is taken out. Nevertheless the formula for the remaining correction factors still gives a good indication whether import, long-term socio political stability or depletion for an individual country or region influences the gas supply security. The first step in the original article, share on TPES is used, has become redundant. The remaining correction factors still contain the same kind of information, but only for one source in this case.

Allowance for import dependence

This first correction factor gives a view to which extent a country is dependent on importing gas. This depends on the share of imports on the total gas supply and to which extent this share is balanced between the sources of origin.

$$c^1 = 1 - m\left(1 - S^m / S^{m,\max}\right) \tag{20}$$

$$S^m = -\sum_j \left(m_j \ln m_j \right) \tag{21}$$

$$S^{m,\max} = -\ln\left(1/N\right) \tag{22}$$

m = share of net imports in gas supply
m_j = share of imports in gas from region j in total gas supply
S^m = Shannon index of import flows
$S^{m,max}$ = Maximum value of Shannon index of import flows of gas (equal to …. For …regions of origin, excluding home region)
j = 1…N: index for (foreign) region of origin. A total number of N regions of origin are distinguished.

When the number of countries which one can import gas from is larger than one this gives the opportunity to spread the imports throughout two or more sources. When this opportunity to balance the import share per source of origin is used to the maximum no correction on security of supply is necessary (S^m/ $S^{m,max}$=1). Of course in reality this is usually not the case.

Allowance for import dependence and socio-political stability (source)
The second correction factor is an expansion on the previous correction factor. Only this time a correction is added due to socio-political stability. When gas is imported from a certain region its social en political stability is of influence whether this trade will be continued in the future or that disruptions may occur. This stability is measures throughout the Human Development Index (HDI). This contains data about the life expectancy at birth, literacy rate, education index, GDP per capita. These variables are considered to indicate human development. Assumed is that when a country is more developed it will also be more stable with respect to society and politics, therefore diminishing the probability for sudden gas supply disruptions.

$$c^2 = 1 - m\left(1 - S^{m*} / S^{m*,\max}\right) \quad (23)$$

$$S^{m*} = -\sum_j \left(h_j m_j \ln m_j \right) \quad (24)$$

$$S^{m*,\max} = -\ln(1/N) \quad (25)$$

S^{m*} = Shannon index of gas import flows, adjusted for political stability in regions of origin
$S^{m*,max}$ = Maximum value of aforementioned Shannon index (equal to …. For … regions of origin, excluding home region)
h_j = extent of political stability in region j, ranging from 0 (extremely unstable) to 1 (extremely stable)

When the HDI is at its best it will indicate a 1, which of course no county will have. The better the HDI, the lesser of a correction on supply security is needed. Therefore importing from countries with better HDI is considered better for supply security. The share of imports will determine the eventual effect of the socio-political stability on the total supply security. When the share of gas imports from a certain country is small, than its effect on the security of supply will be small and therefore inherently its socio-political stability will be of a lower influence.

Allowance for source depletion
The third and last correction factor is again an expansion on the previous correction factor using the depletion rate. In this case not only is looked at the Shannon index. The Shannon index is used for the import of gas. But in the case of having gas fields in the home country this of course will also be of influence for the security of supply. Therefore the home depletion rate is taken into account times the share of gas on total supply that is not imported. When home depletion rate become higher (faster depletion), a larger negative effect on the supply security is obvious. Due to the threshold of fifty years to depletion, only imports from sources with a lower "years to depletion" will invoke a correction on supply security.

$$c^3 = \left(\left[1 - (1 - r_k)(1 - m)\right] * \left[1 - m\left(1 - S^{m**} / S^{m**,\max}\right)\right]\right) \quad (26)$$

$$S^{m**} = -\sum_j \left(r_j h_j m_j \ln m_j \right) \quad (27)$$

$$S^{m^{**},\max} = -\ln(1/N) \qquad (28)$$

$$r_j = Min\left[\left(\frac{(R/P)_j}{50}\right)^a ;1\right] \qquad (29)$$

$S^{m^{**}}$ = Shannon index of import flows, adjusted for depletion
$S^{m^{**},\max}$ = Maximum value of aforementioned Shannon index
r_j = depletion index for gas in import region j
a = 2
r_k = calculated the same way as r_j

The following assumption must hold:
$c^1 > c^2 > c^3$ (30)

CHAPTER 6 Results

6.1 Results

To get the results as presented in this section data was used from the International Energy Agency, BP Statistical Review of World Energy and EUROSTAT to determine net gas import share of total gas supply, share of imports in gas from region and the United Nations Development Program using Human Development Indices for determining the social and political stabilities of the countries. The result of using this data in the suggested model is given in the table below.

Year	c1	c2	c3
2008	100,00%	100,00%	16,95%
2007	100,00%	100,00%	21,08%
2006	100,00%	100,00%	18,28%
2005	100,00%	100,00%	19,67%
2004	100,00%	100,00%	17,92%
2003	100,00%	100,00%	26,42%
2002	100,00%	100,00%	27,02%
2001	100,00%	100,00%	26,80%

Table 6 Results on correction factors

Correction factor 1 on the gas supply security for imports

$$c^1 = 1 - m\left(1 - S^m / S^{m,\max}\right) \qquad (20)$$

Due to the fact that The Netherlands is a net gas exporter the correction factor is 100% (m=0,00%), therefore no correction is made on the supply security.

Correction factor 2 on the gas supply security for imports and socio-political stability

$$c^2 = 1 - m\left(1 - S^{m*} / S^{m*,\max}\right) \qquad (23)$$

The same is applicable with the second correction factor, because of the use of the same variable *m*.

Correction factor 3 on the gas supply security for imports, socio-political stability and depletions of sources

$$c^3 = \left(\left[1 - (1 - r_k)(1 - m)\right] * \left[1 - m\left(1 - S^{m**} / S^{m**,\max}\right)\right]\right) \qquad (26)$$

The same is also applicable for the third correction factor, because of again the use of the variable *m*. Only now the depletion rate of foreign and domestic gas reserves is taken into account. Therefore the domestic depletion rate does have an influence. Due to the Dutch their self-sufficiency the depletion rate influences the correction factor significantly. Noticeable is the fact that the depletion rate has worsened over the past eight years, with the exception of

the year 2007.[22] Over the past 8 years the proved reserves have become smaller. The production rate has not been very stable
Nevertheless in 2008 an exceptionally high production rate was noticeable and would concur with the high correction in the model.

Solely looking at the correction factors, one would conclude The Netherlands is not dependent on imports and therefore not dependent on the social and political events in countries of origin. Only the home depletion rate is of a large influence and has gradually worsened over the past decade. Concluding the supply security according to this model has only been at stake considering the depletion of home country sources, which in 2008 predicts total depletion (assuming no changes in reserves and production rate) will occur in 20 years.

Year	1[23] (S/Smax)	Δ_{1-2}	2[24] (S*/S*max)	Δ_{2-3}	3[25] (S**/S**max)
2008	47,15%	5,00%	42,14%	23,89%	18,25%
2007	47,31%	4,63%	42,68%	26,48%	16,19%
2006	48,88%	3,77%	45,11%	31,33%	13,78%
2005	48,76%	3,87%	44,89%	30,29%	14,60%
2004	45,15%	3,82%	41,33%	24,61%	16,72%
2003	44,43%	3,64%	40,80%	24,92%	15,88%
2002	36,06%	3,51%	32,56%	11,23%	21,33%
2001	26,33%	1,91%	24,42%	10,27%	14,16%

Table 7 Results on Shannon Index (used formula 21, 22, 24, 25, 27 & 28) [26]

But has the risk for supply security being breached really been that small as resulted by from this model? After taking a closer look at the results within the model a different perspective is shown. Looking at the table above some additional conclusions can be drawn. This table also represent the results if the Netherlands were importing 100% of its gas in the current underlying import shares.
Beginning from the year 2001 there is a clear improvement considering import dependence (1) [27]. Because The Netherlands is actually net exporting this has no influence on the results of the total model.

Looking at socio-political stability (2) only a small added correction is made in every observed year. When you take a closer look at the difference between step one and step two, one notices an increasing difference, especially in the years 2002, 2007 and 2008. Between 2002 and 2007 this difference stayed almost the same. The stability of the countries of origin in total decreased after 2001, this is mainly due to the fact that Russia (HDI_{2002}=0.795) increased its share against the decrease in share of the UK (HDI_{2002}=0.936), which is more stable considered by the Human Development Indices. In the year 2007 and 2008 The Netherlands did not import from Denmark (HDI_{2006} = 0.952) any more and starting importing gas from Other Europe & Eurasia (HDI_{2006} = 0.814).

[22] Production decreased and proved reserves increased causing an improvement Also shown in appendix 2
[23] Shannon Index correction for import dependence
[24] Shannon Index correction for social and political stability
[25] Shannon Index correction for depletion rates
[26] Look at appendix 1 for input variables of the model
[27] The balance of import share improved and a larger number of sources was used (moving from 3 to 5)

Interesting to see in table 6, in the latter column (c3) only the depletion rate of the Dutch reserves are taken into account, due to the net exporting status, showing a worsening situation. Analysing the Shannon index (3) in the table above noticed is that only the depletion rates of the imported sources are taken into account, looking at formulas 27 and 28. This shows that the past two years (2007 and 2008) the depletion rates overall improved for the imported sources. Taking a closer look at the input variables, this is mainly due to the larger share of *Russia* and *Others Europe and Eurasia* and the smaller share of Germany and Denmark in the Dutch imports.

6.2 Conclusion

Concluding from this model, over the past eight years the supply security of the Dutch was good considering that import dependence and socio-political stability were of no influence. But the home depletion rate gradually worsened of the past eight years, therefore addressing the necessity of thinking ahead. Analysing whether other safety-nets improved except from being self-sufficient clearly shows that this is the case. The Shannon indices show an improvement for the balance and variety of imports. Social and political stability slightly decreased, but still stays at a high secure level. Taking depletion rates of imported gas into account shows a small improvement in past two years. These results also give a good view on how supply security can be improved by changing from importers and their amount of share.

Returning to the hypothesis of this research:

Hypothesis
H0: The supply security of gas in The Netherlands worsened over the past decade.
H1: The supply security of gas in The Netherlands stayed the same or improved over the past decade.

Prediction outcome answer: *Rejecting the Null-hypotheses, with respect to this model*

Looking at the models results *H0 can not be rejected!* Besides the usual arguments that gas is scarce and the world eventually will run out of gas, being self-sufficient this means supply security for the Dutch will worsen for the upcoming decade and has done so previous decade. Net importing countries will feel the negative effects even worse. Unless discovery of new gas fields growths quicker than the depletion rate, the trend of becoming more dependent will continue.

After taking a closer look at the supply security, the basis of securing supply for gas in the future improved due to fact that The Netherlands improved the balance and variety of imports and was able to even improve on depletion rate in the past two years with changing source countries. It is important to be prepared for a time when Dutch gas sources are depleted.

Therefore the predicted outcome for rejecting the null-hypothesis was wrong.

The current model suggests that the Dutch gas market will become more dependent due to depletion of home sources. The question remains whether this model covered all aspects considering supply security of gas for the Dutch gas market. This will be discussed in the next section.

CHAPTER 7 Discussion

7.1 Gas Balance Sheet

```
+ Production
+ Import
------------------------------
- Consumption
- Export
+/- Stock
```

Figure 8 Gas Balance Sheet

Considering the above scheme there are some critics on the used model for this research. In all cases Production and Imports should be the same as Consumption, Export and Stock (not to be mistaken with reserves). Several assumptions could be made trying to replicate reality considering these input variables.

Production

Considering production there is a limit to the speed at which gas can be retrieved from a reserve, therefore creating a maximum amount of production in a year. In a case of efficiency a reserve produces gas at a maximum when prices are high due to high demand (winter) and if possible would pump gas back in these facility when prices are low, shown in the figure 4.

This situation would suggest that in the winter when production is assumed at a maximum, there would be no opportunity to increase production unless other unused reserves/storages are used or more gas is imported.

Import & Export

Import and export are also important factors to consider. Contracts in gas import/export are usually set for a long period. This is to commit certain income and make investments in gas facilities and infrastructure profitable. Without even discussing the physical limitation these contracts makes it very hard to change the direction of gas flows in case of gas emergencies. In the case of importing gas, which is mainly though pipelines, a limitation due to capacity maximum is apparent. To fully profit from investments maximizing gas flows is preferred, therefore creating a certain inflexibility to increase supply in case of gas emergencies. Looking at the exports of gas from the Netherlands is also a delicate case. Because the Netherlands is bounded to their contracts and their reliability as a supplier and reputation in becoming a gas hub it is very important that they will always secure supply for their clients, making it very hard to decrease these flows in case of gas emergencies.

Being a gas hub also has some disadvantages if not dealt with appropriate. Being a gas hub means that the Dutch gas transport network will also be used more as a transit country. This puts even more pressure on the capacity of the network when investments in infrastructure are not parallel with the increase of usage of the network for the future.

Stock
This variable is for the residual gas production/imports when consumption and export is subtracted.

Consumption
The final variable to consider is consumption. Demand for gas is not very flexible; people will use gas to fulfil basic needs, like heating and cooking. Also gas is used in productions of large industries.
In the case of a gas emergency already discussed and assumed is that gas production and import is very difficult to increase immediately. This creates a conflict between consumption and exports. Export flows are determined by contract and considering EU regulation the Dutch will certainly lose some authority with respect to allocating gas in the future. Creating a possibility that consumption needs to be decreased in case of gas disruptions (depending on the caloric value). Affecting basic needs like transportation and cooking or affecting the industry which could be very expensive. Decreasing exports, enabling consumption to be unaffected, could damage relationships with clients for the future and even cause loss of income from exports in gas. Therefore a critical gas disruption or emergency forces a trade-off between diminishing consumption or exports.

In this case flexibility is the keyword. Flexibility is bounded by long-term contracts and physical limitations like pipeline and production capacity. This is not reflected in the used model. One of the reasons for this is the short term character of these problems. The model reflects long-term supply security. Nevertheless these short-term problems can be avoided, when disruption due to capacity problems of the gas transport network are anticipated with investments. The model used in this research only looks at gas supply security for the long term, not taking in account short term problems that could arise.[28]

[28] Appendix D shows the Gas Balance Sheet for The Netherlands

7.2 Shannon index

When the possible number of sources of import becomes larger, this influences the outcome and could give biased results. Mainly because there could be a good balance and variety, an increase of possible sources interpreted by this model results that balance and variety decreased.

$$c^1 = 1 - m\left(1 - S^m / S^{m,\max}\right) \quad (20)$$

$$S^{m,\max} = -\ln\left(1/N\right) \quad (22)$$

Discovery of gas in a new country could bias the correction factor, because this increases the outcome of formula (22), but does not decrease supply security for The Netherlands in reality. Due to this increase of the maximum, their will be a higher correction all ceteris paribus. Even when not importing from this new country the discovery could improve the supply security, because there is less competition due to the increase in supply for gas. This is not reflected in this model.

7.3 Human Development Index

The Human Development index is used as a proxy to indicate the level of social and political stability. But at what point does social and political stability cause gas disruptions? This is a rather arbitrary threshold. The way the formula is stated in this model, every decrease in the Human Development Index indicates a higher risk for social and political instability, which could cause higher risk for gas disruptions.
A suggestion would be to research the countries which have caused energy/gas disruptions and take a weighted average to determine a threshold for the HDI. Below this weighted average the social and political stability becomes a risk.

7.4 Transit countries

In the model transit countries are not taken into account. The original model does not use this as well. But as the literature and reality suggests the risk of transit countries interfering with gas supplies is apparent.
This problem is not as easy to fix as one would like. You would need data from gas flows per individual pipeline and through which country the gas travels.

$$S^{m*} = -\sum_j \left(h_j m_j \ln m_j \right) \quad (24)$$

Looking at formula (24) one would need to add an extra correction. To do this one could correct for share of supply flow through each transit country against the total amount of import from one source. The following formula needs to be used for this.

$$h_{t,j} = \sum_p \left(h_p s_p \right)$$

(31)

$h_{t,j}$ = weighted average HDI transit countries (t) total gas supply flows from original source (j)
h_p = average HDI transit countries of pipeline (p)

s_p = Supply flow of pipeline through transit country divided by the total supply from original source

$$c^2 = 1 - m\left(1 - S^{m*} / S^{m*,\max}\right) \tag{23}$$

$$S^{m*} = -\sum_j \left(h_j m_j \ln m_j \right) \tag{24}$$

After correction factor two a new additional correction factor for transit countries is added.

$$c^{tr} = 1 - m\left(1 - S^{m(t)} / S^{m(t),\max}\right) \tag{32}$$

$$S^{m(t)} = -\sum_j \left(h_{t,j} h_j m_j \ln m_j \right) \tag{33}$$

In this case when gas is transported with ships, transit countries can be avoided and no correction needs to be made ($h_{tr,j} = 1$). When pipelines to transport gas travel through more stable countries the correction will be lower. In the case of gas moving from a pipeline to its destination it will travel through several transit countries for the same share of a supply flow. More transit countries means higher risk. To determine the h_t you take the average HDI of these transit countries.

$$h_p = \frac{\sum_{tr} \left(h_{tr} \right)}{Q_p} \tag{34}$$

h_{tr} = HDI transit country (tr)
Q_p = Number of transit countries pipeline (p) moves through

Another suggestion to determine h_t would be to multiply the HDI's of the transit countries in a certain flow. In this case the more transit countries the gas flow travel through would mean that the correction will be higher. This complies with the literature which stated less transit countries means less risk of disruptions. One could argue whether different countries within the European Union are considered transit countries.

Lack of data bounds this part of the research to be investigated further.

CHAPTER 8 Summary & Conclusions

Gas is the worlds third most demanded and used fossil fuel, therefore being very important for the world economy. Demand for gas is growing globally. To meet demand investments need to be made to keep up. Gas is a scarce and ending commodity. If a country does not own the resources itself, this makes them dependent on other countries. To facilitate trade in gas, large infrastructures like pipelines and storage facilities have been build in the past and needs to be build in the future. The EU also wants to liberalize its internal gas market to facilitate gas trade. The EU mainly imports gas to meet demand. Only a few countries are able to provide gas by their selves. The Dutch for instance have large gas reserve, which can still produce gas for up to twenty years. Governments like that of the Dutch which used to own all gas related activities will play a more facilitating role in the future instead of an ownership role. Due to supply disruptions like the Russian-Ukrainian gas crisis, questions rise whether supply securities of EU countries, and in this case in special The Netherlands, are sufficient. The Dutch have been self-sufficient since 1963 due to the discovery of a large gas field in Groningen. In the beginning the Dutch played its role as a monopolist and earned super-normal profits. Nowadays they follow a more market orientated role. The Netherlands is also aiming at being *the* gas hub of north-west Europe in the future. To do this they invest in infrastructure and storage facilities, like the North Stream and LNG terminals on the Maasvlakte II.

Due to the liberalisation, scarcity and the possibility of gas emergencies/disruptions this research tried to find out whether The Netherlands its long-term gas supply security worsened or not in past decade. To do this a model from the Energy research Centre of the Netherlands is used (ECN). This model was used to indicate the supply security of all primary energy sources. Therefore the model needed a small adjustment for this research. The variety and balance of import share per source country on the total import of gas is measured to indicate the dependence on imports for The Netherlands. In next two steps also social & political and depletion rates are added to indicate the vulnerability of these imports.

At first sight, The Netherlands is totally independent from imports and therefore from social and political stability in supplying countries. Nevertheless they do import gas and also export their own gas. Due to their home depletion rates concluded is that the supply security worsened over the past decade. Because the production of gas is larger than the proven reserves per year, this is a logical conclusion. Taking a closer look at the input variables, shown is that variety and balance of the imports for The Netherlands improved over the past decade. Although the change was small, the social and political stability of these imports slightly decreased. This was mainly due to the change in gas supplying countries. Not importing from Denmark anymore and decreasing imports from Germany with respect to increasing imports from Russia and *Others Europe and Eurasia.* Due to this change the depletion rates of imports did improve significant.

Although the model did not cover all aspects of supply security, it does give a good indication for the long-term supply security. Nevertheless it is still important to look to other information besides a certain model to fully capture the essence of supply security.

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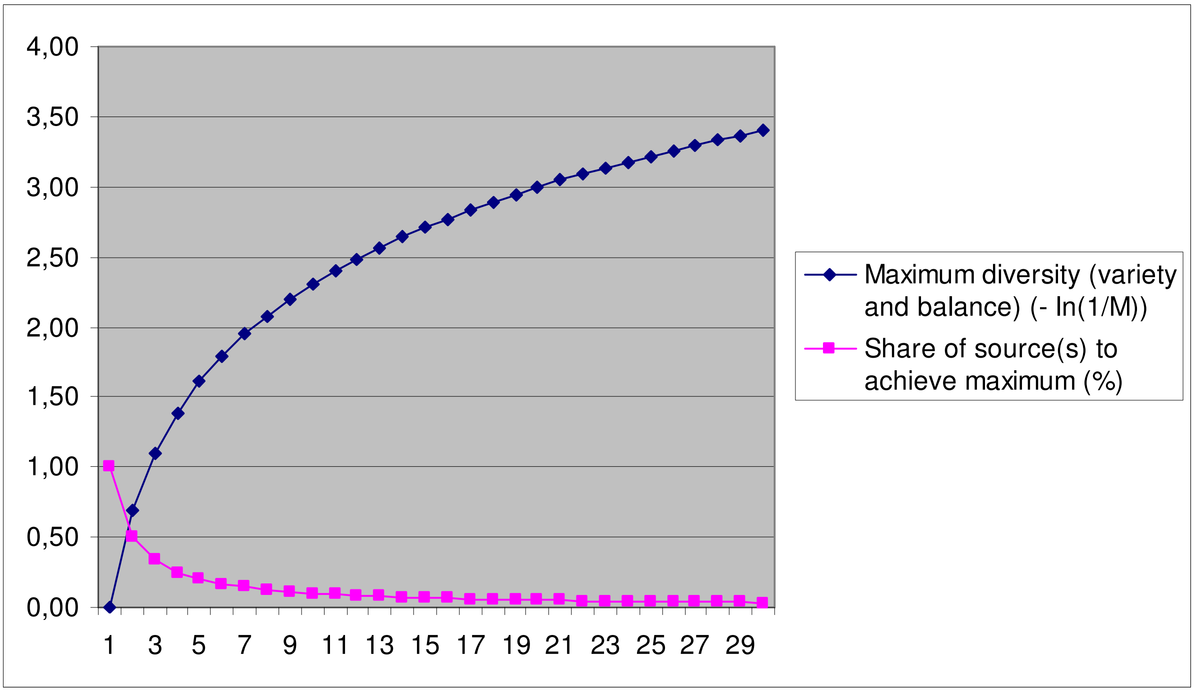
APPENDIX A

A closer look at the Shannon index



Graph 1 Shannon Index

When variety increases M increases, the maximum of the Shannon index increases as a results. This increase is decreasing. The purple line indicates the share of each source when shares would be in perfect balance.
The benefits of increasing source diversification are decreasing to a certain point that the diversification effect will be minimal. Knowing that the maximum amount of sources in the world lays around 22 countries, the maximal diversification point will not easily be reached (due costs of diversification: politics, technology and infrastructure).

APPENDIX B

Year (HDI)	2008	2007	2006	2005	2004	2003	2002	2001
Denmark			0,952	0,949	0,947			
Germany	0,940	0,940	0,940	0,938	0,937	0,935		
Norway	0,968	0,968	0,968	0,967	0,967	0,966	0,956	0,944
U.K.	0,942	0,942	0,942	0,944	0,942	0,937	0,936	0,930
Russia	0,806	0,806	0,806	0,801	0,802	0,797	0,795	0,779
Other Europe & Eurasia	0,814	0,814						
Average	0,894	0,894	0,922	0,920	0,919	0,909	0,896	0,884

Table 8 HDI Index[29]

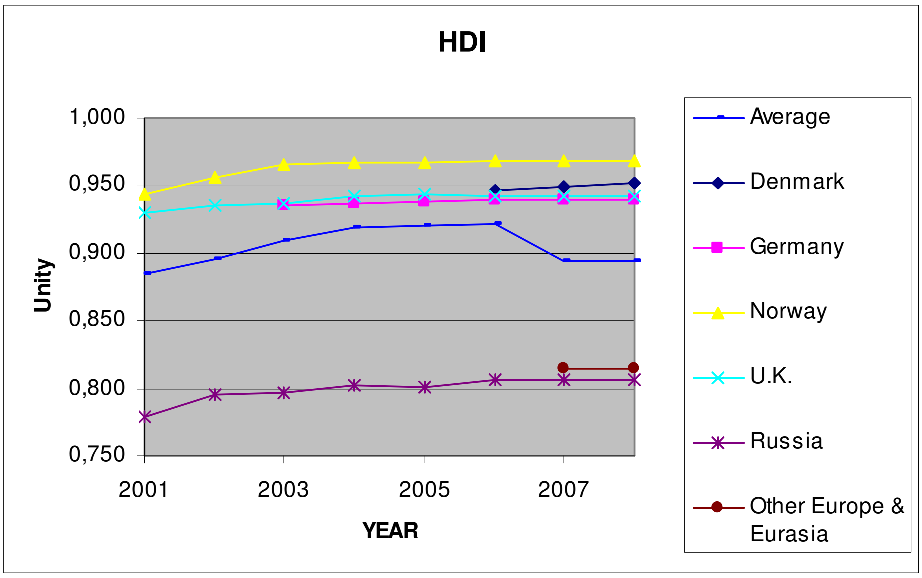
Year (share per region)	2008	2007	2006	2005	2004	2003	2002	2001
Denmark			0,121	0,121	0,019			
Germany	0,244	0,292	0,243	0,256	0,332	0,327		
Norway	0,346	0,371	0,378	0,350	0,318	0,224	0,343	0,419
U.K.	0,050	0,097	0,098	0,104	0,134	0,340	0,504	0,571
Russia	0,241	0,122	0,160	0,169	0,197	0,108	0,153	0,010
Other Europe & Eurasia	0,119	0,119						
Average	0,200	0,200	0,200	0,200	0,200	0,250	0,333	0,333
# Sources	5	5	5	5	5	4	3	3

Table 9 Import Shares

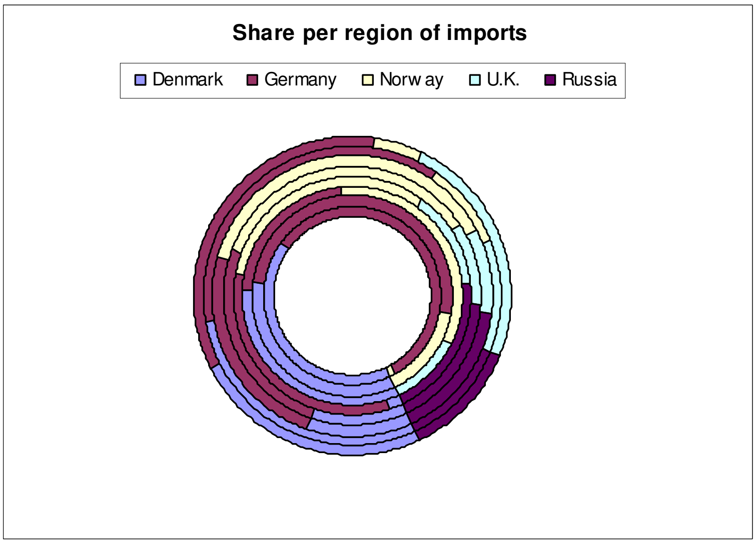
Year (R/P)	2008	2007	2006	2005	2004	2003	2002	2001
Netherlands	20,6	23,0	21,4	22,2	21,2	25,7	26,0	25,9
Denmark			11,5	11,7	14,0			
Germany	9,2	9,6	9,9	11,3	11,7	11,7		
Norway	29,3	32,1	33,0	35,4	40,3	43,6	56,0	71,1
U.K.	4,9	4,8	5,2	5,5	8,6	8,8	9,6	10,4
Russia	72,0	73,2	72,9	74,6	75,5	77,4	78,9	80,5
Other Europe & Eurasia	43,2	40,1						
Average	31,7	32,0	26,5	27,7	30,0	35,4	48,2	54,0

Table 10 Depletion rates

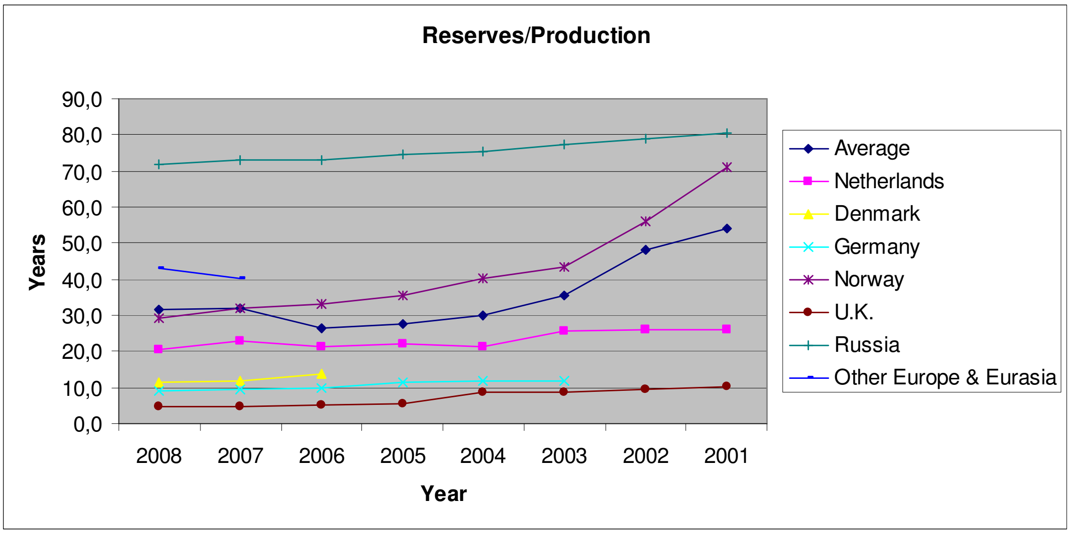
[29] For the years 2008 & 2007 the HDI of 2006 is used, due to unavailable statistics. HDI for Central and Eastern Europe and the CIS is used to indicate socio- and political stability for *Other Europe & Eurasia*



Graph 2 HDI Index



Graph 3 Share per region of import



Graph 4 Years to depletion

APPENDIX C

Natural Gas: Proved reserves								
Trillion cubic metres	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Netherlands	1,62	1,57	1,49	1,45	1,39	1,32	1,39	1,39
Denmark	0,14	0,13	0,14	0,13	0,12	0,12	0,07	0,06
Germany	0,24	0,22	0,21	0,19	0,18	0,16	0,14	0,12
Norway	3,83	3,67	3,19	3,16	3,01	2,89	2,88	2,91
United Kingdom	1,10	1,00	0,91	0,83	0,48	0,41	0,34	0,34
Russian Federation	42,35	42,53	43,44	43,26	43,28	43,27	43,32	43,30
Other Europe & Eurasia	0,45	0,43	0,42	0,42	0,43	0,43	0,43	0,44
Natural Gas: Production *								
** Excluding gas flared or recyled.*								
Billion cubic metres	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Netherlands	62,4	60,3	58,1	68,5	62,5	61,6	60,5	67,5
Denmark	8,4	8,4	8,0	9,4	10,4	10,4	9,2	10,1
Germany	17,0	17,0	17,7	16,4	15,8	15,6	14,3	13,0
Norway	53,9	65,5	73,1	78,5	85,0	87,6	89,7	99,2
United Kingdom	105,8	103,6	102,9	96,4	88,2	80,0	72,1	69,6
Russian Federation	526,2	538,8	561,4	573,3	580,1	593,8	592,0	601,7
Other Europe & Eurasia	11,0	11,3	10,7	11,1	10,7	11,5	10,8	10,3
Natural Gas: Depletion Ratio								
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Netherlands	25,886	25,988	25,701	21,167	22,177	21,375	22,958	20,586
Denmark	16,822	15,389	17,075	13,997	11,678	11,523	7,481	5,451
Germany	13,910	13,182	11,702	11,668	11,263	9,928	9,628	9,181
Norway	71,119	55,984	43,597	40,260	35,392	33,009	32,098	29,305
United Kingdom	10,394	9,633	8,798	8,572	5,455	5,152	4,759	4,928
Russian Federation	80,482	78,939	77,382	75,454	74,600	72,867	73,170	71,968
Other Europe & Eurasia	40,427	38,329	39,447	37,965	40,133	36,998	40,112	43,162

Table 11 Natural gas proved reserves & Depletion Ratios

APPENDIX D

Million tonnes oil equivalent	2008	2007	2006	2005	2004	2003	2002	2001
Gross Inland Consumption	**34,724**	**33,396**	**34,300**	**35,324**	**36,745**	**35,998**	**35,842**	**35,547**
Final Consumption	unknown	18,453	19,722	19,844	21,149	21,226	20,551	21,116
Industry	unknown	5,378	5,534	5,751	5,993	5,905	5,369	5,358
Transport	unknown	0,001	0,001	0,000	0,000	0,000	0,000	0,000
Other Sectors (households, agriculture)	unknown	13,074	14,187	14,093	15,156	15,321	15,182	15,758
Total Production	**60,769**	**54,833**	**55,436**	**56,265**	**61,585**	**52,212**	**54,275**	**55,713**
Primairy Production	unknown	54,759	55,395	56,265	61,585	52,212	54,275	55,713
Recoverd products	unknown	0,074	0,041	0,000	0,000	0,000	0,000	0,000
Import	**unknown**	**18,438**	**18,042**	**16,440**	**13,502**	**18,256**	**19,175**	**15,321**
Export	**unknown**	**39,895**	**39,173**	**37,381**	**38,362**	**34,460**	**37,624**	**35,495**
Total Stock Change	**unknown**	**0,019**	**-0,004**	**-0,001**	**0,020**	**-0,010**	**0,017**	**0,006**
Total Primairy Gas Supply (TPES)	**33,395**	**33,395**	**34,301**	**35,323**	**36,745**	**35,998**	**35,843**	**35,545**
Total Net Import	**-21,457**	**-21,457**	**-21,131**	**-20,941**	**-24,860**	**-16,204**	**-18,449**	**-20,174**
Supply side	unknown	73,271	73,478	72,705	75,087	70,468	73,450	71,034
Demand side	unknown	73,291	73,473	72,705	75,107	70,458	73,466	71,042
Difference	unknown	-0,020	0,005	0,000	-0,020	0,010	-0,016	-0,008

Table 12 Results for Gas Balance Sheet[30]

Table 12 shows a somewhat stable gas balance sheet. Consumption by households and agriculture shows a small decrease. Export shows a small increase.

[30] TPES and Total Net Import (2008) are assumed the same as the previous year (2007), due to lack of data