University of Stavanger

Faculty of Science and Technology

MASTER'S THESIS

Study program/ Specialization: Offshore Technology / Industrial Asset Management	Spring semester, 2013 Restricted access
Writer: Eric Lywood Risa	……………………………………… (Writer's signature)
Faculty supervisor: Jayantha Prasanna Liyanage External supervisor(s): Audun Brandtzæg (Gassco), Helge Nesse (IKM Ocean Design)	
Title of thesis: Norwegian Pipeline Gas from an Asset Management Perspective: Present and Future	
Credits (ECTS): 30	
Key words: Natural Gas, Gassco, Gassled, Energy, Strategy Map	Pages: 221 + enclosure: 4 Stavanger, 14-06/2013 Date/year

GASSCO

IKM Ocean Design

University of Stavanger

Present and Future

Norwegian Pipeline Gas from an Asset Management Perspective

Eric Lywood Risa

Abstract

With the growth of demand for new energy, natural gas was predicted to be in a golden age, where the energy commodity would act as a transitional energy source (due to its low emission) towards greener energy goals within EU countries. This prediction is losing ground, especially in the short term, where low American coal prices and EU recovering from financial turmoil is affecting the predicted demand for the natural gas, which is relatively expensive under the current pricing policies and practices.

Norway is one of the leading natural gas exporters in the world, serving a large portion of Europe's energy demand through its subsea gas pipeline infrastructure. In light of not only global uncertainty, but also with respect to the potential market position, a major question of commercial interest is that what types of challenges are present in a specific critical downstream asset such as a subsea natural gas pipeline when striving to uphold the position as leading gas supplier to Europe. This is also a question of future opportunities in the ongoing energy debate despite the current economic conditions.

This thesis, based on a Case study on a section of the large gas transportation infrastructure, examines a wide range of multiple challenges ranging from conflicts of interests between owners and other stakeholders, to the physical third party damages, all of which could possibly challenge and pose a risk for the reliability and future demand for Norwegian gas. It elaborates on the current and future threats/challenges when striving for optimal asset availability.

Acknowledgements

I would like to express gratitude to Audun Brandtzbæg (Gassco) and Helge Nesee (IKM Ocean Design) in their general guidance whilst performing my thesis. Highlight should be due on the fact that the report does not represent Gassco nor IKM's vision or attitude towards certain topics within this thesis. All assessments and conclusions are derived from my own research on the basis of primarily public information.

In addition I would like to express my very great appreciation to my advisor Professor Jayantha Prasanna Liyanage for giving me the freedom to explore whilst aiding in valuable and constructive feedback throughout the process.

And finally, a special gratitude is due to my partner and fiancée, May Kristin Figved who has shown patience and understanding throughout my studies.

Acronyms and abbreviations

ALARP	As Low as Reasonably Practicable
AUV	Autonomous Underwater Vehicle
BarA	Absolute Pressure
BCM	Billion Cubic Meters
BTU	British Thermal Unit
CP	Corrosion Protection
DFI	Design, Fabrication and Installation
ESV	Emergency Shutdown Valve
GNG pipeline	Generic Natural Gas Pipeline
GVI	General Visual Inspection
ICS-CERT	Industrial Control Systems Cyber Emergency Response Team
IMR	Inspection, Maintenance and Repair
KP	Kilometer Post
KPI	Key Performance Indicator
LNG	Liquefied Natural Gas
MPE	Ministry of Petroleum
MSm^3	Million Standard Cubic Meters
MTOE	Million Tonns of Oil Equivalent
NCS	Norwegian Continental Shelf
NOK	Norwegian Krone
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PJ	Petajoule
PRS	Pipeline Repair System
ROV	Remotely Operated Vehicle
SDFI	The State’s Direct Financial Interests
TBTU	Trillion British Thermal Units
TCF	Trillion Cubic Feet
TIGER	Transport Infrastructure for Gas with Enhanced Resolution
TSP	Technical Service Provider
TWh	Terawatt hours
UCAV	Unmanned Combat Air Vehicle.

Conversion Table

Base Unit	Alternative unit	Alternative unit	Alternative unit
1 NOK	0.17 USD	0.13 EUR	
1 Inch	25.4mm		
1 Bcm	35.31 Tbtu	0.035 Tcf	0.8306 Mtoe
	11 TWh	38.74 PJ	

Contents

Figures

Tables

1. Introduction

1.1 BACKGROUND

Our modern world needs energy in order to fuel society. Families require heating and industries need operational machines. Our western civilization especially, has an unprecedented reliance to energy in order to function properly. Therefore a nation's wellbeing and efficiency is often tied to its ability to supply reliant and a sufficient amount of energy to its citizens and industries.

Throughout time, new energy commodities have been adopted in order to feed this demand. Ranging from the implementation of large scale coal utilization during the industrial revolution in the 1800's, to the development of petroleum as a main energy product in the early 1900's, followed shortly by natural gas.
By continuously adopting new sources, old energy commodities never completely disappeared but where rather further developed in order to increase their effectiveness. Together the various sources of energy constitute what is often referred to as an energy mix.

The various mixes of energy are all different depending on region and individual nations, where political forces are often the underlying backbone of how the individual energy mixes are composed. This in the means of what type of infrastructure, agreements and political incentives have been granted and funded by the political forces present in order to promote/demote various energy commodities.

In order to provide reliable energy to the localized national energy markets, most countries would like to be as energy self sufficient as possible. In the 1970's the United States saw domestic oil production falling, thereby forcing an increase in overseas oil supply. This dependence on foreign oil meant that the US became vulnerable. An example was the oil embargo of 1973 from the OPEC nations, leading to oil prices quadrupling, causing huge disruptions in local US markets. Consequently, somewhat forced close US ties to large oil suppliers in the middle east has resulted in a political burden for decades. US energy independence has as a result of this burden been their wholly grail ever since (Mann, 2013).

As the US in the 1970's saw their localized resources becoming depleted, most large westernized countries in turn also experienced the same.
Subsequently, energy dependencies to foreign suppliers have grown over the past years.

Norway, a large oil and gas nation, is such an energy provider for many European nations in the means of Natural gas. Through its extensive gas infrastructure and export capacities, Norway supplies a substantial part of European natural gas demand and consumption.

From 1977s, when the Norpipe gas pipeline became operational between Ekofisk and Emden, Norwegian gas infrastructure has been continuously developed and maintained in order to transport natural gas to shore for processing, and export to foreign buyers.

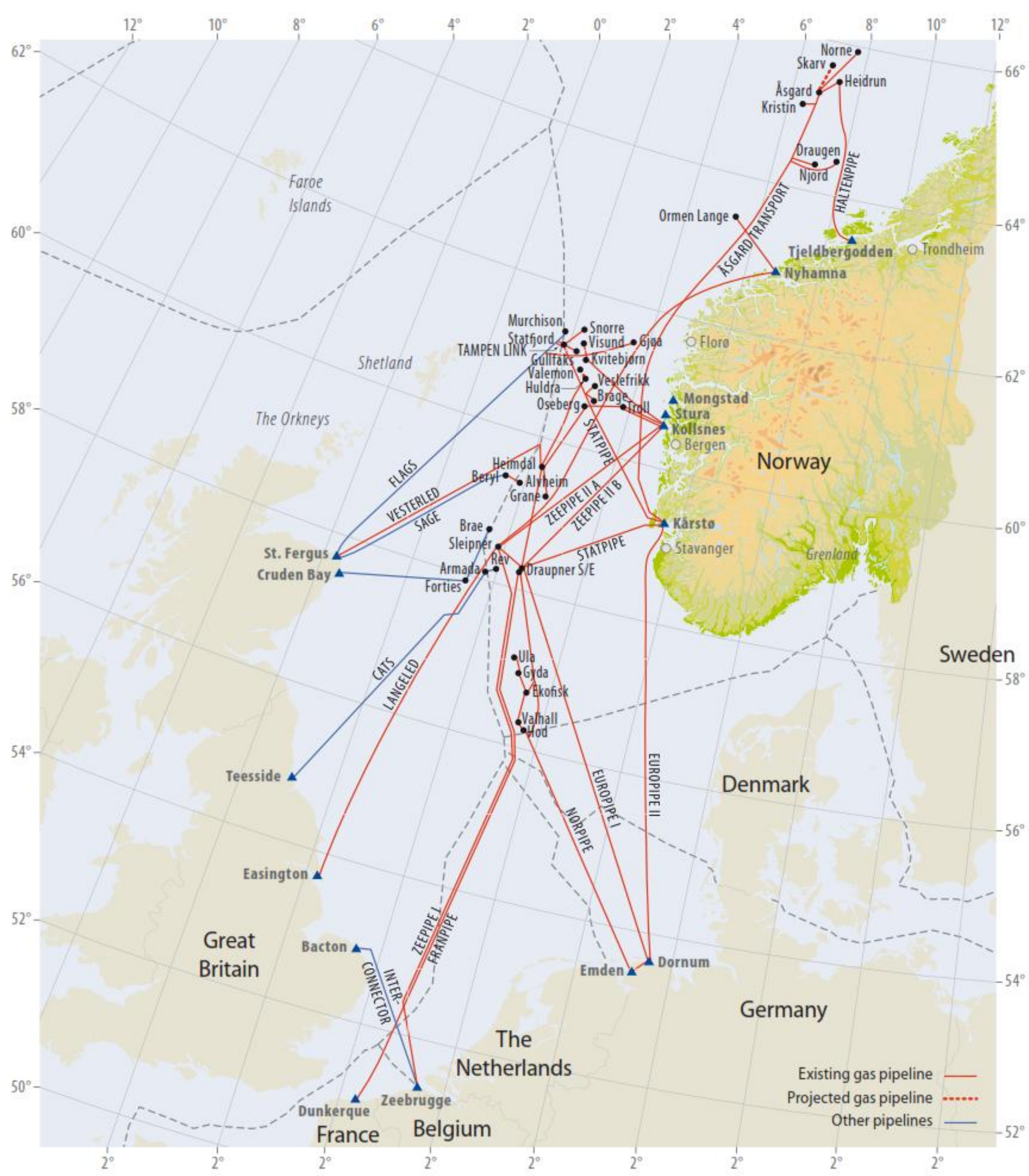


Figure 1-1 Norwegian natural gas pipeline infrastructure (NPD, 2012)

As the above image depicts, all red lines, are pipelines operated by Gassco, a Norwegian state owned company. Together, the pipeline infrastructure is the largest of its kind in the world, encompassing a total of 7800km of mostly subsea pipelines.

In the mid 1990's global energy demands had increased by 21% over the previous 15 years, and in the same period, natural gas demand was up 46%, predicted to increase rapidly another 30-40% (Appert, 1998). A golden age for natural gas was predicted.

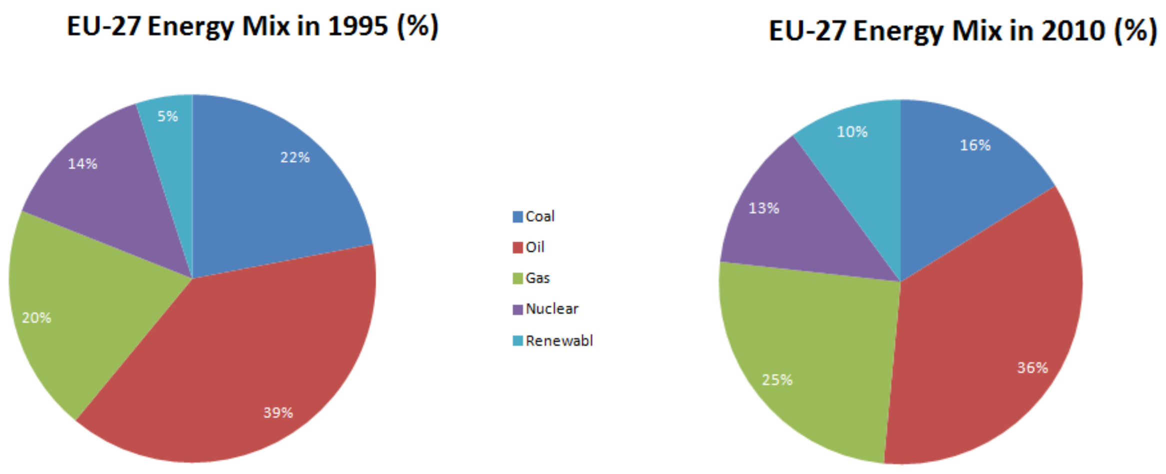


Figure 1-2 European energy mix, 1995 compared to 2010 (source: European Union, 2012)

Today's European scenario is slightly different from what was projected. Europe is in harsh economic turmoil in the aftermath of the 2008 financial crisis, resulting in a need for cheap and reliable energy in order to create value within its borders.

Energy demands are modestly growing, and the European energy mix is changing. Times are uncertain. Historical data leading up to 2010 saw gas sales increasing. From Figure 1-2, one can see that gas consumption in EU increased in 1995 to 2010 on the expense of oil, nuclear and coal energy (as predicted).
But recent studies have introduced a lot of uncertainty within the natural gas markets.

Leading up to 2010 natural gas saw a positive consumption growth, but has fallen the past years following 2010, dropping 11% in 2011 compared to 2010. The same negative trend is further present, with third quarter 2012 seeing the lowest quarterly consumption the past decade, down 6% from same period 2011 (Figure 1-4). The historic low can be related in conjunction with a EU recession period in Q2 & Q3 2012 (Figure 1-3).

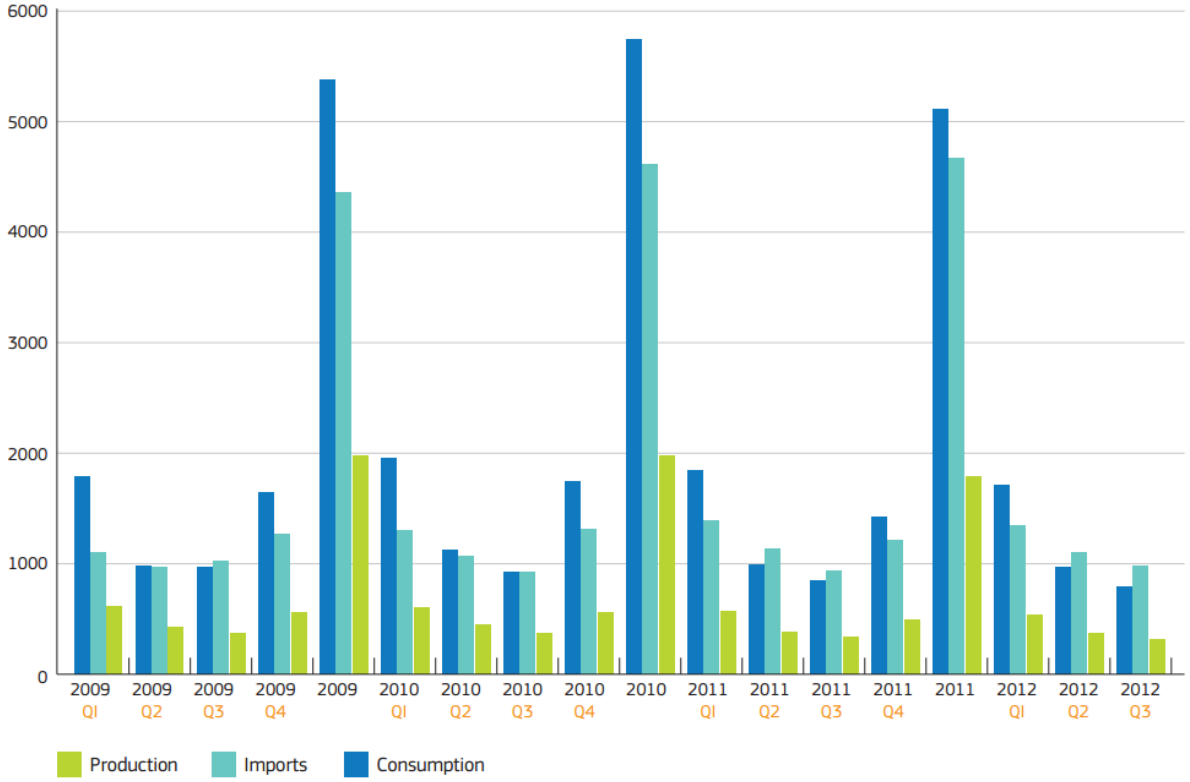


Figure 1-4 EU 27 Gas Consumption, imports and production (in TWH) (DG, Energy 2012)

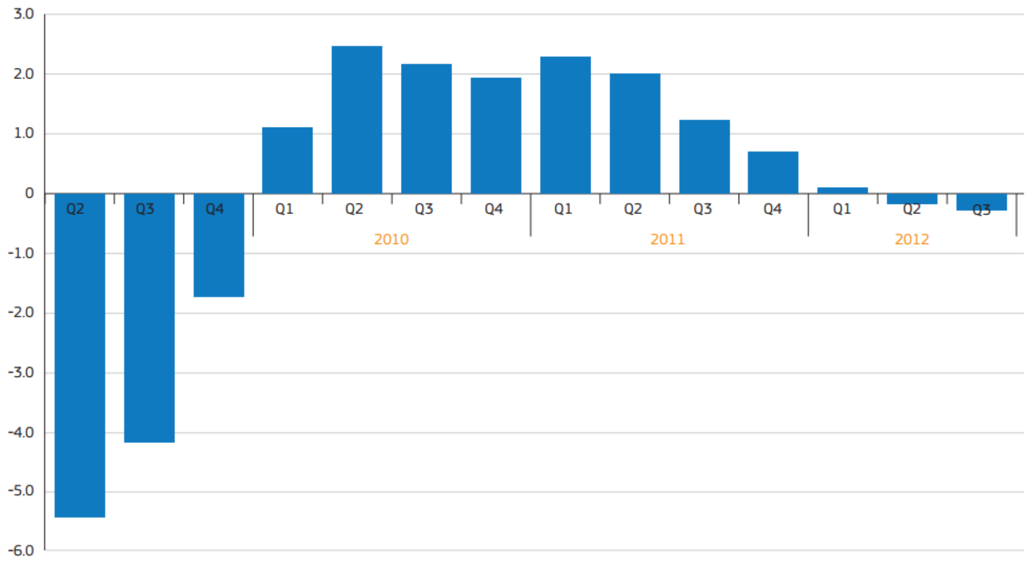


Figure 1-3 EU 27 GDP Q/Q-4 Change (%)(DG, Energy 2012)

Although EU financial problems can in part explain lower natural gas consumption, there are other factors in which have most likely made natural gas less attractive by European Power utilities the past few years.

Energy has throughout the past years become easier to move. Examples are coal and LNG which are relatively simple to transport over longer distances, versus pipelined dry gas, that tends to be more localized around a certain market.

Consequently, energy markets are becoming more volatile, whereby trade flows of energy commodities (gas, coal etc.) are being directed to where the asking price and demand is the highest (DG Energy, 2012).

As an example, recent new technologies have allowed huge, large scale US unconventional shale gas reserves to become economically viable. Subsequently, Americans are enjoying was has been dubbed "the shale gas revolution", where they are the moment producing so much gas, that US natural gas prices are a below a third of its price than that in Europe (Figure 1-5).

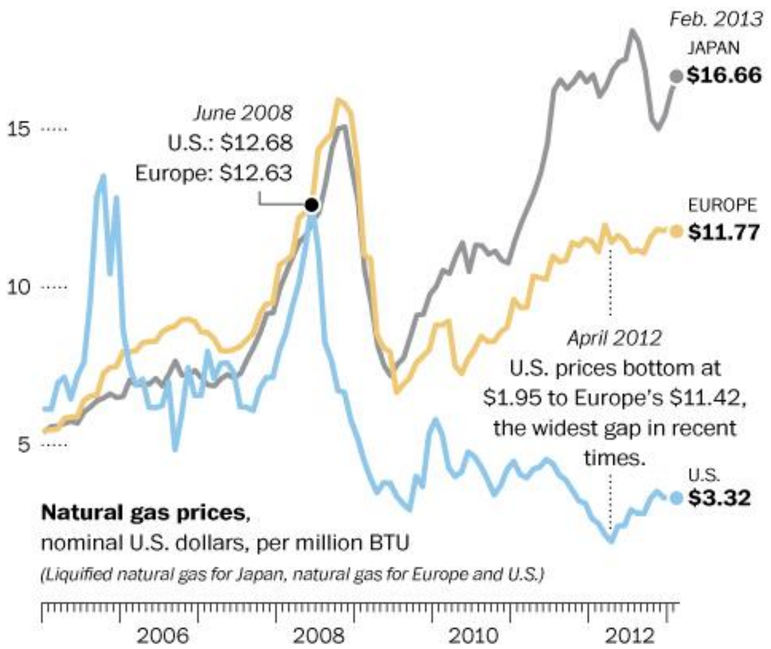


Figure 1-5 Natural gas prices (Binbaum, 2013) Source: World Bank Commodity Markets

A result of such cheap energy, is that as US companies switch from oil and especially coal, to cheap natural gas, US energy producers (especially coal producers) are having to find buyers elsewhere. The excess coal in the local US market is being exported to amongst others Europe, at relatively low prices compared to the local European natural gas prices.

"The relative price of coal and gas is crucial to the health of European utilities. At the beginning of November 2012, according to Bloomberg New Energy Finance, a research firm, power utilities in Germany was set, on average, to lose €11.70 when they burned gas to make a megawatt of electricity, but to earn €14.22 per MW when they burned coal."(The Economist, 2012a)

Consequently, Figure 1-6 shows, not only is the aggregate coal import to EU substantially higher the past years, but specifically coal from the US has steadily increased, actually doubling since 2009 periods.

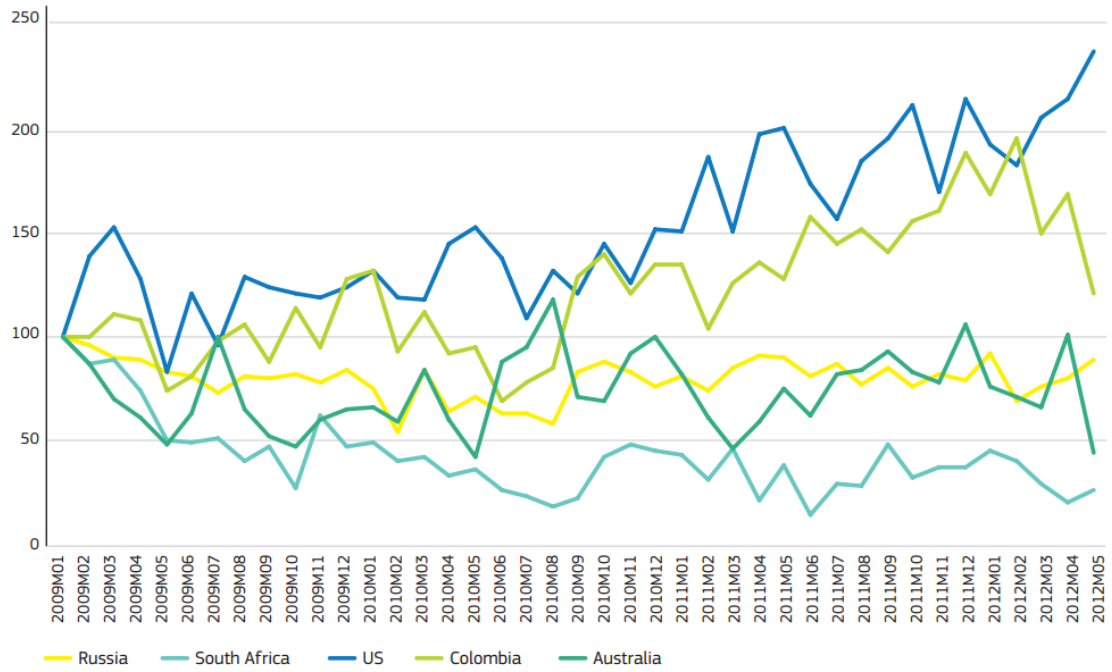


Figure 1-6 EU 27 origin of Hard coal imports (index, January 2009 =100) (DG Energy, 2012)

Comparing spot prices between coal, gas and oil in Europe, Figure 1-7 shows how, as oil and gas prices have steadily risen since 2010, coal prices have declined further increasing the relatively dirty energy source's (compared to natural gas) attractiveness in a struggling Europe.

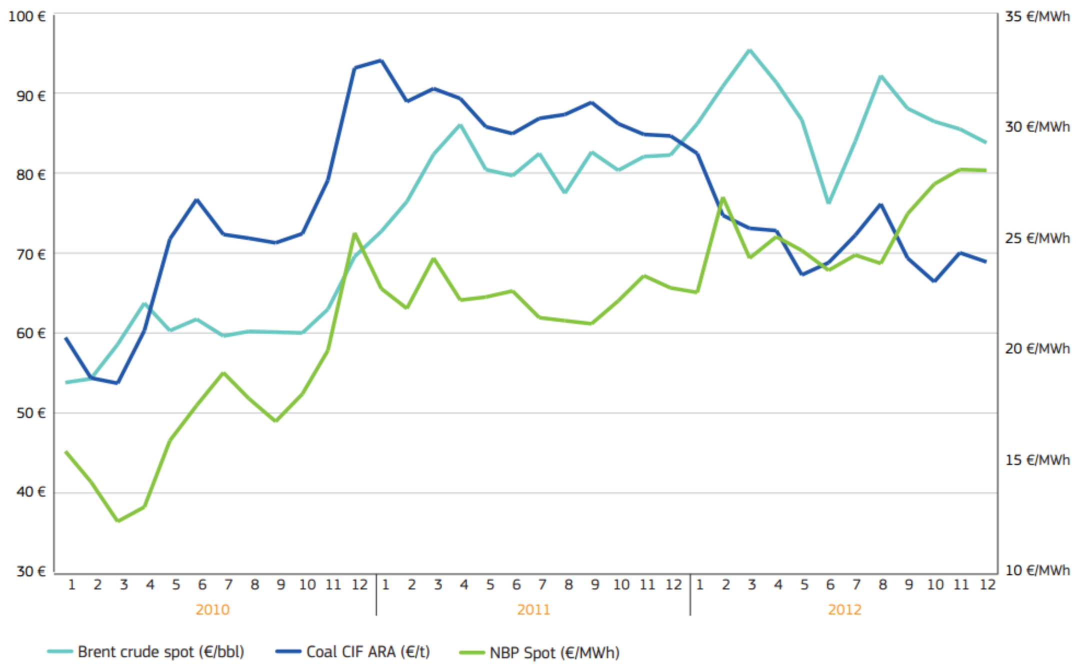


Figure 1-7 Average monthly spot prices of selected energy commodities. (DG Energy, 2012)
Left scale: Oil (Brent, €/bbl) and coal (CIF ARA €/tonne) Right scale: Gas (UK NBP, €/bbl/MWh),

Europe's ultimate goal is to as energy self-sufficient as possible through green renewable sources such as wind, solar and wave energy. By 2050 carbon emission should be reduced by 80%. For short term goals, EU has set carbon emission reduction targets by 2020 known as the "20-20-20" targets, (encompassing amongst others reducing greenhouse gas emission by 20% compared to 1990 levels). Pressure to utilize energy sources with low carbon emission in order to meet both short and long terms goals are high. Increasing coal consumptions is not aligned towards any of these goals. Roughly speaking, coal produces double the amount of carbon dioxide compared to natural gas when burned to produce power (Mann, 2013).
Due to this fact, natural gas (and not coal) has over long time been thought to be the transition energy source of choice in order to attain short term emission goals, towards a time where renewable energies will constitute the major share within the European energy mix.

Along with European gas demands and factors which affect its price, reliable Norwegian gas supply, specifically priced at competitive prices, will be some one of the key factors in keeping Norwegian gas a key supplier of low emission energy to Europe, whom for the moment seems to value costs above carbon emissions.
In order to facilitate such competitiveness, handling Norwegian pipeline assets in a proficient manner in the coming years will be imperative.

Asset management is a discipline in which draws elements from multiple areas of an asset such as financial, technical, operations and maintenance management (IAM, 2012) in order to improve and maintain long term expert performance of the asset as a whole (thus including relevant stakeholders such as shareholders, owners, buyers etc.).

A draft ISO definition of Asset Management is: "*the coordinated activities of an organization to realize value from its assets*" (IAM, 2012).

The term asset management is often correlated with specific fields, such as financial services, infrastructural asset management or physical asset management. None of which individually nor together describe what asset management delves in to.

According to the Institute of Asset Management (IAM, 2012), good asset management:

- Should be 'enterprise' wide
- Applies to asset owners, managers and those with delegated management responsibilities
- Has to balance costs, risks and performance on different timescales
- Applies to tangible/physical and intangible assets
- Applies to public and private and not-for profit organization
- Will be strategic (aligned with the organizational strategy)

In order to strive for such overall goals on a broad matter, gaining a good understanding across the whole breadth of the knowledge base is thus crucial.

1.2 SCOPE & OBJECTIVES

Delving in to a large scale infrastructure as the Norwegian gas network, both from an above and technical point of is a daunting task. Instead, a single pipeline has been chosen to represent as a base value for the following thesis.
Due to political and company sensitivity of the nature of gas infrastructures, the specific pipeline will be from here on named Generic Natural Gas pipeline (GNG pipeline).

As an asset, a large infrastructural pipeline such as the GNG pipeline has high initial costs. But how should one best manage such an asset as to ensure optimal reliability, availability, maintainability and safety of the system in order to maintain gas as a reliable and attractive source of energy for Europe? In addition, how does one focus on mitigating and reacting to threats and seizing opportunities when they arise?

The scope encompasses the physical pipeline itself whilst also investigating factors which affects the value and condition of the pipeline not only currently, but also in the future. The scope also involves the organizational structure and how their routines are best applied in relation to the pipeline.

Information will mainly be gathered from publicly published articles and papers. In addition, regarding specific GNG pipeline information, Gassco will aid in providing further details and information through internal documents. As all other master thesis', my learning and understanding from the Offshore Asset Management master course at the University of Stavanger will be utilized across the board.

In applying a broad holistic approach of asset management as a discipline, certain limitations must be set in order to be able to complete the thesis within the time frame set (section 1.5).

All in all, the thesis is set to uncover the fundamentals, and not the intricate details, of the issues at hand in order to conform to the bullet points set by the Institute of Asset Management for good asset management (section 1.1).

1.3 STRUCTURE OF THE THESIS

Chapter 1. Introduction

The introduction chapter forms the basis for the thesis, as it describes both the underlying scenario and the direction in which the thesis will take.

Chapter 2. Status Quo

Status Quo describes to the broadest extent (within the realm of what is relevant for the thesis) the current condition and scenario in which the GNG pipeline positions itself in. The chapter delves further into aspects such as current and future energy trends, ownership structures, pricing structures, IMR, integrity management and the actual physical condition of the pipeline at present time.

Chapter 3. Threats & Challenges

In order to gain an understanding of both current and future threats and challenges, multiple factors in which affect the GNG pipeline are to be found, discussed and quantified in order to act as basis for chapter 4.

Chapter 4. Asset Management Strategy

On the basis of the threats/challenges uncovered, the chapter tries to converge all major stakeholders within the organization landscape around a single strategy. By utilizing strategy maps as a tool acting as a road map for long term value creation, inherent challenges, both long term and short term can be managed in an illustrative, systematic manner.

Chapter 5.Multiple Future Scenarios

Merely as a prediction, the chapter briefly describes multiple scenarios in which could become an eventuality and how the organization should adapt, based on the given threats and strategy previously discussed.

Chapter 6. Discussion

A short discussion regarding the thesis and possible future work the thesis lays a foundation for is highlighted.

Chapter 7. Conclusion

All data, discussions and applied methods culminate to a short conclusion regarding the material presented as a whole.

Chapter 8. References

Chapter enlists what the heading dictates.

Chapter 9. Appendices

Chapter enlists what the heading dictates.

1.4 METHODOLOGY

In order to gain a broad understanding across multiple disciplines and issues at hand, research has mainly been in the form of literature study of amongst other: books, journals, published articles, applicable standards et cetera,
The research began by attaining relevant contacts in Gassco in order to review the isolated case of the GNG pipeline through technical documents provided by Gassco contact.
By reviewing received documents, a bottom up approach was applied, where questions such as: who owns the pipeline, how does the tariff system in essence function, what are common physical pipeline threats based on relevant guidance's, drove the thesis look at a wide array of disciplines and issues in which affects the isolated GNG pipeline in both present and future scenarios. Once a full specter of subjects relevant for the GNG pipeline's condition was understood (within limitations), a risk evaluation based on personal opinions and those found within the literature, was performed in order to quantify the threats and challenges at hand.

The next step was to create a strategy based on the treats uncovered in order to attain long term value. In addition the uncovered factors where briefly applied to possible future scenarios and what outcomes could arise.

1.5 LIMITATIONS

As result of the extensive nature of the thesis and its interdependencies, certain limitation to the amount of research given to the individual issues at hand must be present. Especially in order to balance the necessity of critical information, whilst covering a large degree of factors to fully encompas the bulletpoints in which the institute of Asset Management deem necessary for good asset management (section 1.1).

Overall Limitations

Delving in to a large scale infrastructure as the Norwegian gas network, both from an above and technical point of view becomes a daunting task. Instead, a single pipeline has been chosen to represent as a base value for the following thesis.

Due to the essence of certain issues at hand, published articles will be to a large extent used. Such articles may hold a certain degree of bias, in which may be hard to fully expose. Consequently, if applicable, multiple references to different opinions will be highlighted if found, but no further research is to made in to the absolute "truth" of the published articles as long as the general consensus in the media is mutual on the subject.

Within the thesis and risk evaluation, the issue of extensiveness is limited to the author's personal judgment on the basis of facts and impressions gained from the research.

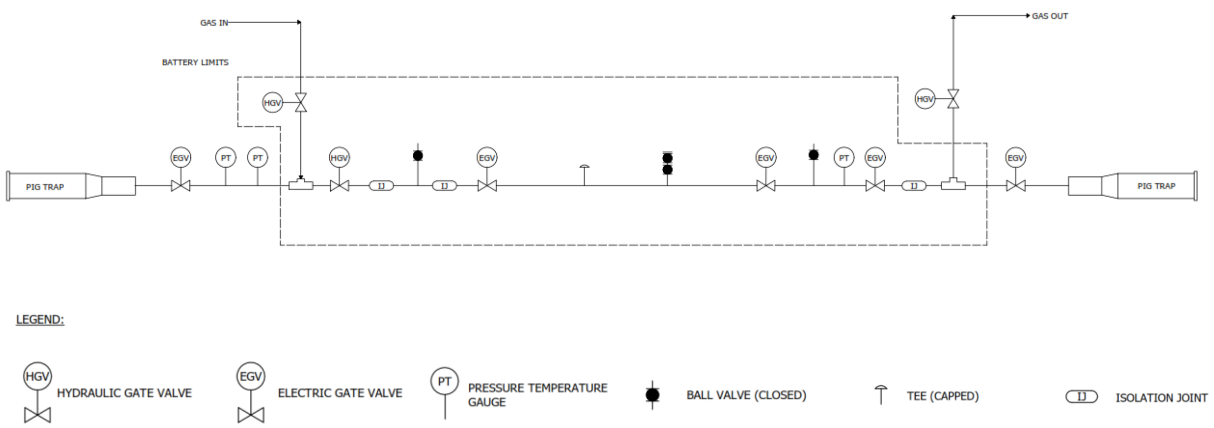


Figure 1-8 Physical Battery limits of simplified GNG pipeline Schematic. Data Source: DFI GNG pipeline

Physical Limitations

All physical aspects regarding threats are limited to the scope given within the dashed lines below:

Examples of issues not related, are for example, transmitting and receiving terminals, unplanned upstream shut downs et cetera.

Although the limitations are surrounding the physical GNG pipeline, it should again be highlighted that the specific case can viewed as a generalization of the many other pipelines encompassed within the Norwegian natural gas infrastructure.

It is assumed that all physical aspects before and after pipeline are fully operational.

2. Status Quo

In order to know where you are going, you must first know where you are. Following a top down approach, the subsequent chapters delve further into aspects affecting the specific GNG pipeline at hand. Some of the aspects within this chapter will be further covered in the consecutive chapter 3: "Threats and Challenges".

2.1 GLOBAL ENERGY DEMANDS

As the energy demand is predicted to further grow, uncertainty seems to be the common denominator in most energy markets of today. Transportation of energy between global markets has become increasingly common, resulting in a more globalized energy market. This has lead energy markets becoming more volatile whereby trade flows of energy commodities are being directed to where the asking price is the highest and where surplus energy is often exported instead of stored (DG Energy, 2012).

An event in one localized market will often affect the whole global energy market. Examples are abundant. Japan's nuclear Fukushima incident raised questions not only in Japan, but also in Germany regarding the safety of Nuclear power. Public opinion and politics were leading factors in a sharp decline of nuclear output in Japan (-44.3%) and Germany (-23.2%) (BP, 2012), thus forcing these nations to import energy from elsewhere in the global market. Japan's demand for non-nuclear energy resulted in LNG imports rising 11,2% from 2011 to 2012 (LNG-World News, 2013) leading to an increase in regional LNG gas prices.

The US has seen huge energy independence benefits in the wake of its shale gas revolution. Shale gas is a type of unconventional gas where instead of the gas migrating to permeable reservoir rock, the gas is trapped in low permeable shale, inhibiting the gas from migrating. In order to retrieve the shale gas, a controversial process of hydraulic fracturing, also known as fracking, is utilized. This process has recently become economically viable, meaning that there are vast amounts of energy suddenly available in the region. A direct result of this is their local coal demand is decreasing, meaning that their surplus production of coal needs buyers elsewhere. Germany for example, whom at the time is struggling with financial problems in the euro zone; see their energy needs being fulfilled by now available cheap US coal (in part due to slowing Chinese demand) on behalf of natural gas (German coal import up 4.9% from 2011 (Bloomberg, 2012)). Even though carbon emission from coal is substantially higher than natural gas, it has become more profitable to buy carbon permits (sold under the EU Emissions Trading Scheme) for the surplus emission, than shift to other energy sources (Burgess, 2012).
According to Bloomberg New Energy and Finance, a research firm, German power utilities were set on average to lose €11.70 when they burned gas to make a megawatt of electricity, but to earn €14.22 per MW when they burned coal (Andresen, 2012).

Some energy intensive industries such as steel and chemicals use natural gas as a raw material to produce the power needed. Seeing that energy costs has dropped in the US compared to Asian and European price levels, industrial costs for such companies are thus lower in the US, driving investments from Asia and Europe to the United States. The chief executive Wolfgang Eder, of Austrian steelmaker

Voestalpine, has stated that they will have to downsize industrial facilities in Europe in the long term. At the same time the company is investing in an iron-ore processing plant in Texas in order to benefit from their low energy prices. A growing number of European manufacturers are announcing similar statements, such as German chemicals giant BASF, resulting in a further loss for financial stability in the EU region.

Many believe that the EU must show a more aggressive approach to energy production in order to mitigate the migration of such industries to other regions (Birnbaum, 2013).

As the globalization of energy markets in addition to local incidents, industries, politics and public opinions can quickly change the demand and supply scenario for different energy commodities on a global scale, the important issue of where the world's energy mix is heading is a substantial piece of the puzzle when predicting the way forward.

2.1.1 Future

Predicted future energy demands are a large part what steers long-term energy investments in the energy sectors. Global energy demand is mostly affected by two parameters, population and income. OECD (Organization for Economic Co-operation and Development) countries have stagnating growth rates in both these parameters, resulting in peaks of energy consumption in these countries the following decades. On the other side, non-OECD countries stand for almost 93% of the total world growth in energy consumption (BP, 2013).

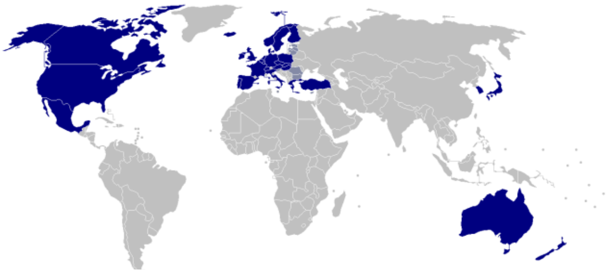


Figure 2-1 World OECD countries

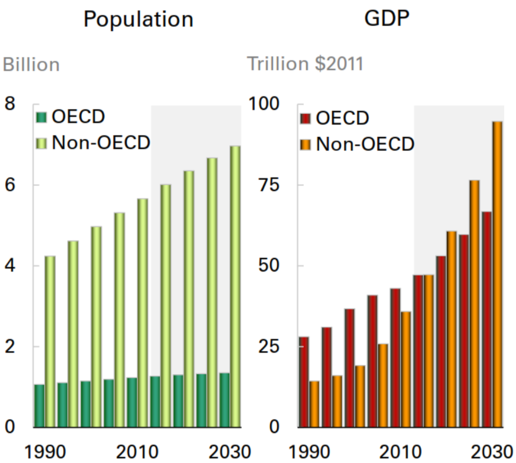


Figure 2-5 Industrialization and growing power demand (BP, 2013)

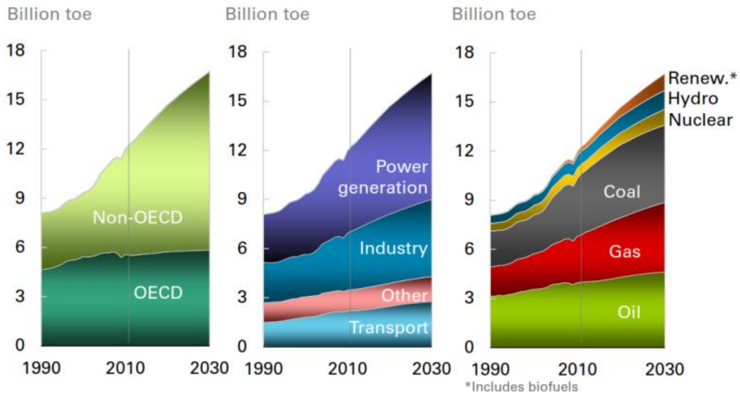


Figure 2-4 Industrialization and growing power demand (BP, 2013)

As energy predictions show, most of the increasing energy demand will be from non-OECD countries. Oil consumption on world basis will stagnate on behalf of other energy sources, whereby renewable sources are predicted to have the highest growth rate averaging at 7.6% p.a. (BP, 2013). Togethe, oil, natural gas and coal is anticipated to provide 80% of the global energy towards 2040 (Exxon, 2013), in part due to them being more economical to develop with existing infrastructure in place.

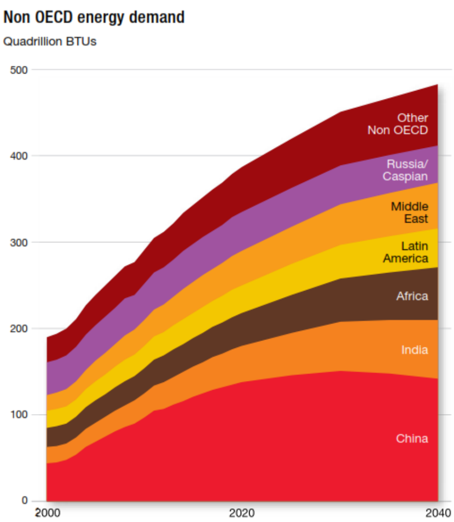


Figure 2-2 NON OECD Energy Demand (Exxon, 2013)

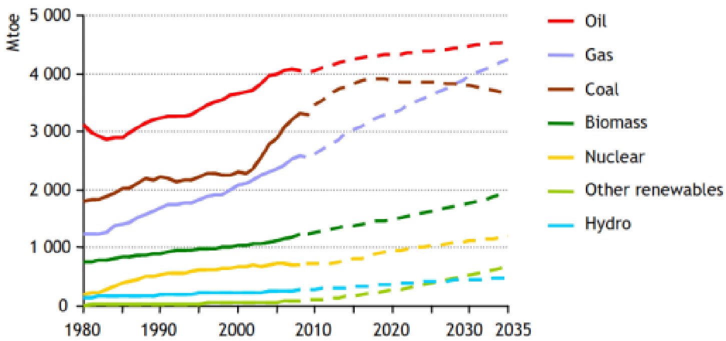


Figure 2-3 Predicted world energy source demand (EIA, 2012b)

Even though coal is on the rise, it is predicted to flatten out around 2030 mostly due to Chinese energy demand slowing down, and the country changing to alternative energy sources like shale gas (BP, 2013).

In a more specific graph, it can be seen that the non- OECD Asian countries will be the nations with the highest growth in energy demand towards 2035 (ref. Figure 2-7).
Such high energy growth rates within Asia are mostly due to a huge increase in population in this area along with high growth in urbanization. Within 2040 it is estimated that 75% of the world's population will subsist in this area (Exxon, 2013). Europe on the other hand is expected to have one of the smallest population growths on world basis. The figure below shows the anticipated world population growth from 2012-2040.

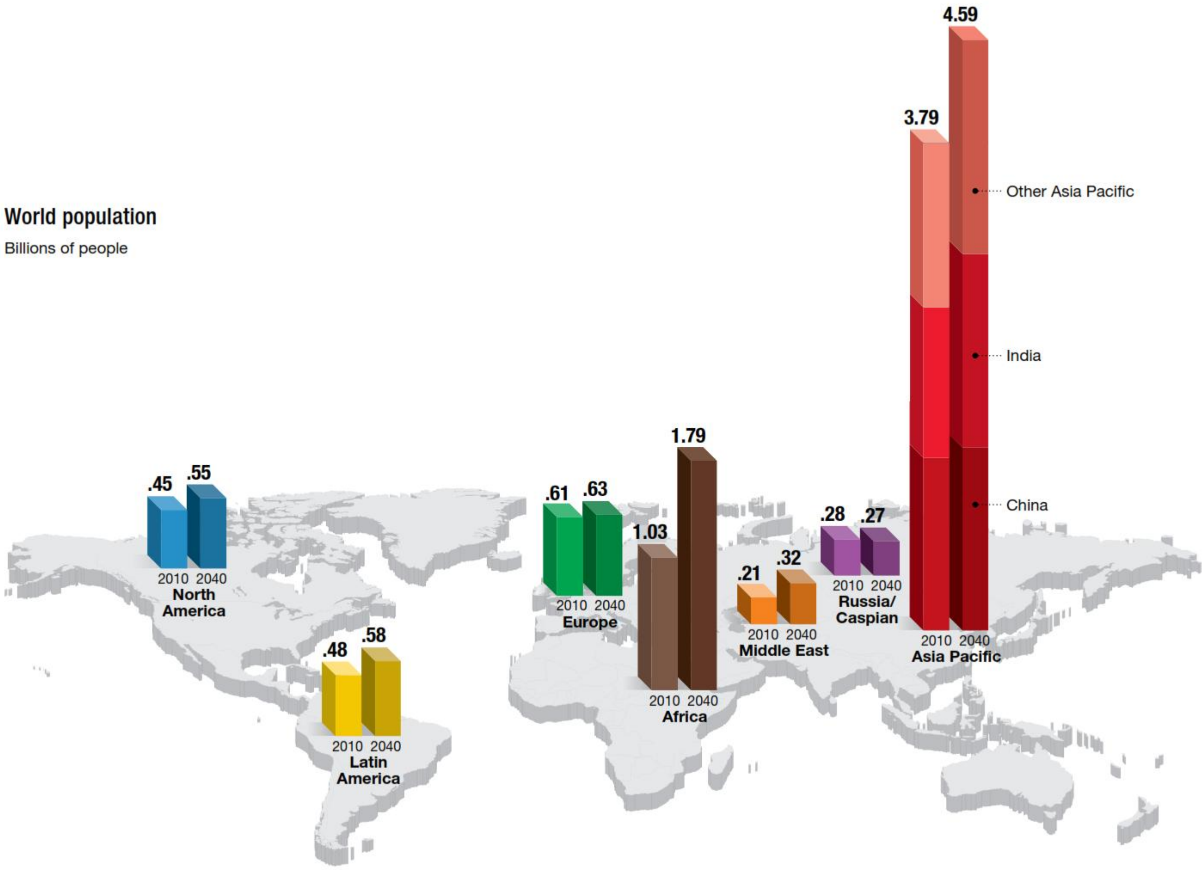


Figure 2-6 World population 2040 (Exxon, 2013)

As non- OECD countries increase their energy demands, one of the main reasons for OECD energy demand flatting off, besides slow population growth, is due to energy-saving practices and technologies. Even if OECD economic output is to grow 80%, energy demand will still be flat due to efficiency (Exxon, 2013).

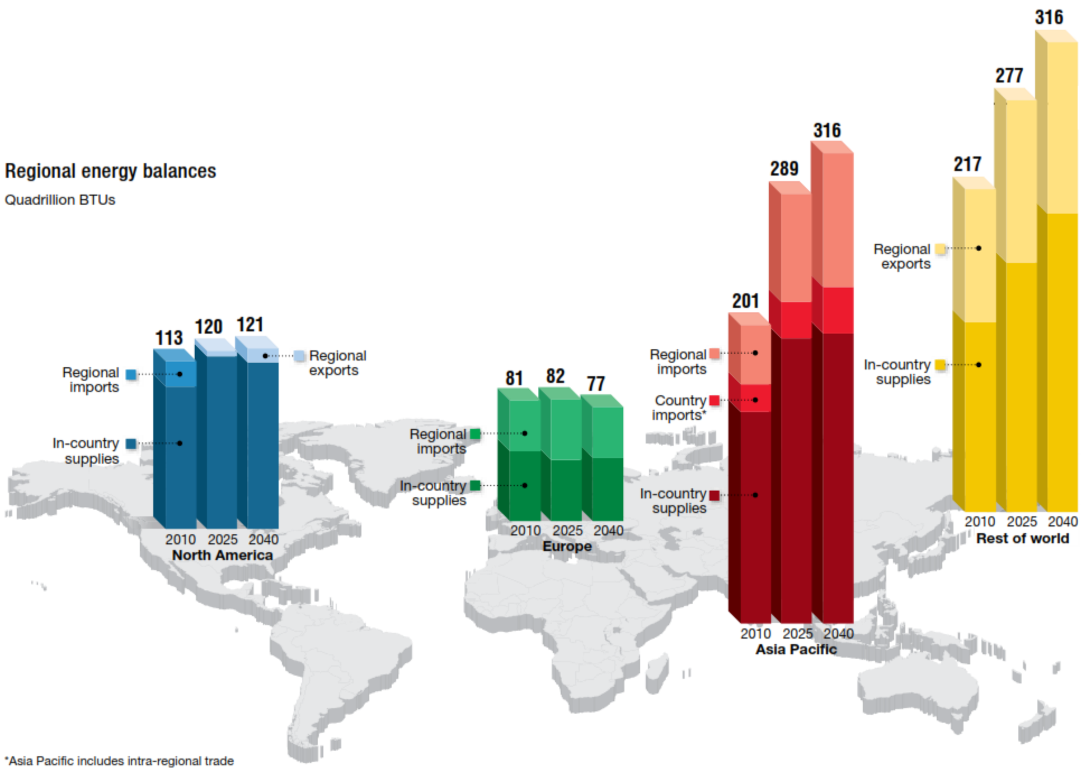


Figure 2-7 Regional energy balances (Exxon, 2013)

As European energy demand flattens off, they are still dependant on importing most of their energy. Figure 2-7 depicts just this, whilst also showing the substantial need for energy import in Asia and the rest of the world. One of the most important predictions to take note of is the North American energy sovereignty, which is predicted to take place around 2025. The region has, and is ,capitalizing on advanced technologies in order to produce energy from resources that were previously not viable alternatives. One of the main contributors to the regional energy independence is shale gas.

As Figure 2-9 shows, US shale gas production has recently increased substantially, and is predicted to continue to do just so within natural gas production.

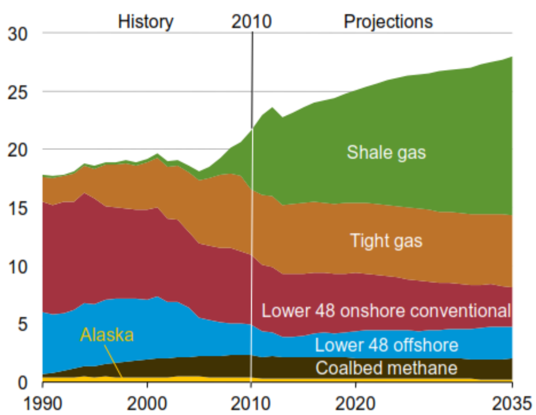


Figure 2-9 US Natural gas production by source, 1990-2035 EIA, 2012a)

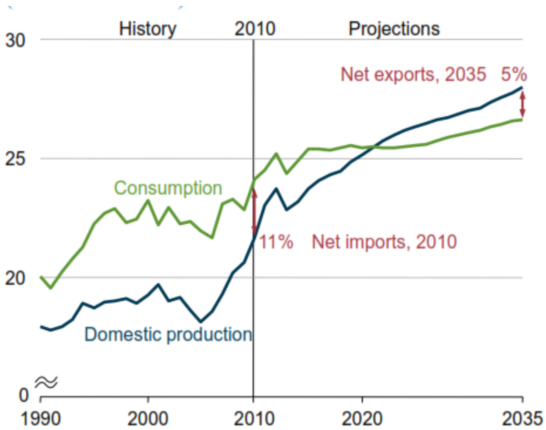


Figure 2-8 Total US natural gas production, consumption and net imports, 1990-2035 (EIA, 2012a)

Note: Figures given in (trillion cubic feet)

This rise in US shale gas changes the country's status as a once sorely energy import dependent country, to a more or less energy self-sufficient state. The shift in going from an energy importer, to an energy exporter will undoubtedly change the globalized market, where there suddenly instead of being a large importer and consumer, becomes an exporter, competing with other global natural gas supplier.

As a supplier of unconventional gas, North America will be unprecedented (most of which will be consumed locally), where over half of the growth in unconventional production the next two decades will be in this region.

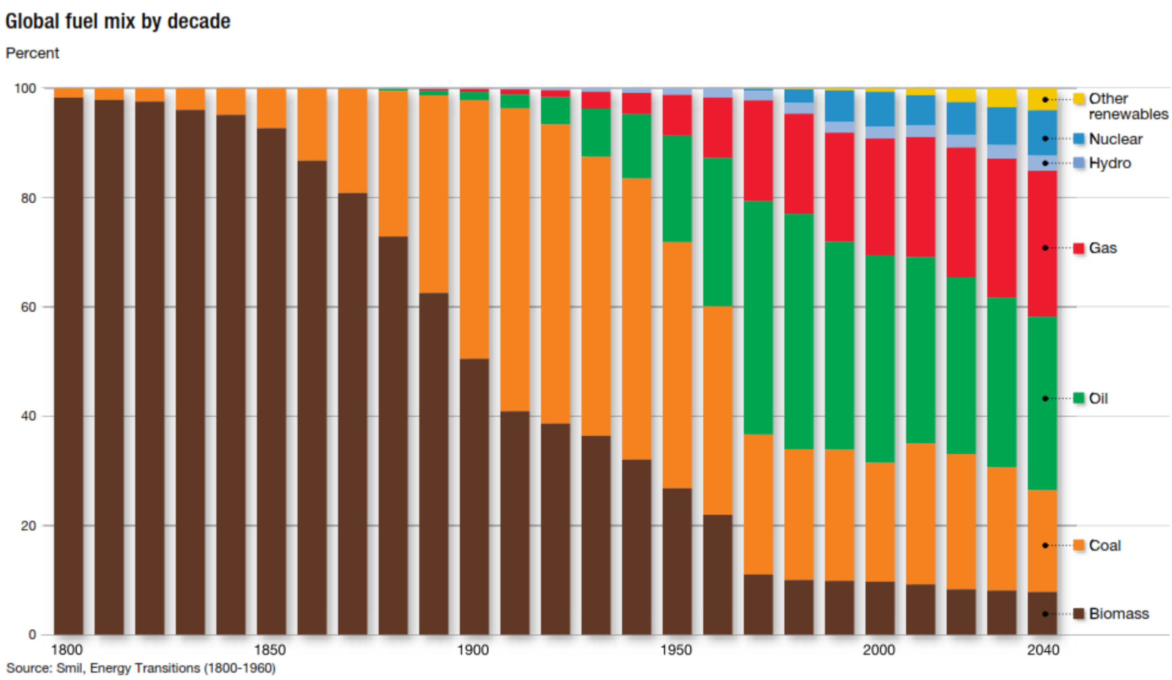


Figure 2-10 Global fuel mix (Exxon, 2013)

As an energy commodity, natural gas portraits a natural shift towards to a more environmentally friendly energy source which is reliable and available (Exxon, 2013).

As coal was the energy source of choice from 1900's to 1960's, oil and gas took over from 1960's to the millennia. Now it seems, from a globalized perspective, coal and oil will stagnate whilst gas will be the fastest-growing major fuel towards 2040 (Exxon, 2013). Natural gas is becoming the main contributor in the future's energy mix, whislt renewable resources will see the highest growth rate within the total energy mix. Although renewable are a threat to hydrocarbon production, it must not be forgotten that it took 100 years from the first oil well discovery, until oil became the leading source of energy in the world. It takes time to scale up energy sources and implement them into society, whilst also being economically competitive.

Historically gas has been traded and consumed locally within regions through large pipelines, but Liquefied Natural Gas (LNG) by ships at sea is seeing its rise, at the moment nearing 10% of world gas supply (Melling, 2010). With LNG it is now possible to transport gas over vast distances, without the need for long interregional pipelines.

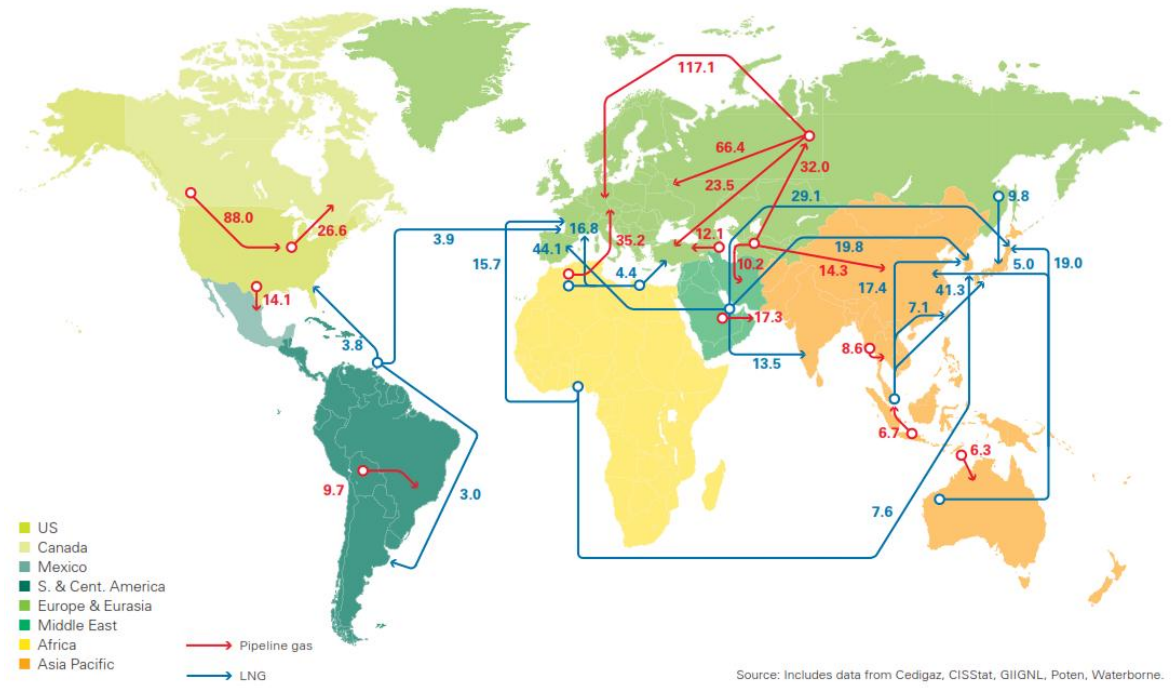


Figure 2-11 Major worldwide gas trade movements [Bcm] (BP, 2012)

LNG is growing at 4.3% in use, whereby Australia and Qatar are the largest contributors to the LNG market (BP, 2013). Inter regional pipeline transportation is growing by 3% (BP, 2013), showing that both trade forms are being developed in order to supply the increasing global demand of gas in the coming years.

Natural gas markets are thus becoming globalized due to LNG, and as a result, convergence of regional and global prices is expected to increase, with the exception of North American who will mostly become self-sufficient and likely become isolated from the global gas market (EIA 2012b).

The International Energy Agency has written a report regarding the importance of gas in the future asking "Are we entering a golden age of gas?". All indications and predictions point in this direction, but one of the main concerns regarding its success, is whether or not unconventional gas will gain traction due to possible environmental and social damage (IEA, 2012b).

As technology further evolves, numerous unconventional energy supplies which were once too hard to attain, will undoubtedly in the future gain traction in the market. As the current energy revolution is within fracking technologies, the next wave may come from large methane hydrate deposits trapped in shallow layers beneath the seabed. Japan for one, has spent huge amounts of money on methane hydrate research programs the past decade. India, China, and South Korea are following suit. At great depths where high pressure and cold temperatures are present, methane and water molecules link into crystalline lattices that trap methane molecules, looking much like snow or ice. One cubic foot of methane hydrate can contain 180 cubic feet of methane gas. As Japan, the leading developer of such energy has optimistically set 2018 as a target goal for commercialized methane hydrate production, it may still take a few more years for it to become a viable source for their energy mix. According to some scientists, methane hydrate is twice as abundant as all other fossil fuels combined (Mann, 2013), being present across the whole globe.

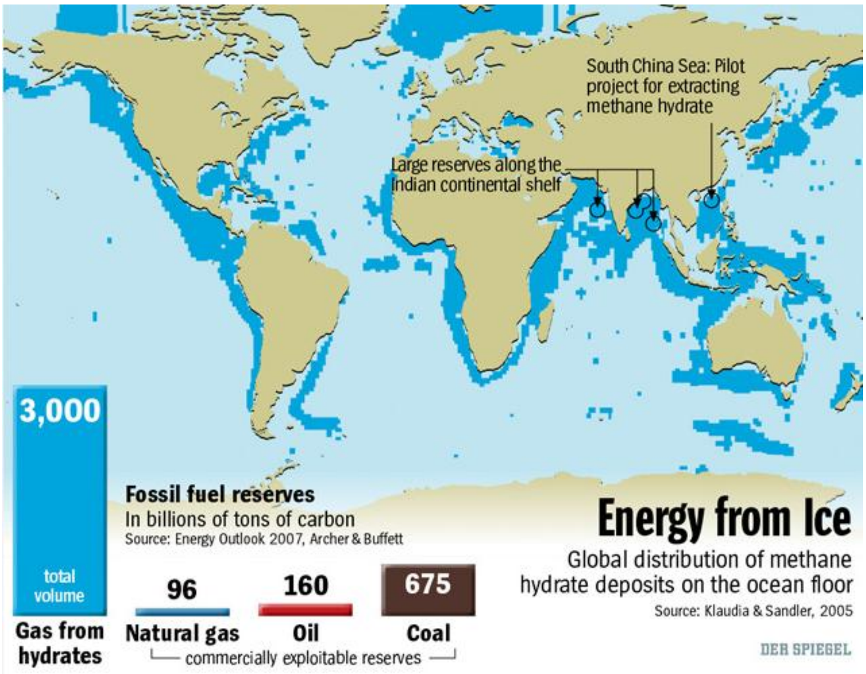


Figure 2-12 Methane Hydrate present in the world (Der Spiegel, 2007)

If methane hydrates was to be commercialized in a wide scale, it could, as shale is currently is, become the next influx of cheap gas to an ever increasing globalized market. A new wave of change, both politically, environmentally and economically will most likely take place.
Future industrial investments would most likely further seek ventures outside of high energy priced regions unless local energy prices, as those of natural gas and electricity, are similarity priced.

It is highly unlikely that methane hydrates will become a source for consideration for future gas markets within the next 15 years. In fact, methane hydrates are probably the least likely of unconventional resources to be taped for natural gas within the next few decades. But still, one should take the new unconventional source in to consideration in time frames exceeding two decades (Ruppel, 2011).

As the fact of uncertainty must still be acknowledged, one actuality seems certain, demand for natural gas is surging in the US and Asia, further providing incentives for unconventional gas development. Europe on the other hand may skip the golden age of gas altogether, burning predominantly coal and focusing heavily on growth within renewable energy sources.

2.2 EUROPEAN GAS DEMANDS

Europe is currently the largest net importer of gas in the world, accounting globally for 46% of total gas imports (Enerdata, 2013), where Russia and Norway are the top exporters to the EU (Eurostat, 2011). Russia and Norway mainly supply gas via pipeline to Europe.

Even as coal has gained traction and has become a cheap alternative to gas, Europe is still depended on gas import to be able to supply its consumption. Approximately 48% (excluding Norway) of European consumption of gas in 2011, was imported (Gazprom, 2012). Of Europe's imported gas (excluding Norway) was in 2011 approximately 68% through pipeline and 32% via LNG shipments (BP, 2012).

Thus pipeline import stands for a large proportion supplying Europe's gas demand and will do so in the years to come as indigenous European conventional gas production declines.

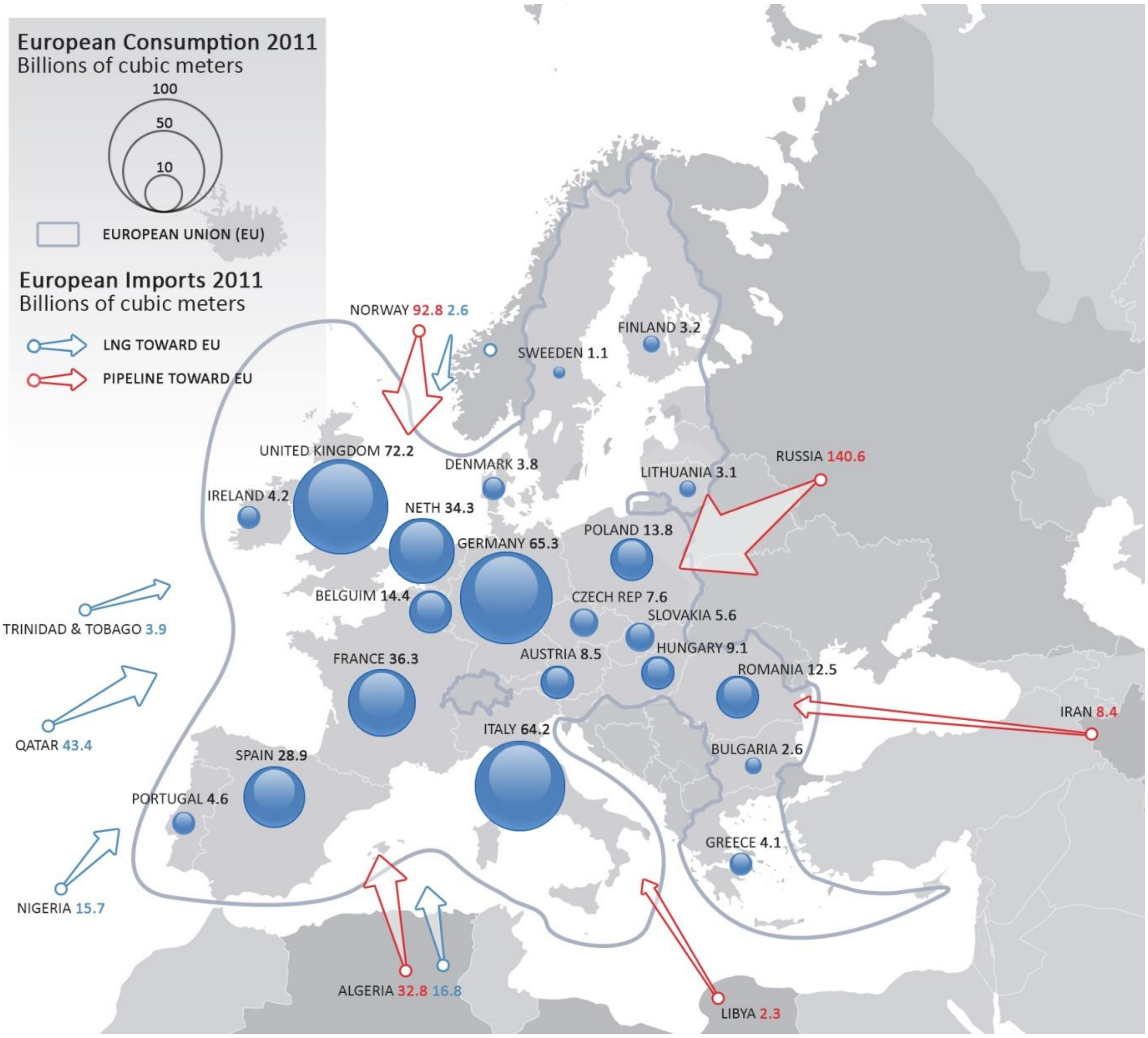


Figure 2-13 European gas import 2011. Data source: BP 2012

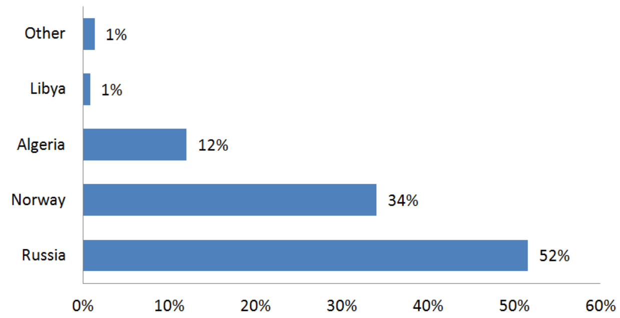


Figure 2-14 Natural Gas Supplied Foreign countries by Pipeline to Europe in 2011. Source: (BP, 2012)

Natural Gas as an energy source has the past decade coincided well with European political ambitions of utilizing cleaner fuels. Along with other drivers, this has in the past amounted in gas consumption within Europe to steadily increase up till 2009 (Eurostat, 2012). The financial crisis hit in 2008, growth stagnated, and directly impacting energy needs. As the figure below shows, the total energy consumption in Europe fell to pre-millennia levels, and so did also in turn the consumption of natural gas, down -9,9% from previous year (BP, 2012). At the moment, stagnation is still present within the region. In 2012 BNP in the European Union declined 0,6 percent, where the forthcoming year is expected to yield a 0,4 decline (recently adjusted further down from 0,3)(Landre, 2013).

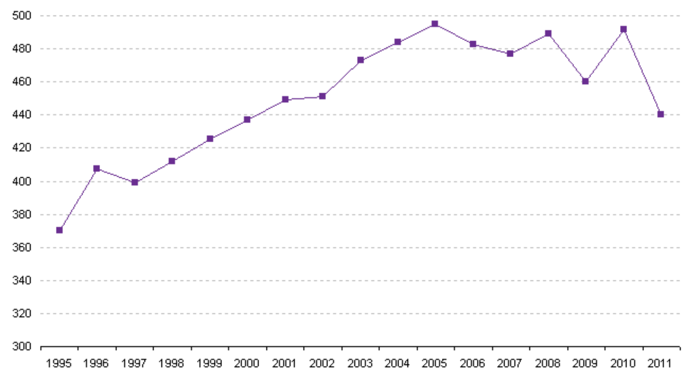


Figure 2-15 EU 27 Natural gas consumption [Mtoe] (Eurostat, 2012)

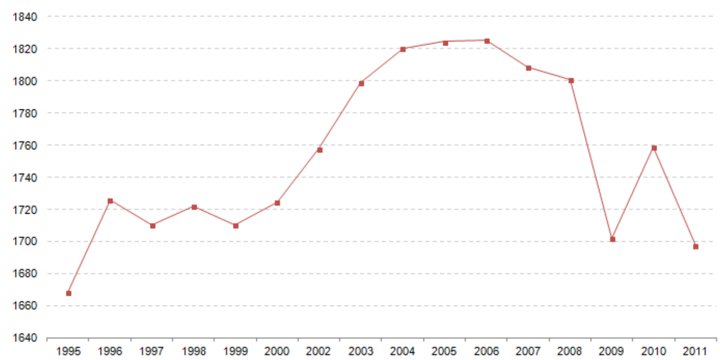


Figure 2-16 EU 27 Total energy consumption [Mtoe] Source: Eurostat

As Europe struggles to accomplish growth, they are still to a large extent dependent on foreign natural gas suppliers in order to maintain the current level of indigenous consumption. Relations to Europe's main gas importer Russia, from a European point of view has become somewhat of an issue following the Russian-Ukraine quarrel, where Russia's ability as a steady and reliable gas supplier to Europe (through Ukraine) has been questioned. Russia's dispute with Ukraine (pipeline transit country) between 2006 and 2009 lead to Gazprom (Russian state owned company and the major owner of pipelines between Europe and Russia) turning off their natural gas tap, on multiple occasion, leaving households in central and eastern Europe without heating.
It signified the European dependence to Russia and above all, Russia's inability to provide reliable energy to a major region due to a local issue, basically using natural gas energy as a bargaining chip.

In addition, the European commission launched an investigation in 2012 focusing on Gazprom, regarding suspicion of hindering free gas flow within Europe and imposing unfair prices within the market.
Even as Russian major companies like Gazprom tries to reaffirm their position as a reliable trading provider (through new pipelines such as Nord stream etc., further described in 3.3.1), the damage may already have been done. European politicians have begun to accelerate diversification of energy imports in amongst others, LNG import terminals and subsidiary schemes for renewable energies. Middle Eastern countries like Qatar are building huge fleets of LNG vessels to meet such demands, which has paid off, where 2001 exported 16.54bcm LNG gas (BP, 2002), they in 2011 exported 102.6bcm (BP, 2012)

As Europe tries to diversifying their gas energy import sources (North and West Africa, the Middle East and Eastern Europe etc), the term "security of gas supply" is likely to become increasingly relevant in the coming years due to the possibility of political instability and general supply interruption. For this matter, Europe has and still is expanding their internal gas storage capacities. These storages work not only as buffers against seasonal price and demand fluctuations but also act to stabilize the national energy market should a main gas supplying nation withhold gas supply. Some countries like the U.K have relatively small storage facilities. The UK for instance has only 3% of its annual consumption volume in storage form, equating to only 12 days of full daily utilization. Germany on the other hand covers 23% of their annual consumption in storage, equating to 95 days of full utilization. In the light of previous incidents and the coming years, the EU has proposed its member states to hold a minimum stock to cover 60 days of a countries internal supply (McLeod, et at., 2007) in order to ensure market stabilization and safeguard European nations against short term political pressure from abroad.

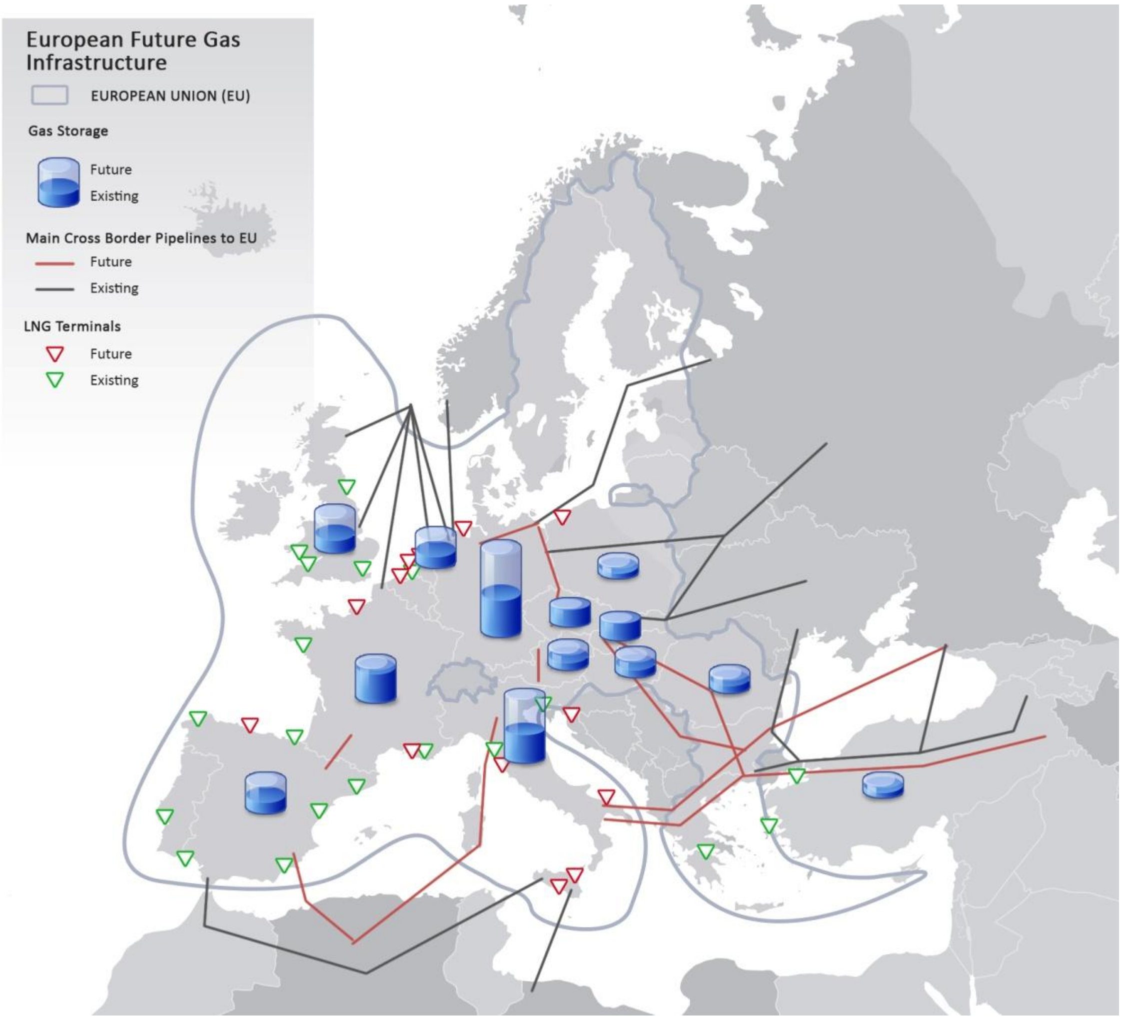


Figure 2-17 Europe Infrastructure Map Source: (Nikl, 2010)

Another major hurdle and topic of concern for Europe regarding pipelined gas import trade, has been on the supplier's pricing of natural gas.
Natural Gas from Norway and Russia has in the past been selling their pipelined gas through long-term oil-indexed contracts, where the price of gas is correlated to the price of oil. The contracts were and are often made in such a way that a certain amount of gas is made available to the buyer, and if it is not needed, the buyer still obligated to pay a certain amount, often referred to as take-or-pay contracts. The long-term oil-indexed contracts were conceived in the days when competition was low or even non present, and long term predictability from the few natural gas suppliers was essential in order to sustain local energy demands. Such contract types do not reflect the current liberalized market. Within the past decades, competition has grown, and Europe has begun to adopt to hub pricing, a more liberalized form, where prices are not linked to a commodity, but sold on the basis of supply and demand.
At the moment, high oil prices and lower demand for natural gas, has meant that buyers of long term oil-indexed contracts are often paying higher sums for their gas than what can be found at the hub markets (further described in 3.3.1).

During uncertain times, when energy demands seem changing, and as European coal consumption increases steadily, Europe needs energy at low prices, not long term contractual agreements linked to high oil prices.

Russia seems persistent in sticking to this way of selling its gas, where Alexander Medvedev, Gazprom's export chief, stating in late 2012, that they will defend their system of long-term oil indexed contracts of all their energy (Adomaitis, 2012a). As an example of its downside to gas buyers, Gazprom sent in late January 2012 an invoice to the Ukrainian government demanding 7 billion dollars for 16bcm which Ukraine had not even used (Shultz, et al., 2013).

Norway, Russia's main competitor, on the other hand seems to seize this opportunity. Norwegian Statoil has just recently signed a 10 year natural gas deal with Germany (Europe's largest gas consumer), which bases its costs on spot prices and not oil-indexation. In addition, Norway has also extended a similar contract with the UK linking gas prices to UK spot prices.

Norway's choices seem to pay off, export wise at least. In 2012 they increased their export 16% (to 107.6bcm), according to Eurostat, whist Russian Gazprom experienced their worst numbers in 10 years, falling 8 percent from 2011. In addition, Norway is possibly planning on further reducing gas transportation prices in the hopes of further increasing demand for Norwegian gas whilst also increasing the incentive for further exploration and production in the upstream sector.

Along with European gas demands and factors which affect its price, reliable Norwegian gas supply, priced at competitive prices, will be one of the key factors in keeping Norwegian gas a key factor of low emission carbon energy within Europe's energy mix.

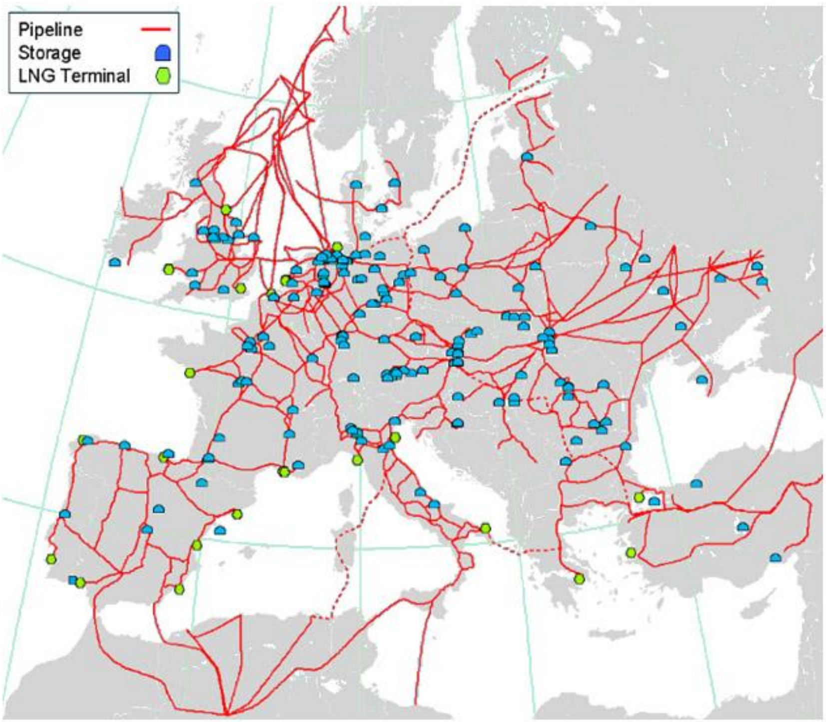


Figure 2-18 2007 European gas infrastructure (Bothe, 2007)

2.2.1 Future

Even though Europe is not anticipated to have a large growth in energy demand, their energy mix is changing. As the world in general is increasing their gas consumption, Europe is at the moment, due to economic restraints wavering between coal and gas.
Andrew Horstead, a risk analysis at Utilyx, an energy consultancy puts it: "The economics are telling us to burn coal rather than gas".

Over time, coal consumption in Europe is predicted to flat out and decline. Old decaying coal power plants and implemented EU environmental policies will likely be a main contributor in reducing coal's popularity amongst energy providers.
An example is a directive which comes into force beginning 2016, which raises the acceptance level of coal-fired plants. Meaning that the plants will either have to shut down, or install expensive pollution-control equipment (The Economist, 2013a). In addition, the UK is introducing a carbon floor price, setting a cost on carbon that is higher than in the European trading scheme, which in turn has resulted in plants burning as much coal as possible before then. Other countries are following suit, such as coal taxes in the Netherlands, coal phase-outs in Denmark and Finland, and coal subsidiaries ending in Spain (Chazan, 2013).
On the other hand, as Europe tries to balance costs and carbon emissions, new power plants, such as one of the largest coal-fired power plants in the world was recently opened in Germany in 2012.

One thing is for certain, Europe, especially Germany, is on the forefront of renewable power. Attaining a large percentage of renewable sources within its energy mix will not only ensure regional energy independence, but also reduce carbon emissions drastically. German Environmental Minister Peter Altmaier has stated that Germany has set a goal for 35 percent renewables for 2020, and where goals for 2050 are 80 percent.
Challenges with renewable energy sources such as wind and solar, are that storing their energy is a major technical challenge, at the moment the electricity produced is fed directly in to the grid. Such renewable sources do not provide a steady flow of electricity to the grid, as most conventional energy sources do. They instead fluctuate widely, depending on sunniness or windiness of the day, and also more importantly, of the seasons.
Consequently, as Europe transitions to renewables, there is still a large portion of its energy mix that needs to counter affect the fluctuational challenges of the new green sources.
Due to renewable sources being heavily subsidized (especially within Germany), the result is that the costs are passed on to consumers. Consumer groups estimate an increase in German electricity bills of 20 to 60 percent the next decade due to green energy promotion. This puts even further price pressure on the remaining non-renewable energy sources compensating for the fluctuational challenges within the mix. Unless natural gas prices fall, or coal prices increase drastically, coal power may be favored over the cleaner natural gas in such a scenario.

There is still a lot of uncertainty regarding the extent of future natural gas demand for Europe, most of which depends on European politicians and their will to implement additional environmental policies, making coal less economically viable. Even though new European LNG terminal plants are becoming operational, and Japan's gas demand is pushing LNG prices up in Europe, it seems like the most reliable and price competitive source for European natural gas is likely to be from Norway, granted that there is deliverable gas found and available.

Although Norwegian gas may be able to position itself in a competitive manner amongst its natural gas competitors (Russia, LNG etc.), the true threats lies in whether or not gas becomes a main contender in the European energy transition towards renewable energy sources.

2.3 NORWEGIAN GAS EXPORT

In the early 2000's high expectations of Norwegian gas export was envisioned, especially predicting large finds in the Norwegian Sea and Barents Sea. Growth ambitions resulted in grand plans for building many more future gas pipeline on the NCS. In 2007, the current oil and energy minister Åslaug Haga predicted a stable export of 125 to 140 bcm within 2020. Disappointing small and few finds have resulted in the predicted export capacity the next decade to be between 105 and 130 bcm, where fields such as Troll and Ormen lange have been given lower production allowances than the operators desire (Løvås, 2011).

In 2012, Norway exported 107.6bcm of natural gas to Europe (Førde, 2013), and as Europe consumed an estimated 466bcm in 2012 (Enerdata, 2013), this means almost a fourth European in 2012 got their energy from Norway. The figure below depicts which European countries are the main importers of Norwegian pipelined gas.

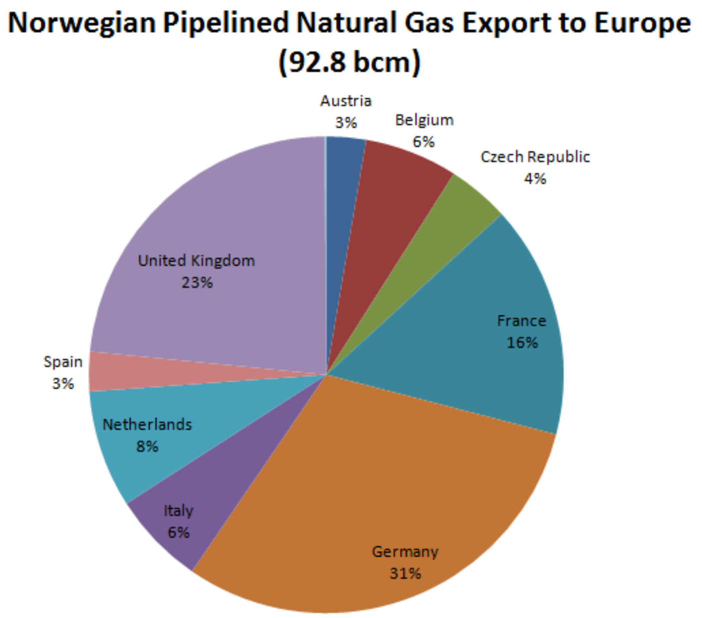


Figure 2-19 Norway natural gas pipeline exports to Europe 2011 Source: (BP, 2012)

As export volumes for 2012 were record high at 107 bcm, chief executive of Gassco Brian Bjordal said in an interview that the system is close to its maximum capacity, being able to handle slightly less than 120 bcm per year. Subsequently as export volumes are expected by the Norwegian government to further increase up to 110 bcm in 2013 and 112 bcm in 2014, the infrastructural capacity will definitely be put to its test (Adomaitis, 2012b).

In 2011, The government put forth publication predicting that gas production from existing fields and finds most likely peak between 2015 to 2025.

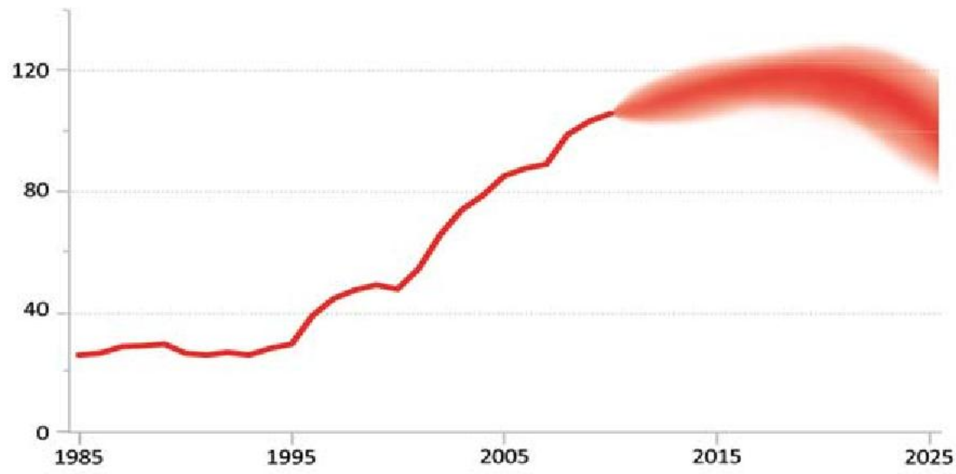


Figure 2-20 Gas production from NCS from existing fields and proven finds [BCM per year] (Gassco, 2012)

According to Bjordal, the production system is more or less at its maximum, where there are no present fields in which can introduce more gas.

As unproven resources are predicted to be further north, clear signals from European policy makers regarding the future role of natural gas in Europe is a crucial step in order for further investments within the Norwegian natural gas industry, both searching and expanding the infrastructure.

Norway's importance as a natural gas supplier to Europe is highlighted by the following points:

- Most of Norwegian gas is directed to the large players in the EU, namely Germany, UK and France (ref Figure 2-19).
- Norway has lately been aggressive in its natural gas pricing, further leaning towards spot price indexing.
- Norway is seen upon as a politically stable nation.
- Gas contracts are often long-term, thus making export stable regardless of market fluctuations.
- Norway has gas fields to sustain long-term deliverances.
- Low CO_2 emissions in comparison with LNG and Russian gas (Gassco, 2012).

Mainly because of these reasons, Norwegian positions itself as a high valued natural gas supplier, where export volumes are increasing on behalf of Russia.
In addition, Norway has a well-established pipeline system in which most large infrastructural investments can be assumed to be down paid, thus allowing larger price flexibility (in comparison to Russia who the past and coming years have invested heavily in new natural gas pipelines).

As low gas prices in 2011 resulted in less interest for oil and gas investments, now high gas prices result in lower demand for the gas itself. Striking a balance between the two will most likely be difficult, but likely necessary in order to sustain export quantities and value, whilst also ensuring competitive Norwegian gas prices.

The matter of whether Europe will demand more or less gas in the long-term will as previously stated, be mostly up to policy makers in Europe, ultimately leading to whether or not they will strive for less emission by replacing coal with gas as they move towards renewable sources. All in all, Bjordal is

optimistic, highlighting the fact that global gas consumption is on the rise and carbon emission reduction is necessary in order to meet climate policy goals. Gassco anticipates a slower growth demand rate than previously seen the past decade, but predicts demand to stay at current or higher levels than what is to be found now, thus running the infrastructure at full capacity in the coming years (Adomaitis, 2012b).
One thing is certain, Europe needs reliable energy, and Norway seems to be a viable contender in supplying this need.

2.4 NORWEGIAN CONTINENTAL SHELF

Since the beginning of the Norwegian oil and gas adventure in 1969 at Ekofisk, large sums have been invested in exploration, field development, transport-infrastructure and land facilities. This has resulted in a huge network of both topside and subsea facilities extracting, transporting and processing these valuable resources for mainly export purposes.

The Norwegian continental shelf itself encompasses a large area (stapled line as seen below), and although the area is large, only a small portion of it is open for petroleum activity in present time, namely the North Sea, Norwegian Sea and the Barents sea South.

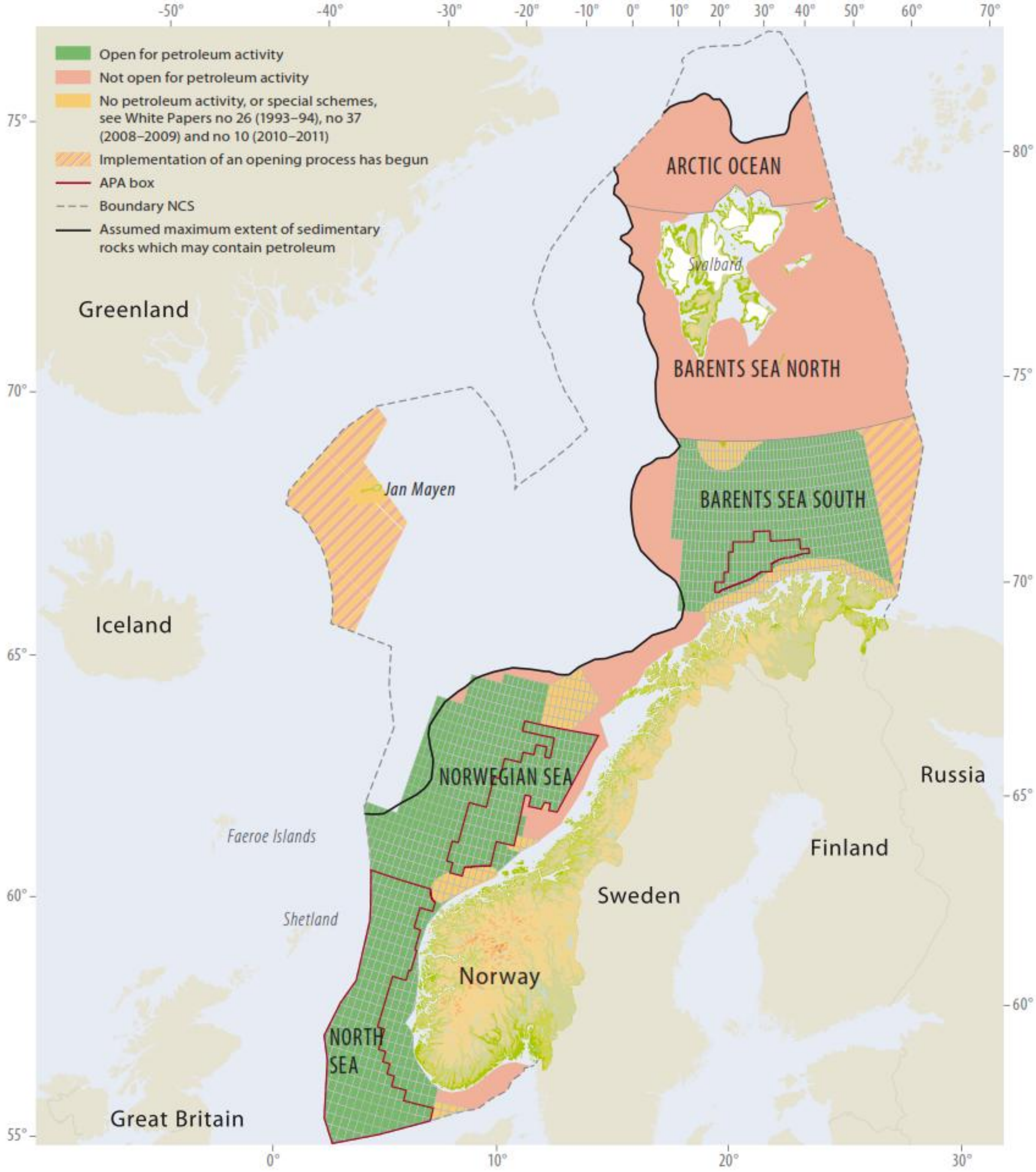


Figure 2-21 Norwegian Continental Shelf (NPD, 2012a)

Within these sectors there are 71 trillion cubic feet (tcf), translating roughly to 2031 billion cubic meters (bcm) of proven gas reserves as of 1 January 2012 (IEA, 2012c). This vast amount of gas in such a small country of 5 million inhabitants, results in a large rate of energy export, thus making Norway as of 2011 the 3rd largest natural gas exporter in the world.

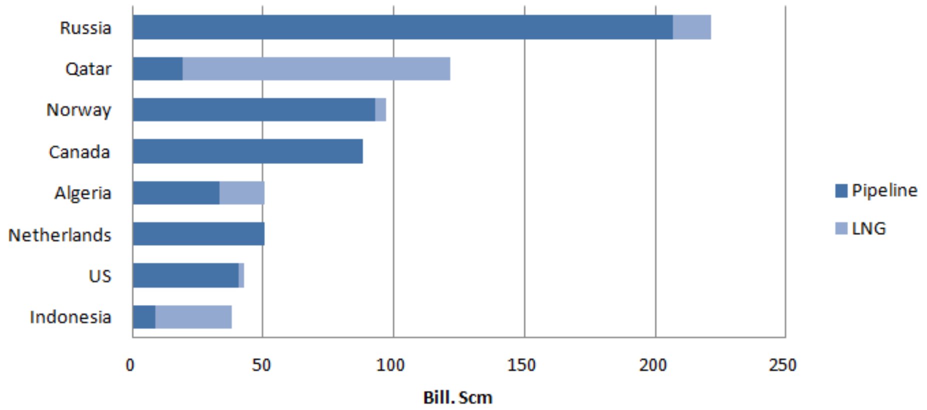


Figure 2-22 World Natural gas export 2011 values. Data Source: (BP, 2012)

Norway saw the peak of crude oil production in 1999 (Figure 2-23), and has since then produced, and hence also exported substantially less crude.
The main reason for this is that the large giant oil fields are becoming depleted, and even though the recovery factors have drastically increased, the fact is, that these oil giants are harder to come by. Meanwhile as crude oil has declined, natural gas production in Norway has seen an opposite trend (EIA_3 2012), as seen in graphs below.

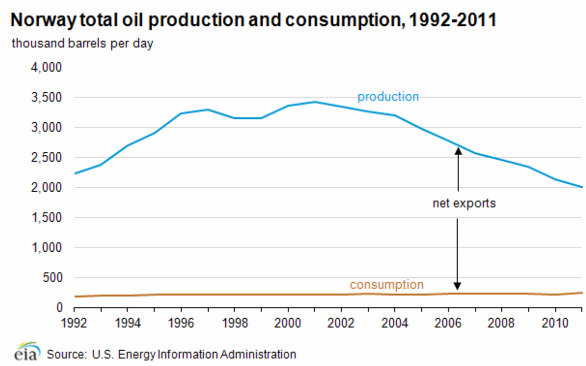


Figure 2-23 Norwegian total oil production and consumption, 1992 -2011 (EIA, 2012c)

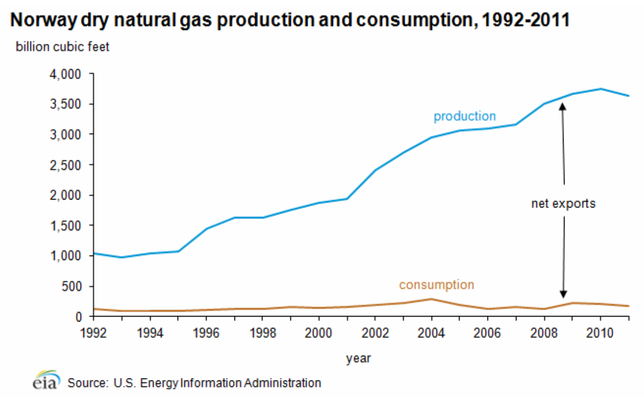


Figure 2-24 Norwegian dry natural gas production and consumption, 1992-2011 (EIA, 2012c)

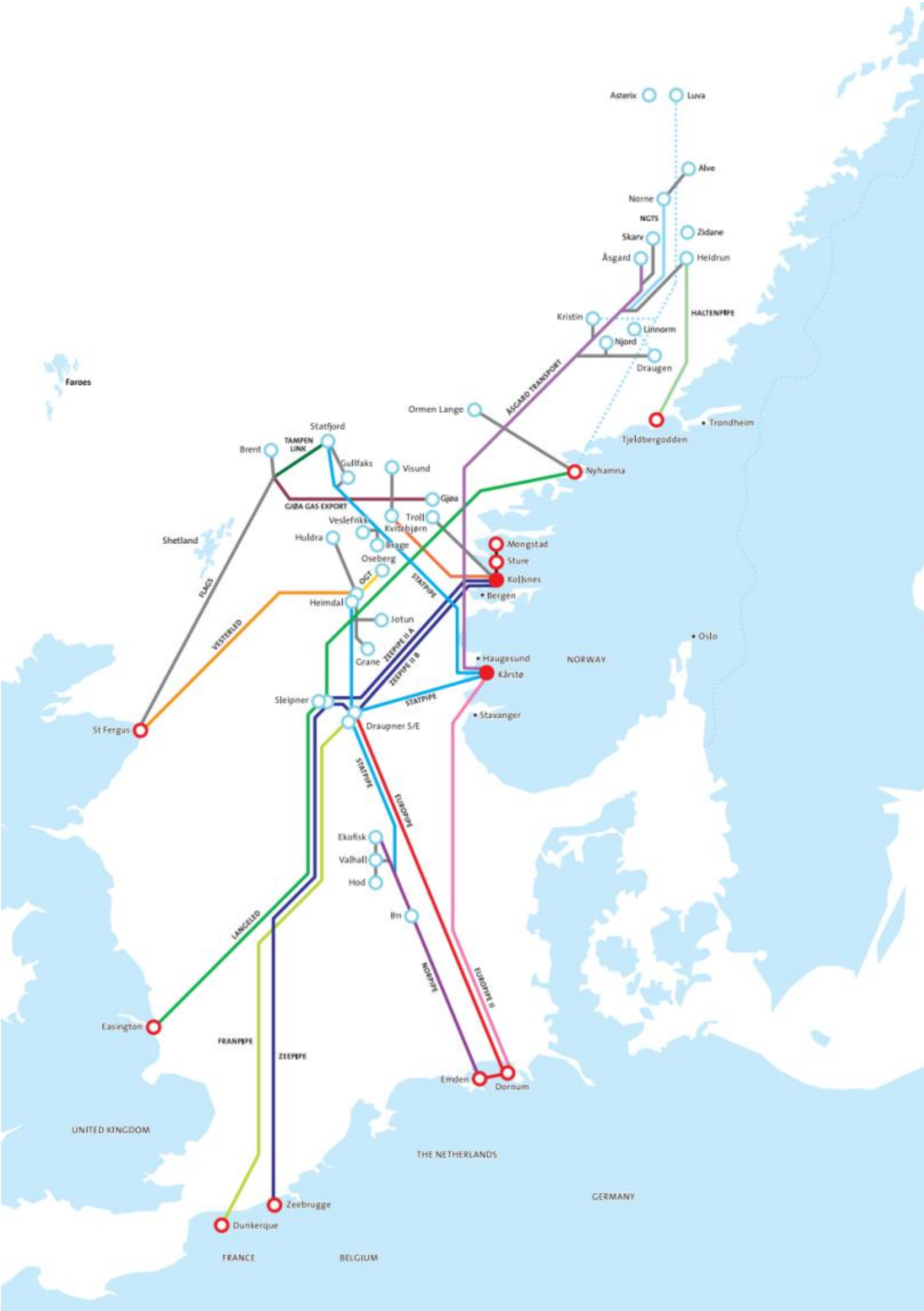


Figure 2-25 Norwegian natural gas pipeline infrastructure (Gassco, 2013)

A fourth of all natural gas produced in Norway amounts from the maturing gas field Troll (world's third largest offshore gas discovery) (Bjordal, 2011).

Gas from Troll is transported via a 133km pipeline to shore, a small part of what is known as the NCS gas transport system, the largest pipeline network of its kind with its 7800km of pipelines (Figure 2-25). Once at shore, the gas is processed and refined to be labeled as sales gas, where it is sent back through the pipeline infrastructure to the UK or European mainland.

The infrastructure system is operated at high pressures of up to 210 bar, (Nørstebø and Dahl, 2007) theoretically being capable of exporting 120 bcm per year according to Gassco's president and chief executive Brian Bjordal (Adomaitis, 2012a).

The subsea pipeline system connects transport gas from as far north as Norne down to the UK and continental European market. An example of its uniqueness: one of its pipelines (Langeled) is 1166km long, ranking it the world's longest underwater pipeline. In addition, a new pipeline expecting to be operational at end 2015 will be the world's deepest of its size (36 inch), being laid down to a 1265 meter water depth.

An important element to note is that Norwegian export capacity varies seasonally. During the winter the seabed becomes colder, resulting in the gas being transported, also decreasing in temperature. This temperature decrease, causes the gas to become more compressed, thereby increasing the possible capacity of the pipeline. This acts favorably for Norwegian exporters as energy demands in Europe are high in this period, due to increased energy consumption during colder months.

Annual planned maintenance periods on the NCS are between April and October, meaning that production on offshore fields may be limited within these periods.

The infrasctructure is owned by Gassled, a joint venture between offshore operator companies and foreign investors.
Within Gassled's asset portfolio, we find rich and dry gas pipelines: Europipe I, Europipe II, Franpipe, Norpipe, Oseberg Gas Transport, Haltenpipe, Gjøa, Statpipe, Tampen Link, Versterled, Zeepipe, Åsgard Transport, Langeled, Norne Gas Transport System and Kvitebjørn Gas pipeline.
Onshore processing facilities: Kollsnes gas processing plant, Kårstø gas and condensate processing plant.
Offshore platforms: Draupner S/E, B-11 and Heimdal Riser.

It should be mentioned that Gassled is not the sole owner of all gas pipelines on the NCS, but they hold most major routes and therefore act as the main infrastructural asset owner on the Norwegian continental shelf.

Although the infrastructure is regionally extensive, the few pipelines that are not owned within Gassled's portfolio are: Draugen Gas Export, Grane Gas Pipeline, Heidrun Gas Export and a few others.

Note: *Although there are immense gas infrastructures present today to transport the gas to facilities onshore, 26% of all Norwegian gas is re-injected in order to increase oil recovery factors, thus deferring the produced gas to a later point in time (EIA, 2012c).*

The actual operator of the whole infrastructure is Gassco, a fully state owned company whose overall goal is to transport Norwegian gas with the highest possible delivery regularity (Gassco, 2013).

Regarding NCS boarders, Figure 2-21 show just how extensive it is. Up till July 2011, there has been an ongoing dispute concerning maritime boundaries in the Barents and Arctic Seas between Norway and Russia. The issue has finally been resolved, and an agreement requires both parties to jointly develop fields in which crosses their now agreed upon boundaries.
The result of this agreements, is that the Norwegian government has gained an additional 54 000 square miles of continental shelf (IEA, 2012c).

2.4.1 Export

As Norway exports the majority of its gas, most produced gas therefore is trasnsported through subsea pipelines to foreign boarders. As buyers of natural gas expect a certain quality when importing to foreign terminals, all major norwegian export pipelines transport solely dry gas, or sales gas at it is often refered to.

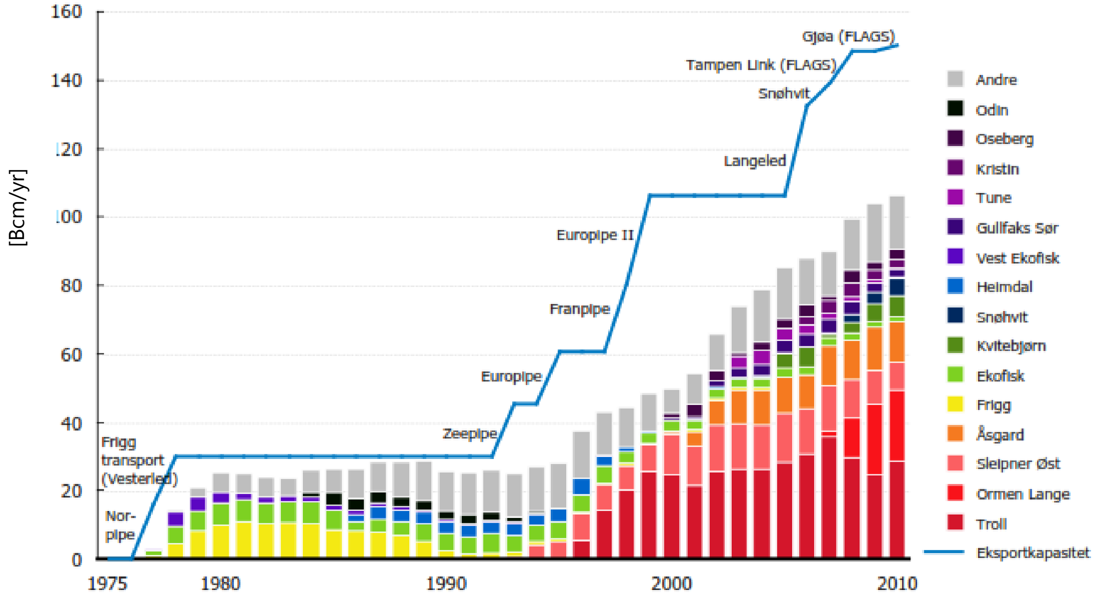


Figure 2-26 NCS gas production and theoretical export capacity development (Gassco, 2012)

The above figure shows the average utilization of the whole infrastructure throughout a year. It should be noted that the graph gives reason to believe the maximum export capacity of the infrastructure is approximately 150bcm/year. This is assumed to be a technical figure, where the real export capacity is as previously stated, slightly less than 120bcm/year according to chief executive Brian Bjordan of Gassco (Adomaitis, 2012b).

Due to significant cyclical production in certain fields, the overall utilization is considerably higher in parts of the year where demand and prices high.

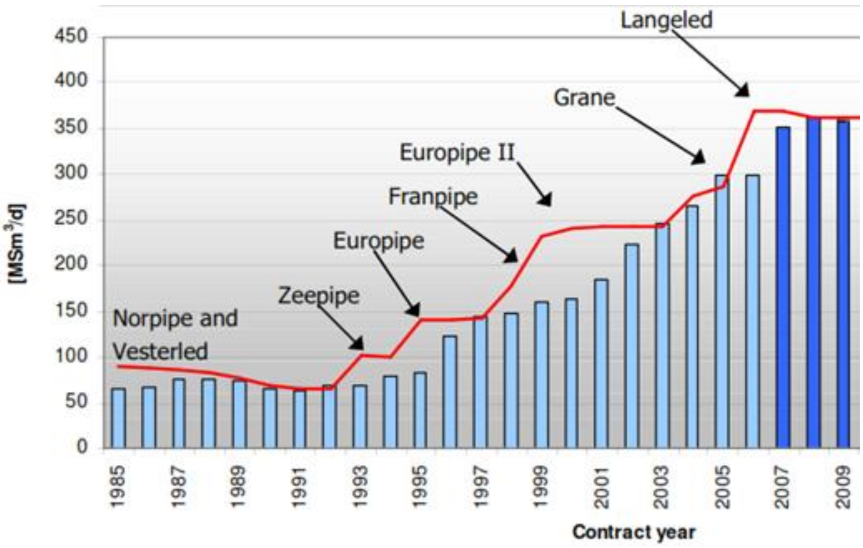


Figure 2-27 Daily Maximum deliveries vs total capacity (Hendriks, 2012)

Figure 2-27 plots the maximum daily deliveries against the overall export capacity. As an observation, it can be seen that after a new export line is commissioned, it takes a few years until maximum capacity is achieved if only ever so briefly (day to day basis).

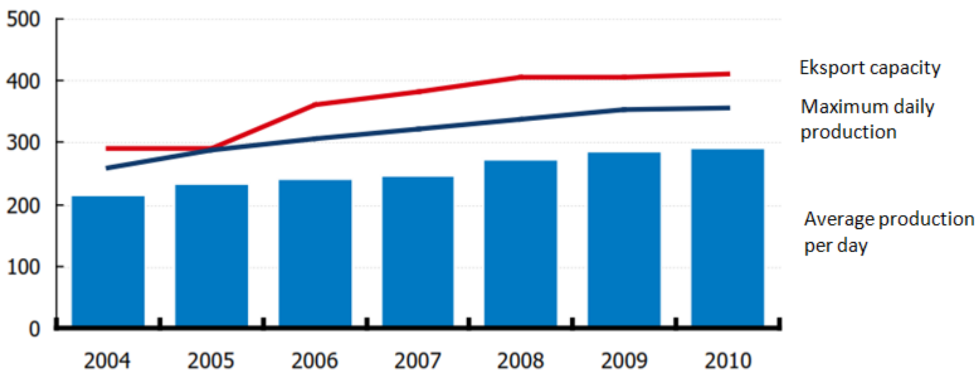


Figure 2-28 Historic gas export from NCS (MSm^3/day) (Gassco, 2012)

Another relevant data set regarding export capacity and utilization, is the average daily gas export per day. As Figure 2-28 shows, average production steadily increases on yearly basis, always leaving a certain marginal export capacity which can be utilized for supplying clients during high peak demands.

The infrastructure in general is not overutilized as the figure above depicts, but as most infrastructuress, there will always be a certain threat for bottlenecking towards the final destination (abroad) during high demand periods, or if long term demand increases.
The pipeline network's main routings and subsequent flow directions are shown below, where the receiving terminals are *written* in red.

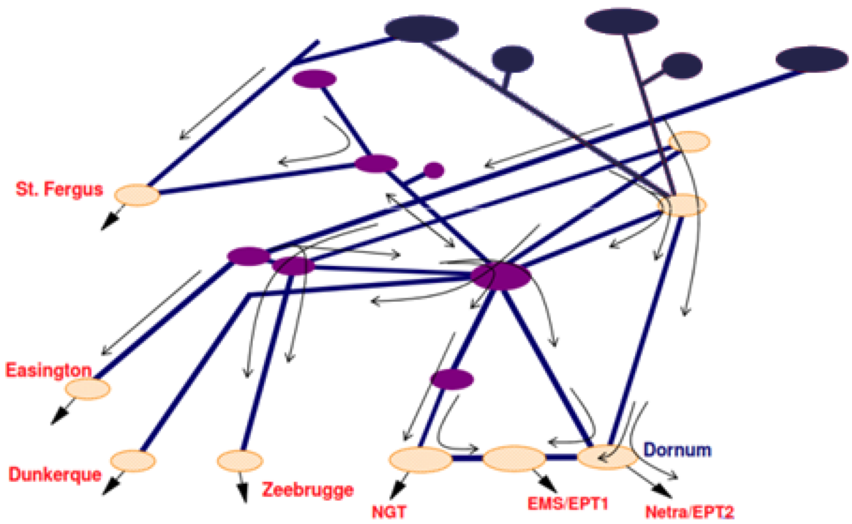


Figure 2-29 Main routings (Hendriks, 2012)

Exit pipelines NCS		
Pipeline	Diameter	Capacity [MSm^3/d]
Europipe I	40"	45.7
Europipe II	42"	71.2
Statpipe	30"	44.4
Franpipe	42"	54.8
Zeepipe	42"/30"	42.2
Langled	44"	72.1
Vesterled	32"	36.9
Flags	36"	30

Table 2-1 NCS exit pipelines

In total eight main gas pipeline constitue what can be called Norway's main exit pipelines.
Historically, the capacity of these pipelines has been sufficient in some periods whilst other periods have been pushed to its limits. As Figure 2-27 from 2005 depicts, the export system was then estimated equal to the maximum demand and capacity needed during peak periods. As total yearly export volumes are seeing an increase (Table 2-1), the pipeline export system becomes increasingly sensitive to unplanned shutdowns in order to supply the agreed upon quantity of gas.

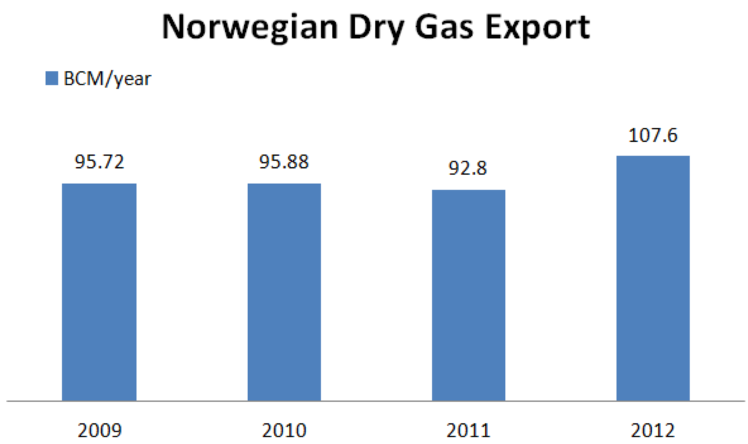


Figure 2-30 Norwegian Pipelined Dry Gas Export. Data Source: BP world statistical reviews & (Førde, 2013)

According to specialists, regarding the condition of Gassled's infrastructure, it can be assumed that the majority of pipelines have a high technical integrity, ensuring future operations for decades without any major investments. The onshore terminals on the other hand have in the past, required complicated rebuilding and upgrading resulting in high investments (Løvås, 2011).

2.4.2 FUTURE

Even though only 44% of total proven natural gas recoverable resources have been produced, Norway is depended on new finds in order to merely sustain its current production levels to meet predicted future European gas demands (NPD, 2012a).

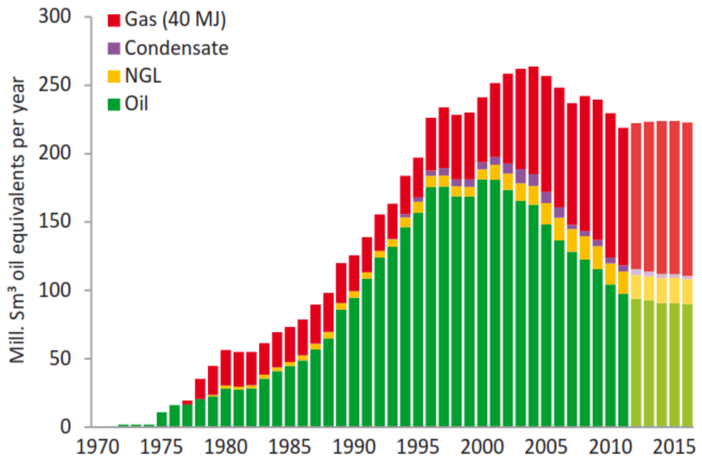


Figure 2-31 Historical production of oil & gas along with production forecasts the coming years (NPD, 2012a)

This has resulted in an increasing amount of investments on the NCS in finding and developing new oil and gas resources. 2011 saw sums over 125 billion NOK being invested, with 2012 having total expected investments exceeding 172 billion NOK (Bjerke, 2011).
A fifth of these investments have been aimed towards exploration in search for more oil and gas reserves, and as Figure 2-32 shows, the amount of exploration wells spudded over the past years has drastically increased, signifying Norway, and its operators' commitment and belief in supplying the energy marked with new resources.

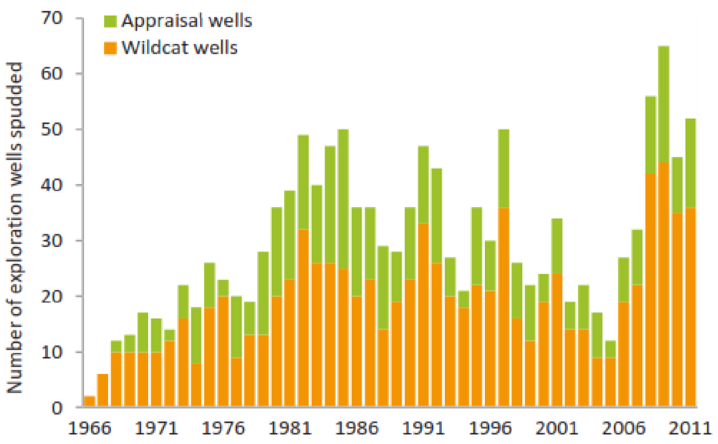


Figure 2-32 Oil and gas exploration wells spudded on the NCS 1966-2011 (NPD, 2012a)

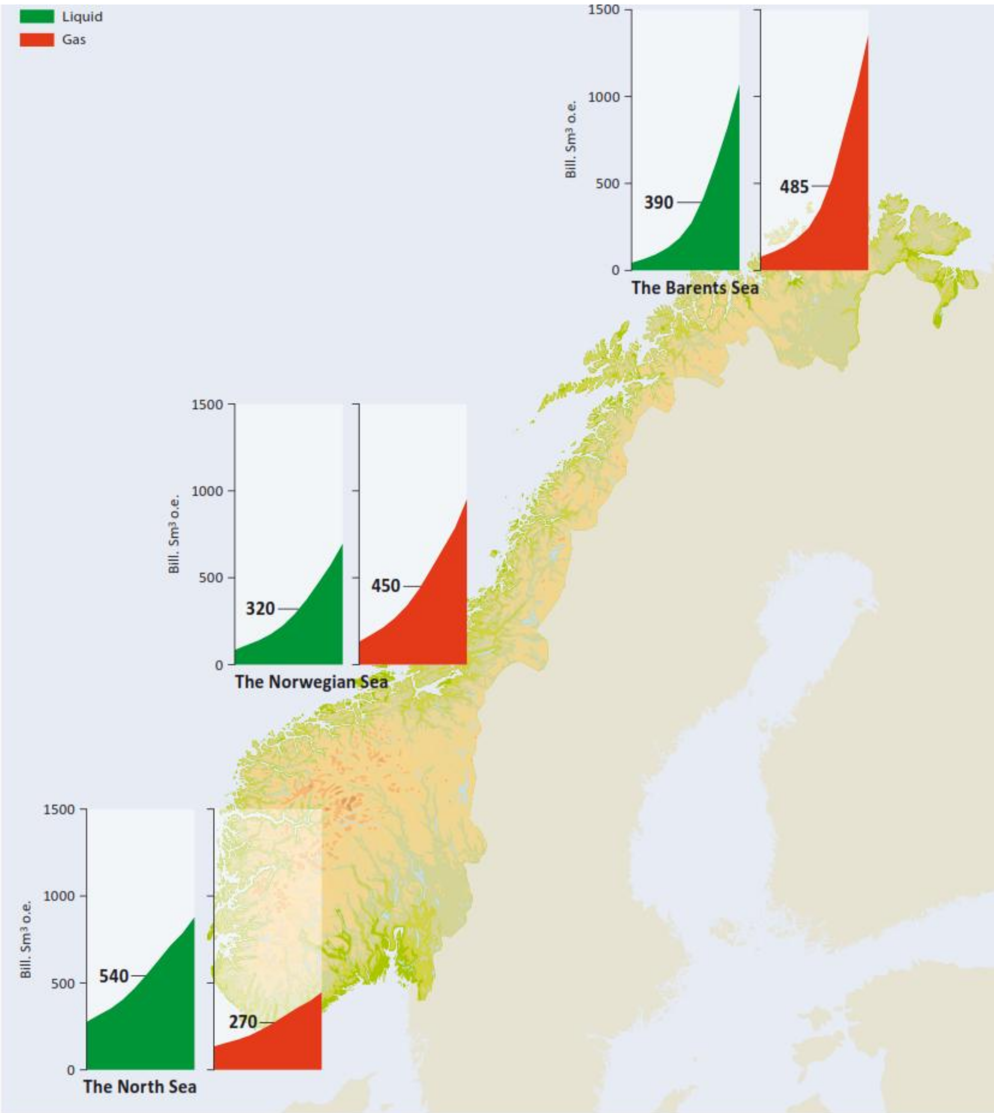


Figure 2-33 Undiscovered expected recoverable resources distributed by area with slanted line indicating uncertainty (NPD, 2012a)

Norway's coastline is extensive, and even though the Johan Sverdrup oil field discovery in 2010 (largest discovery on NCS since 1980's) was found in a mature area thought be already fully developed, most of the untapped reserves are estimated to be further north, especially regarding gas resources as seen in the Figure 2-34.

The search for new resources further north is especially relevant when the possibilities in finding larger fields increase when searching in undeveloped areas. One of the larger issues regarding gas finds is how to transport the natural gas resources to the gas markets.

A study performed by Gassco in January 2012 delves further in to this question detailing different scenarios depending on the multiple outcomes of undiscovered resources. Some of the viable options include transporting all resources from the Barents Sea to the onshore processing plant at Melkøya for further LNG export by boat.

Figure 2-34 Possible future pipeline infrastructure to sustain high resource find (Gassco, 2012)

The majority of solutions presented by Gassco are weighted on expanding the pipeline infrastructure. An example can be as seen on Figure 2-33 (illustrating possible new pipeline infrastructure (in bold red) to sustain a high resource find scenario).

As resources are proven at higher latitudes, signifying a larger distance from field to market, the choices of how to transport the gas to the market become harder. For instance, as the pipeline lengths increase, the capital expenditures required, rise drastically until a point where it becomes economically unviable to transport by pipeline. As Figure 2-35 shows, the Capex slope of piped transportation is substantially steeper than any other means of natural gas transportation.

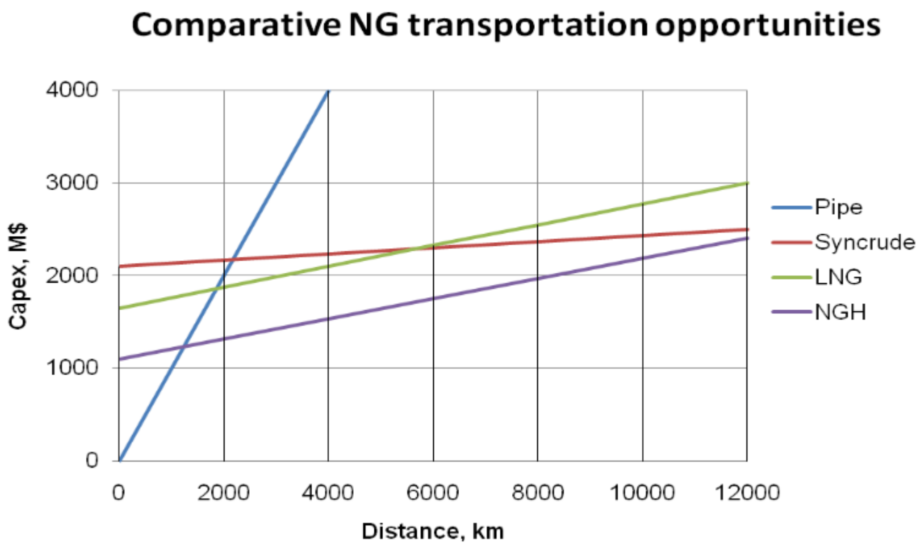


Figure 2-35 Opportunities for natural gas transportation (adapted from an estimate made by NTNU in 2002) (Zolotukhin, 2011)

Brian D Bjordal, President and CEO of Gassco describes the years towards 2030 as optimistic, especially in regards to smaller fields being tied in to existing infrastructure, thus further increasing production rates. He highlights the importance of good decisions in order to seize opportunities, ensuring long-term gas supplies to Europe (Gassco, 2011a).

2.5 NATURAL GAS

Seeing as a large part of the thesis is regarding natural gas, a brief explanation of what encompasses natural gas, and what types are applicable to Gassco, its pipelines and facilities are due.

When producing from an offshore field, there are three main components in which are extracted from the well in varying degrees, namely: water, sand and hydrocarbons.
Hydrocarbon is a naturally organic compound, formed over millions of years, trapped by specific geological conditions along with high levels of heat and pressure.
The composition of the hydrocarbons can be quite different, ranging from as simple light gas carbon, like methane, to thicker more viscous substances such as heavy crude. As such, hydrocarbons can be found in gas, liquid and solid form, all depending on its composition.

The gas form is referred to as natural gas. In the early days of oil production, natural gas was impractical to handle and transport, and was therefore discarded by burning, also called "flaring". In later years, this form of hydrocarbon has found its use, by either exporting through an extensive pipeline network (or by LNG vessels), reinjection the gas to increase recovery factors, or by deferring the production in order to retrieve it at a later point in time.
Other places in the world, where natural gas infrastructures have not been developed, the gas is still flared. Such flaring activities are highly damaging to the environment, and therefore such activities are banned in many offshore regions.

When natural gas is found in a reservoir, it can be either associated gas, meaning that the gas is found along with other liquid or solid hydrocarbon forms, or solely alone as non-associated gas. Whether the natural gas is associated or non-associated does not necessarily denote what kind of gas composition the find holds.
Natural gas's main constituent is Methane [CH_4], with ethane [C_2H_6], propane [C_3H_8], butane [C_4H_{10}], and pentane [C_5H_{12}] being some of the other main molecules found.
Thus, depending on the amount of percentage of different elements within, natural gas in itself can be split in to the two main categories: rich gas (also known as wet) and dry gas (also known as sales gas).

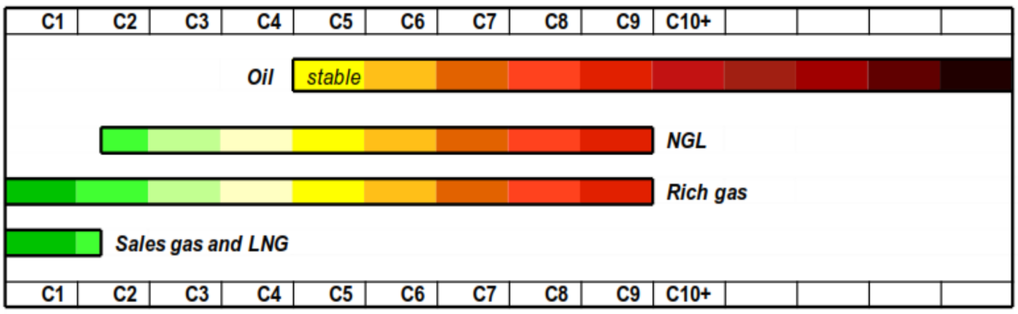


Figure 2-36 The basic hydrocarbon elements which encompass main different forms of pipelined natural gas (in addition to crude oil). (Odland, 2011)

Rich gas is a composition where there is a significant amount of heavy hydrocarbons present. Such heavy hydrocarbons will be found in a gaseous state in the reservoir where the pressure is high, but as pressure and/or temperature decreases during extraction, some of the heavier elements will condensate to liquid form. These heavier elements of rich gas (propane, butane, pentane, hexane etc.) are referred to as natural gas liquids, since they're mainly in liquid form at atmospheric conditions.

To be able to transport such gases through pipelines, the pressure in the pipeline must be held above the vapor pressure in order to keep these hydrocarbon molecules in their gaseous state.

Dry gas (sales gas) on the other hand is limited to a composition of only the lighter gases, being methane and ethane. Most often dry gas is extracted from the rich gas, where the remaining heavier components have their own uses and products which are processed and sold.
Dry gas is foremost transported through large intercontinental pipelines, connecting via export and import terminals. Although pipelines constitute the main means of dry gas transportation, various other forms exist (and are becoming increasingly used), such as liquefied natural gas (LNG) tankers. Within the LNG system, dry gas is cooled down to below its vapor pressure (approx −162 °C) where it becomes liquefied and thus far more energy dense (1/600th of volume compared to gaseous state). This denseness makes transportation by tankers highly practical due to its flexibility to supply any buyer in the world as long as they have receiving LNG facilities.

The hydrocarbon flow from reservoir to consumer is split in to the main fields: Up-stream, Mid-Stream and Down-stream (as shown in Figure 2-37). The pipelines transporting rich gas are mainly part of the transition between up-stream and midstream, where the gas is processed at a gas terminal, like for instance Kårstø. At such a processing facility the natural rich gas is fractioned to its designated products, one of which is dry gas. Furthermore, the transition between mid-stream and downstream is through dry gas pipelines (i.e Europipe, Franpipe etc.) to terminals in other countries (UK, Germany etc.) .

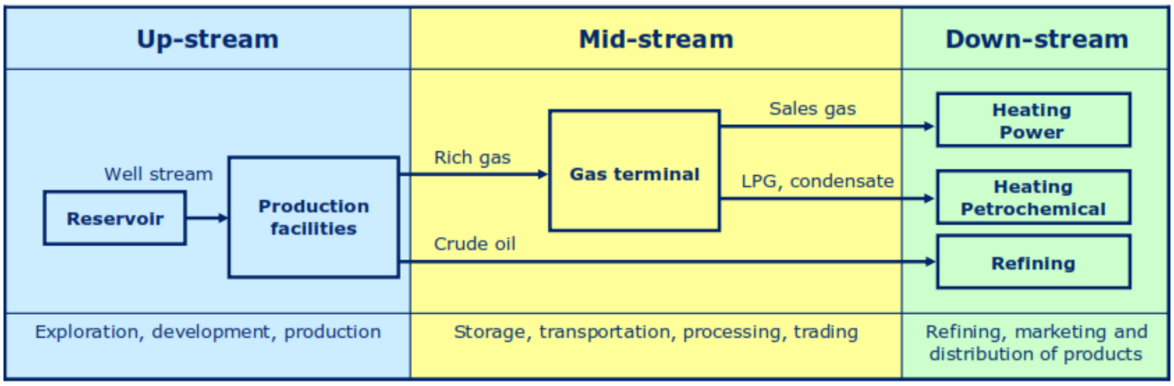


Figure 2-37 Hydrocarbon flow from reservoir to consumer (Odland, 2011)

In any leg and type of gas pipelines, there are usually restrictions of the composition and quality of the natural gas flowing through the pipeline. Especially liquids are a component that must be removed before the gas can be transported through a pipeline. Such coarse gas processing is often performed at offshore platforms before further exporting through rich gas pipelines to onshore processing facilities.
Onshore, NGLs are extracted and further fractioned to usable products such as Liquid Petroleum Gas (LPG) etc. In addition, CO_2 along with further amounts of water are removed before the gas can be transported through dry gas pipelines to the gas markets.

Quantity of natural gas is commonly measured in many forms. The most important factor for measuring gas is its reference condition.

The two most common conditions used as reference are:
Normal cubic meter (Nm^3) - Temperature: 0 °C, Pressure: 1.01325 barA
Standard cubic meter (Sm^3) - Temperature: 15 °C, Pressure: 1.01325 barA

Thus knowing which condition a cubic meter of gas refers to is important, since 1 Nm^3 is actually 8,9% more than 1 Sm^3.
When dealing with higher volumes of gas, like for instance yearly gas export quantities, billion cubic meters is often used. The problem here is that different suppliers may have different reference conditions for their measurements. For instance, the International Energy Agency measures gas at 15°C whilst Russia uses 20°C as their reference standard. The volumes will therefore vary slightly depending on who is measuring the gas. An example would be that 1 bcm of natural gas measured by the IEA, is equivalent to 1.017 bcm Russian natural gas.

Throughout the thesis, IEA's form of reference will be used regarding natural gas quantities.

Quality of natural gas from the NCS varies a lot. In order for Gassco to meet contractual standards, various grades of quality gas must be blended from a variety of fields. Morten Carlsen, head of Gassco's gas transport control centre, describes the scenario that if a field with good-quality gas produces less than expected, other fields producing under par quality gas must as a result, reduce their output in order for total blend of export gas dry gas to be correct.

In essence, the quality of gas is important because it:

- Ensures unproblematic transport and processing of gas.
- Prevents condensation of liquid, ice, hydrates, corrosion and erosion.
- Ensures interoperability and interchangeability.

The specifications of output of dry sales gas quality can be seen in the table below:

Sales (dry) gas specs	
Designation and unit	Specification
Hydrocarbon dew point (°C at 50 barg)	-10
Water dew point (°C at 69 barg)	-18
Maximum carbon dioxide (mole%)	2.50
Maximum oxygen (ppmv)	2
Maximum hydrogen sulphide incl. COS (mg/Nm^3)	5
Maximum mercaptans (mg/Nm^3)	6.0
Maximum sulphur (mg/Nm^3)	30
Gross Calorific Value (MJ/Sm^3)	38.1 - 43.7
Gross Calorific Value (MJ/Nm^3)	40.2 – 46.0
Gross Calorific Value (kWh/Sm^3)	11.17 – 12.78
Wobbe Index (MJ/Sm^3)	48.3 – 52.8
Wobbe Index (MJ/Nm^3)	51.0 – 55.7
Wobbe Index (kWh/Sm^3)	14.17 – 15.47

Table 2-2 Sales (dry) gas specs (Andrea, 2012)

2.6 OWNERSHIP STRUCTURES & DECISION FLOWS

The above chapters have briefly described the energy and resource scenario in which this thesis's pipeline takes place. In this chapter, the ownership structure and the actors, within the main decision flows in which primarily affect the **specific GNG pipeline** is discussed. The first consecutive sections describe in general terms the actors, whilst the following subsections delve in to the relations therein.

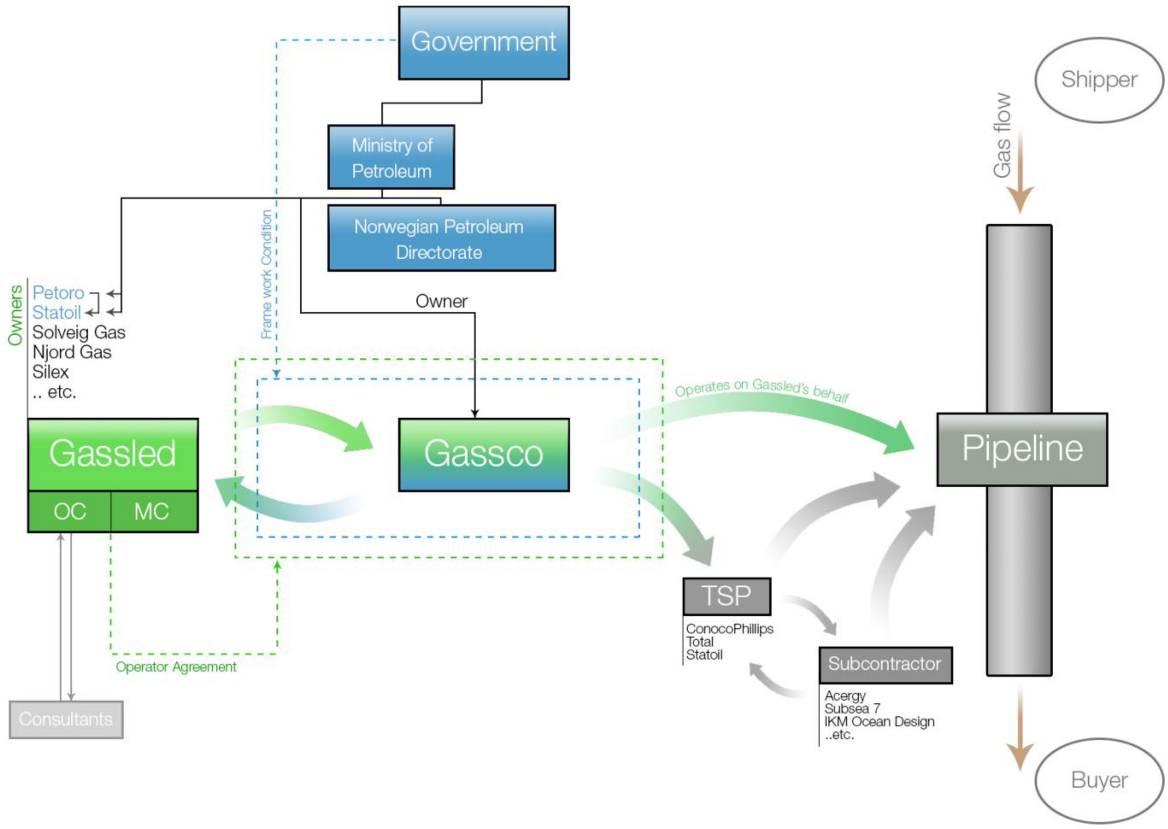


Figure 2-38 Ownership structure & Decision flows

2.6.1 TSP & Gassco

Taking a bottom up approach, the daily operation and maintenance of the transport system (plants, installations, pipeline etc.) are mainly performed by technical service providers (TSPs) through long term agreements on behalf of Gassco. These agreements have not been attained through market competition, but through political decisions (Hynne, 2007).

There are three companies which serve as TSP on behalf of Gassco (depending on the pipeline or installation at hand), namely Statoil, ConocoPhillips and Total. These companies can further appoint subcontractors for tasks such as pipeline inspections, cathodic measurement surveys etc.

Gassco, whom is the operator of the pipeline, deals with everything from administration of the infrastructure, to capacity management and future development projects. Gassco is owned solely by the Norwegian government and acts as an operator on behalf of the infrastructure owners, namely Gassled. An important point to note is that Gassco retains overall responsilibity for safe and efficient operation in accordance to Gassco's Operator Agreement (with Gassled) and Norway's Petroleum Activities Act (with Government).

Financial wise, Gassco does not make any profit or loss, where TSP services stand for approximatley 80% of their expenses (Hynne, 2007).
The government states that Gassco is to "carry out its operatorship in a neutral, efficient manner in relation to both owners and users" (NPD, 2012c).
Being owned by the government in order to operate Gassled's infrastructure, the company has thus three main entities it must conform to: Gassled, the Government, and users of the infrastructure, namely shippers and buyers (further details in chapter 2.7).

2.6.2 Gassled

Gassled, the owner of the Norwegian pipeline network is a joint venture between multiple stakeholders. As of 05.11.2012, the following owners are given below, along with their rightful weight within the venture.

Gassled Owners	Percentage
Petoro AS	45.793%
Solveig Gas Norway AS	24.756%
Njord Gas Infrastructure AS	8.036 %
Silex Gas Norway AS	6.102 %
Infragas Norge AS	5.006 %
Statoil Petroleum AS	5.000 %
Norsea Gas AS	2.261 %
ConocoPhillips	1.678 %
DONG E&P Norge AS	0.983 %
GDF SUEZ E&P Norge AS	0.304 %
RWE Dea Norge AS	0.081 %

Table 2-3 Gassled Ownership

The major stakeholder in Gassled is Petoro, which is a fully state owned company. Potero has the duty of ensuring highest possible value creation of Norway's petroleum resource portfolio (The State's Direct Financial Interests, SDFI) on the Norwegian shelf.

Specifically Petoro has three main tasks in which it is obliged to undertake, namely:

- Managing government holdings in such joint ventures as Gassled.
- Monitor Statoil's sale of the state owned petroleum.
- Manage the accounting aspect of the SDFI.

Within recent years, the organizational structure of Gassled has changed considerably, where oil & gas producing companies like Shell, Exxon and Total have sold all their holdings, and Statoil has sold a 24% stake.
These holdings have been mostly bought by foreign long term investment firms such as:

- Solveig Gas, a company owned by Canada Pension Plan Investment Board Allianz Capital Partners, a subsidiary of Allianz, and Infinity Investments SA, a unit of the Abu Dhabi Investment Authority (Treloar, et al., 2013).
- Njord Gas, as subsidiary of UBS Intentional Infrastructure Fund and CDC (Treloar ,et al., 2013).

- Silex Gas Norway, a company owned by Allianze Group, a global financial service provider of amongst others, property and life insurances (Allianze, 2013).
- Infragas Norge, a company owned wholly by the Canadian pension fund PSP.

This shift in ownership may change the way in which Gassled as an organization functions. The only oil and gas producing companies left in the joint venture is Statoil, ConocoPhillips, Dong and GDF Suez, making them a minority within the organizational structure.

Issues regarding ownership changes are further discussed in to in chapter 3.2.

2.6.3 Government

The Norwegian government has had a large impact on the petroleum industry in Norway from even before the first oil was produced on NCS. They have been actively taking part in the industry, and stand for major shares within most fields and aspects of the sector.
As Gassco is a fully state owned company, it is thus regulated by the government.

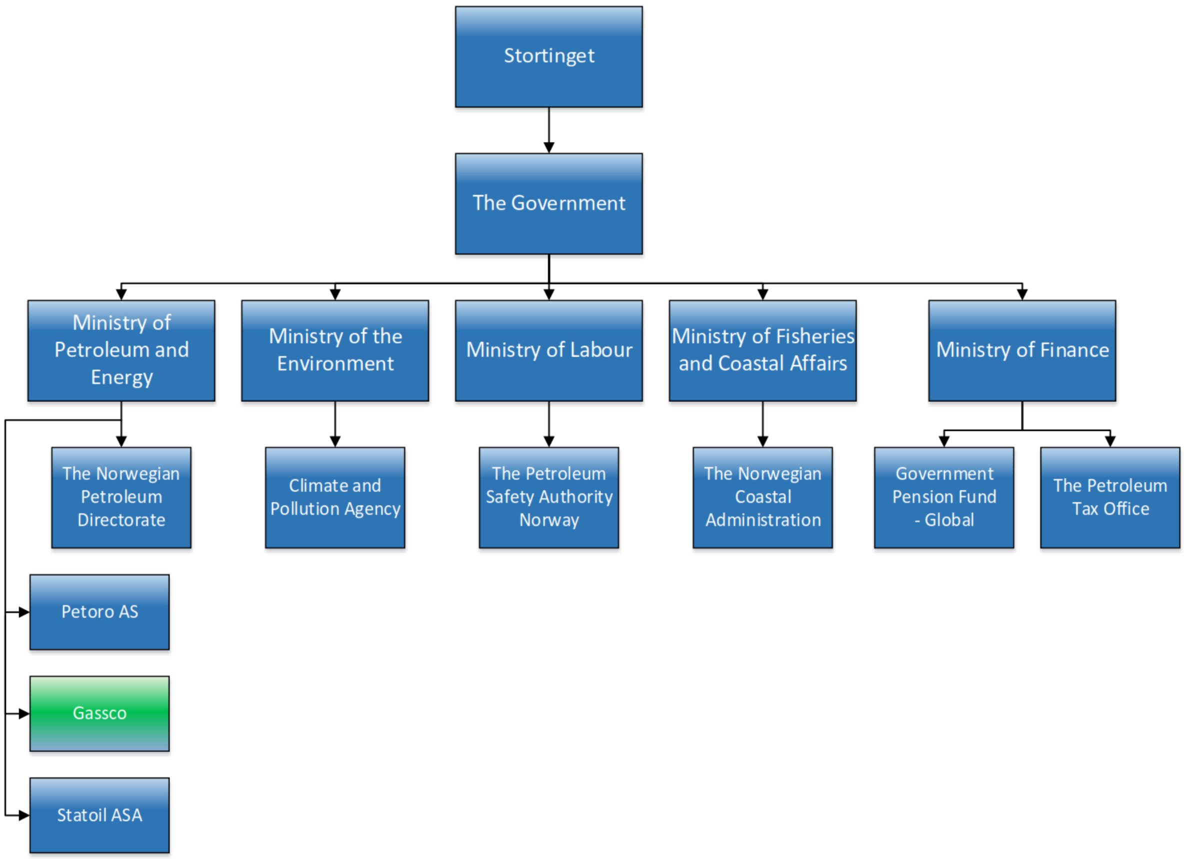


Figure 2-39 Hierarchy showing the relevant bodies within the government regarding petroleum policies, Data Source: (NPD, 2012a)

"**The Storting** (Norwegian Parliament), sets the framework for the petroleum activities in Norway, in part by adopting legislation. Major development projects and issues of fundamental importance must be deliberated in the Storting. The Storting controls the **Government**, which in turn exercises executive authority over petroleum policy, and answers to the Storting as regards to policies. To carry out its policies, the Government is assisted by the ministries, underlying directorates and supervisory authorities" (NPD, 2012c).

"**The Ministry of Petroleum and Energy** (MPE) has the overall responsibility for managing the petroleum resources on the Norwegian continental shelf. The Ministry must ensure that the petroleum activities are carried out in accordance with the guidelines set by the Storting and the Government. The Ministry also has owner's responsibility for the State-owned companies Petoro AS, and Gassco AS, and the partly state-owned oil company, Statoil ASA" (NPD, 2012c).

The Norwegian Petroleum Directorate is more of a technical body, advising the MPE through its professional integrity and interdisciplinary expertise. They exercise administration authority in connection with exploration for and production of petroleum deposits on the NCS. Which includes stipulating regulations and making decisions under the petroleum activates regulations. (NPD, 2012c).

The Government (and all instances within) stipulates their main authority in relation to Gassco, through a Framework condition, primarily the Norwegian Petroleum Activity Act. An act which encompasses all subsea petroleum deposits under Norwegian jurisdiction (NPD, 2012c).
An additional noteworthy regulation imposed on Gassco, is the regulation relating to the stipulation of tariffs. The Government has the authority through this regulation to change certain elements within entry, exit and processing tariffs of different areas of the infrastructure. A change in such values will in turn affect the cost and demand of Norwegian gas, especially important regarding export (further details regaring service pricing see section 2.7).

2.6.4 Crucial Decision & Information Flows

This section is meant as more a means to show which type of communication flows are present, ultimately affecting all stakeholders. Real case examples where applicable will be used.

2.6.4.1 Government Relations

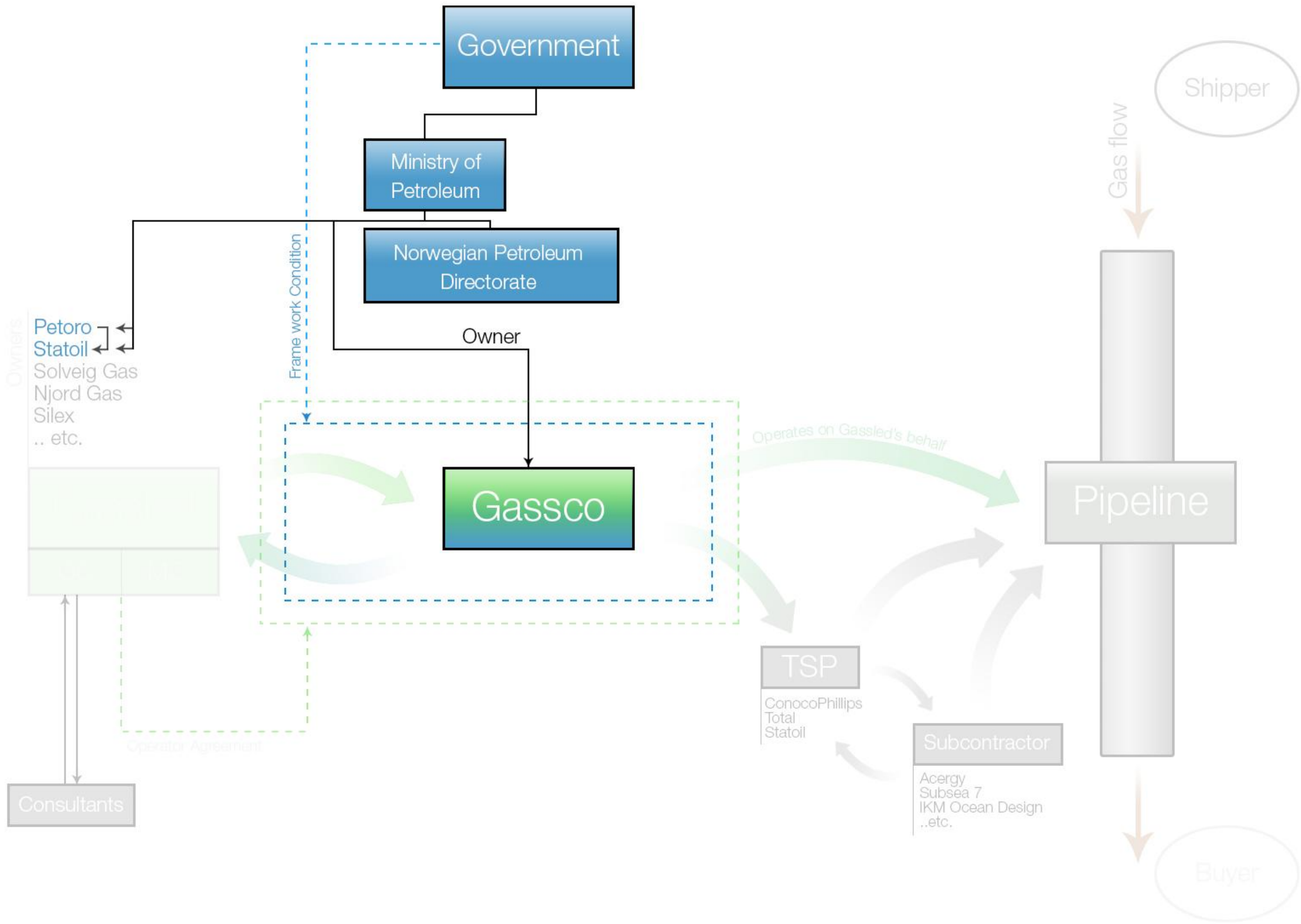


Figure 2-40 Government-Gassco relations

Not only does the government own Gassco, but in addition, both Petoro and 67% of Statoil are state held. All these three companies are the primary subject for supervision by the Ministry of Petroleum, ensuring that their regulations and goals are met and upheld by these companies. Furthermore, one of Petoro's key duties is to "monitor Statoil's marketing and sales of petroleum produced from the SDFI, in line with the instruction issued to Statoil by the MPE" (Regjeringen, 2013). As such, not only is approximately half of Gassled's ownership under direct influence of the government-owned bodies, but there is also a substantial amount of monitoring ensuring that these governmental bodies act accordingly to governmental policies. Thus highlighting the key role in which the Norwegian government has, in not only the operation of the infrastructure (Gassco), but also the ownership of the infrastructure (Gassled).

This large amount of influence and oversight by the government can result in politically motivated decisions being imposed to not only Gassco, but also the infrastructure and Gassled's non-government stakeholders.

Regarding the financial aspect, all remaining profit within Gassco is paid to Gassled and thus its sub-parties (mainly according to weight, some of which go directly back to the state via Petoro and Statoil). This profit is one of the major drivers for the new owners' participation in Gassled, namely gaining a certain amount of dividends in a low risk, long term asset such as a pipeline infrastructure.
The total profit is for the most part influenced by tariffs. The tariffs are set by the government through a formula within a regulation explicitly regarding stipulation of tariffs, and are at the moment ultimately set for Gassled owners to gain a minimum yield of 7% rate of return on total capital invested in the infrastructure within 2028 (before tax) (Løvås, 2011).

2.6.4.2 Gassled Relations

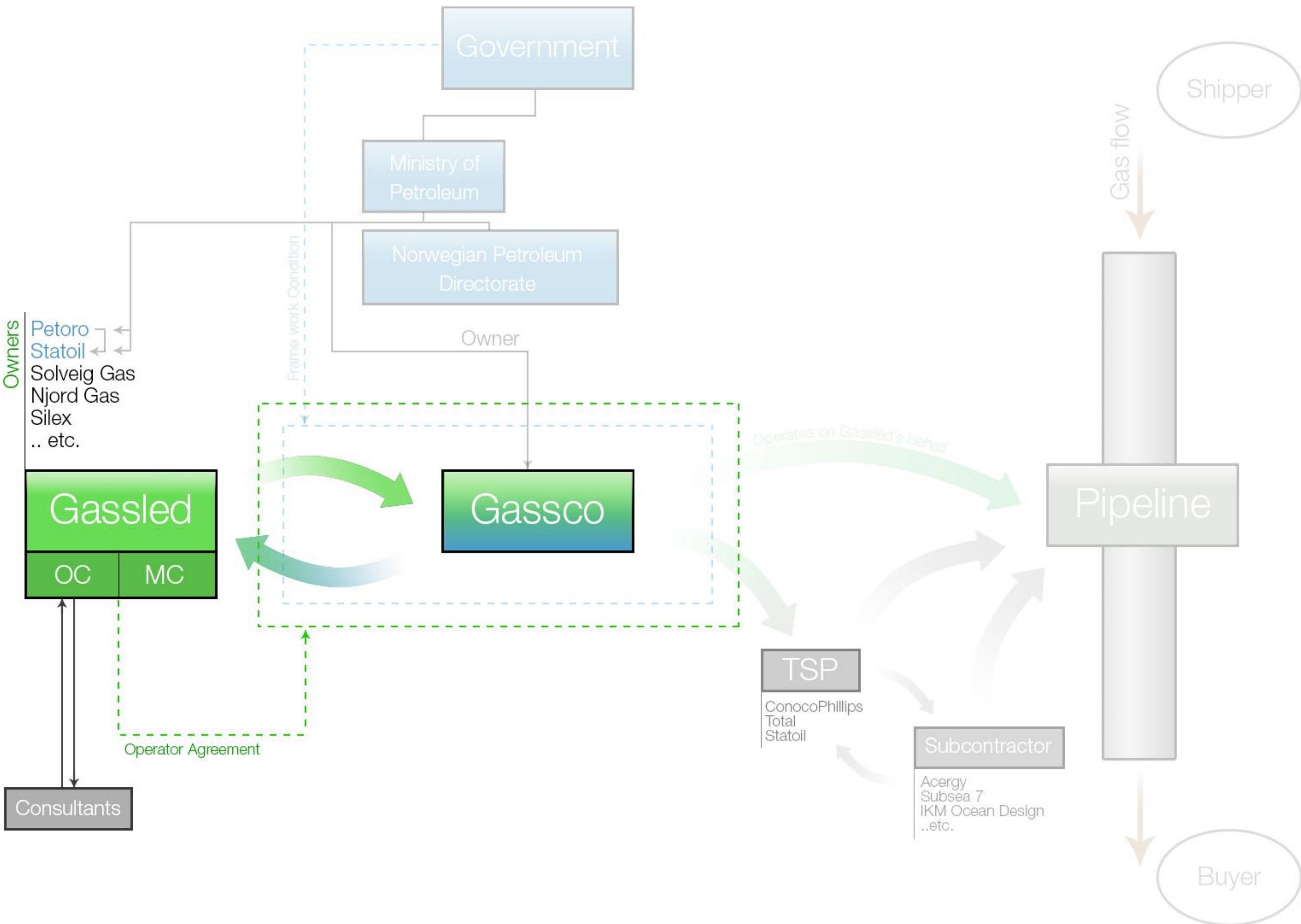


Figure 2-41 Gassled-Gassco relations

As the joint venture Gassled is the owner of the infrastructure, they, along with the government have oversight over Gassco's operations. In this respect, there is a mutual communication between Gassled and Gassco. This communication is segmented in to two forms, namely through Gassled's Operational Committee (OC) and their Management Committee (MC) each of which meet with Gassco 5-6 timers per year discussing relevant issues within their committees proficiencies.

Gassco is on their side required to present to the Gassleds' committees, recommendations and investment proposals based on an overall assessment of development needs and resource management. Approval from Gassled on the basis of recommendations will depend on the willingness to invest displayed by owner companies within the joint venture along with resource owners (upstream shippers) on the NCS (Gassco, 2013).

Seeing as the ownership change within Gassled was fairly recent, the amount of interaction between Gassled and Gassco may increase due to the fact that new investors have a newly acquired asset and wish to see it run in a most proficient manner.

Increasingly relevant following the large ownership changes is external consultants hired in order to perform specialized evaluations. Such services are most likely evident in order for Gassled to make best possible decisions for their asset.

Seeing as Gassco is managing Gassled's assets, Gassled impose their control over Gassco through their operator agreement "Terms and Conditions for Transportation of gas in Gassled".
The agreement is 150 pages, containing appendices: Operations Manual, Transportation System Description and NGL/Condensate Lifting Procedure Kårstø Gas Plant.
Basically the operator agreement states how Gassco should run Gassled's infrastructure in broad terms, ranging from the limited amount of consecutive shut down durations for planned maintenance to audits and tests which must be performed.

2.6.4.3 Gassco Relations

Gassco plays major part in the gas value chain from upstream, through to downstream and thus also the specific pipeline which applies to this thesis. Seeing as the relations from Gassco and up, have already been covered in previous chapters, Gassco as operator of the infrastructure communicates with other stakeholders of the system.

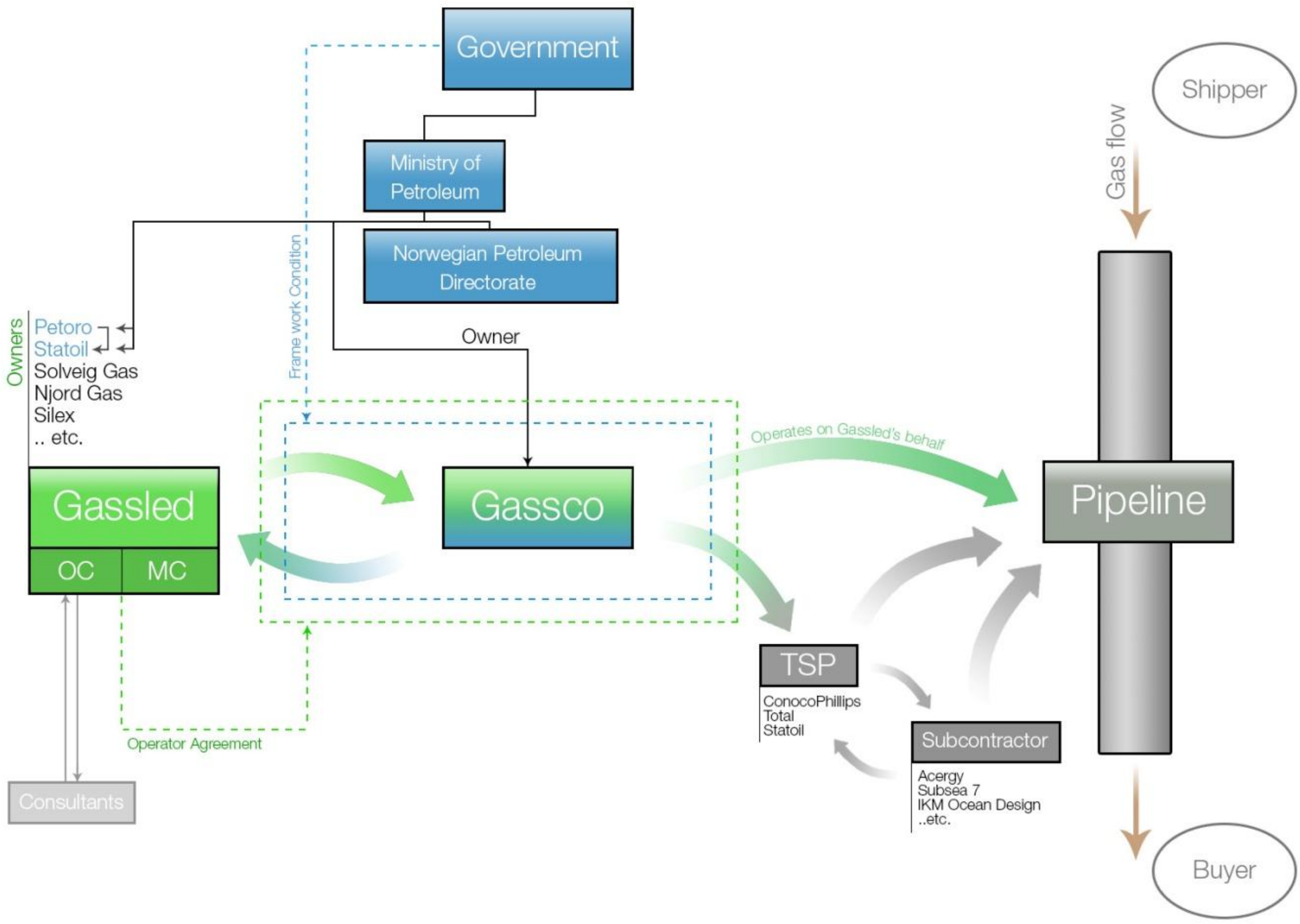


Figure 2-42 Gassco relations

Apart from Gassled and the government, Gassco communicates with following participants in the gas value chain when transferring gas through the GNG pipeline (indicated in blue in figure below):

- Field Operator (varying from platform to platform throughout the NCS).
- Upstream shipper
- Downstream Operator
- Technical Service Providers

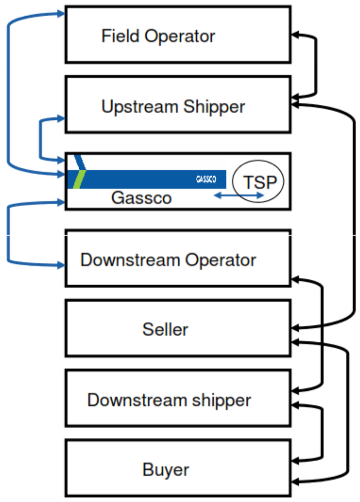


Figure 2-43 Participants and roles in gas value chain (Hendriks, 2012)

Information flows between Gassco and other main stakeholders (except TSP) are normally routed through the GasviaGassled booking system (further details: 2.7.3). Any other communication is directed to Gassco headquarters in Haugesund Norway. Communication of such sort may for instance involve production problems or future planned shut downs from field operators.

Most day to day activities are held via Gassco's control centre located at Bygnes in Karmøy, north of Stavanger where gas flow is constantly monitored and controlled in order to facilitated amongst others, the correct quality blend and possible rerouting in order to deliver the agreed amount of gas.

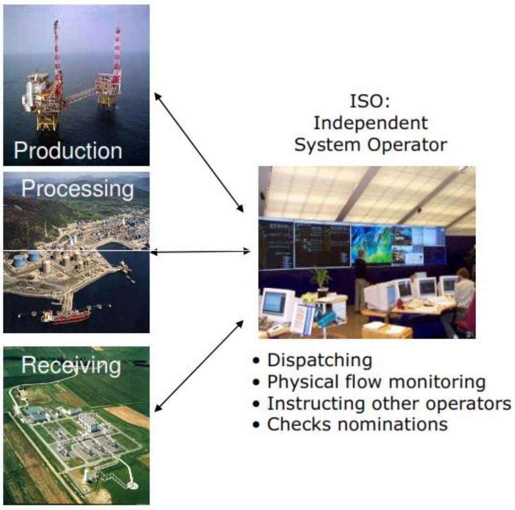


Figure 2-44 Gassco Control centre (Hendriks, 2012)

Seeing as Gassco poses the role as Operator they hold overall responsibility for the operation of the system. Their main communication flow is thus with TSP, who acts as lead technical service provider in activities where Gassco itself is not fully present in. Similar to Gassco, the TSP also acts within a type of frame work agreement stating how to conduct its operations on behalf of Gassco.

2.7 PRICING THE SERVICES

Gassco's main task in the natural gas value chain is to transport gas from Norwegian offshore fields through pipelines to processing facilities and then ultimately transporting it as sales gas. The figure below shows their position in reference to both upstream and downstream actors.
Due to limitation in the scope, only the pipeline aspect is relevant, and the following subsections are meant as giving a brief overview over how the cost for transporting the gas is set.

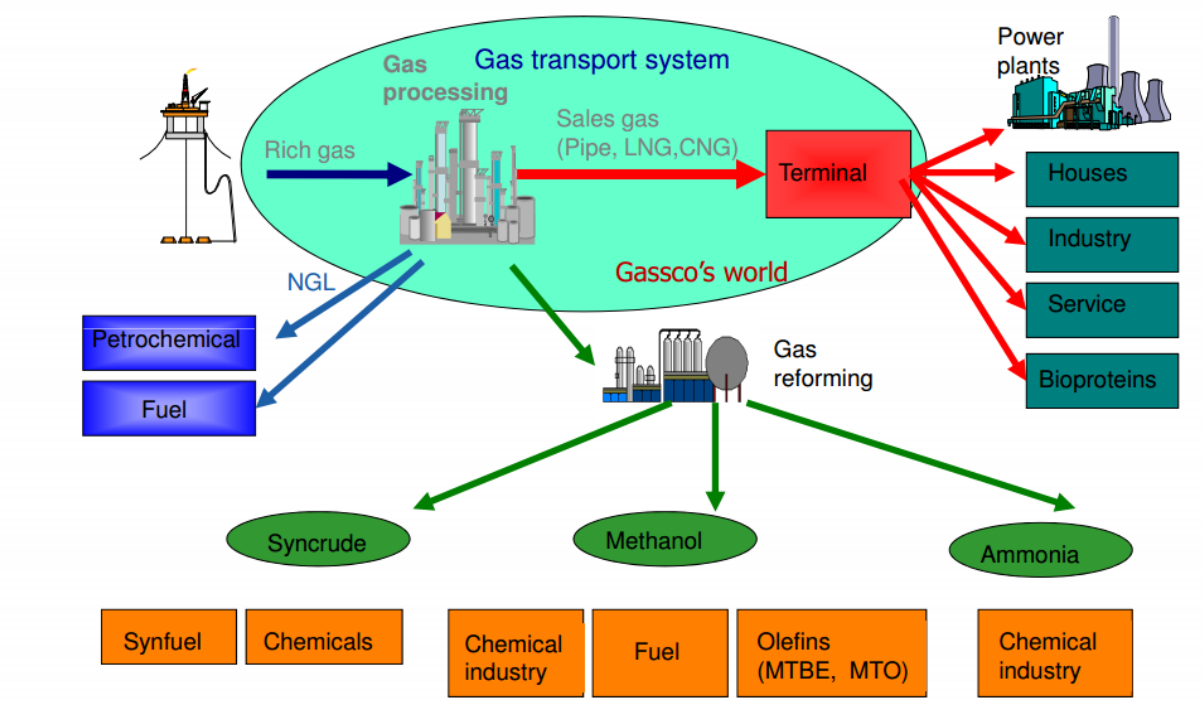


Figure 2-45 Value chain for natural gas (Hendriks, 2012)

Gassco supplies many geographical markets, but within their booking regime called GasviaGasled (more to come in section 2.7.3) two markets, namely the primary market and the secondary market exist. As such, the revenue gained from transporting the gas is attained through these markets.

Since the establishment of the new Norwegian regulation regime introduced in 2001, one of the main changes from the prior regime, was that the largest profits should be gained at the offshore fields and not from the infrastructure itself and that the majority of pipelines within the infrastructure was collected under one joint ownership, namely Gassled. The owners of the individual pipeline network were to receive its share of ownership interests based on the value in which they brought in to Gassled with their respective pipelines. Owners within Gassled were then to receive priority pipeline capacity in the infrastructure, and where any other non-owner gas operator would gain similar conditions as owners within Gassled. Both types of users of the system are often referred to as shippers.

2.7.1 Primary Market

The primary market is where the shippers of the gas, book capacity that they believe they need for medium to long term periods. Currently there are 31 qualified shippers, whom have constantly varying capacity needs often depending on their production status offshore. Bookings are held twice a year, and owners of the infrastructure have preferential rights up to two times the ownership interest (Johnsen, n.d.). The infrastructure system is handled in such a way that it exploits all possible transportation routes in order to maximize utilization. Thus, if a shipper has a need to transport more gas than previously booked, the shipper must buy capacity from someone else within the market (Gassco, n.d.a).

As Gassco is just an operator in charge of the transportation of the gas, the price a shipper has to pay for this service, is Gassco's handling fee (tariff). The shipper's selling agreements with buyers are most often long term contracts, thus the shipper books a certain amount of long term capacity from Gassco, where the cost for transportation is set by a tariff.

The NCS spans over a great distance, thus transporting gas from the fields up north through multiple pipelines and terminals to for instance Germany, will cost the shipper more, than if gas from the North Sea is shipped directly through one single pipeline to continental Europe. As such, the NCS is dealt up on areas.

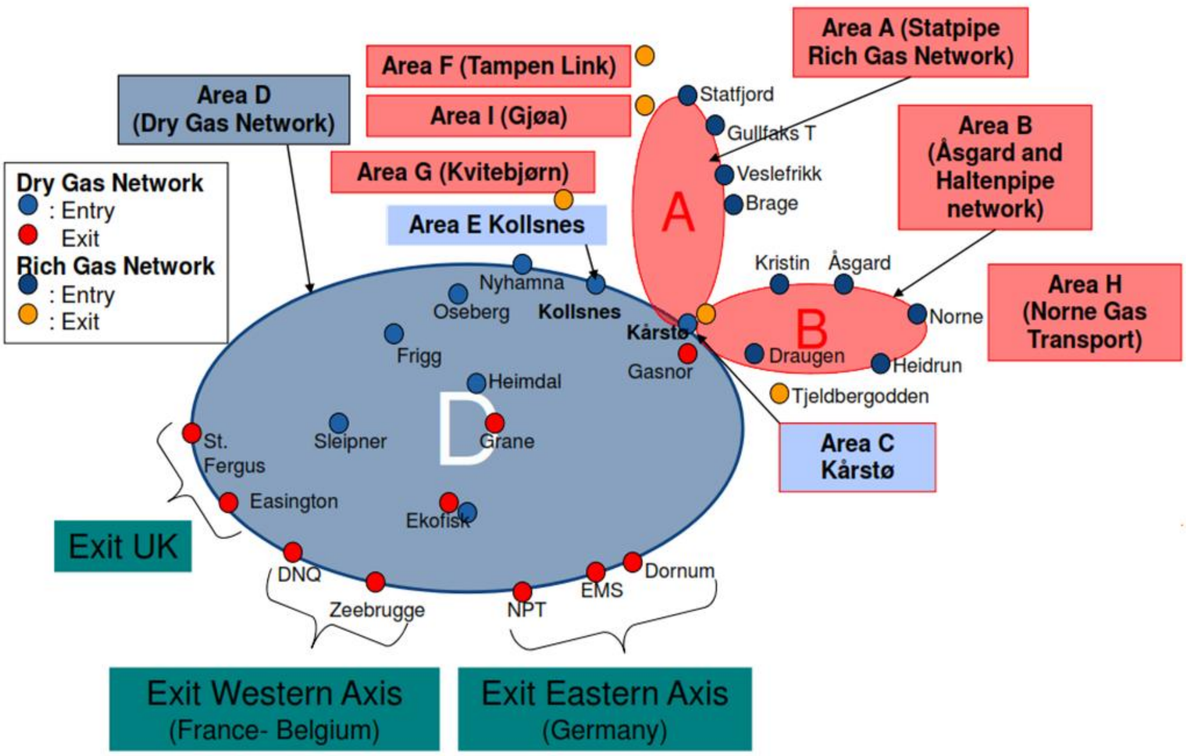


Figure 2-46 Gassco Booking and Tariff regime (Hendriks, 2012)

For every area the gas has to transit through, a new tariff is introduced for the specific leg for the righ to use an entry, exit or processing point.

Gassco’s tariff for each area is stipulated by the “Regulations related to stipulation of tariffs etc. for certain facilities” § 4 with the following formula:

$$t = \left(K + \frac{I}{Q} + U\right) \bullet E + \frac{O}{Q}$$

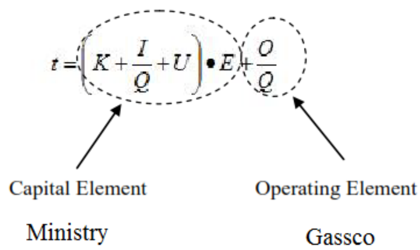
t = tariff per unit for the right to use an entry, exit or processing
K = fixed part of the capital element per unit
Q = estimated aggregate reserved capacity for the year in question
I = annual element calculated for investments to maintain the system
U = element calculated for investments related to extensions of the system
E = escalation factor (annually stipulated on the basis of Norwegian consumer price index)
O = anticipated operating costs

The Ministry has a large influence on multiple factors within this formula (described below) as to regulate the overall tariff “t”.

<u>Factors stipulated by Ministry:</u>
K, I, U and E

<u>Factors stipulated by operator (Gassco):</u>
Q and O

As such, the formula can be broken down in to two elements, namely the capital element, and the operating element (Regulations to PAA Section 63). In which the ministry stipulates the capital element (excluding Q) and the operator (Gassco) stipulates the operating Element.



<u>Any regulation by the Ministry</u> within this formula must coincide with the *Regulations to Act related to petroleum activities*, where some of its main points are:

- When the Ministry stipulates the capital element, not only should the best possible management for resources be considered, but also ensuring that the owner can expect a reasonable return on the capital invested (currently a minimum expected 7%).
- The operating element must ensure that the operator (Gassco) has neither profit nor loss beyond “the return stipulated in the fourth paragraph” (referring to rate of return of 7%).

These are overall regulations regardless of area, transport legs and local costs.
Consequently, specific K, I, U, Q, O values vary for explicit entry, exit and processing points within area to area.

Any regulation of Gassco to the anticipated operating costs (O) for a specific area has to coincide with the *Regulations relating to the stipulation of tariffs etc. for certain facilities,* where some of the main points are:

- Stipulation of the anticipated operating costs (O) shall occur at the beginning of the year.
- Any **individual** investment sums exceeding operating costs shall not exceed the sums as given in table below for the corresponding area.

Area	Up to
A og B	40 mill. kroner x E
C	250 mill. kroner x E
D	200 mill. kroner x E
E	250 mill. kroner x E
F	40 mill. kroner x E
G	40 mill. kroner x E
H	40 mill. kroner x E
I	40 mill. kroner x E

Table 2-4 Gassco investment sum limitations

- The **sum of individual** investments shall not surpass three times the amount of the limitations given in the table above.
- The operator must exercise due diligence when stipulated the anticipated operating costs (O) for the coming year, as not to unreasonably impacting the overall area tariff.

Any infrastructural costs above the allowed values (set by regulation above) in “O” the Ministry retains involvement through the factors “I” (Investments related to maintenance of the system I) and “U” (Investments related to expansion of the system), both of which in turn are part of the capital element.

Therefore, the overall area tariff “t” in the primary market, depends on where the gas is sold from and transported to/through and is not affected by market demand and supply (unless regulated by the Ministry).

A contractual agreement of amount of gas capacity allocated to a shipper for a certain period holds a tariff of the determined rate when the agreement was made. Any future changes to the tariffs will not affect the cost imposed by Gassco to the buyer of the gas.

Should the buyer in the primary market not utilize the capacity given, the cost shall be 50% of the tariff for the applicable area(s).
But, the right to use the capacity in the pipeline network may be transferred by agreement in the **secondary market** if a party in the primary market does not need all or part of the capacity allocated.

2.7.2 Secondary Market

As opposed to the primary market, the secondary market is mostly a selling and buying ground for third parties. The prices in the secondary market are not price regulated by the Ministry through tariffs, but rather a market-clearing price where the quantity supplied is equal quantity demanded (in essence, affected by buyers and sellers).

The secondary market allows shippers to re-sell their already attained booking capacities from the primary market. There is no extra fee in re-selling, but the shipper has the possibility to add or give discounts on the bookings. Shipper must regardless, uphold the payment obligations for the bookings in the primary market (Gassco, 2010).

As stated in the regulatory act, it is Gassco as the operator who has the overall responsibility in arranging and conducting a market place for transferring rights to use capacity in the network. This market place is called GasViaGassled.

2.7.3 GasViaGassled

GasViaGassled is a secure web-enabled solution used for buying and selling capacity in the Norwegian gas transport system (Gassco).

For an entity to gain access to the service they must become an authorized shipper. When shipper has attained access, the shipper can book/check and sell capacity in both the primary and secondary market.

Should a shipper in the primary market as stated earlier, not require all capacity allocated in the primary market, shipper can through GasViaGassled sell this capacity in real time to the secondary market.

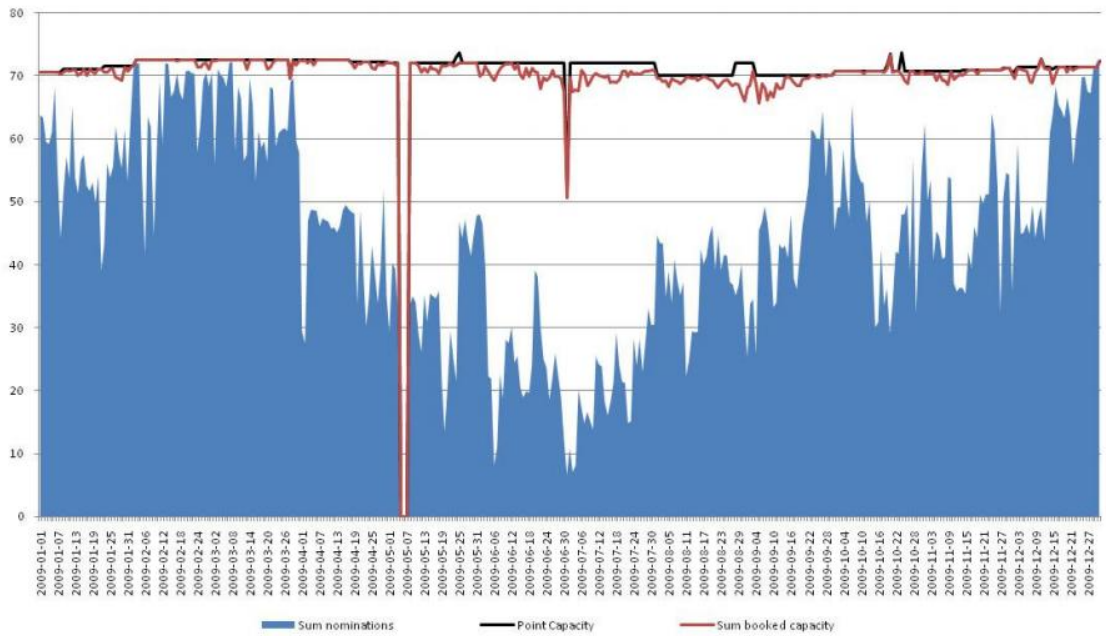


Figure 2-47 Easington booked capacity, nominations and point capacity (Gassco, 2010)

Most often contracted capacity is already stipulated in capacity products such as long term annual capacity, monthly capacity or daily capacities. The shipper then submits a nomination on how much gas it is indicating to transport within its capacity limits. All of which is performed within the GasviaGassled interface system.

AsFigure 2-47 shows, the booked capacity is close to the maximum capacity of the pipelines for Easington, but the amount of gas nominations is far less in certain periods.

2.7.4 Tariff Price Level

Regarding the natural gas price itself, contractual agreements between shipper and buyer state a certain price (or price model) in which the buyer is willing to pay, and the seller is willing to sell the natural gas for. Finding this balance is a delicate processing involving many aspects, such as demand for natural gas, competitor's pricing etc. When a contract between buyer and seller is signed, the shipper (seller) books a certain amount of capacity which it needs from Gassco in order to supply its buyer. The current and future costs of the service Gassco takes for transporting the gas is fixed from when the contract is agreed upon until the contract expires. Thus any future changes to the tariff will not affect the already booked capacity within a contractual period.

The tariff Gassco takes for its service affects many aspects of the natural gas value chain:

- The tariff imposed on the transportation has to be sufficiently high in order to maintain the infrastructure, and provide the necessary off take for Gassled's investors which again can be used to further invest in developing the infrastructure.
- The profit to shipper must be high enough in order for them to defend future development of fields.
- The overall price paid by buyer has to be competitive in comparison to other fuels in order to maintain gas as a competitive energy source over time.

2.8 FINANCIAL FLOWS

Knowing how basic financial sums move throughout the companies regarding the GNG pipeline is a part of how these individual entities relate to one another. As shippers and buyers commit to transactions through GasViaGassled, shippers are obliged to pay a handling fee to Gassco in the form of tariffs. The revenue gained from such tariffs are distributed in the means of paying for maintenance, R&D, operations etc. along with Gassled owners' rightful return of investments. Any financial flow leaving the system is signified as red arrows, where TSP, Subcontractors and external consultants take their form of profit as incentive to perform their various tasks. Most of the financial sums directed to the government through Petoro and Statoil will most likely not affect the GNG pipeline, but the possibility is there. Green arrows signify routes in which financial sums are directly benefitting the GNG pipelines' wellbeing.

The most prominent investor for any large future financial issue regarding the GNG pipeline (failure/upgrade) will be the owners of the infrastructure, namely the joint venture Gassled.

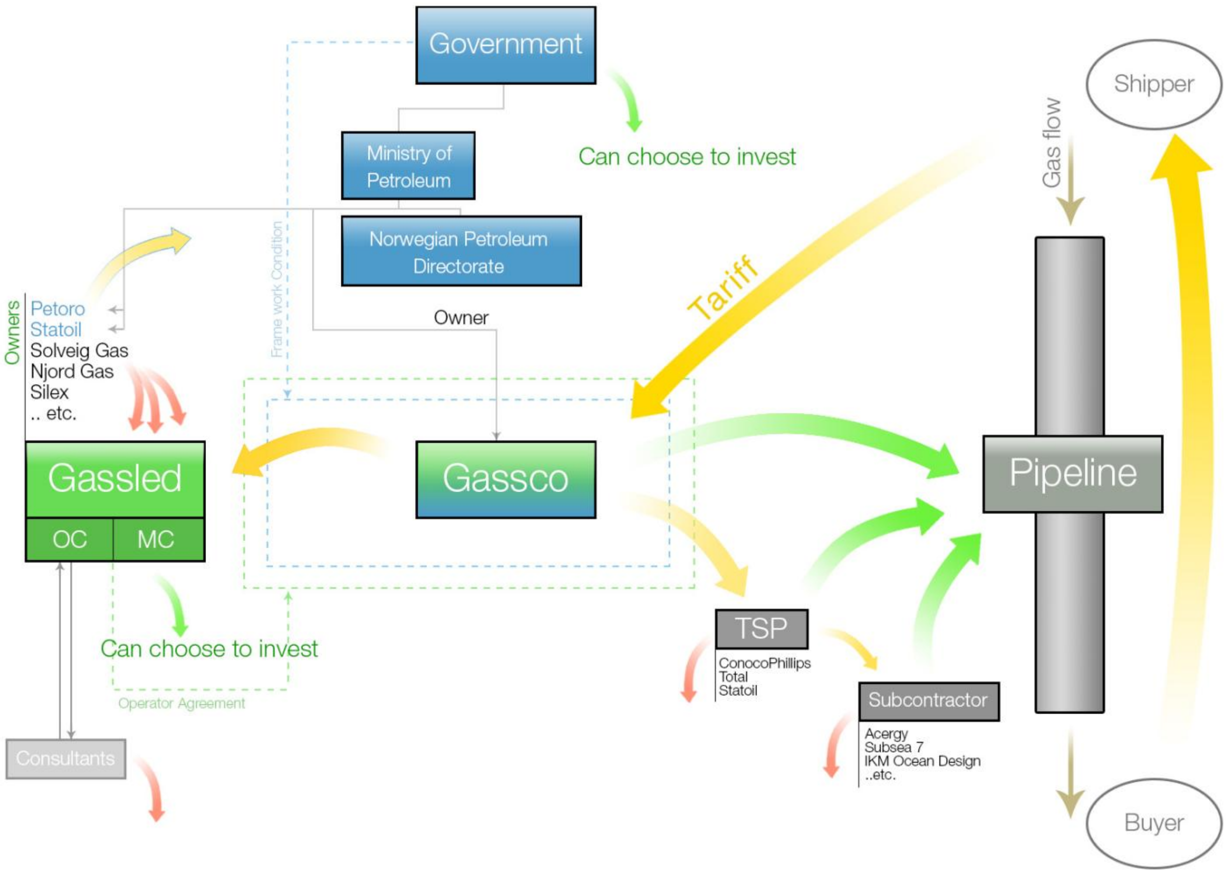


Figure 2-48 Financial flows within system

The Government has through its ownership in Gassco, the possibility to further invest funds if they see fit. As an example, the proposed Skanled pipeline stretching from Kårstø to Sweden's west coast was anticipated to be 30 percent financed by the Norwegian Government. Lack of oil and gas industrial interest saw the project halt in 2009 (Løvås, 2009).

The possibility of governmental investment within the specific GNG pipeline is highly unlikely, but seeing as Gassco is a non-profit company, it is most probable that they wish Gassco be as self running as possible.

As seen in the figure above, the whole financial in-flow of funds is dictated by the tariff. A change in tariff is going to dictate the amount of funds distributed within the system.

2.9 REGULATORY REQUIREMENTS

In order to guarantee a baseline standard promoting safety, reliability, productivity, efficiency and technical integrity, numerous documents often set as a minimum requirement are imposed on assets, amongst others in the design, construction, operational and decommissioning phases.

Utilizing a top down approach, **codes** are large, extensive internationally recognizable guidelines, developed by a consensus of often international experts. Such codes are frequently deeply technical detailed, and are widely used in the industry (ASME, DNV etc.), where they are mostly used as a set minimum obligation for the project at hand.

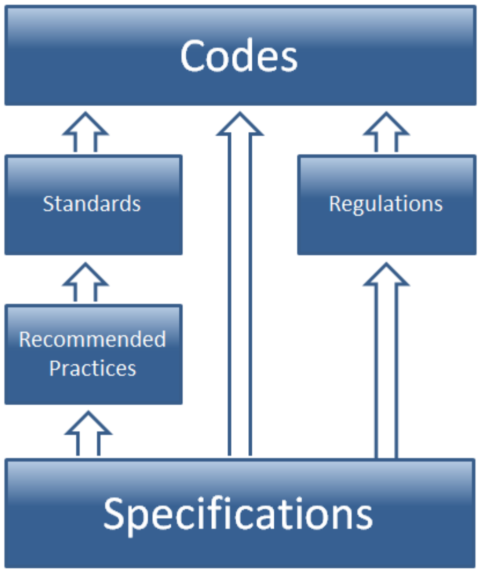


Figure 2-49 Regulatory requirements

Regulations on the other hand, are regional or national documents, which often are based on, or refer extensively to international codes. The regulations are set either to extend the codes, by for example implementing specifically viable elements which would only apply to the region, such as snow loads, not being applicable in warmer conditions. Emission policies, accident prevention or safety regulations are also examples of requirements which may differ from country to country.

Standards are often based on international codes, but are limited to a selected area of interest. A selected standard can be used widely across the world, where the limited scope of the document ensures a high technical level of the issue at hand, where a legislator or client instead of referring to an extended code of 1000 pages, can rather state the specific detailed standard of 80 pages, decreasing the complexity, whilst also assuring a high level of quality of the issue at hand.

Recommended practices are often standards in development. They are often not completely verified with enough real world applications in order to completely justify its authority, but acts rather as a recommendation based on experts within the field. As the recommended practice is used, improvement potentials are often reported, and after a few years the practice becomes a full worthy standard.

Individual companies may have their own **specifications** of how tasks should be undertaken and designed for. They often base themselves on codes, regulations, standards and recommended practices, but in addition, add further safety factors or increase the detailed level of requirements ensuring increased benefits for the company, like for instance higher structural integrity, lower emission, lower risk, higher performance etc.

Requirements applicable for the GNG pipeline are abundant. Without going in too deep of detail, there are a few main categories of which constitute main laws/regulations the pipeline must at all time abide to throughout its life cycle from the design phase through to decommissioning. In addition, certain requirements also become viable in order to efficiently manage the pipeline.

As standards and codes evolve and get created, the relevant requirements for the physical attributes of the GNG pipeline are ones in which where available at the time of creation, and not new revisions or documents which would prove relevant in today's scenario.
The below figure is a brief overview over **some** of the applicable requirements the GNG pipeline must conform to.

Design

Codes:	-ASME (B31.4, B31.3, B31.8 ,B16.25, B16.34 etc) -ASCE -DNV (Rules for Submarine Pipeline systems -NPD: Regulation Concerning Pipeline Systems in the Petroleum Activities -Norwegian Standard 3479
Regulations:	-UVV – Accident Preventing Regulation -API – Guide for Pressure Relief and Depressurizing Systems -NPD : Regulations and Provisions for the Petroleum activity
Standards:	-Norwegian Standards (NS3570,8141 etc.) -ASME (B16.9 Factory made Wrought Steel Buttwelding Fittings, 16.20etc.) -DNV Environmental Conditions and Environmental loads -API (6D Specification for Pipeline valves, 6FA etc.)
Recommended Practices:	-ASTM -Royal Norwegian council – Frost Action in Soils -DNV On-bottom stability design of Submarine Pipelines -DNV Trawl Loads on Pipelines Design Guidelines -DNV Rules for the Design, Construction and Inspection of Offshore Structures
Specifications:	-Specification for Design Cathodic Protection -ASTM – (A 615 Specification Of Steel Bars for Concrete and Reinforcement etc.) -F-SD-101 Design Specification for Offshore Installations – Offshore pipeline systems -Specification of Line Pipe -API (Specification for Pipeline valves etc.) -Risk Acceptance Criteria in TSP group -Specification Pipeline Protection System

Operation

Acts:	-Petroleum Act: Act related to petroleum activities (the Petroleum Act), 29 November 1996, No. 72
Regulations:	-Petroleum Regulations: Regulations to the Act relating to petroleum activities, 27 June 1997, No. 65Standards: -Regulations relating to stipulation of tariffs, etc. for specific facilities, 20 December 2002, No. 1724;
Standards:	-DNV-OS-F101 Submarine Pipeline Systems -ISO 13623 – Petroleum and natural gas industries, pipeline transportation systems
Recommended Practices:	Integrity Management of Submarine Pipeline systems
Specifications:	Gassled Terms and Conditions

By ensuring proper use and application of all relevant requirements, safety, reliability, productivity, and efficiency, technical integrity can be upheld throughout the asset's design life time of 50 years.

The above documents are extensive and complex, encompassing multiple aspects of the pipeline infrastructure in the form of amongst others: design, operation, pricing, shutdown periods, abandonment etc. As an example, the Gassled Terms and Conditions, gives Gassled the authority to reduce downtime of the GNG pipeline (down to 0), where the normal limiting amount of downtime due to maintenance is set to 20 consecutive days.
Due to the standards' wide-range of applicability to the infrastructure, only a few parts become explicitly relevant for the thesis at hand.

In addition, there are regulations and agreements stipulating how the interactions between parties within the gas transport system:

- Regulations regulating the transport regime and tariffs
- Terms and Conditions for transportation of gas in Gassled (developed by Gassco, approved by Ministry)
- A booking Manual
- Shipping Manual
- The natural gas law
- An agreement for use of Secondary Market

2.10 INSPECTION, MAINTENANCE AND REPAIR

The battery limits (current and future sections) regarding physical boundary is set by what is encompassed between the pig receiver/launchers on both sides (as seen in schematic below).

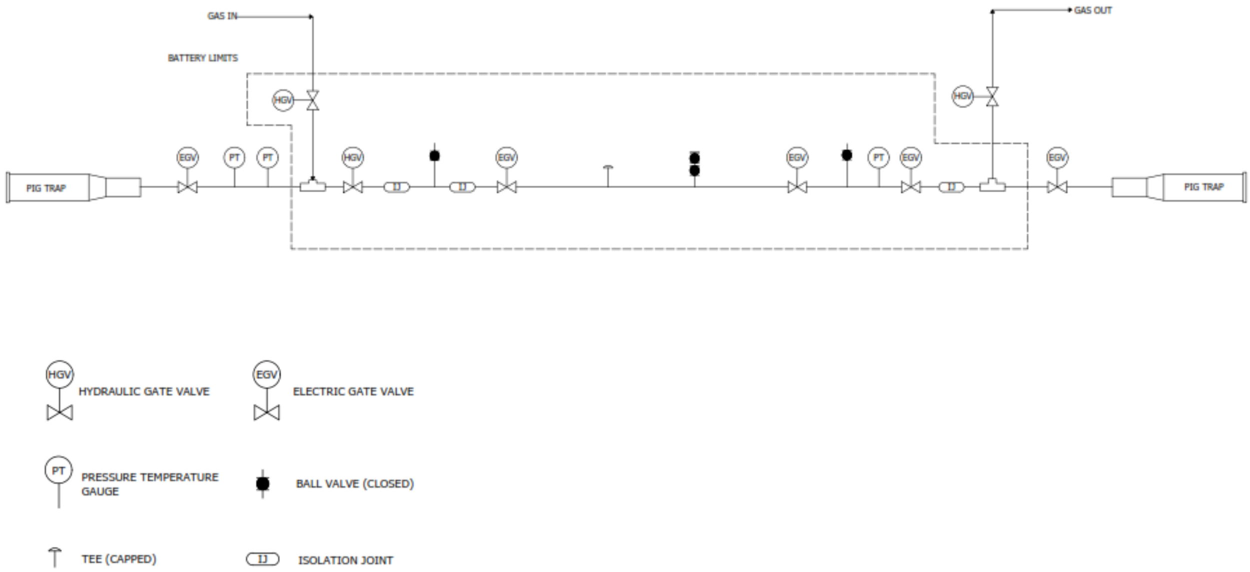


Figure 2-50 Battery limits GNG Pipeline

Note: It should be mentioned that the schematic above is a simplification of the true schematic in order for the subject of anonymity still being valid.

As previously written, the tasks regarding inspection and maintenance of the GNG pipeline are given to TSP.
On completion of a major infrastructural pipeline as the GNG, an as-built survey along with a commissioning survey will give any future changes during inspections, a base value in which deviations can be quantified.

Annual inspections are performed in order to reveal any system non conformance, where non-conformances are reported and correction if due, is performed.
Although there are many components within the system that need checking (Pig traps, valves etc.), the largest activity within the overall Gassco operating budget is according to Audun Brantzæg, a Gassco asset manager, externally inspecting the pipelines.
This statement is meant as an overall description, but it also signifies the weight given to such inspections for the GNG pipeline.

2.10.1 Common External/Internal conditions

In order to fully understand the current status of the pipeline, a brief introduction to common lifecycle occurrences in similar applicable subsea gas pipelines is given below.
Any changes to the physical pipeline can be categorized in external and internal conditions.

2.10.1.1 External Conditions

Free spans
Large pipelines are normally laid directly on the seabed (not buried or trenched). As such, geological conditions change, moving, lifting and in general imposing new forces to the pipeline lying on the seabed.

Figure 2-51 Free spans (FishSafe, n.d.)

Some of the most prominent issues involve pipeline free spans occurring. Due to the variation of seabed terrain, the pipeline is not fully supported throughout its whole distance. During installation the pipeline is laid in such a way to limit the amount of free spans occurring especially in areas prone to trawling.
Pipelines installed on an uneven seabed will tend to form free spans rather than conform to the topographical features of the seabed. Scouring or eroding may also occur, either way, resulting in an unplanned unsupported length of pipeline. One issue is that if such free spans become large, excessive loading can be subjected to the pipeline via amongst other vortex induced vibration (VIV) caused by current flowing above and beneath the pipeline.
Although VIV can be a threat, the main risk in such occurring pipeline free spans, is the risk of third party snagging (briefly discussed further down).

Pipeline walking (snaking)
Another common issue is pipeline walking, which occurs during multiple start up and cut off cycles of gas transferrals. When pressure is applied to the pipeline (operational), heat is induced to the pipeline making it expand. In opposite effect, when the pressure is relieved the heat dissipates and the pipeline retracts. In both instances assuming that in order for the pipeline to expand, the temperature of the gas needs to be higher than the sea temperature at the specific depth. Consequently as a form of mitigation, the exported gas is cooled down and temperature continuously monitored in order to prevent the pipeline from expanding. Should the export temperature rise above a certain value, the gas export system is automatically stopped until the problem is solved.
Note: There is one heat exposed zone in the beginning of the GNG pipeline which is subjected to temperatures above these levels. The pipeline is at this section primarily gravel dumped in order to prevent upheaval buckling due to pipeline expansion.
Temperature variations aside, due to varying friction factors in the seabed, and geological factors, the pipeline may inevitably tend to move away from where it was initially laid independent of gas

temperature.
Any major movement causing large compressive forces to a pipeline can cause **local buckling**, or local upheaval buckling. Such buckling scenarios are especially viable where a pipeline is fixed, restricting axial movement. Larger pipelines (like the GNG) are not normally trenched or buried (except in especially high risk prone areas). The pipeline is thus more free to flex and bend without stress concentrations occurring which could lead to buckling. Therefore, as a result of this freedom, the pipeline is more prone to snake laterally across the seabed (pipeline walking), but at some points bending strain may become an issue due to local lateral buckling.

Pipeline Burial
As the pipeline is laid, and during the course of time, certain segments of the pipeline may find itself "sinking" or digging in to the soil, thus becoming partially buried. Such events are mostly beneficial seeing as the pipeline is less exposed on the seabed. On the other hand, the opposite may also occur, where the pipeline may unbury itself, becoming exposed.

Field Joint Damage
Before offshore installation, pipeline segments are produced in typically 12-24m lengths with additional protection (concrete coating etc.). The protection mass is not applied to the point of where the intersecting segments are to be welded.
On the pipeline laying vessel, the segments are placed together, welded, and welds thoroughly checked.

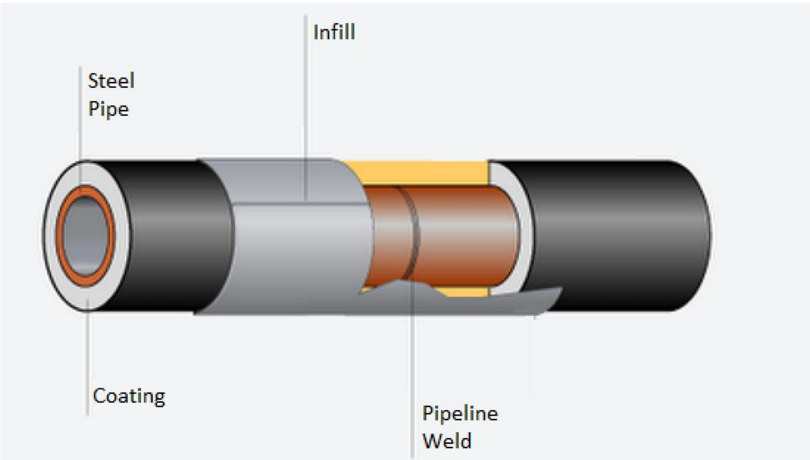
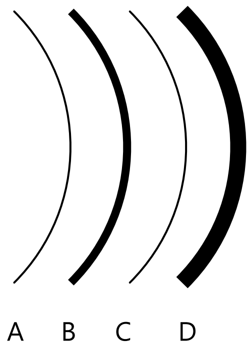


Figure 2-52 Field Joint. Source: (ASRO, 2009)

Before the pipeline can be submerged and laid, extra coating and concrete needs to be applied as to conform to the rest of the segments. These parts of the pipeline are called the **field joints**. Due to the fact that the infill coating is applied away from factory, the quality and performance of the coating is not as good as the rest of the segment coating (line pipe coating) which is applied in a stringent onshore factory location. Thus the field joints become one of the weakest external locations in a long infrastructural pipeline, especially in relation to third party impact loads such as trawl boards or anchor impacts.

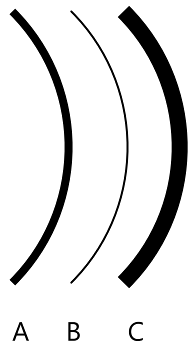
The comparison below shows the different layers on factory segments compared to field joint segments of the pipeline. In addition Figure 2-53 shows damage to one of GNG pipeline's field joint.

Pipeline onshore factory segment



A) Thin film Epoxy (internal)
B) Steel pipeline
C) Anti corrosion coating
D) Reinforced concrete

Pipeline offshore field joint segment



A) Steel pipeline
B) Serviwrap (corrosion coating)
C) Infill (solid polyurethane foam etc.)

Figure 2-53 Typical damage to filler joint (Polyurethane filler), where corrosion coating is exposed at field joint.
Source: GNG pipeline visual ROV inspection.

Corrosion

Due to the nature of submerged metal in seawater, the issue of corrosion becomes important. Even though protective coating is applied around the metal, the electrochemical potential between the electrolyte (seawater) and the pipeline is still substantially prominent to cause corrosion to occur. Therefore sacrificial anodes (often made of zinc) are placed on the pipeline along its length. Zinc has a lower potential than the pipeline metal, meaning that the anodes oxidize and not the pipeline. During inspection, the electric potential of the pipeline, along with the amount and presence of placed anodes are evaluated.

Trawling Impacts

Third party impacts are one of the main contributors threatening a pipeline's external integrity. There are multiple ways in which third party entities can affect a pipeline.
Fishing vessels on the NCS are one.

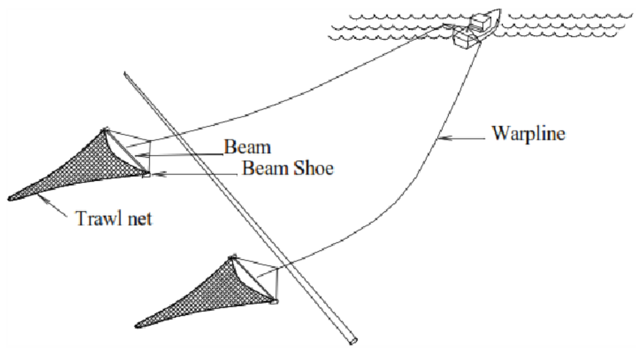


Figure 2-54 Typical beam trawl gear crossing a pipeline (DNV, 2010b)

Fishing vessels utilize trawl boards when catching fish, consisting of nets, designed to scour the sea bottom for fish. They stay on the sea bottom by attaching heavy weights which are dragged along the seabed keeping the net at the same depth.
These weights can, impact, overdraw or hook up on the pipeline and the amount of damage such trawl boards can cause, vary a lot. Overdraw is when the trawl board is drawn sideways over the pipeline, and hook up is when the trawl board gets caught under the pipeline.
Trawl scars are often common, where the weight or cables has hit the pipeline, removing some of the protection concrete and left bare pipeline metal subject to possible sea water corrosion. Pipelines are normally designed to withstand trawling loads such as impact, overdraw or hook up. One of the main barriers against trawl board damage is the concrete coating.
The concrete covering of the steel pipeline not only acts as added weight, increasing the pipeline's stability, but also acts as protection against local impacts.
As previously described, the pipeline's field joints are especially vulnerable for such damage, due to lessened strength, amongst others due to lack of reinforced concrete present.

Not common, but relevant information: Trawl impact can in addition to just damaging the coating, actually move a pipeline off its designated resting spot, breach the pipeline coating, deform steel pipe and in worst case cause the pipeline itself to rupture (smaller pipelines).

Anchor Damage

The largest threat of third party impacts is from anchors. These anchors are in many ways just like trawl board impacts in which they can snag, scrape and dent the pipeline. The anchors on the other hand often belong to larger vessels such as shipping vessels which possess much larger mass and speed than trawling ships. Anchor impacts from such larger vessels can often result in substantial displacement and/or damage to the pipeline. Anchors can interact with a subsea pipeline in many ways.

- Normally a ship is brought to a halt before the anchors are deployed. Most often, during routine anchorage, the captain will inspect various sea charts in order to make sure that the site is designated for anchoring. During such a scenario, the anchor penetrates the seabed vertically. Should the ship either not have sufficient maps onboard stating the presence of a pipeline directly beneath the ship, or during an emergency anchorage, the pipeline may be subjected to the vertical impact of the anchor, resulting in a dent or gouge.
- After the anchor has hit the seabed, the ship normally releases more anchor chain. As the ship starts to drift, the anchor is pulled horizontally across the seabed until it digs fully in to the soil attaining maximum holding power, securing the ship from further drifting. During this drag, the anchor may cross the pipeline, possibly causing a dent or gouge.
- In the event of the anchor snagging the pipeline, the kinetic energy from the above vessel will be transferred to the pipeline causing damage or even displacement until either the anchor chain breaks or the anchor is pulled over the pipeline. During any case, the pipeline is most likely displaced, and in severe cases resulting in local buckling which could or already have developed in to a possible rupture (Jones, 2011).

It should be noted that the likelihood of an anchor impact is significantly lower than impact from trawling gear.

Sinking Ships

In addition to trawling, a sinking ship is also a threat that should not be taken lightly, particularly in areas with high shipping traffic. One ship has sunk close to the GNG pipeline, where the wreck finally rested within a kilometers distance from the pipeline. Had the wreck hit the pipeline on its descent, the results may have been serious, especially since the resting point was in deep water (Annual GNG pipeline report).

2.10.1.2 Internal Conditions

Corrosion can become an issue internally due amongst others water being transported via gas, ultimately possibly condensing on the pipeline wall and thus causing oxidation of the metal.

Note: Although seemingly important issue, more information is not presented due to the composition of gas flowing through the GNG pipeline (discussed in later sections).

Deformation of the pipeline is also something that can be measured internally. Such deformation may occur due to dents by third party objects like trawling or even boulders.

Such factors are often checked via pipeline pigging.

2.10.2 TSP Pipeline Inspection Routines

Following methods and routines are used during general inspections (not necessarily specific for the GNG pipeline).

2.10.2.1 Methods

<u>Offshore pipeline segments</u>

ROV General Visual Inspection (GVI).

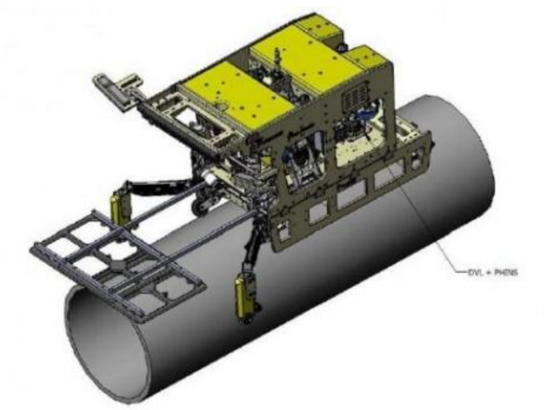


Figure 2-55 ROV General Visual Inspection (Oskarsson, 2012)

An intervention vessel launches a remotely operated vehicle (ROV), which follows the pipeline on the seabed. The ROV is typically equipped with cameras recording the pipeline from top and both side views. In addition, cathodic protection levels are also continuously measured, whilst at all times relevant positional data is recorded such as KP, depth etc.

In general, such an inspection evaluates the pipeline in respect to laying comfort, free span distribution, pipeline damage, debris, cathodic protection, coating and any other observations regarding the pipeline's integrity.

This normal method of ROV GVI inspection is very time consuming and thus also expensive. As the figures below show, costs for inspection per km length of pipeline has increased the past years, amongst other, due to an increased amount of time spent per km of pipeline.

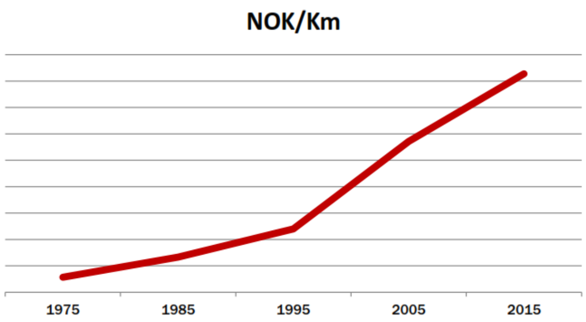


Figure 2-57 Costs of ROV GVI (Oskarsson, 2012)

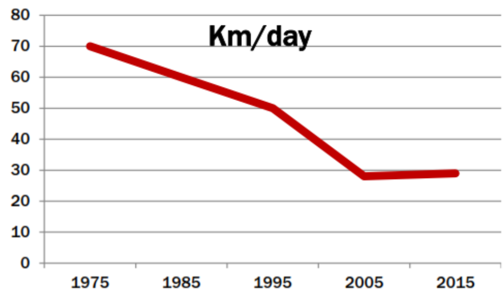


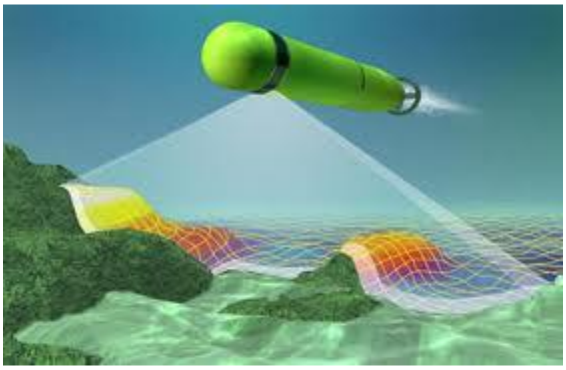
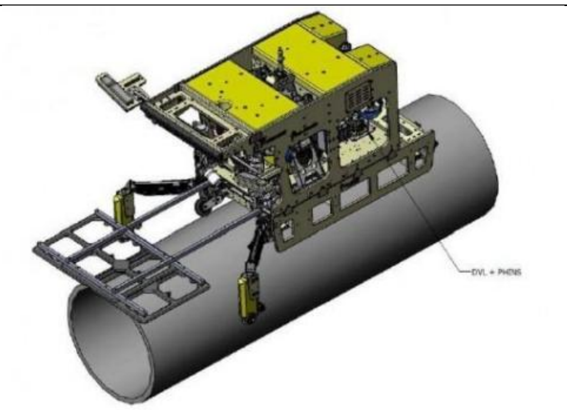
Figure 2-56 Km/day ROV GVI (Oskarsson, 2012)

An implication of such high costs, result in targeted inspection being held, where a certain amount of pipeline segments are selected through risk based inspection, in order to mitigate the likely hood for long term undetected damages or damages which develop over time (more in 2.10.2.2).

In general a pipeline inspection program needs to be able to observe an initial damages *prior* to it developing in to a failure. Thus the optimal method would be a continuous monitoring program, but due to the pipeline's remote location subsea, along with its long distance, such programs become too cost inefficient, at least at the moment.
Note: New technology research is trying to incorporate continuous monitoring by integrating fiber strings within newly designed pipelines, which can pick up vibrations, ovality, heat etc. in real time.

Subsequently, encompassing a larger distance of pipeline within the annual inspections becomes important in order to find damages and issue before they develop further.
Note: By targeting a more cost-effective solution, a team of leading offshore partners (Statoil, ConocoPhillips, Total, DNV etc) have sought to optimize inspection by developing utilizing new technology.

The main equipment *available* at present for inspection is at present point (with various degree of field implantation):

Quick description of inspection equipment	
<u>Autonomous underwater vehicle (AUV)</u> The vessel is a robot without a fixes cable which has no remote control capabilities. It tracks the pipeline at a certain altitude from sea bottom avoiding any unanticipated obstacles whilst continuously recording data. When battery is close to empty or storage is filled up, the AUV returns to a preset location where data packages or battery can be retrieved and changed for further operation. The AUV cannot stop and perform detailed surveys.	 Figure 2-58 Concept photo of AUV (MBARI, 2013)
<u>Remotely Operated Vehicle (ROV)</u> Controlled through an umbilical, the ROV is always connected to a moving vessel above whilst recovering live video and collecting vast amounts of data. ROVs are self propelled and not towed.	 Figure 2-59 ROV GVI (Oskarsson, 2012)

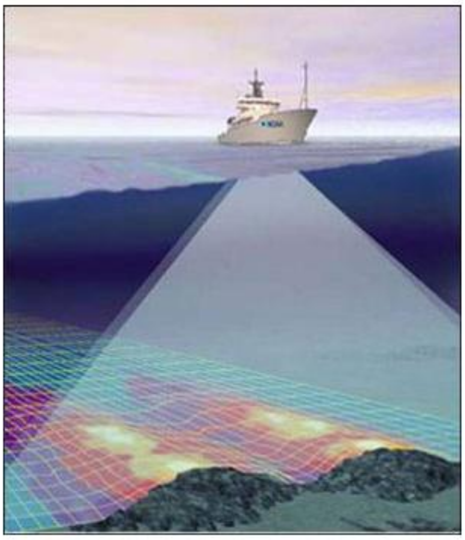
Hull mounted: Sonar devices are mounted to a ship's hull where depending on the equipment and functions used, can detect various parameters of the pipeline.	 Figure 2-60 Hull mounted inspection (Hawaiianattols, 2013)
Remotely Operated Towed Vehicle (ROTV) By towing an operated vehicle along the pipeline at low depths, detailed information can be retrieved.	 Figure 2-61 Remotely Operated Towed Vehicle (MacArtney, 2013)

Table 2-5 Brief description of offshore inspection equipment available

The various tasks and efficiency in which the different inspections tools can perform are listed below. Some technologies are well developed and continue to be improved (ROV Hull Mounted), whilst others in early development stages are beginning to gain operational experience (AUV).
Often technologies are utilized together, where most often the common feature is hull mounted acoustic inspection along with ROV, AUV or ROTV.

Task	AUV	ROV	Hull Mounted	ROTV
Visual	Imagery from straight above. Medium image resolution. No motion blur, BW, GeoTIFF images can be integrated in GIS database and accessed from a GIS	Video from 3 cameras cover all visible angles. Medium video resolution. Motion blur, colour. Video can be integrated in GIS Database with relevant software.	No imagery	Imagery from straight above. Medium image resolution. No motion blur, BW, GeoTIFF images can be integrated in GIS database and accessed from a GIS
Hydro acoustics	Hi res hydro acoustics between 3-10m flying height. Single head multibeam.	Hi res hydro acoustics between 3-10m flying height. Dual head multibeam.	High res bathmetry <50m depth	Hi res hydro acoustics between 3-10m flying height. Dual head multibeam.

Swath coverage (width)	One head, results in less reliable pipe data coverage than dual head.	Two heads, leads to more reliable pipe data coverage	Excellent coverage	Excellent coverage
Freespan detection	Good	Good. In addition video can be used to QC 3d model	Good	Good
Feature detection	Good	Good	Satisfactory	Good
Noise	Low noise generation from AUV	High noise levels from ROV	Very low noise	Very low noise
Course stability	In general good but strays occasionally. Needs fixing.	Good	Excellent	Good
Survey Speed	4 knots with good resolution	1.2 knots with good resolution	6-8 knots	5-6 knots
Operation time	20h/day LARS needs	24h/24h Service time could be 22h/day operation	24h (weather permitting)	22 hours/day
Personnel	2 surveyors + one team to launch and recover	4-6 pilots /24h + on team to launch and recover	2 surveyors	4 surveyors

Table 2-6 Pipeline inspection methods (Oskarsson, 2012)

As the table above indicates, the ROV based inspections hold slower survey speeds along with an increased amount of required personnel. In an effort to become further cost-efficient, the annual 2012 survey inspection of the GNP pipeline utilized AUV, ROV and Vessel in order to both implement new technology whilst also covering a larger amount of kilometers pipeline.

Due to the nature of the GNG pipeline, the depth dictates the type of inspection method utilized. Following methods where uses:

- Acoustic Deep water Hull mounted inspection with AUV
- Acoustic Deep water Hull mounted inspection with ROV
- Acoustic shallow water vessel based inspection

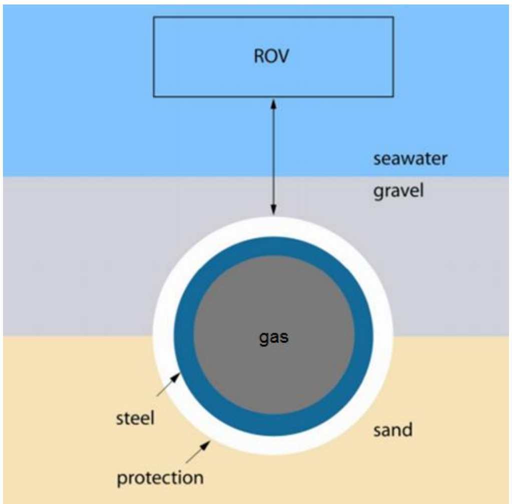


Figure 2-62 Pipetracker system (Fristedt and Silfverduk, 2009)

Below is a further detailed table of what possibilities lie within the different forms of inspection technologies.

Threat Group	Threat	AUV (not fully tested)					ROV						ROTV				Hull Mount		PIG (ILI)			
		Photo (from above)	Sidescan sonar	Multibeam	Pipetracker	Sub bottom profiler	Visual / Video / photo	Sidescan sonar	Multibeam	Pipetracker	Sub bottom profiler	CP inspection	Sidescan sonar	Multibeam	Pipetracker	Sub bottom profiler	Multibeam	Sub bottom profiler	Magnetic Flow Leakage	Ultrasonic Testing	Geo	Calliper
DFI	Construction /material	▒					■					■							■	■		■
Corrosion /erosion	Internal corrosion																		■	■		
	External corrosion											■							■	■		
	Erosion																		■	■		
Structural	Free span	■	■	■			■	■	■				■	■			■					
	Lateral Buckling	■	■	■			■	■	■				■	■			■					
	Upheaval buckling	■	■	■	■		■	■	■	■			■	■	■	■	■				■	
Natural Hazards	Landslides, boulder, scouring	■	■	■		■	■	■	■		■		■	■			■	■				
Third party impacts	Anchor, trawling etc.	■	■	■		■	■	■	■				■	■					■	■	■	■
Incorrect operation	Incorrect proc, human errors etc.)																		■	■		

Table 2-7 Inspection capabilities (Offshore section) (DNV RP-F116) in addition to vessel hull mounted equipment

Explanations from DNV RP-F116 2009:

Sidescan sonar	By transmitting sound waves and analyzing the echo, images are created. Targets specifically the pipeline in order to find observations such as 3rd party impacts etc.
Multibeam echosounder	Utilizing the same principle as the sidescan sonar, it is very useful in order to map typography in the vicinity of the pipeline, whilst also measuring pipeline placement relative to the seabed.
Pipetracker	In addition, due to the concealed nature of a buried pipeline, Pipetracker is used to detect and survey buried pipelines on the basis of merging existing complementary data of seabed depth to provide the actual burial depth of the pipeline. The tool uses most often electromagnetic systems in order to measure lateral and vertical distances from sensor to pipeline.
Sub bottom profiler	Acoustic based tool which penetrates the seabed providing pipeline burial depths.
Calliper	Measures pipe-out-of roundness, indicating dents buckle etc.)
Magnetic Flow Leakage	Measures wall thickness, detecting both internal and external metal loss.
Geopig	Measures global curvature, and when linked with seabed typography can pose a powerful tool

In addition to inspection pigs, internal corrosion monitoring is achieved through continuously analyzing the transported product. Consequently, by always knowing the content of the pipeline (H_2O, CO_2 etc. values), the amount of corrosion can be controlled to a point where conditions that can lead to corrosion is eliminated.

Other inspection methods present:

<u>Onshore pipeline segment inspections</u>

- General Visual Inspection is done by either foot or by plane.
- Corrosion protection, by electrode potential measurements.

<u>Onshore Equipment inspection</u>

- Function check of valves

Future Technologies

As warfare gives large incentives for development companies to invest large resources in technologies, the innovations made has had a tendency to be implemented in industries in other contexts. An example is the internet, which was originally developed by the US military in the 1960's. Currenty, the US military is shifting large resource towards a new wave, namely that of autonomy. According to Noel Sharkey, a professor of robotics, the future of technologies is where autonomous entities move where they want, pick their own targets and act on them, all within a given set of predefined rules and parameters. The military's push for such technologies over normal man controlled drones, is that in future warfare against a sophisticated force, the enemy will be able to jam all signals in and out of the battlefield, thus making feedback and control of the systems impossible. According to Sharkey, the US have since 2004 been discussing the next stage, from man in the loop, to man on the loop, to man out of the loop. Consequently, the new X-47B unmanned combat air vehicle (UCAV) is currently finalizing its tests and is set to become operational in 2015. It is fully autonomous from take off to landing (even from aircraft carrier), being able to decide for itself whether to shoot down a target or not (Lefranc, 2013).

Subsequently as the industry learns and increases their knowledge and expertise of such autonomous vehicles, partially on the basis of large governmental military funding, such innovations are applied to specific industrial tasks, such as subsea pipeline monitoring.

As continuous monitoring is the optimal form of inspection regarding reaction times and in general mentoring the wellbeing of the asset, future weight is given to AUVs and the technologies within, in order to provide dramatic improvements in cost, performance, safety and reliability of pipelines. Future predictions are that AUV's can become "field resistant", in a way where they continuously monitoring the pipeline, moving back and forth without the dependence of vessels (Nash, 2011), automatically selecting points of interests and further examining, relaying information in real time back to the control centre.

Regarding the internal condition of the pipeline, pigs with sensors are utilized by sending them through pipeline, recording relevant data. Within current pigs, there are certain limitations in which new technology is about to supersede. Gassco's new big pig project is based on acoustic resonance technology (ART), where the technology increases reliability, accuracy and speed when performing readings, resulting in the pig being able to travel at the same speed as the gas flow rate, thereby avoiding deliverable gas limitations within the inspection period (Gassco, 2011b), something which was before not possible.

2.10.2.2 GNG pipeline Inspection Intervals

Inspection intervals are to a large extent predetermined by the amount of anticipated failures to the system. As the below graph depicts, the typical variation of failure rate in an operating system asset takes the shape of a 'bath-tub' type curve (blue).

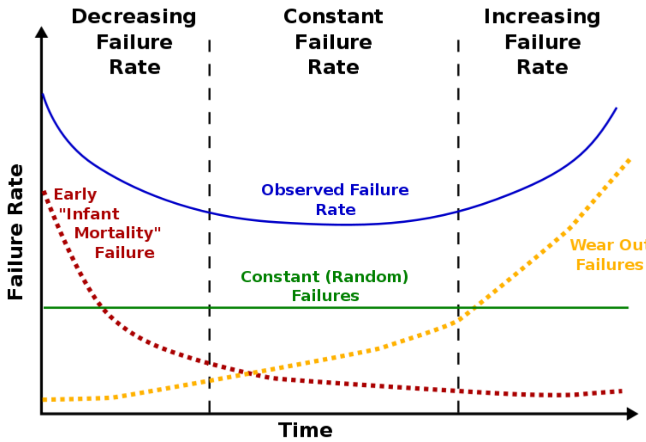


Figure 2-63 Bath tub shape failure rates (Wyatts, 2005)

- The first phase has an initial high failure, but with rates gradually decreasing. Such failures or damages within a pipeline system are due mostly to material defects, incorrect installation, incorrect operation, unanticipated environmental loads and effects (free spans, walking etc.).
- The second phase typically involves random failures due to impacts (anchors, fishing gear etc.) or randomly occurring environmental conditions changing (free spans, scouring etc.)
- The third phase characteristically consists of equipment wear-out or damage due to corrosion, fatigue, anode depletion, fatigue, internal erosion, coating failure etc. (Nash, 2011).

The GNG pipeline was designed for a 50 year operational life (source: DFI GNG pipeline), and without mentioning the exact date of when the pipeline was first operational, the asset is still in its midlife cycle.
The midlife cycle in pipelines often extend for decades, and as such, the GNG pipeline will still be in this phase within the coming years.

Therefore, as an overall brief assumption, one can state that the observable failures rate of the system should be relatively constant where the most prominent risk is the increasing rate of degradation within the system's elements along with the constant danger of randomly occurring events.

As such, as far as possibly, Gassco and the TSP have pre-planned inspection, maintenance and repair activities in order to coincide with weather conditions, tendered contracts and planned pipeline shutdowns.

Unless any unforeseen events occur, the intervals in the below paragraphs are used. Should any new observations be found, the interval periods for certain segments can be changed in order to more closely monitor the situation (example going from 6-yearly to 4-yearly, or even annually).

Inspection: External Pipeline

Both subsea and topside inspection routines are held annually, but not all lengths of the subsea pipeline segments are visually inspected every year.

The subsea inspection intervals vary depending on:

- **Trawling and shipping activities**, which vary between pipeline segments.
  Due to lessened risk of areas with low traffic, such legs are inspected typically pr. forth year based on risk based inspection intervals.
  Legs that coincide with main shipping lanes and high trawling activities are inspected annually due to their heightened risk for potential third party impact loads as previously described.

- **The depth at which the pipeline rests.**
  Due to some of the pipeline segments resting below 180m depth (deep water), the depth constitutes various inspection intervals. The deep water section's contingency cost criticality is substantially higher than sections above 180m. Reason being, is that on the NCS, 180m is the maximum depth divers are allowed to be utilized.
  Should a critical damage occur on a specific location on the pipeline *within* the 180m allowable zone (see Figure 2-66), the following *simplified* events would occur: Detailed inspection with possibly onshore replica constructed for pre-testing procedures. On site, isolation pigs trains would be set before and after the damage, the damaged section would be cut out, concrete sections cut, new segment placed, hyper baric welds connecting the new segment to the existing pipeline performed along with weld check test (NDT etc.) These hyperbaric welds are performed and checked in a welding habitat by welders.

Figure 2-64 Statoil PRS Welding habitat (Nord-stream, 2013)

After welds and weld checks are performed, a corrosion coating is applied within the habitat and isolation pig trains are removed by pressure differential change from shore. The repaired pipeline section is most likely rock dumped.

Any depth *below* 180m, the method of habitat utilization is not applicable. At the moment there are few viable and cost effective methods of repairing critical damages in deep water without divers. Such a solution would have to be fully mechanical, performing everything from welds and weld checking to corrosion coating etc.
Consequently, sections in deep water which are not rock dumped and protected, are checked more frequently due to the severity of a possible damage.
Should an impact occur, and gas is released from the pipeline, a change in measurable parameters (pressure, flow etc.) would be observed from shore, and the emergency shutdown valves would close. The amount of escapable gas would be limited to the infill volume between the two emergency shutdown valves, further limited by pressure bleed off from import and export side along with physical parameters of pipeline such depth profile etc.

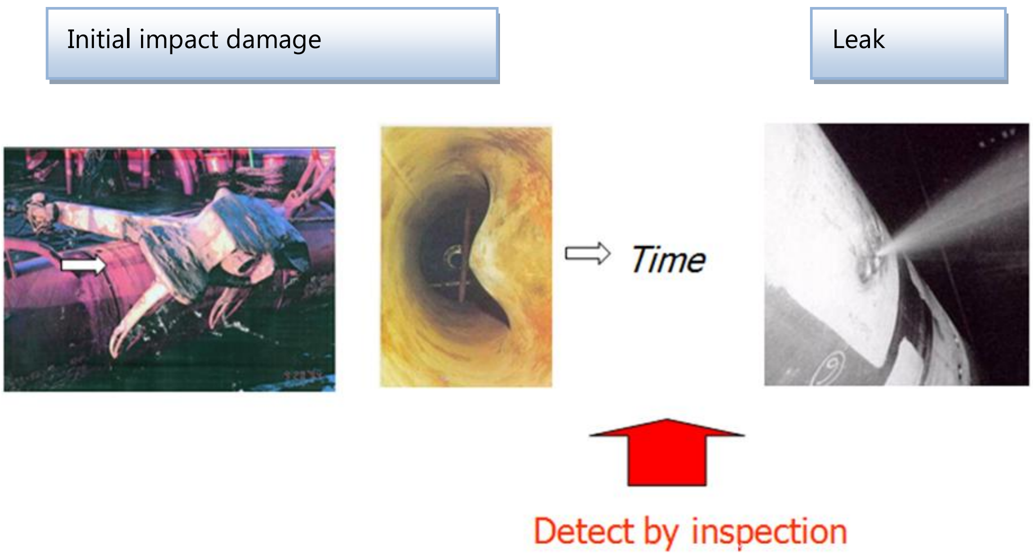


Figure 2-65 Pipeline leak developing over time (Gassco, n.d.b)

However, if an impact without immediate release occurs, no parameters will most likely change, thus the impact will not be known before either fatigue causes the pipeline to rupture, or during routine inspection. The interval between routine inspections thus become extremely crucial in order to mitigate the possibility of deep sea rupture on the basis a developing damage caused by impact, leading to fatigue.
Solutions for deep water pipeline interventions have been highly focused on the past years, where a few solutions are applicable the size of the GNG pipeline.

Below is the depth profile of the GNG pipeline, showing the depth at which diver limitations on the NCS set boundaries for what type of repair methods can be utilized should the pipeline need repair.

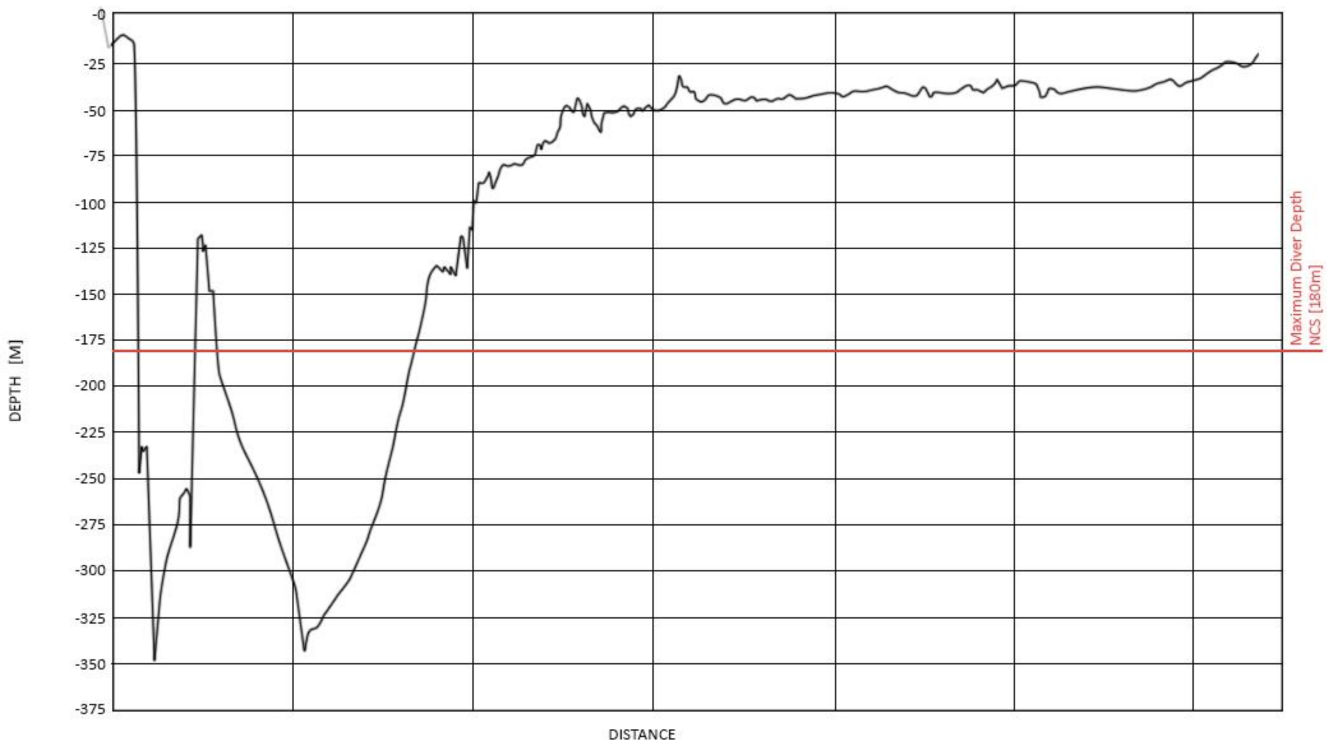


Figure 2-66 GNG Pipeline Profile with diver depth limitation, Source: GNG pipeline DFI

The approximate distribution of pipeline lengths applicable to varying locations, each dictating its own corresponding contingency plan, can be shown by the table below, highlighting the fact that deep water holds a relatively large share within the GNG pipeline.

Approximate Depth Distribution of Pipeline		
Onshore	Shallow Water	Deep Water
4%	78%	18%

Table 2-8 GNG pipeline depth distribution

The onshore pipeline inspections routines on the other hand, are performed more frequently due to the lower cost of inspection. Certain onshore legs are inspected via overhead flight every fortnight, whilst surveys on foot are held quarterly. Such visual inspections look for any abnormalities such as coating damages, cathode protection functionality and corrosion.

The graph below shows the inspection coverage of the entire pipeline length (topside and subsea) the past 5 years, where each color signifies an individual annual inspection. The annual inspection normally lasts between 6-12 days, utilizing the methods as described above.

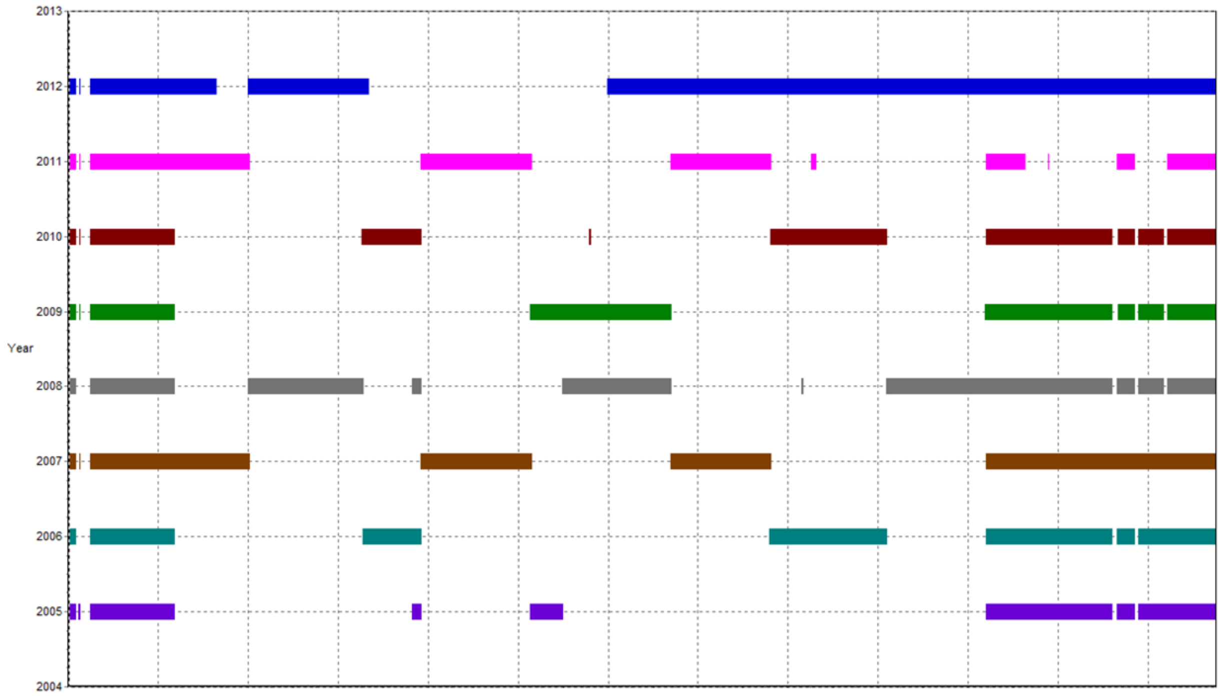


Figure 2-67 Annual inspection coverage along full pipeline distance. Source: Source: Annual GNG pipeline inspection 2012

Inspection: Internal Pipeline

The internal condition of the pipeline is monitored by pigging every 10 years. At the moment, the pigging program needs special flow conditions in order for the program to be successful. Although, by the time the next program is initiated, a new pig is introduced (ART), capable of monitoring the internal condition of the pipeline whilst barely impacting the regular flow of gas.

Inspection: Safety Critical Valves

Inspection is performed annually together with the main annual pipeline. Function tests are performed ensuring that given a certain input signal, the valves perform their designated output action (i.e closing/opening). In addition, the closing time is tested in order to verify that the valves still operate according to their designated standards. Any change in closing time may signify degradation in the valve, requiring attention.
Another test performed is the internal leakage test. Such leaks do not mean gas leakage from the pipeline, but leakage in the valve system. Assume that a valve uses a hydraulic actuator to function. Should there be minor leak in the isolated hydraulic system, pressure will over time drop resulting in valve not functioning properly.

2.10.3 Routine Maintenance & Repairs

Throughout the GNG pipeline's lifecycle, routine maintenance and repair has and will be conducted. Main routine repairs mostly consist of:

Free spans

During the design phase, certain limitations of free span lengths allowable were set. As a result of free spans exceed these limitations, the pipeline's integrity is not upheld unless a fatigue or trawl impact assessment is carried out proving otherwise.

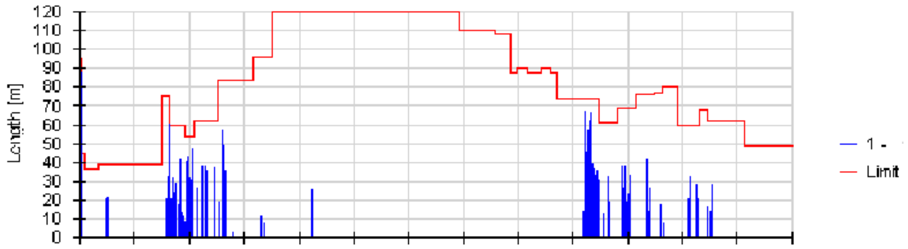


Figure 2-68 Free span lengths within a certain leg of the GNG pipeline. Source: Annual GNG pipeline inspection 2012

The above inspection results show a certain pipeline leg, indicating local free span lengths along with the pipeline's free span limitations.

Upholding the integrity in areas about to exceed or exceeding this limit requires stress analysis and/or subsea rock intervention in order to limit any damage to the material or reduce the risk for snagging. Rock is dumped at the location, filling in the void, eliminating the span.

Concrete & Corrosion Coating damage

Minor damages and trawling scars to the pipeline are mostly not acted upon. Any damage to the pipeline coating which causes bare metal to become visible requires a stab reading of the electronic potential of the metal pipeline. If the reading indicates that the anodes are performing as they should (thus protecting the metal), normally no action is taken.

As previously mentioned, the fields joints are the weakest points of the pipeline. The infill performed on the laying vessel is not as resistant to impact forces as the main reinforced concrete on the pipeline segments. Substantial damage to the joint fields are thus not uncommon, and one way in limiting any further damage, is to rock dump the location, thus deflecting any future trawl boards from repeatedly damaging the same point, most likely causing more further damage to coating and/or metal itself. Often the specific pipeline section is not fully rock dumped, since this will limit the amount of future natural movement of the pipeline, and actually increase the likelihood of buckling, since the rock dump introduces a more or less fixed point to the pipeline. Instead, rock is often dumped to both sides of the pipeline, so any trawling activity is directed over the pipeline.

Rock dump

The stability of the rock dump is monitored in order to ensure that there is no unwanted movement of the heap, and that the pipeline is still buried (if relevant). Any irregular conditions may require intervention in the form of either surplus rock dumping or any other means of involvement in which the situation requires.

Safety valves

Any valves not conforming to stringent requirements during annual inspection rounds, are thoroughly checked and repaired or if needed.

2.11 ANNUAL REPORT

Every year Gassco, the TSP and its subcontractors perform planned annual surveys and inspections in order to ensure the pipeline's integrity both current and future wise.

		Performed By		
		Gassco	TSP	Subcontractor(s)
Pipeline Segment	Onshore		X	X
	Offshore, shallower than 180m			X
	Offshore, deeper than 180m			X
	Internal Corrosion Monitoring (cont.)	X		
	Internal Corrosion Evaluation		X	
	External CP			X

Table 2-9 Annual Inspections

A general description of who performs what during the yearly inspection reveals that for most part, subcontractors are hired to perform the different tasks. These contractors will often work closely in collaboration with the TSP as to ensure highest possible quality of the inspection. Any finds, such as pipeline free spans exceeding certain limits, are highlighted or reported in a First Hand Report given to the TSP. Such finds may need further evaluation before any action can be taken. Evaluations regarding exceeding values are then often performed by another subcontractor, who gives a recommendation on what should be done.

In general, all finds done by an inspection subcontractor is written in a report and handed to the TSP. The TSP then verifies the data from all subcontractors and collects it all in a final annual report which is then given to Gassco.

In the final report, the entire pipeline length is divided in to approximately 30 sections (with KP start and finish values). Within each section, TSP clearly states what has been performed, what has been found, where they have been found, what limits apply to the specific section and what actions have been taken. Should any finds require close monitoring, the risk based inspection interval may change, taking height for increased integrity breach risks.

Sections which are not covered within the current annual survey are not left blank, but instead latest data written in previous annual reports are used. In this way, the status of the whole pipeline is always visible in the report, and new data supersedes the old.

The physical battery limits of the annual report are shown in Figure 2-69.

Figure 2-69

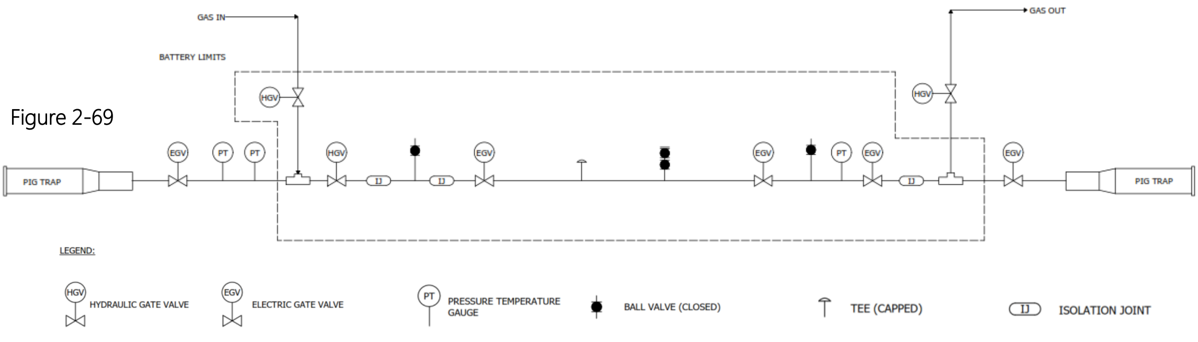


Figure 2-69 Physical Battery limits. Source: DFI GNG pipeline

2.12 PHYSICAL CONDITION OF PIPELINE

Although the scope of the thesis does not involve detailed physical evaluations of the pipeline, the overall integrity and possible routine risk points will be described in the following subsection based on previously performed inspections (methods described in section 2.9).

Following last year's inspection (2012), the overall structural integrity of the pipeline was found to be acceptable. The following risk matrix was given, where "1" implies the whole pipeline as one entity along with its placement in the matrix.

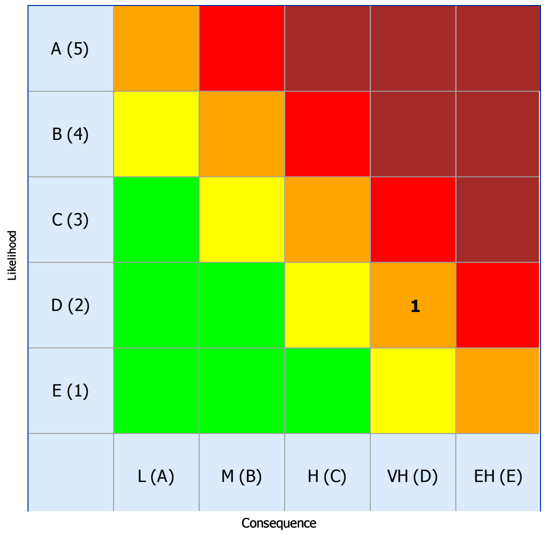
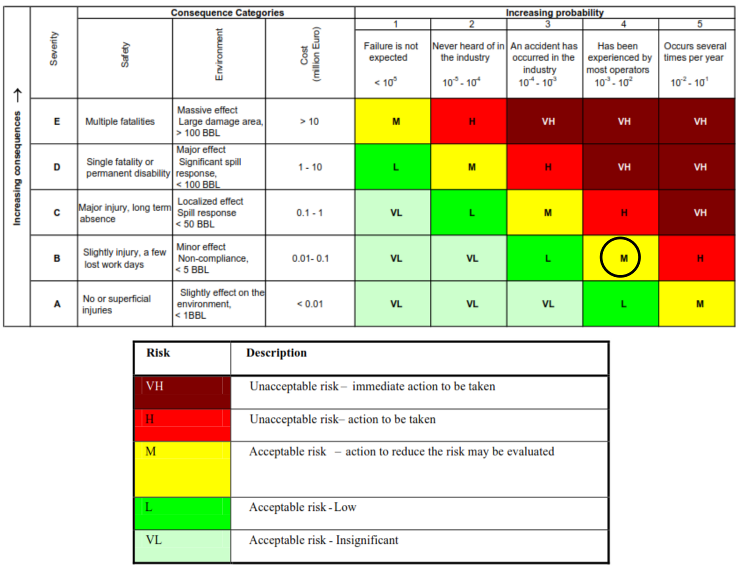


Figure 2-70 Source: Annual GNG pipeline inspection 2012

By comparing the matrix given in the annual report to the graph given in the recommended practice: "DNV RP-116, *integrity management of submarine pipeline systems"*, one can see that the level is set at "acceptable risk – action to reduce risk may be evaluated".



Increasing consequences →	Consequence Categories				Increasing probability				
					1	2	3	4	5
Severity	Safety	Environment	Cost (million Euro)		Failure is not expected < 10^{5}	Never heard of in the industry 10^{-5} - 10^{-4}	An accident has occurred in the industry 10^{-4} - 10^{-3}	Has been experienced by most operators 10^{-3} - 10^{-2}	Occurs several times per year 10^{-2} - 10^{-1}
E	Multiple fatalities	Massive effect Large damage area, > 100 BBL	> 10		M	H	VH	VH	VH
D	Single fatality or permanent disability	Major effect Significant spill response, < 100 BBL	1 - 10		L	M	H	VH	VH
C	Major injury, long term absence	Localized effect Spill response < 50 BBL	0.1 - 1		VL	L	M	H	VH
B	Slightly injury, a few lost work days	Minor effect Non-compliance, < 5 BBL	0.01- 0.1		VL	VL	L	M	H
A	No or superficial injuries	Slightly effect on the environment, < 1BBL	< 0.01		VL	VL	VL	L	M

Risk	Description
VH	Unacceptable risk – immediate action to be taken
H	Unacceptable risk– action to be taken
M	Acceptable risk – action to reduce the risk may be evaluated
L	Acceptable risk - Low
VL	Acceptable risk - Insignificant

Figure 2-71 Risk matrix Source: DNV RP-116, integrity management of submarine pipeline systems

Below is a short description of the pipeline's status gathered from the 2012 annual report:

<u>Onshore</u>

The annual report concludes that important safety critical valves, pipeline segment and cathodic protection is found to be in a state of acceptable condition following the routine tests and inspections.

<u>Internal</u>

The internal condition of the pipeline is on the basis of information regarding product transported in the pipeline, found to give insignificant corrosion rates. The condition is found to be acceptable.

<u>Offshore Free Spans</u>

Following the 2012 inspection, there were no new free spans exceeding limitations set. There are, however two free spans above limits found in previous years, both of which have been analyzed and established to pose no risk on the pipeline's integrity.

<u>Offshore Impacts</u>

By gathering data from the annual 2011 report, which encompasses additional previous years' findings which have not yet been superseded, the following graph can be presented:

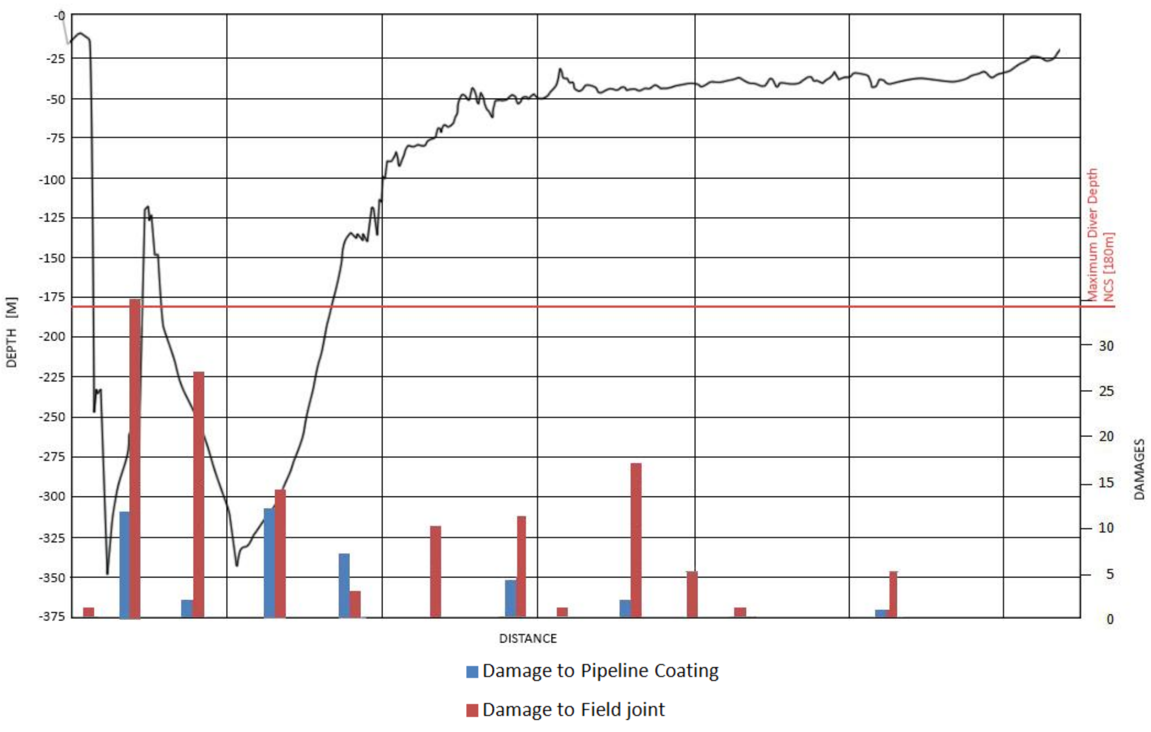


Figure 2-72 Approximate Impact quantity and types distributed along entire pipeline length. Data Source: Annual GNG pipeline inspection 2012/2011

The impact damages could be further severity categorized in to damages resulting in: pipe metal exposure, corrosion coating exposed, reinforcement/armor exposed, concrete spalling, corrosion coating exposed at field joint, and filler damage at field joint. But due to simplicity and lack of specific data in certain regions, the data is sorted in damages to pipeline coating and damages to field joint coating.

2.13 OPERATIONAL TOOLS

Like any major infrastructural asset, natural gas pipelines must be managed and maintained. Overall goals of such infrastructures are zero accidents along with highest possible performance. Likewise, ensuring such targets require diligent management and rigorous procedures throughout its service life.

Through being a leading contributor and partner in an extensive amount of R&D projects and initiatives, Gassco is able to be on the forefront of technology, implementing new tools and knowledge in to their daily activities.
As Gassco is the operator of this large infrastructure, they utilize multiple tools in order to handle their assets with the highest proficiency possible.

Subsequently, there are an abundance of operational tools applicable within multiple levels of the organization, only a few will be listed, in which hold certain relevance for the thesis at hand.

IT solutions in Gassco's control room

- Pipeline Model System (PMS)
- Supervisory control and data acquisition (SCADA) System
- Next-generation Gas Transport Management System (NGTMS)

"The pipeline model system (PMS) is one of three major IT solutions in Gassco's control room. It calculates conditions minute-by-minute in long subsea pipelines where no measurements are available, supplements the supervisory control and data acquisition (SCADA) system with variables which cannot be measured directly, and performs what-if forecasts of future conditions."

Some relevant major R&D projects which Gassco is involved in:

- Leak monitoring – acoustic monitoring of third-party contact with pipelines to ensure the integrity of the latter and to avoid gas leaks
- establishing a programme to secure improvements in external pipeline inspection
- ART- a new internal inspection tool based on acoustic resonance technology able to measure wall thickness in pipelines, with the construction a full-scale prototype and a start to testing
- Implementing a new pipeline model system (new PMS) in Gassco's control room.

2.14 INTEGRITY MANAGEMENT

In the past years, on world basis, high profile asset integrity incidents have proven all too common compared to what the risk picture was thought to be. Light has thus been shed on the subject of managing assets integrity in order to mitigate such incidents. Pipeline systems are no exception, where specific standards such as DNV-OS-F101 "Submarine Pipeline Systems" require integrity management of submarine pipeline systems during the entire service life in order to comply fully with regulations. DNV has prepared the recommended practice DNV-RP-F116 "Integrity Management of Submarine Pipeline Systems" for this exact purpose. In fact, Gassco has been a main contributor towards the recommended practice DNV-RP-F116 through the JIP Steering Committee.

The main objectives through proper integrity management are according to DNV-RP-F116 to:

- Ensure that the operation of submarine pipeline systems are safe and conducted with due regard to public safety, environment and properties
- present more detailed requirements based on these general requirements
- present general requirements reflecting the parts of the DNV offshore standard DNV-OS-F101 that cover integrity management
- provide guidance on how to comply with the requirements
- serve as a guideline for operators and suppliers

Basically the DNV-RP-F116 recommended practice is an extended description, further detailing the requirements set by DNV-OS-F101.

Most companies adopt their own way of incorporating the integrity management requirements, creating systems which are aligned and implemented in their own work structure. The term Pipeline Integrity Management System (PIMS) is often such a result, where the process in ensuring the integrity of the asset is a continuous process.

Figure 2-73 Integrity Management System (DNV, 2009)

Key components of such a PIMS system include (Wenman, et al., 2012):

- Organization/Roles and Responsibilities
- Standards and Procedures
- Competencies and Technical Authorities
- Asset Registration
- Risk Assessment
- Maintenance & Integrity Work Plan
- Data Management
- Integrity assessment and verification
- Reporting of Compliances and Integrity Status
- Management of Change
- Emergency Response
- Reviews and Audits

The systems which are incorporated in to a well functioning PIMS are extensive and require competence over a great deal of disciplines, often summarized in real time computer interfaces with key performance indicators (KPI's) indicating a both leading (for instance integrity requirements based on base line numbers) and lagging indicators (such as dents or leaks experienced).

The thought of integrity management is that it should be fully implemented even before the asset is designed, in order for the asset to be properly implemented in to the company's system and vice versa.

One of the main aspects of the system is instead of "putting out fires" and fixing problems as they arise, one applies a pro-active role in repairing and mitigating possible failures before they occur. By applying prediction models along with inspection/monitoring and testing, failure modes can be predicted and necessary activities can be implemented in order to mitigate the risk.

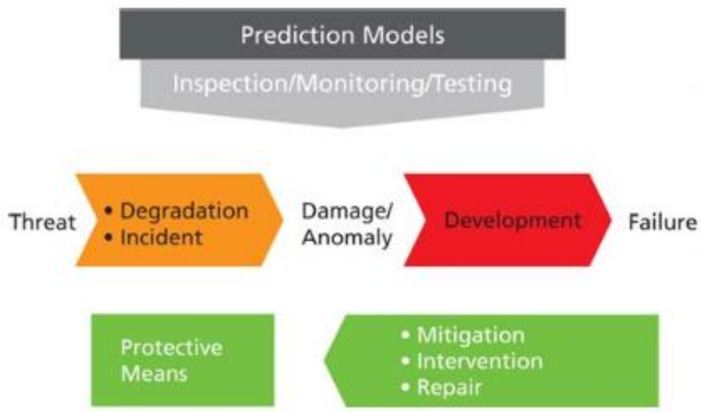


Figure 2-74 Figure 2 61 The development of a threat into a failure and the activities implemented to reduce the likelihood and/or consequences of such development (DNV, 2009)

As a specific example, following a need to further improve their asset management regime, Gassco has developed, alongside the centre for industrial asset management (CIAM) and the University of Stavanger (Uis), an asset integrity process, with especial focus on the management of technical integrity in the loop. By further splitting the term asset integrity in to three sections, each with their own set of processes.

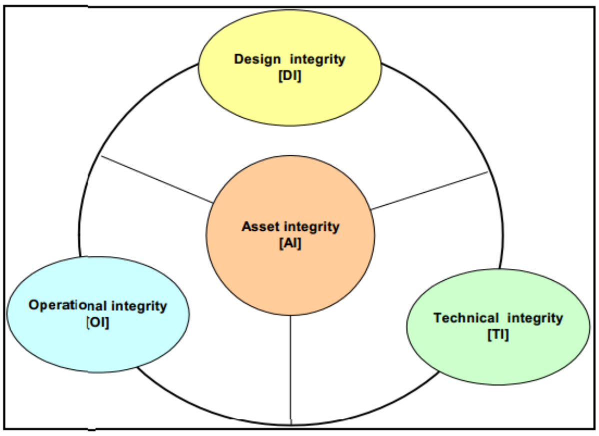


Figure 2-75 Asset Integrity (Gasso, 2007)

The below is Gassco's work flow diagram of their maintenance and condition management loop

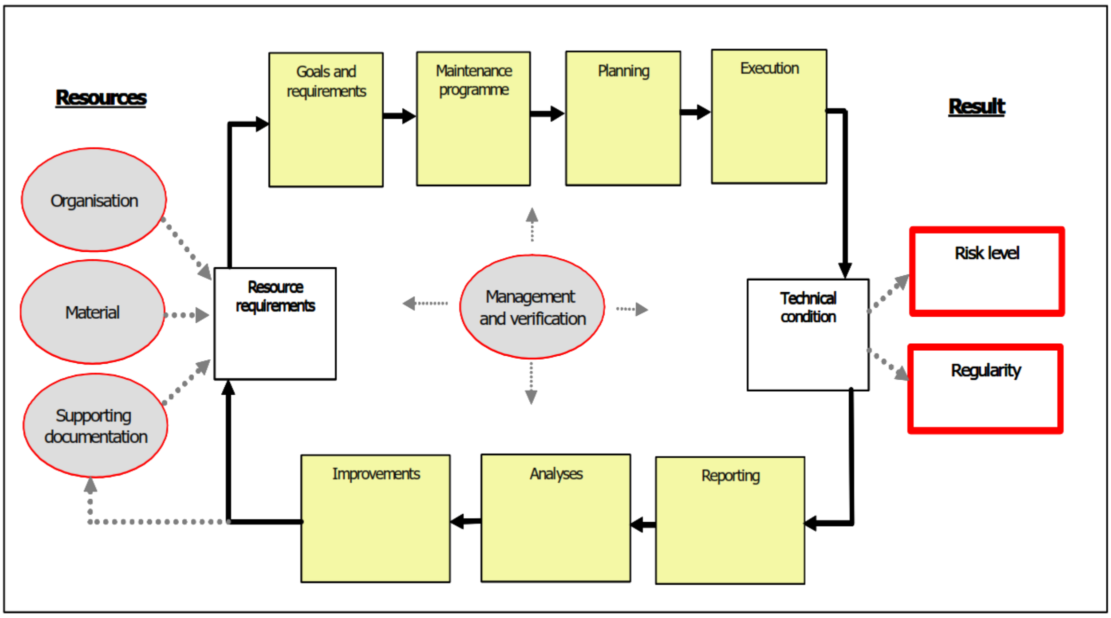


Figure 2-76 Gassco maintenance and condition management loop (Gassco, 2007)

A large part of such predicting is first off, defining a system's threats. According to DNV-RP-F116 "*Submarine pipeline system threats are the root causes that may lead to failure. Managing the risk related to these threats is essential for maintaining the integrity of the pipeline system*."

Accordingly, the remaining part of the thesis will be focused on discussing and weighing internal and external threats in which can and is affecting the integrity of the pipeline system.

3. Threats & Challenges

The importance of a high performing and high availability infrastructure is crucial, independent of which physical needs the infrastructure fulfills (i.e. water, electricity etc.). In the same way, a well planned and well kept highway supports flow of commuters who build personal and GDP value, natural gas pipelines transport energy, facilitating consumers and industries the possibility to produce and consume various products, ultimately leading to overall national and regional growth. Analysis' have shown, and concluded with, that investments in infrastructures promotes increases in income, employment, productivity and thus also national/regional competitiveness. Oppositely a poorly or malfunctioned infrastructure will have negative effects for a whole nation/region. For instance, a congested or closed highway will stifle and limit society's effectiveness, or a gas pipeline suddenly having to close will impact an energy dependant society in a large way. An example is the previously mentioned 2009 gas crisis, where Russia closed off one of their main gas export pipelines to Europe, resulting in propagating problems like cold consumer homes and a huge spike in industry energy demands.
When large infrastructural entities become inefficient or shut off, huge amounts of national and often regional investments are rerouted from productivity-enhancing investments such as education and innovation, to the infrastructure, in order to reconstruct or repair it (Schwab, 2013). Therefore ensuring infrastructure availability will provide long term growth and global competitiveness, and as such, large infrastructures are often prioritized above short term goals. Continuous availability and affecting factors are key words when ensuring national/regional growth and innovation through utilizing well run infrastructures.

In the case of the GNG pipeline one can illustrate a normal operational pipeline transferring gas at maximum average capacity as a straight line. The scenario is such, that supply fulfills the demands, and any lack of supply will therefore increase the demand for the good, likewise any drop in demand will result in less utilization of the pipeline, decreasing its efficiency.

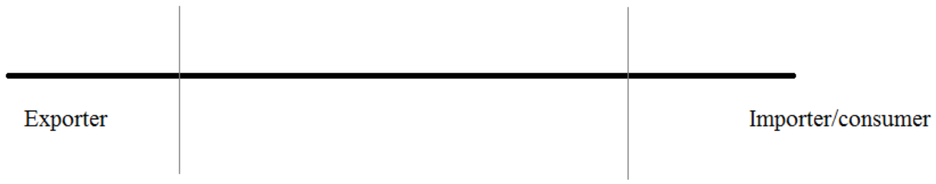


Figure 3-1 Pipeline Healh illustration

Any factors in which might majorly or often affect this goal is treated as a threat, and will be evaluated. Threats in which affect this goal are not only limited to the physical, but also include the organizational, political and systems in which the GNG pipeline is a part of. It is assumed that all applicable rules and regulations are followed.

Gassco, the infrastructural operator, has a very high track record in their yearly availability and a trait they strive to uphold.
2012 figures showed an average availability of their pipeline infrastructure of 99.69% (up from 99,17% in 2011) (Førde, 2013). Their aim was (and is) to meet 99.85% availability beyond 2010 (Gassco, 2007).

3.1 PHYSICAL

As previously mentioned, there are multiple incidents in which pose a threat to a pipeline. Recommended practice DNV-RP-F116 *"Integrity Management of Submarine Pipeline Systems"* highlights the following possible threats and their corresponding potential damage effects to a subsea pipeline system:

Threat group	***Threat***	***Damage / anomaly***
Design Fabrication & Installation (DFI) threats	Design errors	- Metal loss - Dent - Crack - Gouge - Free span - Local buckle - Global buckle - Displacement - Exposure - Coating damage
	Fabrication related	
	Installation related	
Corrosion / Erosion	Internal corrosion	- Metal loss - Crack
	External corrosion	
	Erosion	
Third party threats	Trawling interference	- Metal loss (secondary) - Dent - Crack - Gouge - Local buckle - Global buckle - Displacement - Coating damage
	Anchoring	
	Vessel impact	
	Dropped objects	
	Vandalism / terrorism	
	Traffic (Vehicle impact, vibrations)	
	Other mechanical impact	
Structural threats	Global buckling – exposed	- Crack - Free span - Local buckle - Global buckle - Displacement - Exposure
	Global buckling - buried	
	End expansion	
	On-bottom stability	
	Static overload	
	Fatigue (VIV, waves or process variations)	
Natural hazard threats	Extreme weather	- Dent - Crack - Gouge - Local buckle - Displacement - Exposure - Coating damage - Anode damage
	Earthquakes	
	Landslides	
	Ice loads	
	Significant temperature variations	
	Floods	
	Lightning	
Incorrect operation threats	Incorrect procedures	- Metal loss - Coating damage - Global buckle - Local buckle - Anode damage
	Procedures not implemented	
	Human errors	
	Internal Protection system related	
	Interface component related	

Figure 3-2 Typical damage/anomalies related to different threats in an offshore pipeline system source: DNV-RP-F116, 2009

Although stated as typical, not all of the threats given in the above table are equally relevant and statistically equal for all pipelines.

The PARLOC report made by The Institute of Petroleum, UKOOA and HSE, UK, presented in 2001, pipeline incidents in the North Sea of which resulted in loss of containment dating back to 1971. *Note: Following 2011, only data from the UK continental shelf and not the whole North Sea is reported in the PARLOC reports.*

Incident type	Incidents with loss of containment	Incidents
Corrosion (internal)	10	16
Corrosion (external)	3	3
Impact (Trawl, wreck etc)	9	41
Anchor	8	39
Material (weld/steel) defect)	7	9
Structural	0	6

Table 3-1 Incidents on in the North Sea. Source: Parloc 2001 (Macdonald, 2003)

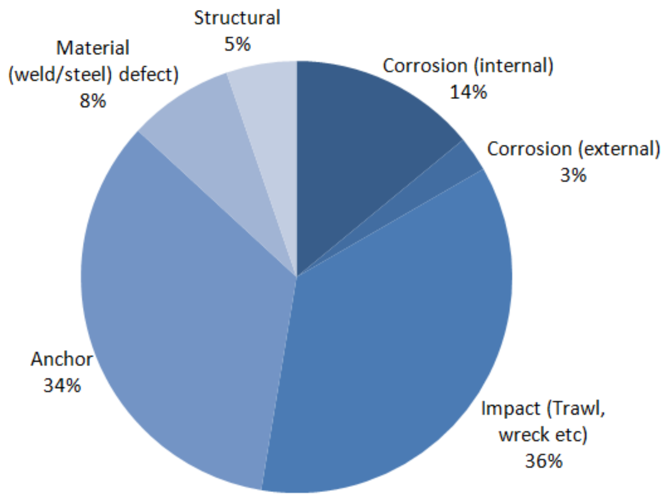


Figure 3-3 Distribution of Physical threats causing incidents. Source: Parloc 2001 (Macdonald, 2003)

Note: Unknown circumstances are not included, but are not in any way a major contributor .

The presented data above is source from 1069 individual pipelines, encompassing a total of 22847km. The presented data has been selected to only cover safety zones, mid line, shore zone and land. Incident data regarding platform, riser, single point mooring and well pipelines have been excluded as to conform to the GNG pipeline's relevance as much as possible..

The data above cannot be completely adopted fully to the GNG pipeline, but it gives an indication of what type of damages cause failure in the physical scenario at which the GNG pipeline is placed. As the data depicts, corrosion and general impacts are that of highest cause to such containment loss.

As the data in the PARLOC report further highlights, the nominal diameter varies within the sample pipeline network.

LOSS OF CONTAINMENT INCIDENTS									
MID LINE			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Diameter (inches)	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	0 to 9	45679.0	7	3.29	7	13.15	7.20E-05	1.53E-04	2.88E-04
	>10	243843.0	4	1.37	4	9.15	8.62E-06	1.64E-05	3.75E-05
	10 to 16	44286.0	1	0.05	1	4.74	1.13E-06	2.26E-05	1.07E-04
	18 to 24	56728.0	1	0.05	1	4.74	8.81E-07	1.76E-05	8.36E-05
	25 to 40	14052.0	2	0.36	2	6.3	2.46E-06	1.37E-05	4.31E-05

Table 3-2 Loss of containment incidents that occurred in the mid line of pipelines, Parloc 2001 (Macdonald, 2003)

*Mid line =The pipeline on the seabed outside the subsea well and platform safety zones and not in the shore approach.

As there are less large diameter pipelines in the PARLOC sample (such as the GNG pipeline), it is an important fact to note the frequency at which such large sized pipelines are prone to containment loss and repair, differs to smaller sizes (as shown in table above). From the PARLOC data it is possible to state that the smaller diameter pipelines have a higher failure rate (HSE 2009).

The amount of not only containment loss, but also damage requiring repair becomes an important aspect when trying to get a better picture of the risks at hand.
Note: Containment loss data is assumed to be included in the repair incident data

The table below shows, that for large steel pipelines on the North Sea, there are 3 times as many repairs than containment losses and it is important to note that a major repair (although no containment incident) may just as likely call for a long shut down period as an incident causing a leak (for example due to the fear of fatigue induced by continous use of a highly damaged pipeline).

REPAIR REQUIRED INCIDENTS									
MID LINE			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Diameter (inches)	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	0 to 9	45679.0	11	6.17	11	18.21	1.35E-05	2.41E-04	3.99E-04
	>10	243843.0	15	9.25	15	23.09	3.79E-05	6.15E-05	9.47E-05
	10 to 16	44286.0	11	6.17	11	18.21	1.39E-04	2.48E-04	4.11E-04
	18 to 24	56728.0	1	0.05	1	4.74	8.81E-07	1.76E-05	8.36E-05
	25 to 40	14052.0	4	1.37	4	9.15	9.38E-06	2.74E-05	6.26E-05

Table 3-3 Incidents which required repair that occurred in the mid line of pipelines, Parloc 2001 (Macdonald, 2003)

Based on the data from PARLOC, one can assume that the two major threats to the physical aspect of the pipeline affecting the pipeline's availability, are corrosion and anchors/impacts.

Corrosion is an evolving flaw in which the driving factor leading up to the failure is often poor inspection and maintenance routines. The mentality of "find it and fix it" often results in large and unplanned costs arising, whilst also constantly increasing in frequency as the asset ages. Adopting well implemented corrosion preventive measures will ensure largest degree of predictability and control over the degradation (if any) of the asset.
Control and monitoring techniques and routines operated by Norwegian companies is considered to be so good that wet gas pipelines do not have a higher probability of corrosion than their dry gas pipelines (OGP 2010). Gas pipelines do not normally hold the required amount of water content in order to provide a corrosive water phase. Only 5 of the 28 cases from the PARLOC study where from gas lines (covering all areas: risers safety zones etc.), but the fact is, that corrosion in gas pipelines does occur. Subsequently, some water does and/or can enter the pipeline, most likely due to an upset in the gas processing facility sending gas with a larger water content than specified through the pipeline. By

implementing software that continuously monitors the content being transferred along with the internal corrositivity, estimations regarding corrosion rates on the basis of corrosion models can continuously be monitored (Gartland, et al., 2004).
Such software is exactly what Gassco has implemented in their system.
Assuming that Gassco performs continuous corrosion monitoring via gas condition monitoring and that TSP's are ensuring anode consumptions and status annually, corrosion will not pose a huge threat to the overall GNG's availability. As a further measure of mitigation, pigging is performed every ten years, further lessening the risk of any corrosion developing within the system.

Consequently, random impacts, especially anchors, pose one of the greatest risks to the physical integrity of not only the GNG pipeline but pipelines in general. Using the PARLOC report as reference, approximately 70% of all incidents on offshore pipelines where due to impact or anchors, and of those 70%, 21% led to a containment breach (excluding risers, platforms etc.).

3.1.1 Trawling

In 1988 the Norwegian Institute of marine research conducted an experiment regarding the overtrawlability of large diameter pipelines, specifically the Zeepipe phase II pipeline. It was found that trawling posed no threat to hooking or any major damage, however, it was concluded that trawl gear would cause wear on the concrete coating over time (Valdemarsen, 1994).
Subsequently, most pipelines are designed for trawl board impacts, but new fishing practices have been registered, involving trawling with lump weights and boom trawls, which are much heavier than methods previously used. Most old pipelines are not designed to tackle such loads and the consequences of such new equipment on pipelines are uncertain (OGP, 2010). In 1988 and prior, trawl gear hooking were a rare occurring event on the NCS. But from 2000 to 2003 a total of 7 events were reported. In most cases when the trawl gear gets hooked, the winch start paying out more line with the pre-set tension onboard the moving vessel. The vessel then tries to unfasten the equipment by pulling by winch power in different directions until the trawl gear becomes unhooked.

Consequently, general impacts and pull over scenarios to the pipeline caused by trawling equipment poses the largest long term wear risk over time for the external pipeline condition. And as mentioned, there are currently multiple scars and damages to the concrete coating and joint fields of the GNG pipeline, caused by impact, most likely due to either trawling or anchors.

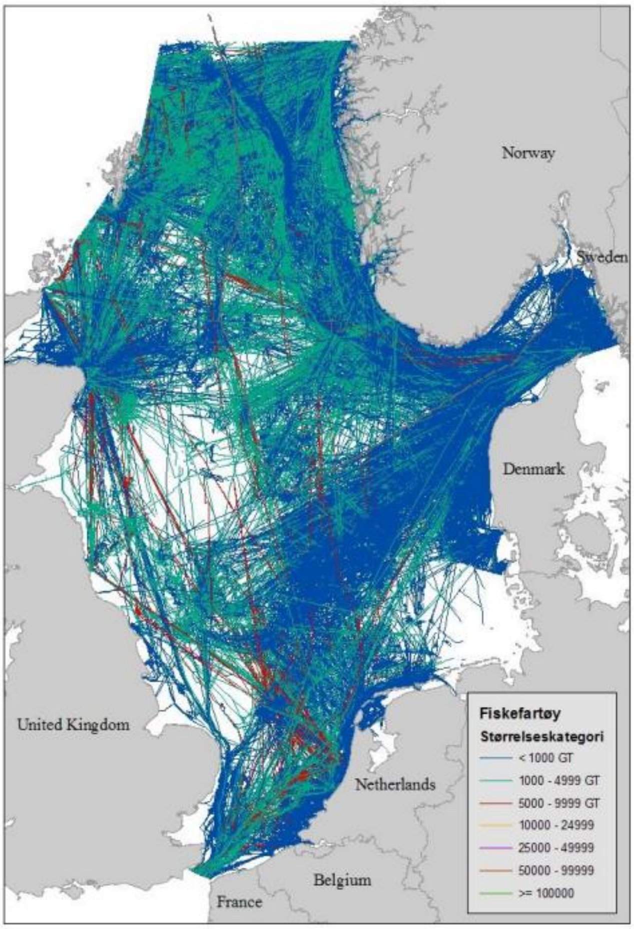


Figure 3-4 Fishing vessel traffic within the North Sea (Kystverket, 2010)

2010 data from the Norwegian Coastal Administration shows the fishing activities in the North and Norwegian Sea along with fishing vessel sizes.

3.1.2 Anchors

As previously mentioned, anchor damage is normally due to:

- Captain not having sufficient information on whereabouts of pipelines during routine anchor drop (ship more or less at stand still).
- Emergency anchoring (drifting ship).
- Unintentional release of anchor during transit (failure of chain braking mechanism or loss of power supply to chain breaking mechanism)
- Ship anchor being dragged during bad weather without crew's knowledge.

Unlike trawling which barely penetrates the seabed under worst case scenarios, a basic rock dump or burial will not protect the pipeline from some anchor scenarios. A large vessel of 100 000 tonnes will have an anchor weighing up towards 30 tonnes. Such an anchor can affect pipelines trenched 1-2m below seabed (HSE, 2009).

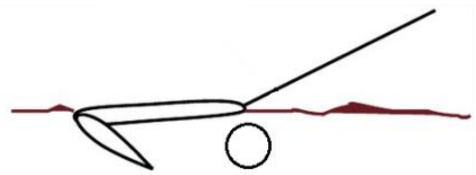


Figure 3-5 Seabed Anchor Penetration (Tveit, 2011)

Available standards such as DNV OS-F101 and DNV RP-107 give limited guidance on how to protect against large modern anchors, merely stating that:

"Effective protection against dragged commercial ship anchors can be obtained by burying the pipeline. The required depth will depend on the size of the anchors of the passing ships and the local soil conditions, i.e. how deep anchors will penetrate." DNV RP-107 - 2010

The effect of such protection methods is according to a report on pipeline anchor hazard written by the British Health and safety Executive, unknown, and that there is insufficient data on the subject (HSE, 2009).
In reference to the PARLOC pipeline database, 57% of all pipeline lengths had some form of protection, either trenching or burial.

As the economic activity in the North Sea increases, such as rising shipping traffic, the likelihood of such impacts also increase. Only recently, three large pipelines have been majorly affected by anchors.

- **Kvitebjørn**

Figure 3-6 Kvitebjørn pipeline showing displacement caused by anchor (Gjertveit, et at., 2010)

During a routine inspection in 2007 the 30" rich gas Kvitebjørn pipeline on the NCS, severe anchor damage was discovered at a depth of 240m (180m NCS diver limit). The pipeline had been dragged by a hooked anchor approximately 53m off its original lay position. During the routine inspection, they found a 10 tonne anchor which had previously belonged to a vessel, laying beside the pipeline. Reports of the case implied that the anchor had accidentally been dropped during transit and had unnoticeably been dragged along the seabed until ultimately being caught in the pipeline, causing deformation until the anchor chain snapped. Later simulations estimated that the pipeline had been lifted as much as 30m off the seabed before the anchor chain broke.
The chain breaking load in later laboratory tests was found to be roughly 500 tonnes. So the actual force of the vessel would mostly likely exceed 5000kN. Although subjected to extreme heavy loads, the pipeline seemed at the time to have not been breached, but during multiple shut down and start-ups sequences, the pipeline ruptured, most likely due to fatigue.
An onshore replica was made, and it was found that the damaged area was piggable, thus allowing an isolation pig train being launched from Kvitebjørn driven by seawater.
A pre designed repair tool called the morgrip (a sleeve type of design) was utilized, which allows deep water pipeline intervention on pipeline diameters up to 30" without the need for divers. The morgrip utilized graphite seals which dig in to the pipeline, and seal when the flanges are tensioned; provide a sufficient pressure and gas barrier according to all relevant standards.

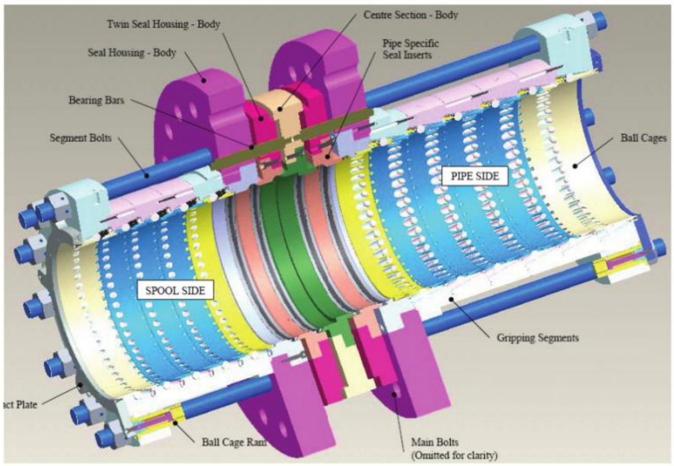


Figure 3-7 Kvitebjørn Morgrip solution (Gjertveit, et at., 2010)

The pipeline was cut in two places, and the damaged section was removed. A new rigid spool piece (section of pipeline) was put it its place, and by using two separate morgrips, the spool was connected together to the main pipeline.

One year and three months after the initial discovery the pipeline was repaired. Within this period, the pipeline was fully shut down for 8 months, where 5 months were considered active repair time.

<u>Main Conclusions</u>
The investigation concluded amongst others that the impact was most likely due to an accidental anchor drop from a vessel in transit. **Further interviews with multiple sea captains revealed that the frequency of such accidental drops were much more common than what had been previously estimated (Gjertveit, et al., 2010).**

The main heightened threat of accidental anchor drop's are due to the ship travelling at greater speeds than if it were intending on a set location, thereby not stopping before releasing the anchor.
The speed, momentum and distance travelled is thus substantially greater during accidental anchor drop, where the kinetic energy applied to the pipeline increases substantially when vessel size and vessel speeds increase. **Anchor drops by vessels in full transit speeds are not possible to protect against** (Gjertveit, et al., 2010).

Repair would be much more complicated if the damage had not been piggable.

Being prepared for the unexpected showed to be important in the form of the predesigned deepwater morgrip solution.

- **CATS BP**

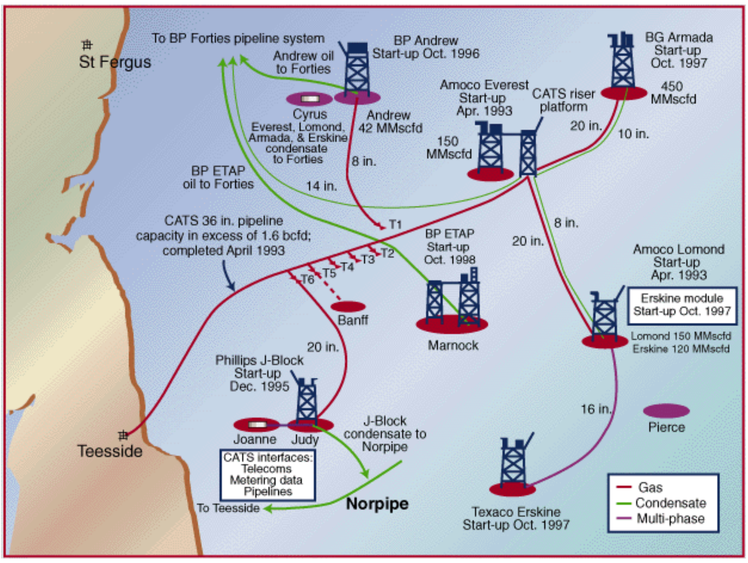


Figure 3-8 CATS pipelines (Pennwellnet, 2013)

The Central Area Transmiisson System (CATS) is a 36" gas pipeline transporting gas from the multiple producing fields to a shore terminal at Teesside (UK) providing a major source of energy for hundreds of thousands of domestic, commercial and industrial consumers (HSE, 2009). Even though the pipeline is trenched near land fall, an anchored ship with a gross tonnage of 56 000 tonnes started drifting off course during a storm in 2007. The vessel along with its anchor was dragged towards the CATS pipeline, where it hooked itself to the pipeline. A total of 94m was lifted up and exposed from the trench (through naturally back filled material), where the largest lateral movement was found to be 4-5m off original lay position. The damaged occurred at approximately 32m depth.

Monitor of flow and pressure found there to be no loss of containment. During inspection, a number of gouges and defects on the pipeline wall were found and during analysis, it was revealed that only one pressure cycle over half the operating pipeline was needed until significant fatigue would occur (Espiner, 2008).

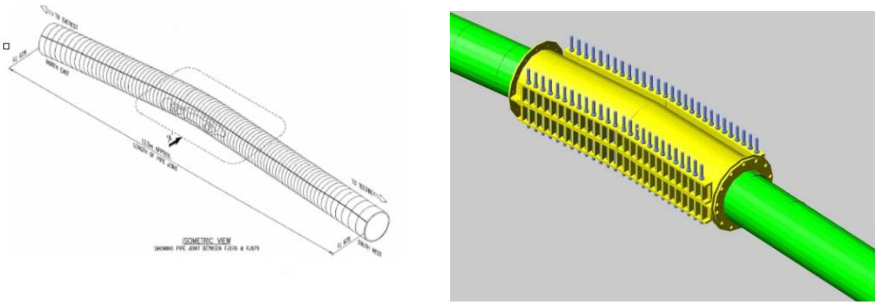


Figure 3-9 Sleeve solution BP CATS (Espiner, 2008)

A complex sleeve encompassing the damage was found to be the most viable solution. The sleeve would have to be designed in such a way that it facilitated the slight bend caused by the impact damage whilst also ensuring the structural integrity of the pipeline section according to all relevant rules and regulations. A steel sleeve was designed with grouting reinforcement in the annulus between the steel sleeve and the damaged pipeline, which was later installed by divers.

The whole period from damage to fully operational again was completed in 9 weeks. It was estimated that the vessel was travelling at 2 knots during impact, causing a kinetic impact energy of an estimated 10 kJ.

- **Transmediterranean Pipeline system**
  The system compromises of a total of 5 gas pipelines laid from Tunisia to Italy, two of which are 26" and three of which are 20". In 2008 a 110 000 tonnes tanker was unknowingly dragging its 12 tonne anchor along the seabed during transit at a depth of roughly 70m. First the anchor hit and jumped the first pipeline, causing only minor damages, but then completely severed the following 26" line before ultimately snagging the third 20" pipeline, displacing it 43m from original lay position, ending with the anchor chain snapping due to the pulling force exceeding its capacity, leaving the pipeline badly bent.

Figure 3-10 Transmed gilliotined pipeline (Orsolato, et al., 2011)

After approximately 9months, the pipeline was repaired and fully functioning.

In the wake of these accidents, the attention towards anchor damage risks has increased, highlighting the need for further guidance regarding protecting pipelines against anchor damages.

For an anchor to be able to hook on to a pipeline, the geometry must be in such a way that it allows lodgment. The fluke on the anchor, along with its relative angle to the shank, be larger than the pipeline OD.

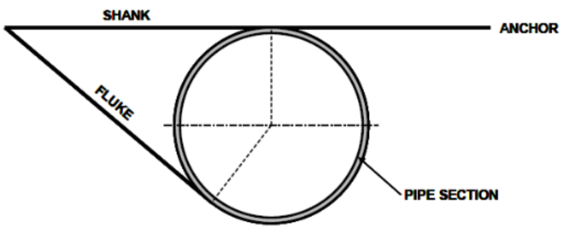
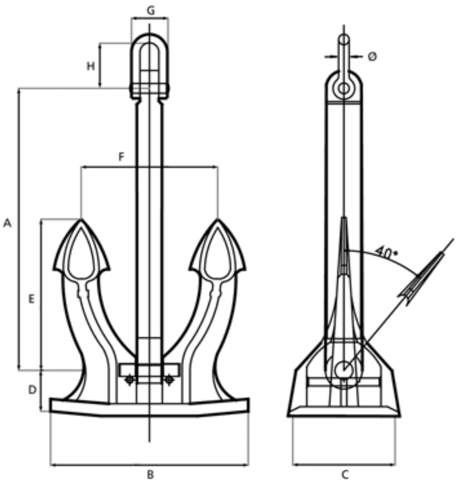


Figure 3-11 Anchor hooking size (Tveit, 2011)

According to Sotra, a leading anchor supplier, the most common types of anchors used for most ships are Stockless anchors such as Hall or Spek.



Weight	A	B	C	D	E	F	G	H	Ø
kgs	mm	mm	mm	mm	mm	mm	mm	mm	mm
3300	2160	1650	720	360	1200	1200	287	380	82
3540	2350	1650	720	360	1200	1200	287	380	82
3780	2430	1850	810	393	1350	1350	310	385	90
4050	2430	1850	810	393	1350	1350	310	385	90
4590	2520	1926	852	413	1400	1400	346	415	100
4890	2520	1926	852	413	1400	1400	346	415	100
5250	2610	2000	870	414	1450	1450	350	450	100
5610	2610	2000	870	414	1450	1450	350	450	100
6000	2700	2060	900	446	1500	1500	350	450	100
6450	2700	2060	900	446	1500	1500	370	480	110
6900	2890	2138	930	456	1550	1550	370	480	110
7800	2920	2138	930	456	1550	1550	380	500	110
8300	2754	2332	1020	530	1680	1700			
8700	3060	2332	1020	510	1700	1700	400	540	117
9300	3060	2332	1020	510	1700	1700	421	580	124
9900	3160	2332	1020	510	1700	1700	421	580	124
10500	3190	2440	1060	531	1770	1770	437	600	130
13500	3440	2632	1146	573	1910	1910	468	640	140
15400	3690	2824	1230	615	2050	2050	498	680	150
17800	3920	2922	1270	636	2120	2120	515	700	155
20000	4070	3028	1314	657	2190	2190	534	730	160
29000	4621	3438	1494	748	2494	2494	611	820	185

Figure 3-12 Stock Spek anchor specifications (Sotra, 2013)

The figure above shows a Spek anchor with its corresponding available stock items. The angle between the shank and fluke is always a set 40°, thus the measurement "E" becomes the driving factor.

Following calculations are based on a master's thesis regarding anchor impact of the Kvitebjørn gas pipeline (Tveit, 2011).
The maximum diameter in which a specific anchor can snag is given by the following formula and figure:

$$D_{max} = \frac{2L(1-\cos\alpha)}{sin\alpha}$$

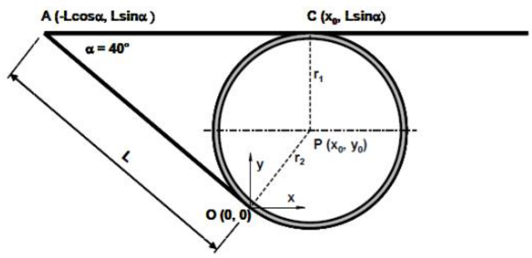


Figure 3-13 Anchor hooking size details (Tveit, 2011)

There is one implication though, and that is that in the D_{max} formula, the width of the anchor shank is not included. Vervik introduces an L modified on order to fully express the maximum diameter an anchor can hook in, and assumes the shank with to be 1/7 the length of C.

Anchor mass [kg]	Fluke angle [deg]	E [mm]	L modified [mm]	C [mm]	Shank width [mm]	Delta L [mm]	Dmax [mm]
3780	40	1350	1170.0	810	115.7	180.0	851.2
4590	40	1400	1210.6	852	121.7	189.4	880.7
6900	40	1550	1343.3	930	132.9	206.7	977.3
9900	40	1700	1473.3	1020	145.7	226.7	1071.8
10500	40	17770	1534.4	1060	151.4	235.6	1116.4
13500	40	1910	1655.3	1146	163.7	254.7	1204.3
15400	40	2050	1776.6	1230	175.7	273.4	1292.5

Table 3-4 Speck Anchor specifications

By assuming that the GNG pipelines has an approximate outer diameter of 1179mm, which includes concrete and corrosion protective layer, only 13500kg Spek anchors and above will be sufficiently large enough to actually hook the pipeline.

Another parameter that must be highlighted is the depth at which a towed anchor can inflict damage to a pipeline. This depth mostly depends on: an anchor's chain length and the speed at which the vessel is travelling.
As a vessel's speed increases, the projected drag force on the anchor thus also increases.
Vervik goes into this in further detail, but a general figure below depicts how the maximum equilibrium anchor depth is affected by a vessel's velocity.

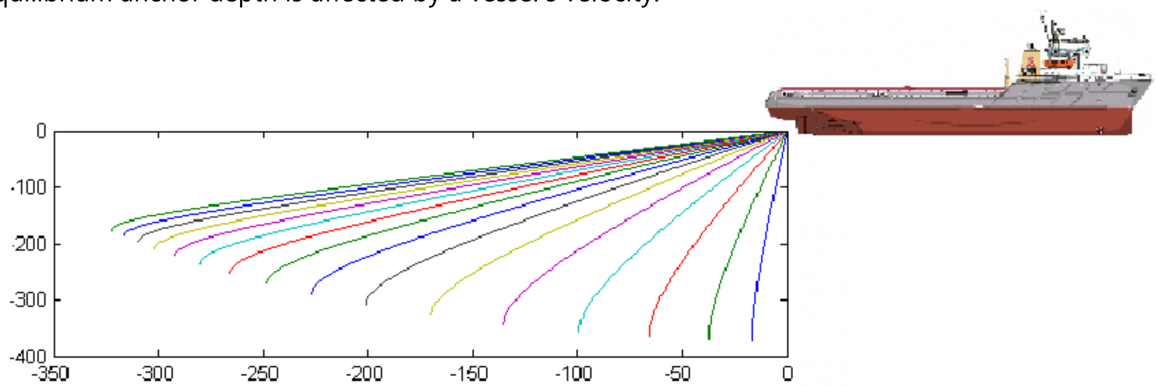


Table 3-5 Typical anchor tow depth for varying velocities 2-17 knots (Vervik, 2011)

By using data found, one can estimate that vessels with an anchor mass over 13 500 kg most likely carry chain lengths exceeding 700m. By plotting such vessels by utilizing data found in Vervik's thesis, the following approximate anchor tow depth profile is found (Vervik, 2012).

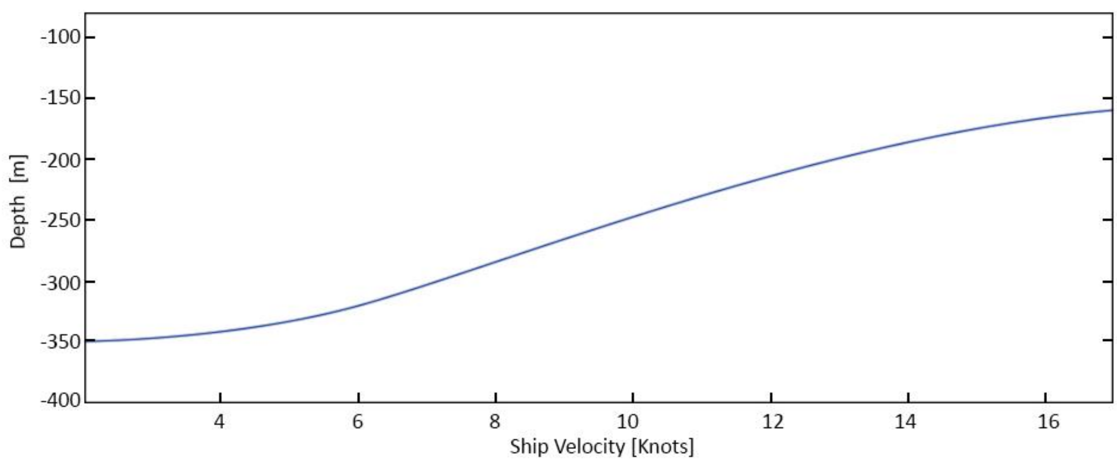


Figure 3-14 Maximum 13500 kg Anchor Tow Depth for Versus Ship Velocity (Source: Vervik, 2011)

According to DNV, the most efficient transit speed of large vessels is approximately 19 knots (DNV, 2010). So by assuming that the largest vessels transit at this speed, the maximum tow depth an anchor is able to reach during optimal velocities, is approximately 150m (by utilizing Vervik's results).
In his study, Vervik has used effort in to linking ships passing the Kvitebjørn pipeline to anchor dimensions. By selecting a few of the vessels which comply to an anchor weight of above 13500kg, the following vessels can be found to be potential vessels in which has the potential to dramatically impact the GNG pipeline by its anchor:

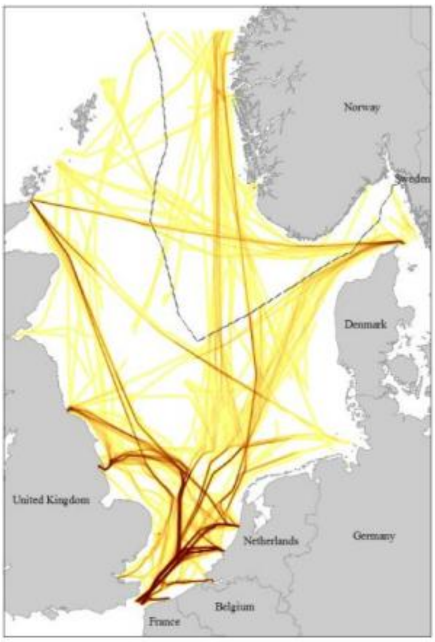
Name	Type	Anchor mass	Chain Length [m]	DWT [ton]
Berge Atlantic	Cargo shipping	16 900	742	172 704
Jack D	Cargo shipping	14 700	742,5	98 358
Arctic Discoverer	Tanker shipping	23 000	770	75 485
Sallie Knutsen	Tanker shipping	17 800	742,5	153 617
Nansen Spirit	Tanker shipping	15 400	742,5	109 239

Table 3-6 Vessels with anchors which could hook the GNG pipeline. Source: (Tveit, 2011)

From the table above, one can further vaguely assume that ships with a dry weight larger than approximately 60-70 tonnes will have an anchor large enough to hook the GNG pipeline. Deadweight (DWT) is how much the vessel can carry. In converting DWT to gross tonnage (volume in which the vessels holds), one can recon that roughly a half of this when dealing with tankers, bulk carriers and vessels in general carrying a lot of load. Thus as pure ball parking, the Gross tonnage weight of vessels most likely having anchors in which can hook a pipeline is in the range 30 000-45 000kg. By being conservative, one can say GT>50 000.

Below are density plots in the North Sea of the most likely vessels in possession of anchors which can hook the GNG pipeline, taken from an activity report produced by the Norwegian Coast guard (Kystverket, 2010).

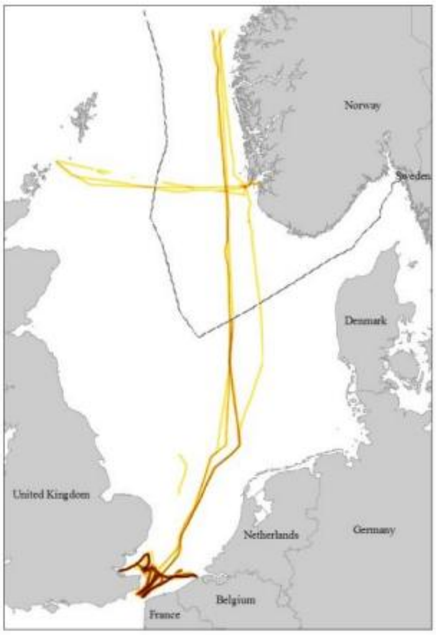
<u>Density plot bulk vessels</u>



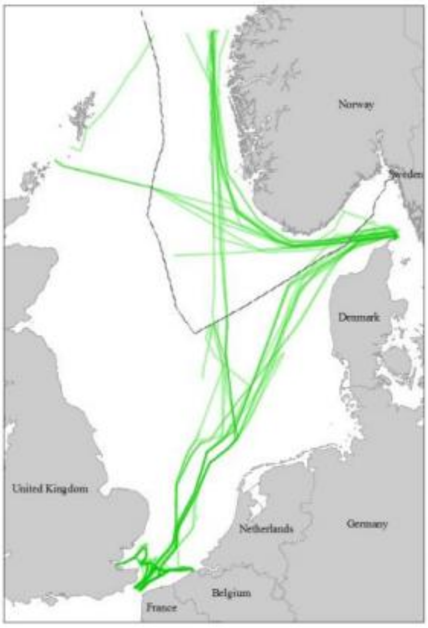
Bulk 50 000 – 99 999 GT

Bulk > 100 000 GT

Density plot Gas tankers

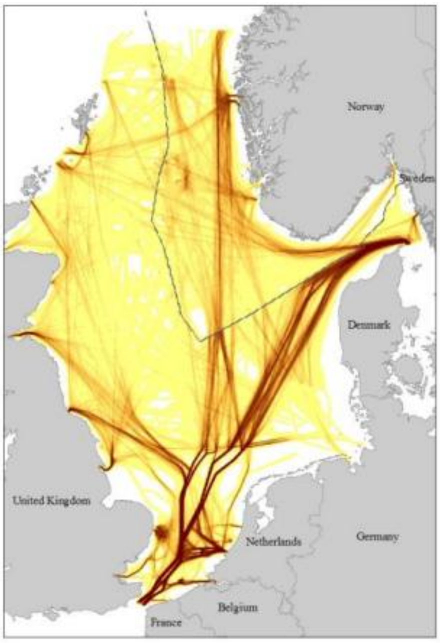


Bulk 50 000 – 99 999 GT

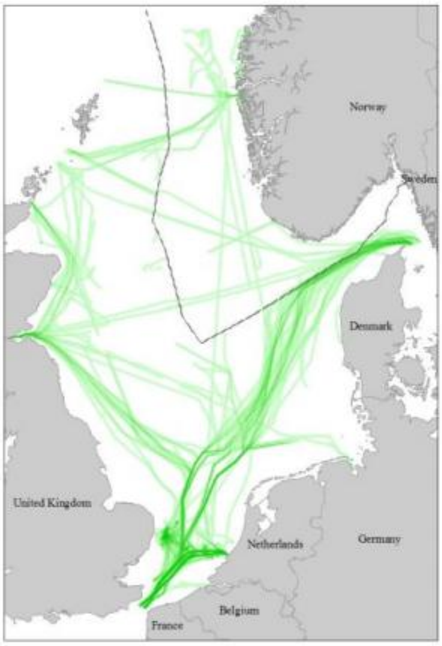


Bulk > 100 000 GT

Density plot Oil tankers

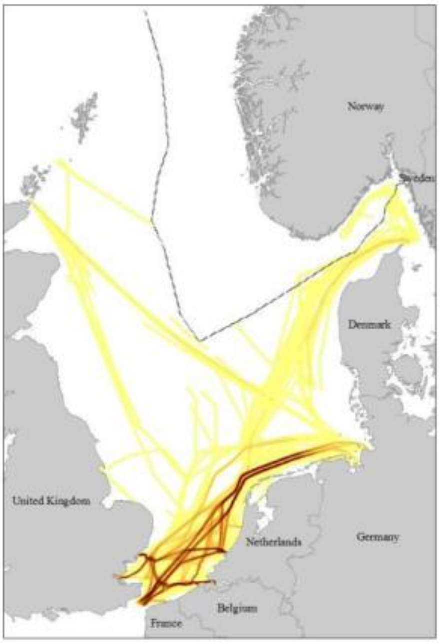


Bulk 50 000 – 99 999 GT

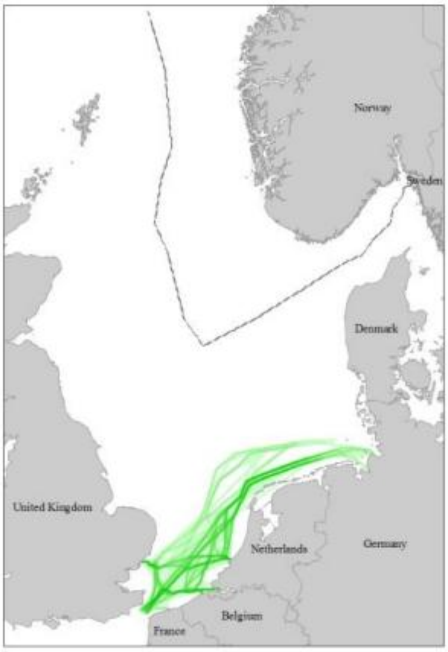


Bulk > 100 000 GT

Density plot container vessels

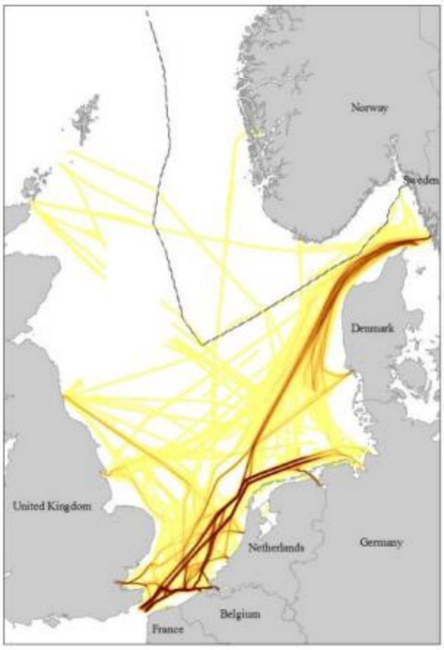


Bulk 50 000 – 99 999 GT



Bulk > 100 000 GT

Density plot roll-on/roll-off vessel



Bulk 50 000 – 99 999 GT

Without mentioning the specific route in which the GNG pipeline is located, it can be mentioned that the shipping traffic is substantial and that the threat of anchor damage should be taken seriously.

On the basis of the previous individual density plots, an approximate vessel density plot of vessels most likely carrying anchors which can hook the pipeline can be layered over the GNG pipeline's depth profile.

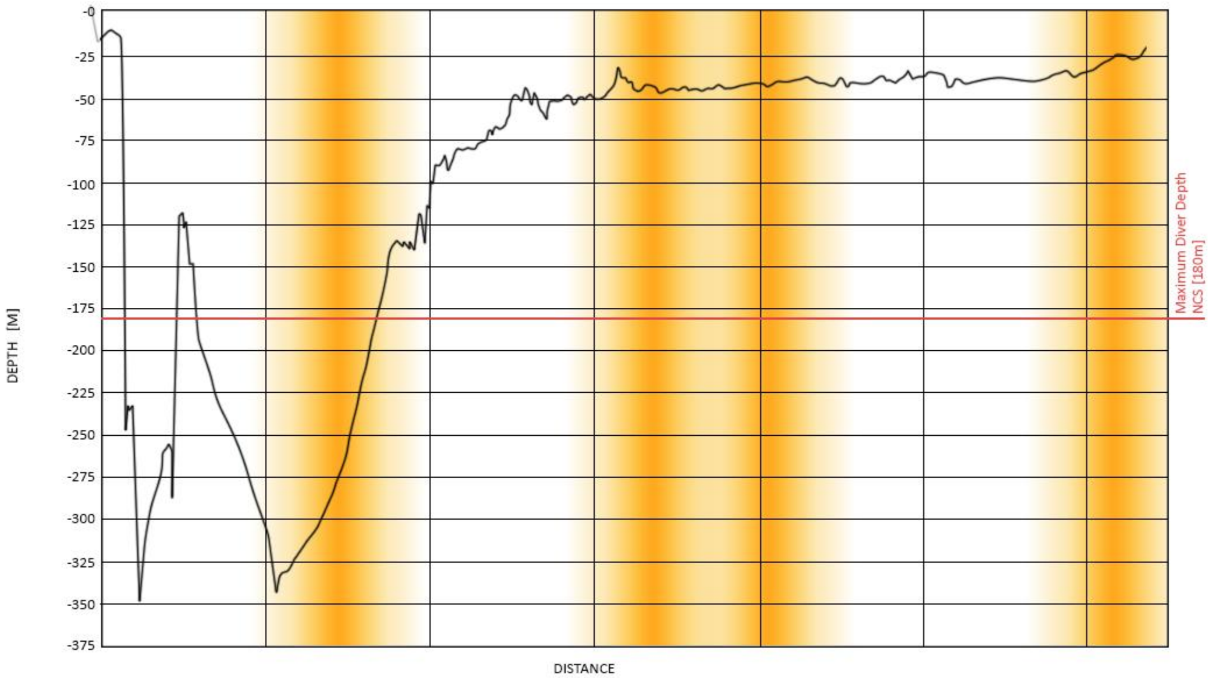


Figure 3-15 Approximate Location Density Movement of Vessels Exceeding 50 000GT (Anchor threat) Along GNG Pipeline Profile

The above image is only a vague estimate, but gives an indication of where possible anchor impacts by large moving vessels are most likely to occur on the basis of large vessel transit routes. Specific vessel size and movement across the pipeline can be found at the Norwegian Coastal Administration's website, but requires special permission. Vervik's master thesis of anchor impacts on the Kvitebjørn pipeline (Vervik, 2011) utilized this way of gaining specific knowledge regarding vessel moving across different sections of the pipeline, where he excluded vessels with anchors sizes beneath a certain weight.

To achieve an overview over a worst case impact scenario, one can first look at the CAT anchor damage, where a vessel travelling at 2 knots caused a 10kJ anchor impact, imposing a severe dent. In comparison a tanker vessel like Sallie Knutsen with a weight of 204 426 tonnes would at only 5 knots, possess 744MJ of Kinetic energy (Vervik, 2011).

One thing is for certain, vessels sizes are increasing and as an example the world container fleet capacity is expected to grow 9.5% in 2013 alone, and as a result a new class "the Triple E class" container ships are being introduced in 2013, becoming the largest vessels moving on sea (Kramer, 2013).

Even though the possibility of anchor impacts is reasonably low, the consequence during an impact of a large anchor during vessel transit is large.
Being prepared for such an incident has proved to be crucial in order to minimize the financial repercussions.

3.1.3 Consequences due to Physical damage

The importance of the pipeline availability is critical, and even a minor damage (with no breach) to the steel can result in a need to reduce the operational pressure for a certain time, and will most likely result in a period of down time where service is needed. Such down time will cause large infrastructural disruptions, both upstream and downstream, having huge financial implications for many stakeholders.

Let us assume impact damage does occur, specifically in deep water, what happens, how long does it take, what are the infrastructural implications and who fixes the problem?

Sequence of events

Any physical scenario majorly affecting the pipeline will limit the availability of the pipeline. The critical point is thus the actual impact point, and most of the activity in regards to getting the pipeline up and running again will be concentrated around this point. As the figure below indicates, the damage impacts the pipeline section, happens quickly, and takes a relatively long time before the availability is back to normal.

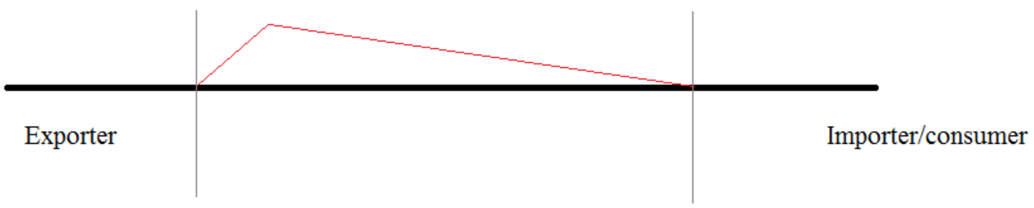


Figure 3-16 Pipeline physical damage effect to health

Initially, a breach in the pipeline will most likely be measured in the flow and other parameter monitoring performed by Gassco. A dent might, if lucky, also either affect the same monitoring or be found during a routine inspection by deep water ROV happening to be at that location within its planned inspection interval segment.
The TSP would immediately inform the operator Gassco, who again would inform the government and the infrastructure owner Gassled.
If no leak was found, most likely a guard vessel would be positioned near the pipeline and a 1000m radius exclusion zone would be implemented around the damaged area.
Should there be a leak, depending on the outflow of gas, a larger exclusion zone may have to be implemented. As gas could pose an environmental threat, there is set up an organizational chart of Norwegian entities which are put in high alert during an environmental incident in relevant territory.
In addition, there are international merger plans such as the Copenahagen and Bonna agreement, which ensures multiple nation’s cooperation should a major contamination incident occur in the North sea. NorBrit is also another such agreement between Norway and Great Britain independent of area, as long as it poses a risk for the individual countries land and sea territory (Kystverket, 2010).

Should a rupture occur in a large gas pipeline , a common concern has been whether a possible gas bubble plume during a rupture could affect a vessel's buoyancy thus resulting in it sinking (i.e. guard vessel or transiting vessels). This has been disproven by studies, showing that radius flow of water being pushed away from the rising plume will also push a vessel away from the plume's breach location (Ross, 2009).

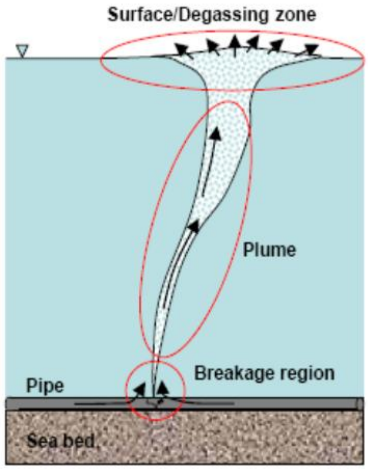


Figure 3-17 Illustration of gas leak from a ruptured subsesa pipeline (Gassco, 2007)

The largest immediate threat for the surrounding area during a full guillotine pipeline breach, is an explosive zone (degassing zone) developing in the air at bubble plume surface breach. According a study team from SL Ross, Sintef and Well Flow Dynamics, a large pipeline breach will result in violent, short-lived, large quantity bubble discharges. In the simulations they ran (on a 36" gas pipeline), the scenario with the largest explosive gas concentration area was found to be within a 1100m radius, beyond this point the gas dispersed, and within a time span of up to 3 hours, the amount of gas discharge would be negligible in relation to an explosive gas concentration.
In any affect, should a breach be found, the TSP/Gassco would most likely initiate the emergency shutdown valves (ESV) and relieve pressure on either side of the pipeline. The amount of gas which could possibly become a pollution hazard would be limited to the amount of infill gas between the two ESV valves on either side (see battery limit figure).

In the wake of rising concerns regarding damages to major North Sea infrastructural pipelines, an emergency entity called the Pipeline Repair System (PRS) was initiated in 1987 in order to be capable of repairing pipeline damages should they occur. The entity collected many main stakeholders of pipelines under one roof, thus sharing development and operational costs. Its main function was to provide a rapid response for pipeline repair ensuring regularity of gas supplies (Crome, 2012).
The entity is owned and developed by many of the stakeholders of pipelines in the region, where Statoil is the operator and has administrative responsibilities. Technip has of 2013 (and up to 2014) through a frame contract, the responsibility of upholding maintenance and operation of the PRS pool service. Their responsibility is to ensure that the system is at all times ready for contingency operations and that there are qualified personnel available at all times should an incident occur (Technip, 2013) to the 14300km pipeline lengths encompassed as of 2012 (Berge, 2012) within the PRS member companies.

As of 2013 the following companies are PRS members:

- BBL Company
- Gassco
- Shell
- Conoco Phillips
- Lyse
- PGS (Teekay)
- Nord Stream
- Statoil

The equipment needed to facilitate any emergency interventions is located in Killingøy, Haugesund, Norway, a centralized position, minimizing response times to the large import/export pipelines (DeepOcean, 2013).

The PRS equipment pool is constantly being developed and is often on the world forefront regarding innovation and application. Such development has often been paid off, for instance with the deep water Kvitebjørn solution, which would most likely have taken far greater time to fix had not the PRS been utilized.

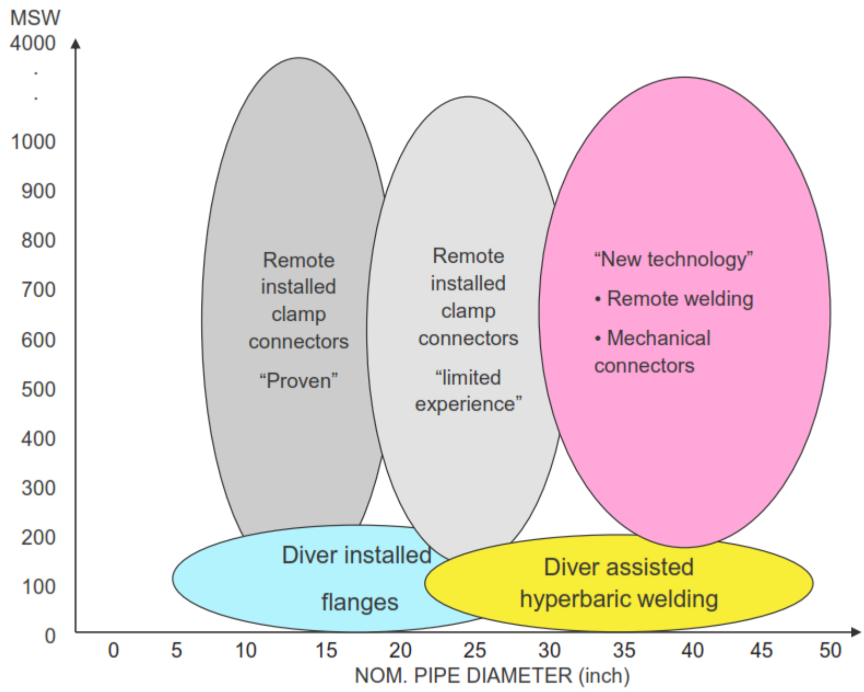


Figure 3-18 PRS solutions as of 2012 (Berge, 2012)

The solutions of the PRS pool service is of 2012 given in Figure 3-18, where the GNG pipeline falls in the pink and yellow category. Any problem in shallow water depths (independent of size), are well proven solutions with extensive field experience.

Pipeline failures below 180m water depth, becomes increasingly complicated as the nominal diameter increases.

In the early days when large diameter pipes were installed in the North Sea (Franpipe, Zeepipe, Europipe etc.) the need for deep water PRS equipment became an issue, which led to Statoil awarding Hydratight Sweeny (the makers of Morgrip) in 1995 a contract in supplying them with Morgrip solutions for the PRS pool. Within the next 10 years, Morgrips of all sizes were produced ranging all the way up to 42" (Morgrip, 2006).

The PRS contingency coverage as of 2012 is shown in Figure 3-19, where a whole range of pipelines with the "pink" area are covered, mainly by the morgrip solution.

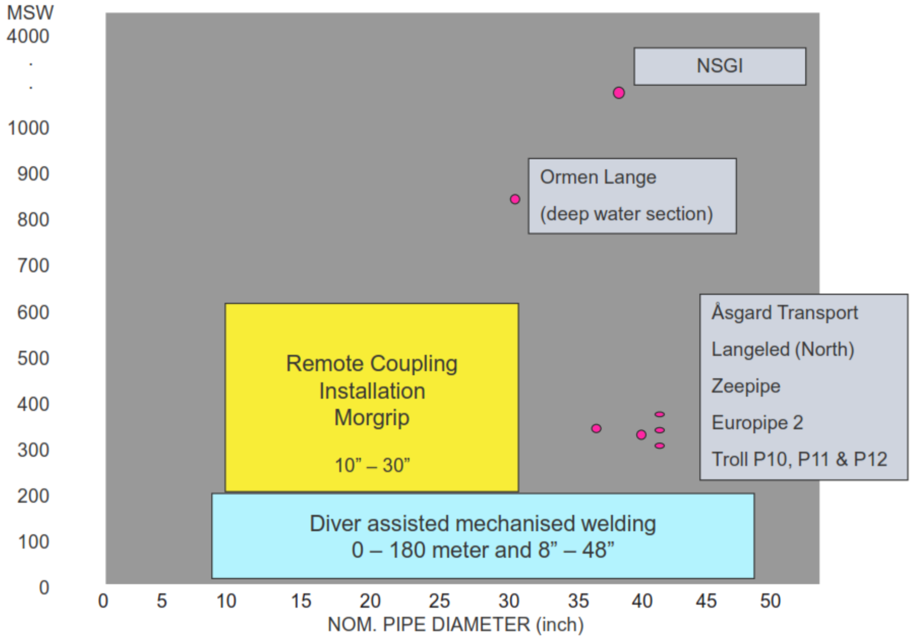


Figure 3-19 PRS contingency coverage as of 2012 (Berge, 2012)

Although tested extensively, utilized in the field and approved by governing authorities, the morgrip has certain negative aspects. Due to the mechanical nature of the Morgrip, it does not act as a fully failsafe barrier as a welded seal would. A Morgrip will most likely involve an increase in inspection intervals throughout its design life, especially since it is at the moment has fairly limited experience on larger pipe diameters.

A weld on the other hand, gives a more "rest of mind" result, in that after the weld is tested (NDT etc.) it is as good as any other weld on the pipeline. This is especially applicable on larger diameter pipelines, since they are most often linked to large vital infrastructural flows where available is key.

Therefore there has been a huge effort the last years within the PRS pool service (and world in general) to be able to weld remotely in deep water on larger sized pipelines.

This new technology is often referred to as a remote operated welding system (ROWS), where the welds between a new inserted spool and the existing pipeline is performed mechanically (subsea).

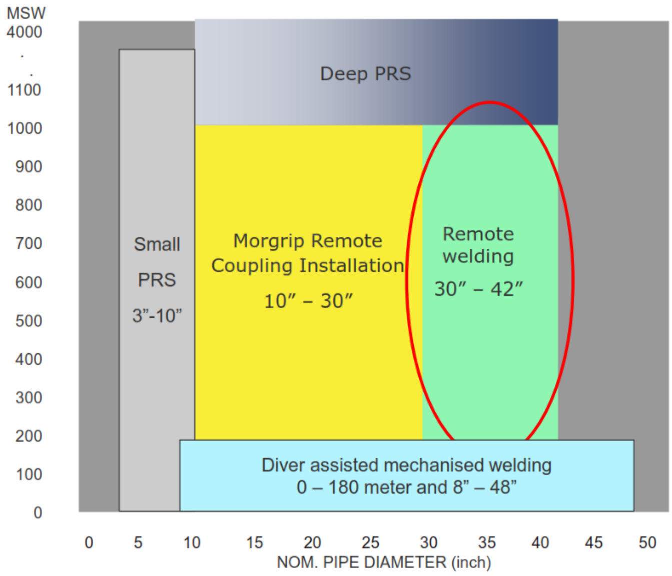


Figure 3-20 Key area of interest regarding GNG pipeline (Berge, 2012)

The PRS pool service has of 2012 large future plans of implementing remote welding technology as one of their repair tools.
Such a remote welding tool has been in development by the PRS pool service in parallel to the Morgrip investments. Throughout the past years, large resources have been spent, and the tool has been heavily tested. But as of this date, the tool has not officially been certified for real life use.

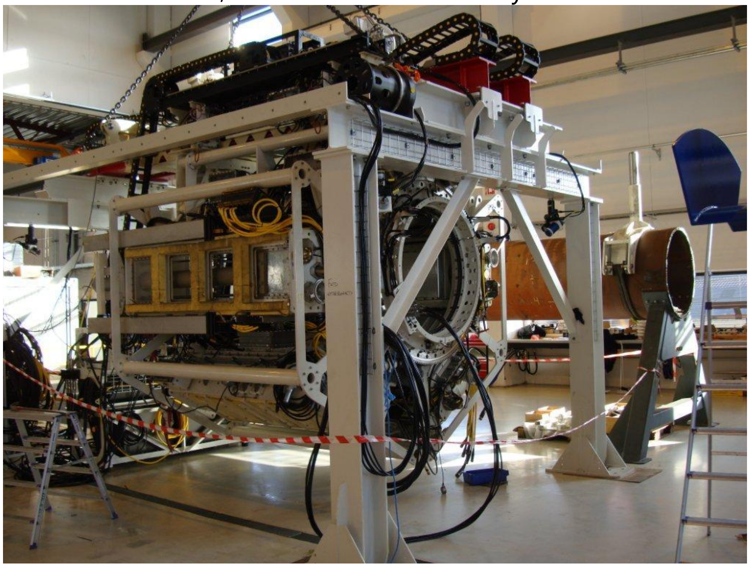


Figure 3-21 PRS Remote welding tool during testing

Any deep water impact on the GNG pipeline as of now, would most likely involve the following possibilities:

- Utilizing Morgrip tool
- Utilizing tools from other PRS pools (Chevron, BP etc. all have different PRS tools)

In an event of a rupture or major damage of the GNG pipeline, the damage must first be evaluated, as in Kvitebjørn. An option might be to reconstruct the damaged section in order to gain a better understanding of the problem at hand. Third party firms may be utilized in order to perform detailed calculations, reconstructions etc. so that the best possible solution is found.

One of the real challenges will be when employing new unproven technology in a real life scenario, conditions change from what may be applicable in a controlled test scenario. Even in the pre phase test process, directly performed before an offshore intervention, unexpected problems may occur. This is something that the Kvitebjørn morgrip experienced, which caused delays in order for the system to be termed acceptable as a permanent solution.

A time frame from when damage occurs to the pipeline is fully operational is largely speculation, but Statoil has projected 40-100 days.

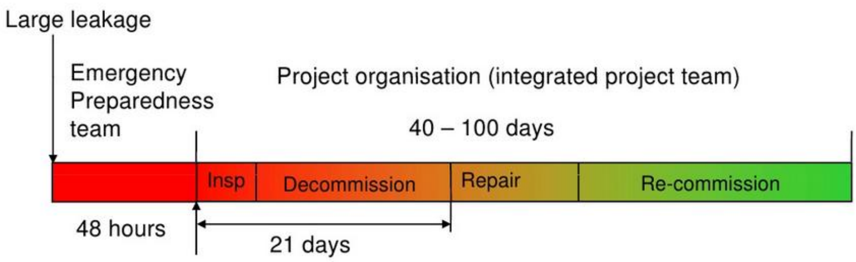


Figure 3-22 Estimated response time from incident to resumed operations (Farrier, n.d.)

In addition, by looking at previous pipeline failures and their down time it may be possible to stipulate an estimated timeframe.

Incident	Diameter	Depth	Down time
Kvitebjørn	30"	Below Diver Depth	8 months
CATS	36"	Above Diver Depth	9 weeks
Transmed	26"	Above Diver Depth	9 months
BP Amethyst (gas pipeline)	*32"*	*Above Diver Depth*	*"several weeks"*

Table 3-7 Large diameter pipeline incidents caused by anchor impact

*****After talking to pipeline specialists, it has become evident that most pipeline damages are kept confidential and operators do not want everyone to know that their pipeline was damaged. Reasons for this are abundant, but financial implications are most likely a factor. An example is the BP Amethyst impact, which was only found barely referenced to, with no specific details.*

Cost and Lost revenue of down time

Note: During GNG downtime, a certain amount of gas will most likely be relocated through other pipelines and either supplied to their designated receivers, or sold on the spot market. The following calculations are based on the fact that no gas is relocated, so as such, form a maximum loss of revenue during for example high demand periods, where all export pipelines are high utilized.

Export data from Gassco, shows a record amount of Norwegian gas export in 2012, 107,6bcm to be exact. By weighing the GNG pipeline's capacity in relation to the total of other pipeline's maximum capacity, the amount of gas delivered through the GNG pipeline in 2012 can be roughly estimated, assuming that the utilization ratios on all relevant pipelines are approximately the same. In 2012 the delivered gas can thus be ball parked to be 18.6bcm.
According to market analyst Lill Sandvik in Bayerngas Norway, approximately half of Norwegian gas export is sold through oil indexed contracts, whilst the rest is sold through short term spot markets. Average oil indexed price through contracts in 2012 was approximately 2.5 NOK/Sm^3, whilst the average spot market price for Norwegian gas was 2.1 NOK/Sm^3 in the same year (Førde, 2013). By halving the GNG pipeline's estimated capacity and multiplying with the corresponding gas prices, a total value of 42 billion NOK per year, or 7.2 billion USD is transferred through the pipeline annually.

By incorporating an averaged 99,69% availability rate for 2012 (Førde, 2013), this gives an estimated daily gas sales revenue of 111 million NOK transported through the GNG pipeline.

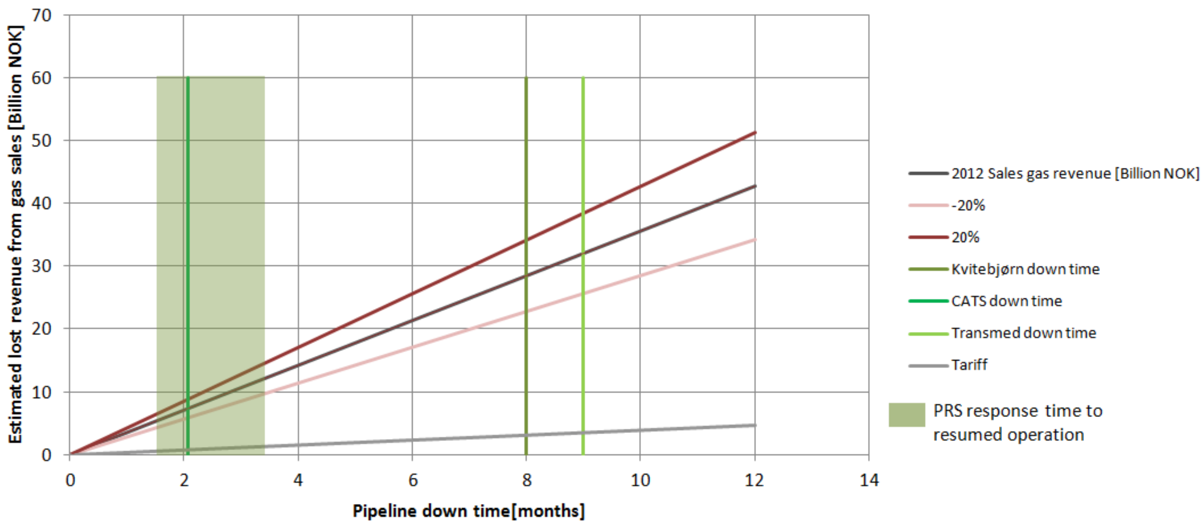


Table 3-8 Lost revenue due to pipeline down time according to previous cases and official estimated PRS response time

The above graph illustrates the estimated lost revenue due to down time of the GNG pipeline assuming that no gas can be relocated through other pipelines. As the underlying parameters are bound to fluctuate (varying gas prices, volumes exported etc.) and the fact that some parameters hold a certain amount of uncertainty (weighted gas export on the GNG pipeline etc) a +-20% deviation has been introduced.

In addition, the lost revenue in the forms of tariffs alone can be vaguely estimated. In 2011 Gassled earned 24.2 billion NOK (Gassco, 2011a) in total tariff revenues, where they in the same year exported 94.2 bcm through their pipelines (Gassco, 2011a). Using 2012 gas price values and spot market- oil index market distribution as written by Førde, overall 2011 gas export revenue would be estimated to be 216 Billion NOK.

By dividing Gassco's 2011 earnings with the total estimated gas export value in the same year, a vague estimate of the tariffs' amount compared to the overall gas value can be found.

$$\frac{24.2\ NOK\ billion}{216\ NOK\ billion} = 11\%$$

It must be highlighted that this ratio is an estimated average for the whole pipeline network, and not for the specific cost of transporting gas through the isolated GNG pipeline alone. This estimate is thus an average ratio which includes all tariff areas such as processing and transportation compared to the overall gas sales value. As such, the 11% will be used as reference to the cost of tariff through the GNG pipeline, but a somewhat large uncertainty must be given to not only this figure, but also the general estimations given regarding revenues and tariffs.

It should also be mentioned, that the formula given earlier regarding tariff costs, holds a number of parameters which are kept confidential, even though some of the parameters are given to the public (K, I and O values). This is the main reason why this formula has not been used to find the applicable overall tariff on the GNG pipeline leg.

Further, by utilizing downtimes of both official repair time estimates (PRS service) and actual cases, a most likely window of possible future repair times can be estimated.

Incident	Down time	Down time [months]
Kvitebjørn	8 months	8
CATS	9 weeks	2.07
Transmed	9 months	9
PRS response time (mean)	70 days	2.3
Mean		5.34
Standard deviation		3.66

Table 3-9 Large diameter pipeline down times

By implementing a 90% confidence interval with base figures in table above, the following best estimate of most likely down time along with lost revenue due to a severe impact is shown.

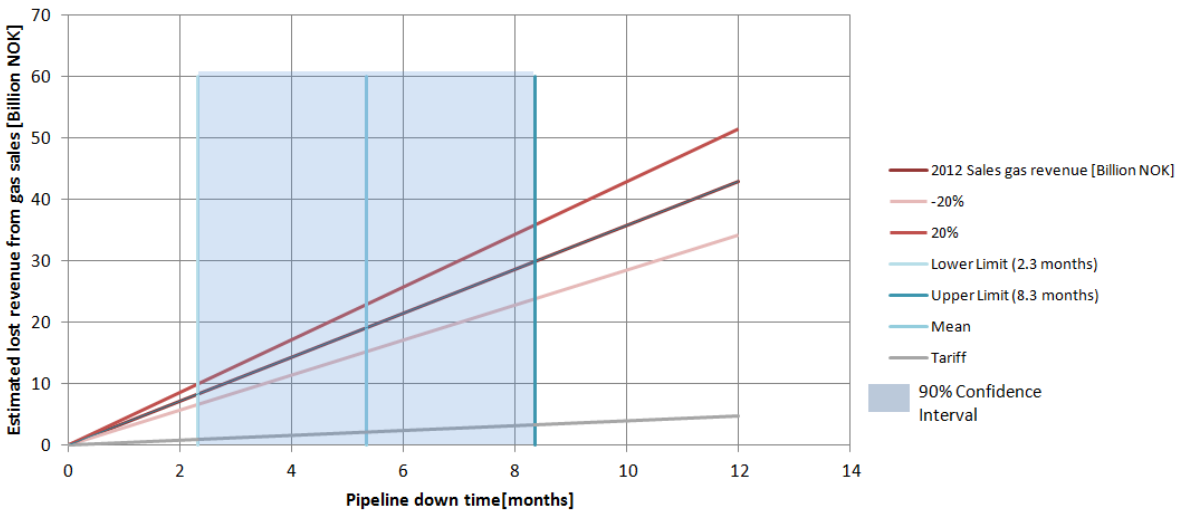


Figure 3-23 Lost revenue due to pipeline down time according to confidence interval

	2012-20%	2012	2012+20%	Tariff
Lower percentile	7	8	10	1
Mean	15	19	23	2
Upper percentile	24	30	36	3

Table 3-10 Lost revenue due to pipeline down time, mean upper and lower percentile [Billion NOK]

According to 2012 values, and estimated gas transfers through the GNG pipeline, should major damage occur, where everything regarding intervention and repair is executed and performed as planned, the minimum amount of revenue lost (lower end of 90% confidence interval on the basis of both planned response times and real response times), would be NOK 8 billion. Whilst if the intervention work does not go as according to predefined contingency intervention plans, like Kvitebjørn, when the Morgrip needed further testing etc, a repair may take over 8 months giving an estimated loss of revenue of NOK 30 billion (upper end of 90% conf. int.).

As being a gas pipeline, **should the pipelines' integrity be breached**, the gas will as previously stated be released to the atmosphere, disperse, and the pipeline water filled. So as time goes by, there is no imminent rush, other than contractual obligations and lost/deferred transfers.
Comparing the lower limit with a well implemented and tested contingency plan, against a scenario where things aren't as fully prepared (upper limit), a differential sum of NOK 22 billion can be estimated. This differential sum is what separates an estimated best case scenario to an estimated worst within a 90% confidence interval.

Variables affecting down time should pipeline integrity be broken

One of the key lessons learnt from the Kvitebjørn incident is how one should be prepared for the unexpected, and it is exactly this mentality which is key, in order to limit the amount of down time should a severe incident occur.

Since the Kvitebjørn incident in 2007, the PRS service has most likely implemented an increased amount of procedures, equipment etc. in order to further improve their preparedness should a worst case scenario arise. Even though contingency plans are already developed, there is still a huge costs involved when an unplanned repair must be set in motion.
Aside from the lost revenue during a shutdown period, the largest economic factors are offshore intervention vessels and onshore engineering/testing.

The moment a major unexpected pipeline repair is termed impending, large engineering and testing teams must be moved away from other active projects to the pipeline issue at hand. Under such conditions, it is essential that large amounts of workers manage to collaborate effectively and become **aligned towards a common** imminent goal as quickly as possible.
A solution must be found, the solution must be tested, and solution must be approved by authorities such as the DNV and PTIL.
Even though pipeline damages above 180m sea level are a "straight off the shelf" solution by utilizing hyperbaric welding, a huge amount of planning and qualification is required before the divers can perform the weld offshore.
The divers must perform a hyperbaric weld on a same size diameter replica, at the same depth pressure onshore. Such facilities are not common, and long waiting periods to use the facilities are therefore expected. Under a top priority case such as this, other customers of the facility or other projects will have to be put on hold by paying them out.
When solutions and welding/equipment procedures has been qualified, the intervention vessel can start mobilization. Such vessels are most often made ready according to frame agreements, and making sure that the offshore repair is performed as efficiently as possible is important when the costs for such vessels are often 3 million NOK per day.

Weather may also play a factor in how long time before a pipeline is re-commissioned. The habitat and H-frames are large pieces of equipment utilized in the contingency plans (habitat for above diver depth scenarios). These objects are not only heavy, but have a relatively large foot print when lowered through the plash zone. To be able to lower these safely through the splash zone, the significant wave height should not exceed an estimated 1.5-2m. Normally such conditions are common from April through to September, but through the winter, the PRS contingency plan may be put on hold for multiple weeks before weather forecasts suggest calmer seas.
The Kvitebjørn repair was done during the winter time, from August through to January, and

weaknesses in the PRS contingency were reported, where room for improvement was highlighted, especially due to winter time intervention (Gjertveit, 2010).

Even though a best case scenario, regarding repair time and costs is performed, there are still huge **ripple effects** in the industry. By utilizing other projects' assets, (both internal and external) in the forms of personnel, ships, equipment etc. large projects may possibly be deferred to the following year. For example if the intervention vessels was supposed to be installing a Tee which was to branch off to a newly developed platform, that platform may have to postpone its production until the year after, when the weather becomes good enough to implement the project.

Who pushes back

Above is a short description of variable parameters in which can affect the monetary outcome of a major incident on the GNG pipeline. But who are the main stakeholder responsible in ensuring that the operation is performed smoothly and who suffers most economically.

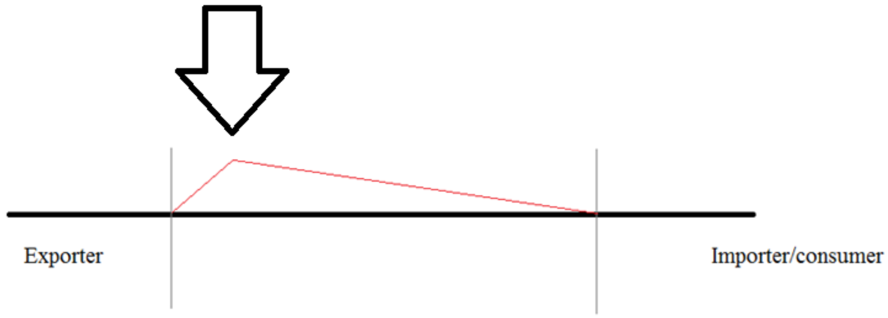


Figure 3-24 Pipeline Health, who pushes back

All tariffs paid by shipper, ultimately affect Gassled (the owner of the transport system) and Gassco, as such, the graph below can be plotted based on previous estimates, where 11% of shipper's sales gas value is in the form of tariffs.

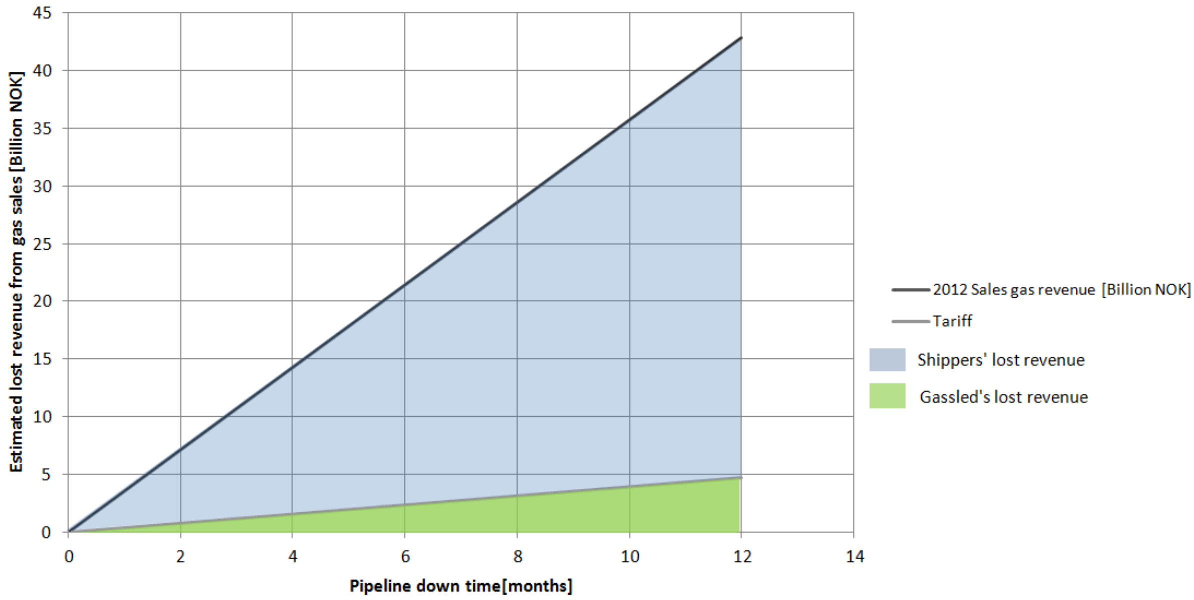


Table 3-11 Major Stakeholders in pipeline down time

As the graph depicts, the main stakeholders to lose revenue are the shippers, Gassled, Gassco and the government (which has ~50% stake in the company through Petoro and Statoil), these are the major players who will most likely be economically affected.

Although there are many stakeholders, it is Gassled who is the actual owner of the infrastructure, and as such, they carry the financial risk. All large costs involved in repairing the pipeline will have to be covered by Gassled, namely the pipeline repair system, engineers, intervention vessels, testing etc.

As most of the major owners of Gassled are investment firms, they do not have as much experience in the oil and gas industry as the larger operators do. This makes a large proportion of Gassled more of a financial contributor on the sidelines, whilst the other half of Gassled and the TSP will most likely act as tangible asset contributors, in the form of coordination teams and engineering. The TSP will most likely take the role as coordinator.
Seeing as Gassled pays annual fees in order to have the right to use the PRS service, they still have to pay for the service to be utilized.
At the same time, Gassco and other stakeholders (shippers, government etc.), will give their guidance, help and knowledge to the TSP.

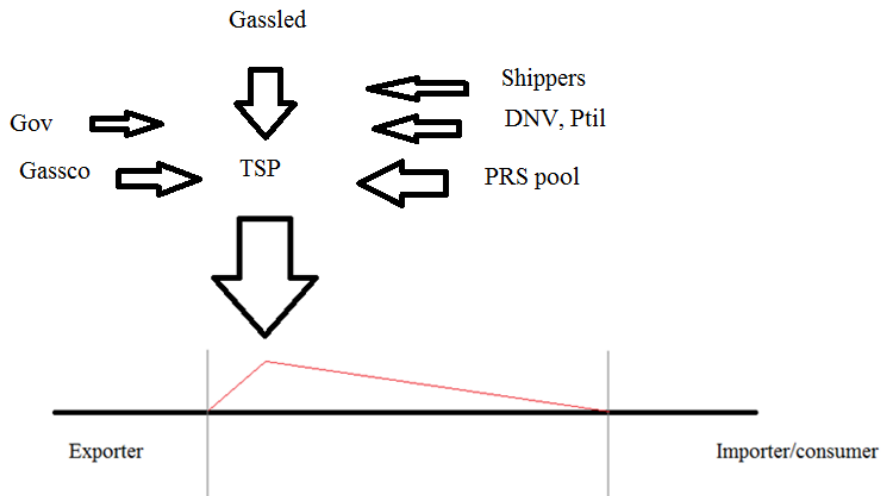


Figure 3-25 Who pushed back during a major pipeline incident

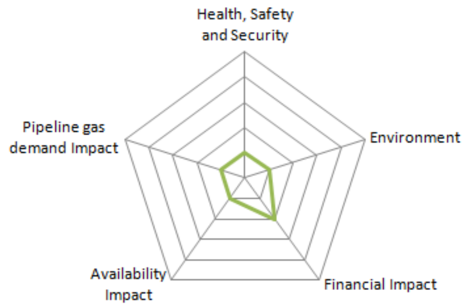
In the event of one of Norway's main gas export lines failing to export the necessary gas quantity, which approximately half is contractually fixed (Førde, 2013), Gassco may most likely divert a lot of their gas through other available pipelines in order to supply the contractually obliged gas. In summer times and periods with low gas demand, this may be possible, but should the GNG pipeline experience a shutdown period during the winter, when demand is high, gas buyers will most likely have to purchase gas from other suppliers on the spot market or at above market prices in order to facilitate their countries' internal gas demand.
Buying countries on the other hand may have the ability to tap in to their stored gas reserves should they feel the need, but doing so, also involves an extra cost which the storage owners charge.

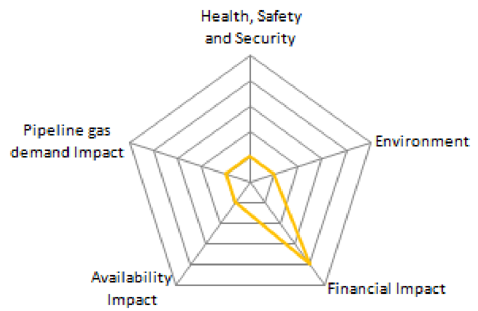
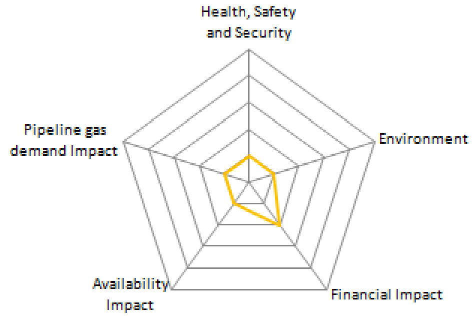
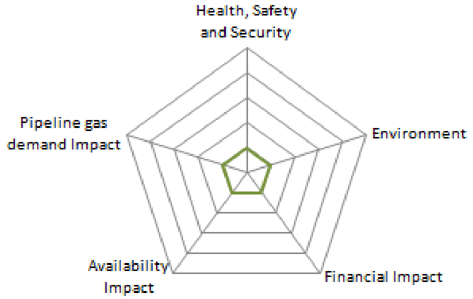
3.1.4 Quantify Physical Threats

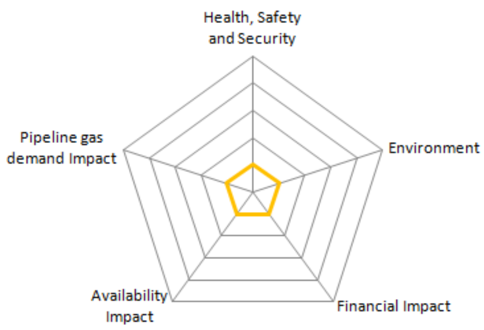
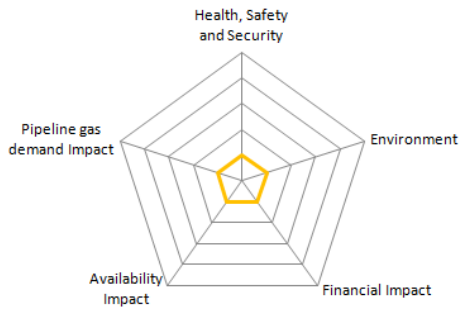
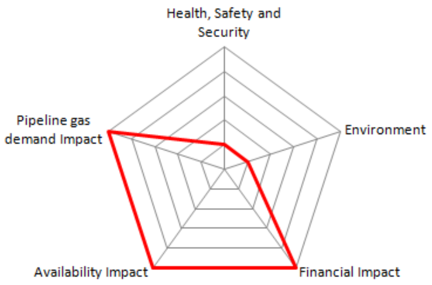
This section will act as a summary of performed risk quantification (ref chapter 9). The risk quantification takes the elements discussed above and quantifies them. Following Physical threats have been quantified:

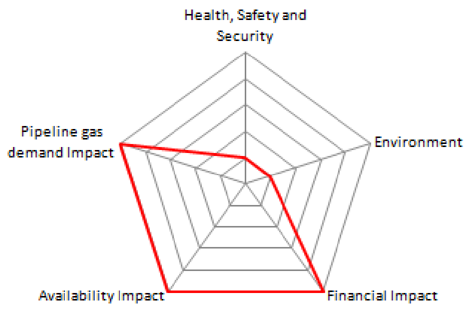
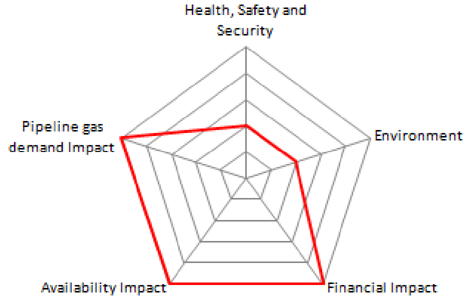
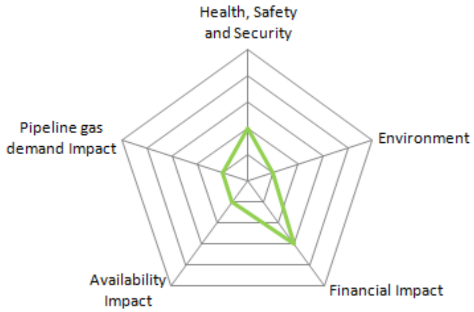
Risk	Description
VH - Very High	Unacceptable region - Immediate action to be taken
H - High	Unacceptable region - Action to be taken
M - Medium	ALARP region - Action to reduce risk may be evaluated
L - Low	Acceptable region - Low
VL - Very Low	Acceptable region - Insignificant

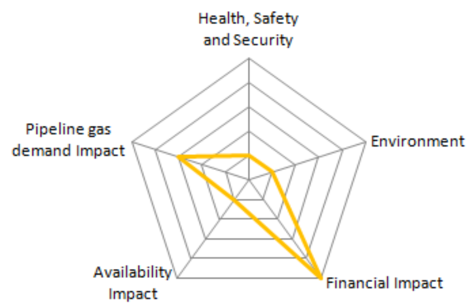
Table 3-12 Risk Acceptance Definitions (DNV, 2009)

Hazard	Hazard Description / Result	Ultimate Event	Threat Spider Diagram
Internal corrosion	Upset in gas processing facility allowing unwanted water content in to gas flow, increasing the possibility of internal corrosion to develop.	Reduced pipeline wall thickness, leading to a possibly overstressed pipeline.	

External corrosion	Outer corrosive protection layer is damaged, along with insufficient sacrificial anode capabilities.	Reduced pipeline wall thickness, leading to a possibly overstressed pipeline.	
Field Joint damage	Third party impact causes field joint to lose its integrity.	Outer protective concrete layer is damaged, and provides insufficient protection against further impact at specific location.	
Free Spans developing	Long free spans can cause the pipeline to become over utilized	Overstressing pipeline	

Trawl Board impact	Trawl board hits pipeline	Trawl board inflicts damage to pipeline concrete coating, revealing bare metal.	
Trawl Board Hooking	Trawl board hooks to pipeline on seabed, or on free spanning pipeline	Trawl board inflicting damage to concrete coating and getting stuck under it.	
Anchor impact	Planned anchor drop. Vessel at rest.	Anchor hits pipeline on its descent causing damage to the concrete coating. Worst case causing local derformation and down time.	

Anchor impact	Anchored vessel is dragged in storm, causing anchor to hit pipeline.	Damage to pipeline coating or possibly local bending/deformation, which could cause failure.	
Anchor impact	Accidentally dropped anchor hooks on to the pipeline during transit	Moving pipeline off original lay position, causing severe pipeline damage and/or causing a rupture leading to leakage. Downtime	
Emergency valves not functioning properly	Valves not functioning during an incident	Leakage at end points	

Extended pipeline down time due to unexpected incident during planned down time.	Reduced reputation	May result in reduced gas sales price in long term contracts	

3.2 GASSLED OWNERSHIP COMPOSITION

Seeing as the owners of the GNG pipeline play a key role in the wellbeing through the amount of funds it invests in not only day to day inspection and maintenance operations, but also the development of the Gassco operational system, it becomes logical to highlight threats which may arise during ownership changes.

Petoro AS*	38.43%
Statoil Petroleum AS	32.07%
ExxonMobil Norway AS	9.4%
Total E&P Norge AS	7.76%
Norske Shell AS	5.34%
Norsea Gas As	2.72%
ConocoPhillips	1.99%
Eni	1.52%
DONG E&P Norge AS	0.66%
GDF	0.09%
RWE Dea Norge AS	0.02%
Total upstream oil & gas operatorship	58.85%

Petoro AS*	45.793%
Solveig Gas Norway AS	24.756%
Njord Gas Infrastructure AS	8.036 %
Silex Gas Norway AS	6.102 %
Infragas Norge AS	5.006 %
Statoil Petroleum AS	5.000 %
Norsea Gas AS	2.261 %
ConocoPhillips	1.678 %
DONG E&P Norge AS	0.983 %
GDF SUEZ E&P Norge AS	0.304 %
RWE Dea Norge AS	0.081 %
Total upstream oil & gas operatorship	7.965%

Table 3-13 Gassled joint venture ownership 2009 compared to 2013

**Petoro serves as the license for the Norwegian state's direct financial interest (SDFI) in petroleum activities (Hendricks, 2012).*

The government through its tariff regulations ensures that the main gas profits are attained at the offshore fields and not in the transportation infrastructure (Ministry of Petroleum and Energy 2011). This meant that in 2009, 58.85% of the owners (10 out of 11) had both direct upstream and midstream interests (Petoro ensures highest possible value creation of Norwegian resources). Most of their profits would therefore be gained through their offshore operations not the actual gas pipeline network itself (thus including the GNG pipeline), whereas the isolated return on investments of the gas infrastructures gave a minimum expected return on capital investment of "only" 7%.

The past decade since the regulation system was implemented, there has been a relative balance between user- and owner-interests within the infrastructure. This balance has changed, and implications are present within the organization.

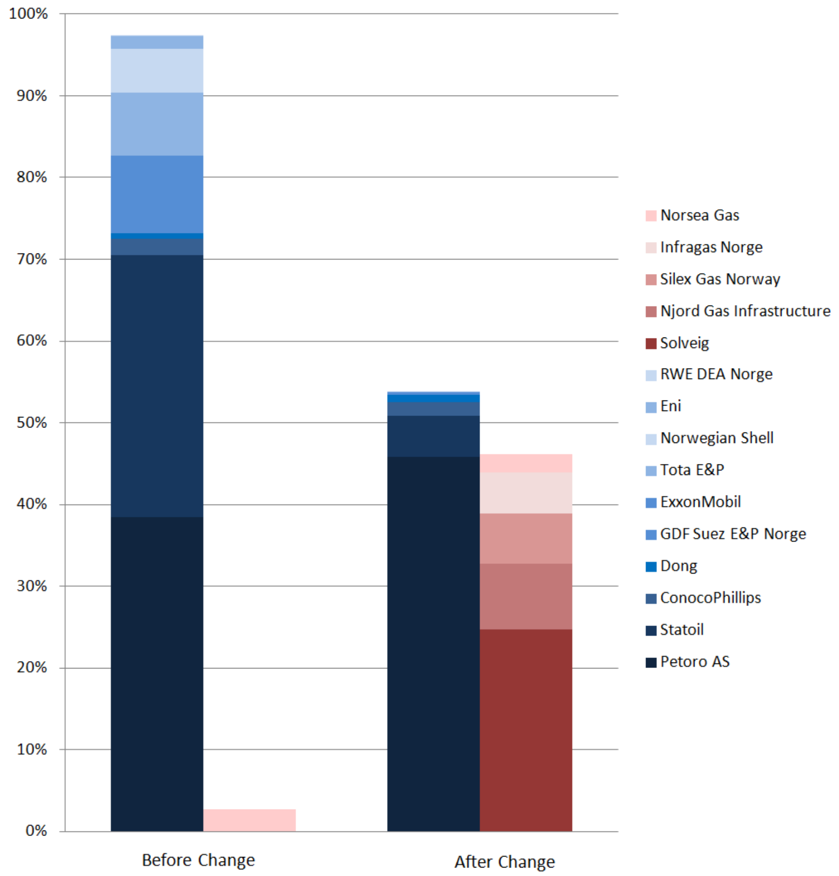


Figure 3-26 Gassled owner's ties to direct upstream interests (shown in blue) before and after organizational change

User vs. non-user of the Infrastructure

From an operator's point of view, the large upstream value is not worth much if it cannot be transported quickly and reliably to sellers in the market, thus ensuring sufficient availability and reliability to maximize the larger profits at the fields becomes important.

Prior to the ownership change, the majority of Gassled owners were direct players in the upstream markets (marked as blue in figure). This meant that most of their incentives to invest lay in the up field sectors, which is also according to the Norwegian government, where the value of the gas should be.

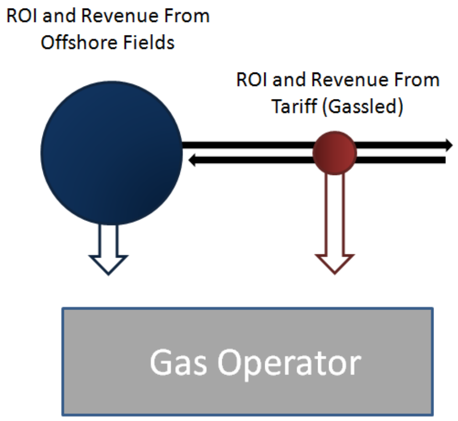


Figure 3-27 Operator ROI

One of their main focuses would according to Alexander Engh, consultant in Deloitte, be to keep infrastructural costs low (Lewis, 2011). Since they as users have a direct interest in cost effective operation and development of the infrastructure. Investing too much in the infrastructure would increase elements within the tariff formula, (ref chapter 2.7.1) in turn resulting in a higher transport tariff affecting them as shippers (users) of the system.

The past years, Gassled's return of investments have been significantly higher than the expected 7% in which the government's tariffs are set to ensure. In 2012 Gassled's real return before taxes was 10%, with a projected return of 10.5% towards 2028 of if no changes to the tariffs were made (Government 2013).

Even though such returns are favorable, many oil and gas operators see themselves investing in higher risk projects in their core activities. Not only are oil and gas companies interests more focused towards the higher value assets in the upstream sector, but any decision to invest in the gas infrastructure would most likely be tied to anticipated future revenue from upstream sales, and not the expected increase of returns through tariffs.

As non-owner users of the infrastructure have gained interests as sole users, there are no longer strategic incentives for oil and gas operators to stay as owners (Løvås 2011).

Throughout 2011 and well in to 2012, most of the major oil and gas operator companies sold wholly or partly all of their shares in Gassled to mostly foreign investment companies. The new ownership change was approved by the government, and the thought was, that in order to gain a more balanced risk of capital invested in offshore field and infrastructures, new financial owners should be included within Gassled, due to such new owners preferring other forms of financial returns than what the oil and gas companies' pursue (Rovik and Fossøy, 2013).

As the total number of oil and gas operators have been reduced from 9 to 5 (of 11), the share of Gassled ownership changed from 58.85% oil & gas operators to 7.9%.

Such a large degree of change results in different set of investment strategies being subjected to the infrastructure.

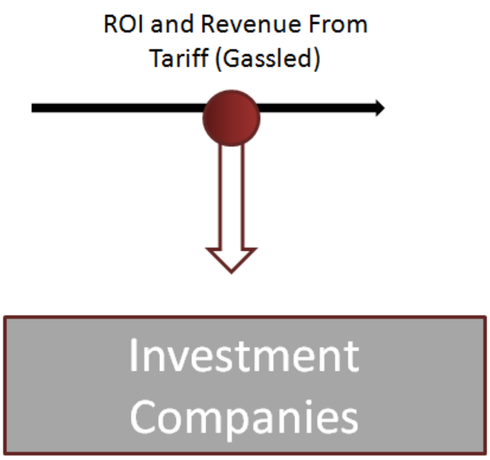


Figure 3-28 Financial investment company's ROI

One of the main changes is that the majority of Gassled owners are now not direct users of the system. They have no direct interest to the upstream market (Figure 3-28). Implications of such changes to strategies are for one that the new owners have no need to keep costs down. On the contrary, the new owners will have an incentive to increase for example maintenance costs thus ensuring higher regularity/availability giving higher profits (Lewis, 2011). These extra costs will be covered by the users of the system, which are not the owners anymore since they are not gas sellers. This could become a positive aspect in relation to the wellbeing of the GNG pipeline, ensuring a high quality standard, but a negative aspect regarding efficiency and above all, competitive natural gas prices.

The increase in financial owners in Gassled may result in certain changes:

- Incentives for new investment owners to implement cost effective operations are reduced, as such, costs are differed to the users through the tariff.
- Political will may be to a higher extent implemented. If the financial owners are guaranteed a set amount of return on their investments, and where a large amount of this sum can be shifted to an increase in tariff (ref. 2.7.3), there is little incentive to go against political will. As a result, previously cancelled projects such as Skanled, may have been implemented had the new ownership structure been present in 2009 (Løvås, 2011).
- Financial owners may not have strong enough incentives to avoid flow disruption. As oil and gas companies have clients in which they are obliged to deliver a certain amount of gas, financial owners may not be that involved in sustaining regularity in deliverances (Løvås, 2011) adhering to customer goodwill.
- A result of less involvement from active industrial owners in Gassled, can be that state owned Gassco would gain a larger influence of the infrastructure, both present and future (Løvås, 2011).
- The fact is, that today's gas infrastructure regulations are made in such a way that they restrict the investment companies in investing in new pipeline infrastructure, where if any new pipelines are to be built, oil and gas companies will build them (being coordinated by Gassco). Consequently, any new pipeline incorporated in Gassled (i.e. Polarled) would dilute current ownership share percentages due to the oil and gas companies who constructed the pipeline gaining shares on the basis of incorporated pipeline's value.

<u>Tariff</u>

The oil & gas operator companies were not likely very strategically in ensuring highest possible revenue from the tariff (seeing as they paid it themselves when using the infrastructure), but rather focusing on the gas sales price, and the quantities delivered. The financial investment companies on the other hand, have invested heavily in Gassled in order to receive a steady amount of income on the basis of approximately 10% (with an expected minimum of 7%) real return on capital investments within 2028.

This percentage is mostly controlled by the tariffs set by the government, so a certain trust in the government and their future policies was and still is a large factor in what profit their investments pay in the future.

Subsequently following the last major oil & gas operator selling its' Gassled holdings (a year later to be exact), the government releases a consultation paper (Høringsnotat) in January 2013, suggesting to change the tariff levels in the Gassled infrastructure network.
Their reasoning in lowering the tariffs was based on the following:

- Due to depleting gas fields, the incentive for offshore companies to search and develop new fields must be increased in order to sustain future gas demands. The tariff as such will form a large cost for such companies which, if too large might sway them from even considering conducting new exploration activities. This especially applies for smaller fields.
- Seeing as the oil and gas industry is moving further north, ensuring that the gas infrastructure becomes a viable means of transportation at a relatively low cost will ensure further growth and development in northern areas.
- Recovery rate and utilization of producing fields may also be impacted of a lower tariff level. Where future gas demands becomes sustainable should there be less future gas finds than anticipated (Government, 2013).

In addition, lowering transportation tariffs results in gas sales prices can also be cut in order to compete with gas export competitors (Russia etc.) and other energy sources (Coal) if shippers see this fit.

Area	Unit	K-element for existing transport agreements	K-element for future transportation agreements	Percentage change [%]
A	Øre/Sm^3	5.5	0.55	90
B	Øre/Sm^3	3.5	0.35	90
C – extract	Øre/Sm^3	10.0	1.0	90
C – Fractioning, storage	Kroner/tonne	220	160	27
C – Fractioning, storage	Kroner/tonne	300	30	90
C – CO_2 Removal	Kroner/tonne	0	0	0
C – CO_2 mixing	Kroner/tonne	211	211	0
C – H_2S Removal	Kroner/kg	105.5	105.5	0
D – Entrance				
Kollsnes	Øre/Sm^3	1.93	0	100
Kårstø	Øre/Sm^3	2.43	0	100
Nyhamna	Øre/Sm^3	0	0	100
Oseberg	Øre/Sm^3	2.43	0	100
Other	Øre/Sm^3	0.43	0	100
D- Exits	Øre/Sm^3	5.57	0.71	87.25
D – CO_2 Mixing	Øre/Sm^3	150	150	0
D – H_2S Removal	Kroner/tonne	1000	1000	0
E – Ekstraction and	Øre/Sm^3	4.5	0.45	90
E – CO_2 Mixing	Kroner/tonne	150	150	0
E – H_2S Removal	Kroner/kg	1000	1000	0
F	Øre/Sm^3	6.0	6.0	0
G	Øre/Sm^3	1.49	0.149	90
H	Øre/Sm^3	3.5	0.35	90
I	Øre/Sm^3	4.05	4.05	0

Figure 3-29 Proposed tariff changes by government

The tariff level change is introduced in the K-element (ref chapter 2.7.1), where the applicable consultation paper changes are given in the table below.

The amount specific amount of implications this has to overall tariff is to writer unknown, but the government specifies through the consultation paper that the owners of Gassled will still be entitled a "reasonable profit" on the basis of amongst others investment and risk.

According to newspaper Aftenbladet, the newly investment owners of Gassled feel tricked by the Norwegian government in what they were thought to believe was a safe investment giving a minimum expected return of 7%. In 2011, CPPIB (holder of Solveig Gas) senior vice president Andre Bourbonnais stated "As a long-term investor, we look for infrastructure assets that will deliver stable returns over a long time horizon and Gassled fits these criteria."
Should these tariff costs be introduced, they anticipate their return of halving, reducing their earnings by 10's of billions of kroners according to the directors of the new investors (Harbo, 2013). Reducing the tariff will result in a wealth transfer of approximately 40 billion kroner from Gassled to shipper of the gas, namely the oil and gas operators. A quick judgment may then imply that the shippers are the winners of such a cut, due to lower transfer costs, increasing their profitability of not only current, but also future projects. In addition the government would also gain profit increases of such future projects, through tax incomes of future found resources, more jobs, and in general social growth (Rovik and Fossøy, 2013).

In addition, should the new owners have their "stable returns" on investments reduced, their willingness to ensure other relevant stakeholder's wellbeing may be affected negatively.
By "gold plating" equipment in order to raise the amount of gas flow, increasing own revenue, the extra cost would be deferred to the users through an increase in tariff. Such overall excess spending would not only lead to dissatisfied shippers (users), but as a second result, social economic loss may occur through cost ineffectiveness.

A conflict of interested thus arises, where the investment owners are seeking a 7% return on investments on midstream level, whilst the state and oil and gas operators want to specifically increase production and sales in upstream location.
Such elementary drivers for profit will negate overall efficiency and introduce conflicts of interests between financial stakeholders within Gassled, oil and gas operators within Gassled, the government and Gassco.

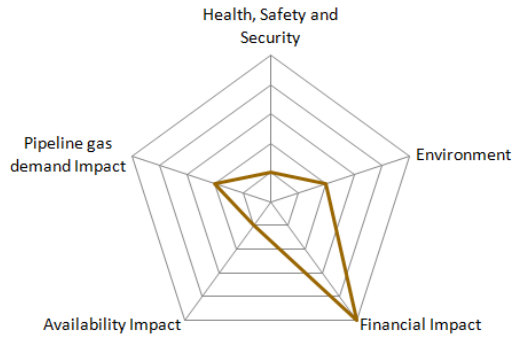
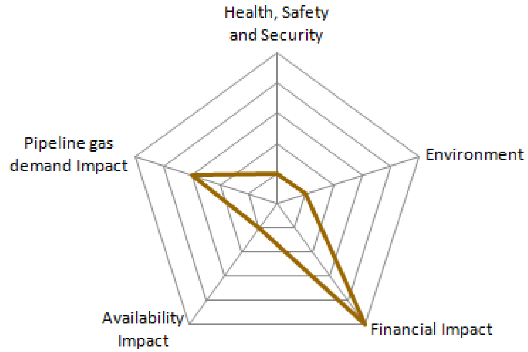
In March 2013, Administrative Dreictor Idar Kreutzer from Finans Norge, an organization representing most of the larger financial institutes in Norway, expressed their dismay to the proposed tariff changes. Prior to any tariff changes, the rating company Standard & Poor assessed Gassled's gas infrastructure as *"...a transparent, predictable, and stable regulatory system exists for tariff review, with a consensus-driven culture. – Transparent and stable tariffs for gas transport prices set by an agreed formula, which passes through all operational and maintenance costs and is not directly exposed to gas prices".*
Such assets are especially favorable for long term investment companies such as pension funds prioritizing long term moderate risk with predictable returns.
Countries which lay a solid foundation for such predictability and stability are given high credit ratings which will draw long term investment sums. According to Kreutzer, should the tariff levels be cut, ripple effects throughout the industry will be felt. They believe that foreign long term capital

investments will think twice before engaging in Norwegian business.
According to Standard & Poor's and Moodys', a tariff adjustment will downgrade the rating on loans issued by the investment companies due to significant market value deprecation of their obligations. Any future investor will see this as a threat to what Norway should be: a stable and transparent regulation regime, which would in turn yield higher interest rates on investor's loans due to an increase in volatility.

Even many of the oil and gas companies see negative effects of such an imposed tariff. By decreasing Norwegian predictability and stability, future investors might opt for other investments in other countries, possibly resulting in the oil and gas operators again, are left with ownership (in Gassled) of what they deem, low interest investments (Rovik and Fossøy, 2013).

3.2.1 Quantify Ownership Threats

This section will act as a summary of performed risk quantification (ref. chapter 9).

Hazard	Hazard Description / Result	Ultimate Event	Threat Spider Diagram
Tariff is changed by government	Gassled owners not receiving anticipated revenues from investments.	Gassled has less incentives to ensure optimal perfomance	
Conflicts of Interest	Conflicts of interest between major stakeholders	Inefficient organization at stakeholder level.	

3.3 MARKETS & POLITICS

Europe is changing, and that fast. In the wake of issues regarding political instability from energy suppliers, Europe is for one set on diversifying and allowing market forces decide gas prices and availability. By planning new buffer storage facilities, LNG re-gasification terminals and future pipelines, the European gas market is changing the way suppliers relate to their main clients, and thus also the demand in which the clients value their various suppliers.

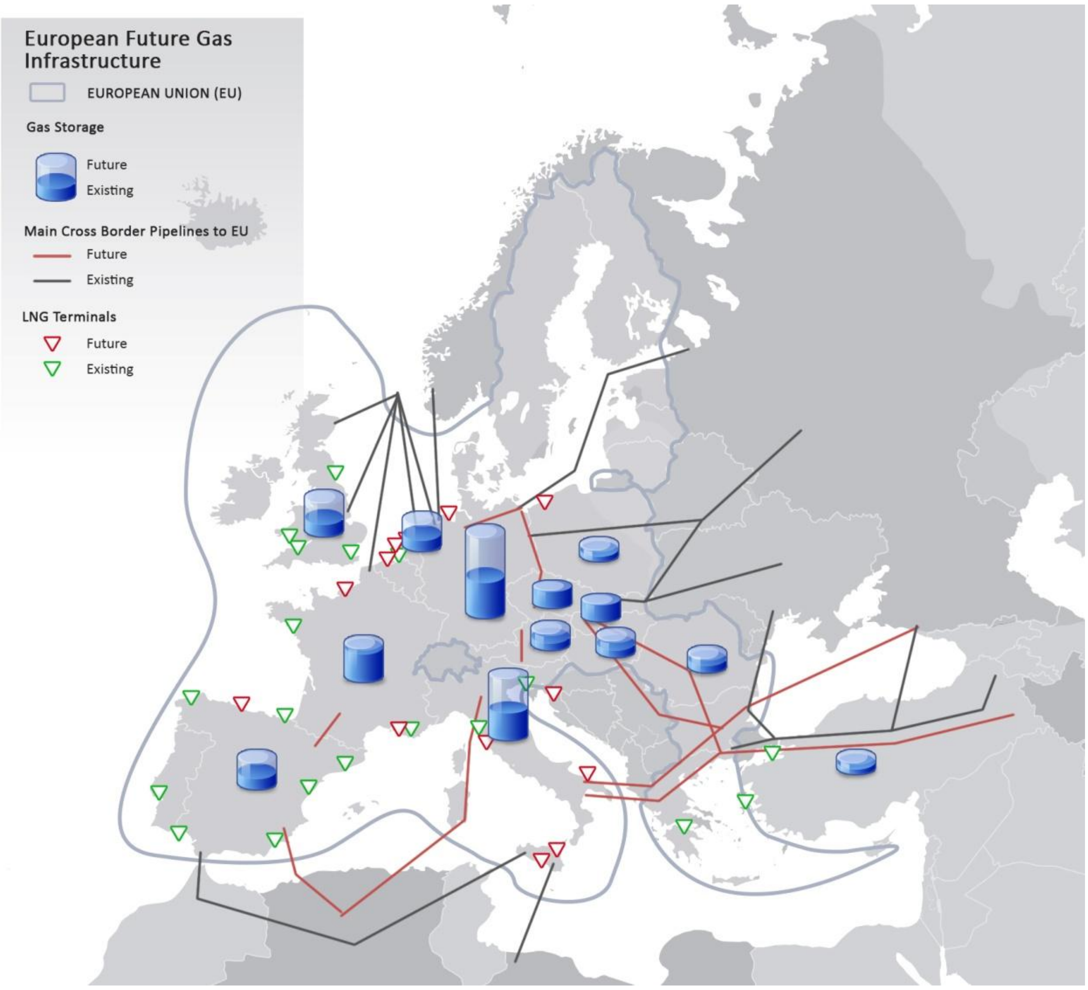


Figure 3-30 Europe Infrastructure Map. Source: (Nikl, 2010)

As Europe was expected to increase their gas demand, the opposite has been felt in light of the recession, along with falling coal prices and low carbon emission quotas.

But exactly what major market and political threats are out there, and to what extent can they affect not only the current flow of gas through the GNG pipeline, but also future demand?

Without going too much in detail, the following issues may pose viable challenges or threats, where a low utilized pipeline may result in less off-take to owners, possibly threatening the amount of future investments not only in Norwegian gas infrastructure but therein proper maintenance and repair of the GNG pipeline.

3.3.1 European Gas Contracting

Europe's gas industry was once a locally, regionally producing and consuming energy market. Contracting structures were localized and therefore evolved independently to one another due to gas not being an internationally traded good as oil. As an example, the US had their natural gas prices, whilst Europe, along with Norway and Russia had theirs.

Eventually two separate models of how to price natural gas arose. One was the oil-indexed pricing, where the gas price (both pipelined and LNG) followed the fluctuations of oil prices, and a second model in which the commodity markets, based on Hub trading, steer the price of natural gas by natural demand and supply.

One of the largest effects of hub trading is that there are a large amount of sellers and buyers competing without governmental interference, and where no individual supplier or buyer is capable of controlling prices. The price is set by market equilibrium between supply and demand resulting in an average price of natural gas. Often the gas is sold and bought three to four times before actually reaching an end-user. Such trading is possible since the gas is a common commodity, where after processing, the quality of the dry gas (sales gas) is more or less the same, independent of where it came from (Norway, Russia, LNG etc.). Historically Europe and Asia opted for the oil-indexed pricing scheme, whilst the United States in contrast were early in adopting commodity markets.

In the early European days, gas trade usually consisted of a producer who sold gas to local distribution companies, who further sold the gas to retail end users such as commercial and residential customers. The natural gas prices were regulated in all areas of the supply chain, leaving no space for external buyers and sellers.

In the 1990's Europe began to change, when the United Kingdom adopted a liberalized market where trading markets developed. In 1998 the UK market was connected via pipeline to Belgium, resulting in the commodity market gaining traction in north western continental Europe alongside the already present oil-indexed pricing.

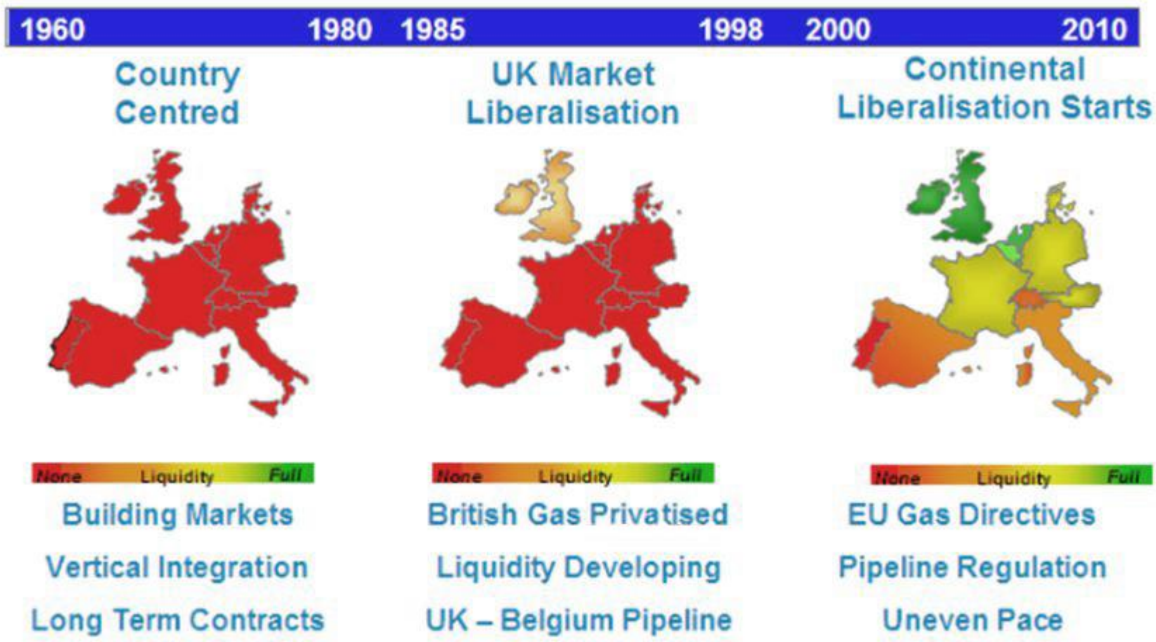


Figure 3-31 Path to Liberalization (Nikl, 2010)

The European Union's vision is in creating a common, open, competitive energy market, aligned with the UK's model, and thus discussions on how to implement such commodity markets in a region where monopolized, often state controlled suppliers where firmly embedded, has been a reoccurring during EU energy conferences, often leading to initiatives.
Directives such as the 1st Gas Directive and 2nd Gas Directive where such initiatives, which were developed to further implement the vision of a unified European energy market. As the continental Europe has seen a slower pace of change than the UK, change is slowly occurring. By separating production, transportation and marketing activities along with an open access to the gas transmission system in Europe, buyer had the option to purchase supply from any supplier of their choosing.

Within the European market, three main pricing categories are apparent (Melling, 2010):

- Government-regulated prices, usually based on cost of service
- Price indexation to competing flues (oil-indexed pricing)
- Spot market pricing in competitive gas markets.

As the Europe turns towards market driven spot prices, it becomes evident that some gas suppliers still rely heavily on long term oil-indexed prices. Russia for example had a mere 4% of market prices spot gas prices in 2008, whilst Norway had 30% (Figure 3-32).

There are many critics favoring either spot pricing or oil-indexed pricing. Some say that by diverging the two, oil and gas producers may opt for producing oil fields instead of oil and gas fields, should average gas spot prices become substantially lower than of oil-indexed prices. On the other hand oil-indexing is not steered by demand and supply, and as such may be higher than what the actual demand is, thus pushing energy consumers towards other sources, such as coal.

INDIGENOUS PIPELINE SUPPLY	2008 Bcm		2009 Bcm	
	Oil-indexed	Spot	Oil-indexed	Spot
Netherlands	49.0	24.2	42.0	27.0
UK	18.0	51.9	11.0	50.0
Germany	10.0	3.8	10.0	3.0
Romania	10.7	0.0	10.0	0.0
Denmark	9.0	1.1	7.6	1.0
Italy	9.0	0.1	8.0	0.5
Other	9.2	0.4	8.8	0.3
Subtotal	114.9	81.5	97.4	81.8

EXTERNAL PIPELINE SUPPLY	2008 Bcm		2009 Bcm	
	Oil-indexed	Spot	Oil-indexed	Spot
Russia	150.0	6.6	130.0	3.0
Norway	70.0	29.2	70.0	30.0
Algeria	35.8	0.0	32.5	0.0
Libya	9.9	0.0	7.0	0.0
Iran	5.8	0.0	6.0	0.0
Azerbaijan	4.0	0.0	4.0	0.0
Subtotal	275.4	35.8	249.5	33.0

LNG SUPPLIES	2008 Bcm		2009 Bcm	
	Oil-indexed	Spot	Oil-indexed	Spot
Algeria	19.1	0.4	20.0	1.7
Qatar	5.1	2.8	8.0	7.5
Nigeria	14.6	0.0	10.5	0.0
T & T	4.5	0.5	5.4	2.1
Egypt	6.4	0.0	6.5	0.3
Other	2.0	0.0	5.5	0.7
Subtotal	51.7	3.7	55.9	12.3

TOTALS	2008 Bcm		2009 Bcm	
Total Supplies	Oil-indexed	Market-priced	Oil-indexed	Market-priced
Subtotal	442.0	121.0	402.8	127.0
Total	563.0		529.8	

Figure 3-32 Sources of Gas Supply 2008 & 2009 by Country and Contract Type (estimated) (Melling, 2010)

Maria van der Hoeven, head of the International Energy Agency believes the oil indexed pricing structures of gas contracts are what is keeping European gas prices so high, cannibalizing European demand (Prodhan, 2012).

Either way, there are numerous pros and cons of contract pricing, but striking a balance with Western European markets and oil and gas producers is crucial in order to uphold Norwegian export and demand along with future investments within the gas sector.

As the two contract forms coexist, a sharp down-turn in spot priced gas would equally effect already agreed upon long-term contracts (often 20 years), where suppliers are pressured in to reducing these already fixed long term prices in order to uphold customer goodwill.

As an example, until 1995-2000, almost all gas sold in Europe were under fixed long term oil-indexed contracts for about 20 years (ending in 2015-2020). As the recession stepped in, energy demand stagnated, gas demand became low, resulting in wholesalers being contractually obliged (through long-term "take or pay contracts" to pay or receive gas they could not sell. In 2010 the two largest suppliers (Gazprom and Statoil) agreed to alleviate some of the contractual pressure by reducing both volume and price of gas to their largest clients (Melling, 2010). In the past couple of years EU gas importers have been able to negotiate discounts up to 10% from Gazprom. Still, where such discounts have been given, no fundamental changes to the contracts terms relating to its oil-indexation has been offered, and will not either be, by the looks of things (DG Energy, 2012).

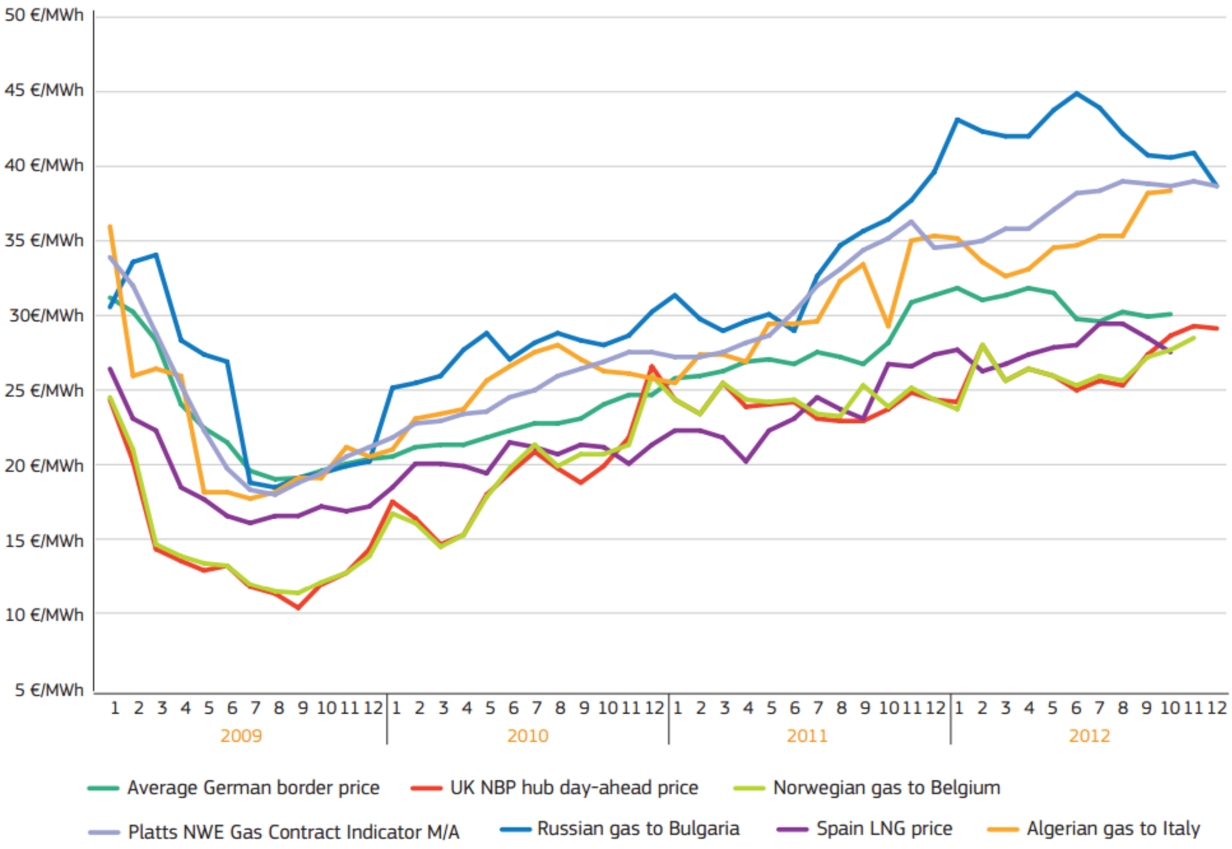


Figure 3-33 Comparison of EU Wholesale Gas Prices (DG Energy, 2012)

Figure 3-33 shows, how EU's cost for natural gas varies depending on where it comes from. 2012 shows a year where Russia during large periods has had substantially larger price differentiation compared to the market in general, where Norway has in recent years always been directly following the UK hub prices.

The figure also shows overall natural gas boarder prices rising constantly since 2009. This is in strong contrast with the European market consuming and demanding less from natural gas as an energy source. According to DG Energy, this signifies a clear disconnection existing in the EU natural gas market between market fundamentals and prices, where demand is certainly adjusting to prices, but prices not in turn following suit, at least not yet. One of the major reasons of this price inflexibility is that only roughly half the natural gas supply to EU is still indexed to oil (DG Energy, 2012).

The threat here lies within that fact that in order to make gas competitive amongst other energy sources (mainly coal), gas contracts and prices must be steered towards prices which are demand and supply driven within the market just like the UK did in 1990's, especially important as long-term contracts begin to expire, and energy power utilities are seeking cheap energy to burn. Consequently, the amount of future contracts involving spot prices are thought to increase, as long-term contracts which are signed before spot prices were introduced begin to expire.
According to Robert Minsaas, founder of analysis group Eclipse energy, Norway will experience greater pressure than Russia to move away from oil-indexed contracts since Norway has a more transparent business model, making it difficult to defend prices during negotiations with buyers, versus closed Russian contracts (NPD, 2012b).

In an effort to strengthen Norwegian gas in the energy market, Statoil recently signed a 10-year gas supply deal to Germany based on spot gas prices, delivering 45 bcm more of its gas to the market. According to Statoil executive vice-president Eldar Saetre, their company is at the moment supplying more than 40 percent of its European gas on spot terms (Adomaitis, 2012a).

This increased focus on shifting contractual forms seems to pay off, as Norway in 2012 increased their natural gas export on behalf of Russia's.

3.3.2 Russian Gas

Up until the break-up of the Soviet Union in 1991, most natural gas supplied to Europe was transported through Ukraine. Conflicts between Russian and the Ukraine date back to this period. Ukraine has one of the highest dependencies to gas as an energy source in the world, and as such, their dependency to Russian natural gas became (and still is) one of their top issues. In the 1990's even though prices from Russia were very low, Ukraine was having problems paying their gas bills. This led to an increase in accumulated debt resulting in Russian gas supplier Gazprom, cutting supplies on several occasions. As oil prices rose in the early 2000's, oil-indexed European gas prices followed suit. Gazprom raised gas prices more hastily in countries whose governments had previously, and still where, hostile to Russia (e.g. Georgia and Ukraine).
In 2006, Ukraine was strongly favoring Europe, and a disagreement on gas prices between them and Russia resulted in supplies being cut for 3 consecutive days.
As a result from previous bad experiences with Ukraine, Russia had planned gas pipelines across Poland to central Europe, but due to further disputes, a submarine pipeline crossing the Baltic sea from Russia to Germany along with South stream crossing the black sea, was set to provide a route which could not be affected by external interference undermining reliability of Russian gas.
2009 saw a new major gas crisis between Russia and the Ukraine where a two week gas supply was cut, seriously affecting the whole central and Eastern Europe. In total 18 European countries stated either a major drop or a complete cut-off in their gas supplies originating from Russia via the Ukraine. The cut was controversial leading to many European countries aiming at diversifying their importers and adding more gas storage facilities (Hafner, 2012).

In the time to come, Russia aims at (Hafner, 2012):

- Increasing control over transition routes
- Diversifying their export infrastructure
- Minimizing the use of transit countries.

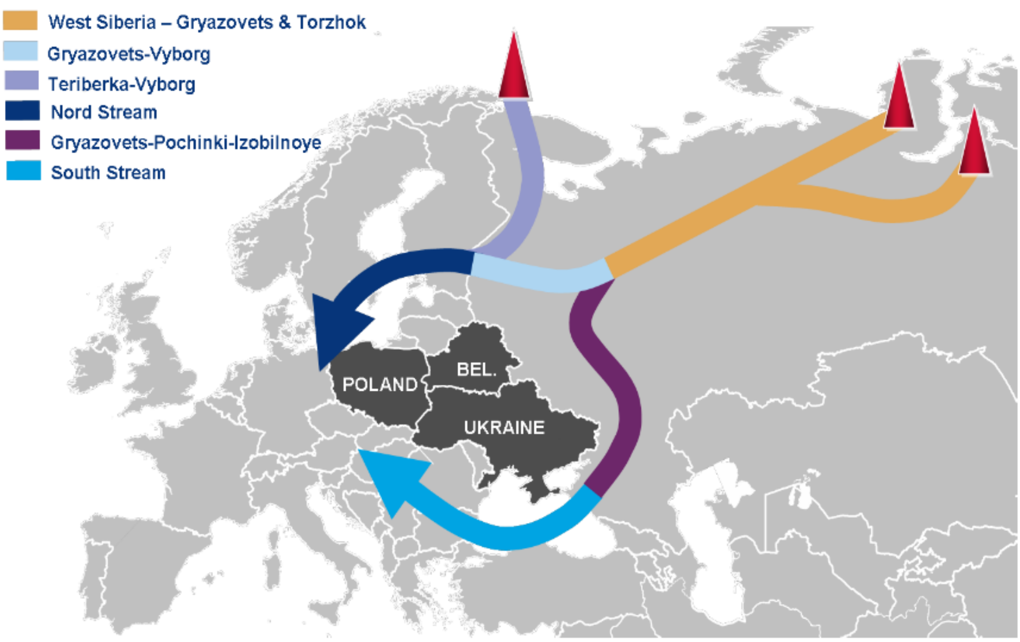


Figure 3-34 Gazprom's Strategy to Diversify Supply Routes and Bypass Transit Countries (Hafner, 2012)

As Russia implements new gas diversification supply routes, its affect to Norwegian export can be questioned. Nord stream aims at providing gas to one of Norway's largest gas buyers, Germany and the effect of this pipeline route in respect to the GNG pipeline and Norwegian export in general may pose a large threat. Especially since a feasibility study regarding Nord stream 3 and 4 are in the works, further expanding capacity to 110bcm through the Barents sea, and possibly linking a future pipeline to the UK (Hafner, 2012).

Pipeline	Capacity	Destination of exports
Via Ukraine:		
Orenburg-Western border (Uzhgorod)	26	Slovakia, Czech, Austria, Germany, France, Switzerland, Slovenia, Italy
Urengoy-Uzhgorod	28	Slovakia, Czech, Austria, Germany, France, Switzerland, Slovenia, Italy
Yamburg-Western border (Uzhgorod)	26	Slovakia, Czech, Austria, Germany, France, Switzerland, Slovenia, Italy
Dolina-Uzhgorod - 2 lines	17	Slovakia, Czech, Austria, Germany, France, Switzerland, Slovenia, Italy
Komarno-Drozdowichi - 2 lines	5	Poland
Uzhgorod-Beregovo - 2 lines	13	Hungary, Serbia, Bosnia
Hust - Satu-Mare	2	Romania
Ananyev-Tiraspol'-Izmail & Shebelinka-Izmail - 3 lines	27	Romania, Bulgaria, Greece, Turkey, Macedonia
Total via Ukraine:	**143**	
Via Belarus:		
Yamal-Europe (Torzhok-Kondratki-Frankfurt/Oder)	31	Poland, Germany, Netherlands, Belgium, UK
Kobrin-Brest	5	Poland
Total via Belarus:	**35**	
St. Petersburg-Finland - 2 lines	7	Finland
Blue Stream (design capacity)	16	Turkey (possible to Greece, Macedonia)
Nord Stream 1 and 2	55	Germany, France, Czech and other
TOTAL EXISTING EXPORT CAPACITY:	**256**	
NEW PIPELINES:		
South Stream	63	Bulgaria, Serbia, Greece, Italy and other
Nord Stream 3 and 4	55	Germany, France, Czech and other
TOTAL PLANNED EXPORT CAPACITY:	**374**	

Figure 3-35 Major Russian gas export pipeline capacities to Europe (Hafner, 2012)

The above figure indicates the current theoretical export capacity of Russia, with the new pipeline segments further expanding this capacity, indicating that Russia is striving to supply a huge amount of natural gas to the, what was once thought to be, surging demands for natural gas within the European market.

A result of such difference between capacity and real gas transferals, is that the Russian infrastructure is underutilized, most likely resulting in cost inefficiency. Cladia Kemfer, of the German institute for Economic Research (DIW) in Berlin believes that the newly invested Nord Stream pipelines will run at a loss for many years to come (Gurkov, 2012).

Nord Stream

Just a couple of years ago, gas demand was expected to rise between 10-40 percent (Bothe, 2007) and as European gas production has been falling, dependency on importing gas would consequently have to rise. Russian Gazpron, as one of the major gas exporters to Europe, decided in 2005 to construct a twin pipeline system which was to be laid through the Baltic sea, supplying a direct route from Russia to Germany. The pipeline system was named Nord Stream, and would consist of two individual pipelines, together roughly supplying a total of 55bcm per year (comparing to more or less half of Norwegian total export in 2012). Line 1 was completed in 2011 and Line 2 in was fully operational by end 2012.

Figure 3-36 Russian gas pipelines to Western Europe (Bailey, 2009)

Not only would this pipeline facilitate European future gas demands, but it would also avoid travelling through the eastern European transit countries, increasing Russian reputation as a reliable gas provider to Western Europe.

Whilst this may be true, the pipeline became a political controversy because it meant that Russia can exert a heightened politic pressure on the eastern European countries (due to sole dependency on Russian gas imports). Russia could then turn off the gas to these countries for political motives, whilst still supplying gas to Western Europe through the Nord stream pipeline.

Between the decision to build the pipeline and completion, Russian disputes with Ukraine caused a large loss of gas supply to Europe in general, further signifying Russian utilizing their gas supply as a political means.
Gazprom is a two part firm. On one side, it is a firm that issues shares to outside investors, but as the firm is majority-owned by the Russian state, it utilizes Gazprom as a political tool to attain its goals. Starting from early 2000's, Vladimir Putin appointed fellow allies to positions in Gazprom, ensuring that foreign policies could be enforced through their position as a dominant supplier of a highly demanded energy commodity. Countries such as Ukraine, Georgia, Belaurs and Moldova are a few countries which have felt Kremlin's policies through the gas market (The Economist, 2013a).

As European markets stand for approximately 40% of Gazproms' revenue (The Economist, 2013b), they are eager to expand and heavily invest in Europe, thus huge investments were made in the Nord stream project.
From an early study held before the completion of the Nord stream pipeline system, its impact on the European gas infrastructure was analyzed. The analysis model was created on the basis of multiple then current and future planned parameters available at the time, such as:

- Production constraints
- Input-output balance
- Storage constraints
- Supply constraints
- Capacity constraints

The output of the analysis (with only one of the pipelines completed) based on their TIGER model (Transport Infrastructure for Gas with Enhanced Resolution) suggested that Norwegian exports through Europipe 1 to Germany would decrease, but would be alleviated by an increase to Belgium through the Zeepipe pipeline.

Natural Gas Exporter	**Base Case,Nord stream not present in predicted 2010 gas export values [bcm/year]**	**Nord stream is realized (only 1 pipeline) [bcm/year]**
Russia	166.3	184.2
Algeria	42.8	41.7
Norway	88.3	88.3
Libya	7.9	7.9
LNG imports	97.6	86.9

Table 3-14 Predicted effects of Nord stream to European gas infrastructure (Bothe, et at., 2007)

The TIGER model shows that as Russian gas export increases through Nord stream, Norwegian export stays the same, whilst LNG imports fall. The report in addition concludes that the Yamal (through Belarus and Poland) and Transgas (Ukraine, Slovakia) pipelines experience a cannibalization effect of the newly introduced Nord stream.

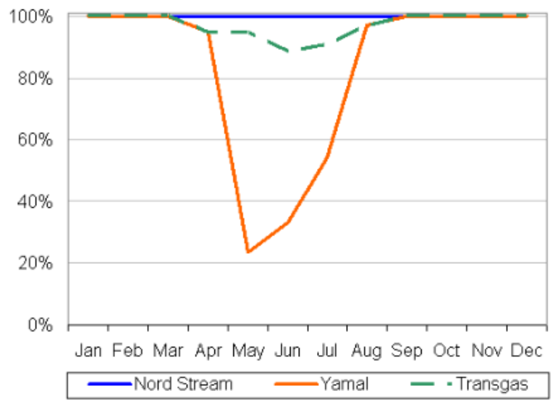


Figure 3-37 Utilization of import pipelines (Bohre, 2007)

As the figure below shows, the introduction of the Nord stream pipeline system (1 of 2 pipelines) impacts the infrastructural flows, where high flows should the pipeline <u>not be introduced</u> are shown in green, and where high flows after Nord stream is implemented shown in red. The thicker the line, the higher the absolute change.

Impacts on the Norwegian infrastructure when the Nord Stream pipeline is introduced (red): is that Norwegian export through Europe I is cannibalized. But instead the export gas is diverted through Zeepipe to Belgium, increasing this specific pipeline's utilization (Bothe, et al., 2007).

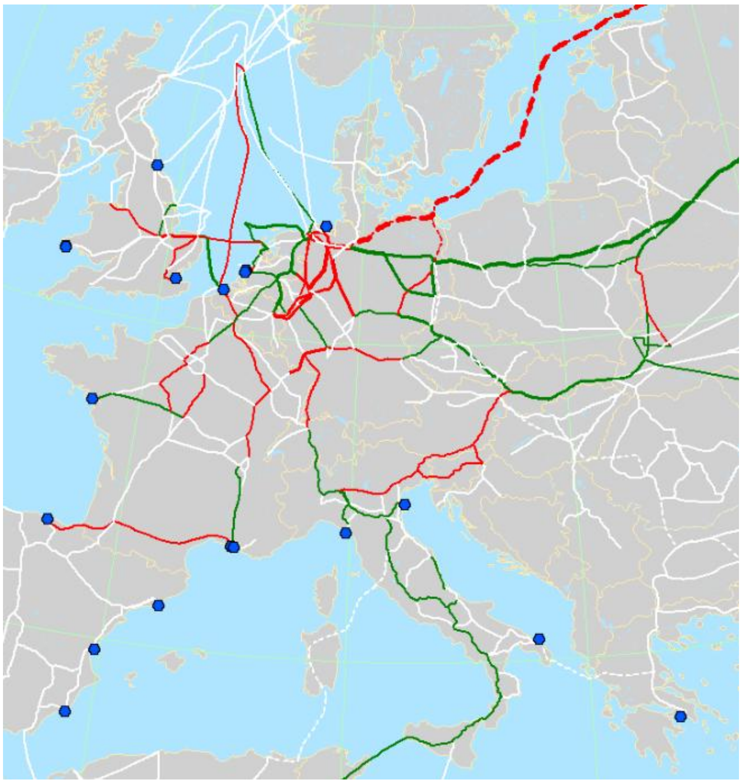


Figure 3-38 Differences in flows between no norstream pipeline and Nordstream implemented scenario for predicted 2011 values (Bothe, et al., 2007)

As the report and analysis was based on predicted values, real values for 2011 reveal certain indifferences.

For one, during the Nord Stream pipeline's initial first 11 months of operation, it achieved only an average of 30 to 40 percent of its maximum capacity, and even after the second line opened in 2012, both are running far below capacity capabilities. According to Jusef Auer, an energy expert with Deutch Bank Research, the macroeconomic and psychological significance is positive, but that Russian oil indexed gas prices are forcing importers to seek other places to buy gas (Gurkov, 2012).

In comparison, Norwegian gas export values for 2011 are greater than predicted by Bothe (92.8 vs. 88.3bcm),in addition Russian export was lower than predicted (140 vs. 184bcm).

The Nord Stream pipeline poses a great threat in its theoretical capacity of 55.5bcm per year, but this does not pose a direct threat if it is not fully utilized, nor affects Norwegian gas export even if fully utilized (according to TIGER model).

The presumed lacking effect on Russian gas on Norwegian total gas exports may also be partially explained by the fact that Norway and Russia supply two main different territories in Europe. Where most of Norwegian gas export revenue is attained through western European countries, Russia gains most of theirs from eastern European countries.

As Russia increases their export through Nord stream, their other pipelines consequently reduce their utilizations (Figure 3-37), merely shifting their route of transportation than increasing their export quantities.

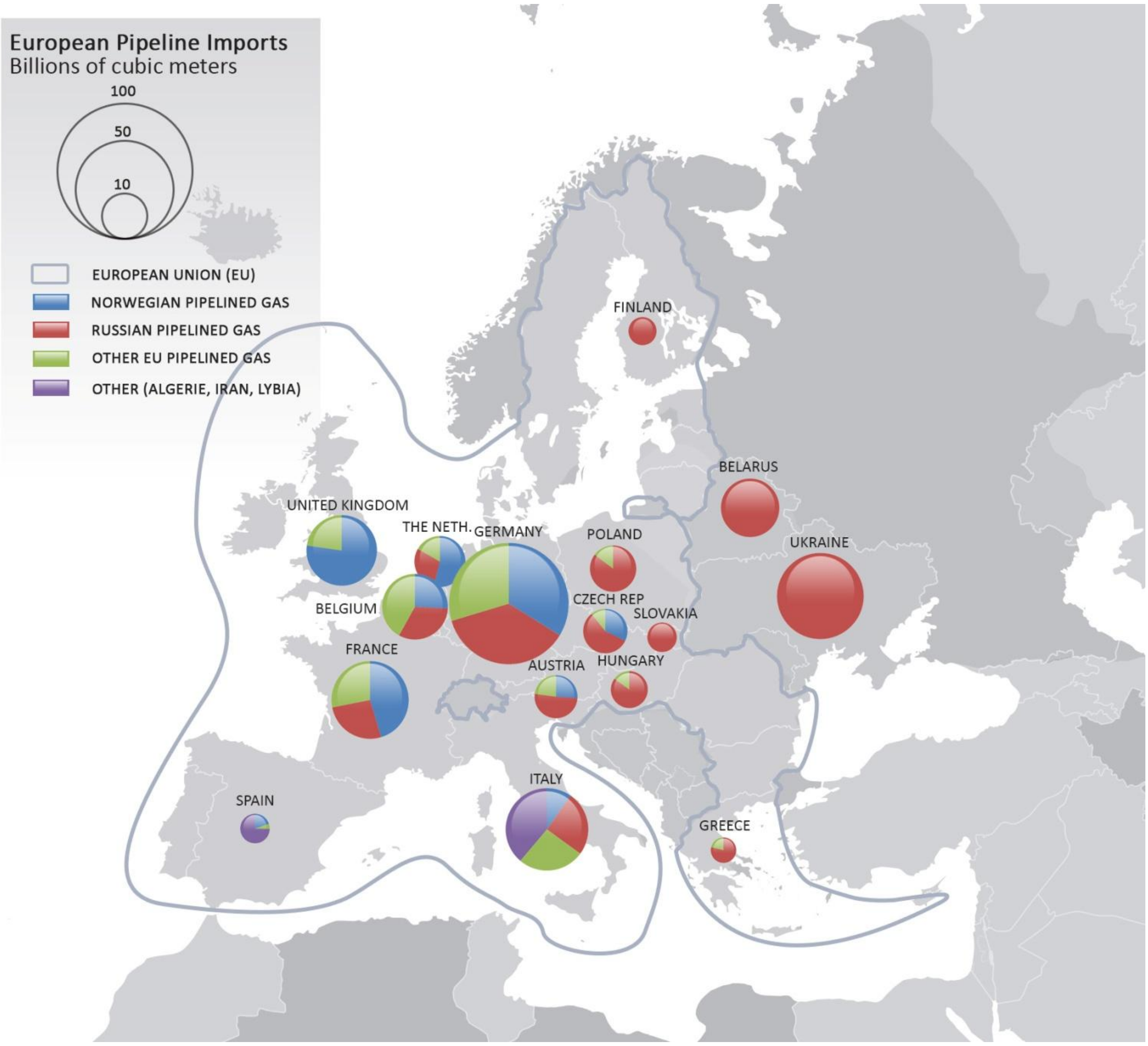


Figure 3-39 Gas imports from country of origin 2011. Data Source: (BP, 2012)

In addition, Figure 3-39 shows the distribution of countries supplied by natural gas, and where it originated from, showing the extent of Norwegian and Russian gas within the European Natural gas mix.

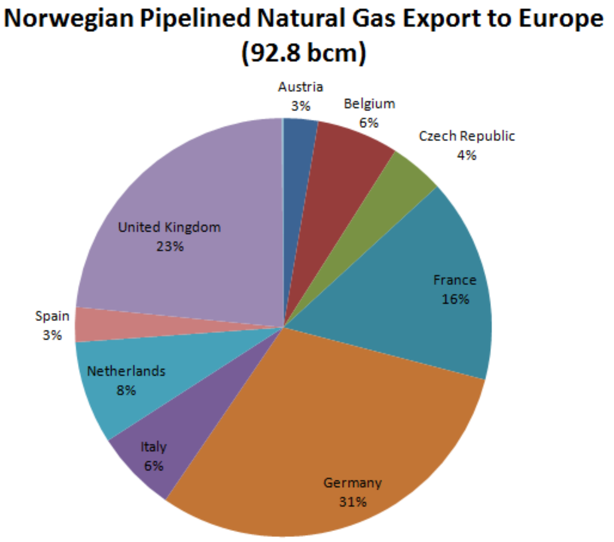


Figure 3-41 Norwegian Pipelined natural gas export, receiving countries. Data source: (BP, 2012)

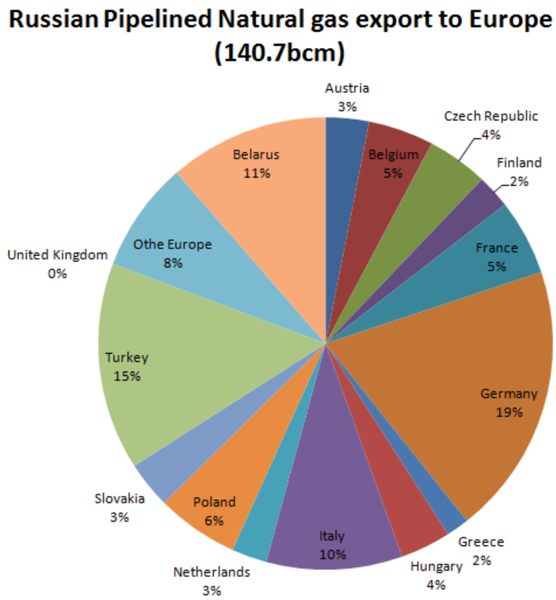


Figure 3-40 Russia Pipelined natural gas export, receiving countries. Data source: (BP, 2012)

Seeing as eastern European countries are monopolized by Russia, Russia has eagerly been trying to further expand their supply to western European countries. This is one of the main reasons why Russian Gazprom built Nord Stream in the first place, to gain market shares towards Western Europe. In addition, Gazprom have in years been interested in the UK gas market, even at one point contacting Gassco in order to start negotiations of utilizing the Norwegian pipeline grid to supply Russian gas to the United Kingdom (BarentsObserver, 2009). Recently Gazprom and BP are in early talks on extending the Nord Stream pipeline to reach the UK. Such deals could already be signed in the middle of 2013 recons BP's Director for Russia David Peattie, where Russian President Vladimir Putin believes Gazprom could deliver 20% of all gas supply to the UK (RT, 2012). Such an agreement would most likely impact Norwegian export negatively due the UK being their second largest buyer, and the main buyer who is not supplied by Russian gas.

As high oil-indexed prices and a monopolized market is what has given Russia its greatest revenues to date, their only way to gain market shares (unless demand for natural gas suddenly surges) in Western European countries is by either lowering their gas prices or adopting to spot market gas prices as Norwegian sellers have begun to do.
The real threat from Russia is then if they adopt a lower price than what Norwegian sellers are delivering to the European market. This will decrease demand for Norwegian gas, most likely lowering the utilization capacity of the main Norwegian export pipelines (including the GNG pipeline). Many believe this will not happen, and that they will stick to the oil indexed pricing for as long as possible. As Russian gas fields are becoming depleted, production has not increased since 2001, they need to find new sources of gas and invest in supplying new markets. According to the economist, from insiders in Gazprom, Gazprom wants to sell gas for as high prices as possible in order to raise necessary revenue to fund the search and development for new gas fields (Economist, 2013b). Up till now, Russia has

been focused on supplying Western Europe, but Asian countries have the past years caught Russian attention. 2011 figures show that a mere 7% of Russian gas was exported via pipeline to China, further negotiations with China to construct larger pipelines have been on going the past 10 years, where price negotiations have been the major hurdle.

Selling gas to Asia would yield higher short and medium term returns than in Europe, due to high Asian gas prices, and as such, Russia seeks to involve itself in one of the possibly world's largest coming gas importers, China, who will most likely adopt to gas when they start to phase out coal burning.

Figure 3-42 Gazprom Share price (The Economist, 2013c)

Gazprom itself is losing reputation, and that fast. As share prices have dropped heavily since 2008, investors think that Gazprom is worth only a third of what it was back in 2008 (The Economist, 2013b). In addition, an antitrust probe initiated by the European Commission is investigating whether or not Gazprom is using its supplier dominance to restrict competition and increase prices. If found guilty, would result in a $14 billion fine and harsh price regulations in some European countries.

In general, it seems Gazprom is very unwilling to reduce already contracted gas prices and thus will not pose a threat in the short term future to the Norwegian gas export in any substantial way. Nord Stream does not theoretically pose a direct threat to Norwegian pipelined export according to the TEGRA modeling analysis (at least not the first phase), whilst also current Russian export values versus Norwegian sees on the contrary, Norwegian export gas volumes increasing on behalf of Russian.

In conclusion, as Russian energy policies have previously been heavily based on anti-competitive monopoly structures, the only way they would pose a large threat to Norwegian gas export, is by increasingly adapting to the Western European way in dealing with energy commodities, mostly in the form of spot prices, whilst moving towards a more transparent and reliable method of supplying stable gas flows to the market.

As of September 2012, it seems as though Gazprom is willing to accept full spot indexation in at least one of its future gas contracts. According to DG Energy: "*UK firm Centrica was reported to have struck a three-year deal in September 2012 with Gazprom, which included price indexation entirely based on the NBP's day-ahead, rather than oil indexation*"

Although the amount supplied is unknown, it is still deliverance to one of Norway's largest natural gas clients through a non oil-indexed contract, which is just the type of contracts which has given Norway their edge the past years.

As the largest Norwegian export companies are actively renegotiation approximately half of its present contracts and introducing pure spot indexation in new contracts, they have managed to gain market share on behalf of other exporters. According to DG Energy, Norway is adapting faster to the new gas market conditions than other exporters. By moving to new price mechanisms they are retaining consumers and even increasing market shares. Even further so, by the government proposing tariff reduction in the infrastructural transportation costs of approximately 90%.

	2011	2012	y-o-y change
Norway total exports (bcm)	99	107.6	+16%
Gazprom exports to the EU (bcm, exluding the Baltic states)	122	112-113 (est)	-8%

Figure 3-43 Summary of Data on exports to the EU (DG Energy, 2012)

The question at stake is whether or not Russia will adopt to Norway's way of dealing with the natural gas market. The new contract with UK Centrica of non-oil indexed contracts, may suggest something similar, but according DG Energy, Gazprom does not seem to be fundamentally changing their pricing mechanisms, but rather offering discounts (DG Energy, 2012).
Some believe that Russia cannot afford to reduce prices too much, due to newly invested high costly infrastructure and the need to invest in more internal search for gas. In addition, Norway is running a much higher utilization of their pipeline, almost hitting its limit of 120 bcm, where Russia has at the moment a theoretical capacity of 256bcm, and exporting 112 bcm, short of half of its capacity, with a possible planned future capacity of 374bcm within a few years (Figure 3-35).

One thing is certain, Norway is at the moment aggressively adapting to the EU price market, whilst Russia seems to be struggling in cutting their costs in order to reduce prices to such levels (Collins, 2013) (Figure 3-33).

3.3.3 LNG Supplies to Europe

LNG has through the past years seen a substantial rise were some of its strongest benefits are that it alleviates a countries' dependency to pipelined gas. As such, LNG gas becomes a direct competitor to all forms of pipelined gas.

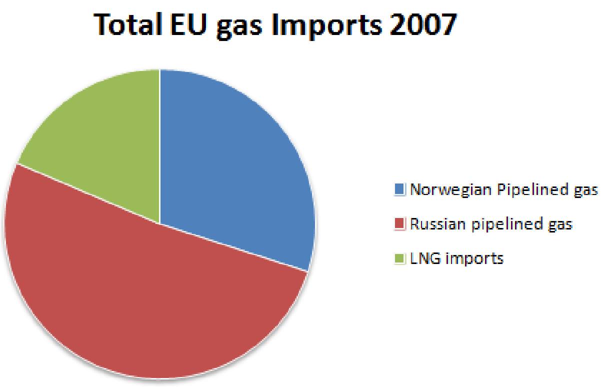


Figure 3-44 Total EU natural Gas Imports 2007.
Data source: (BP, 2012)

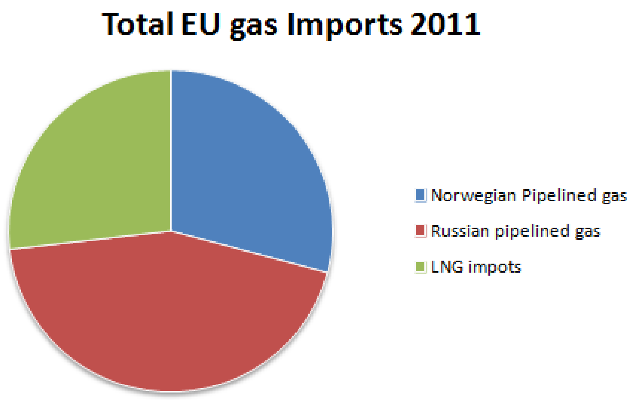


Figure 3-45 Total EU natural Gas Imports 2011.
Data source: (BP, 2012)

From 2007 to 2011, LNG import percentages in regards to total European natural gas imports have risen on behalf of specifically Russian gas. Reasons for this are most likely abundant, where the most prominent have previously been mentioned.
A note to point out is that countries which have increased their LNG import, are exactly the countries were Norwegian gas is prominent.

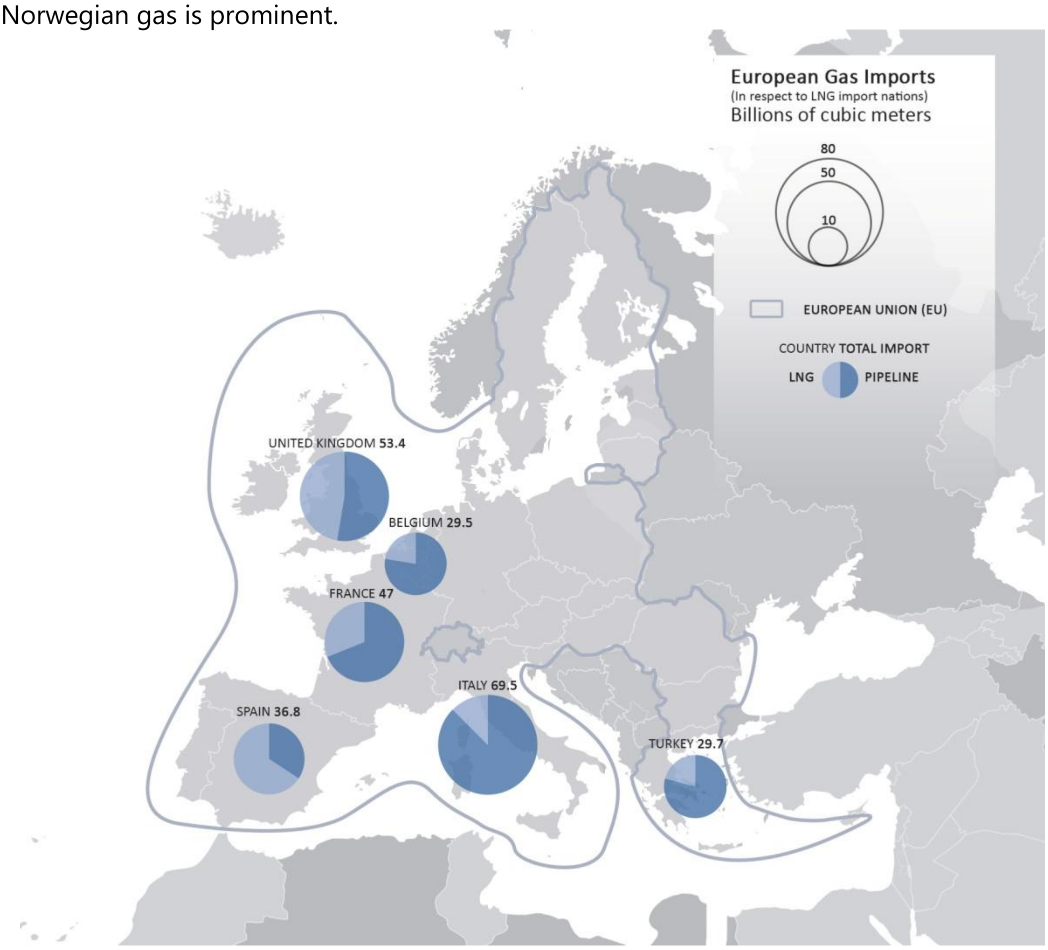


Figure 3-46 European Natural gas pipeline imports vs. LNG imports. Data source: (BP, 2012)

As the Figure 3-46 depicts, many of the large LNG importers coincide with Norway's main natural gas buyers in Western Europe, namely the United Kingdom and France.

These are also the two countries in which Norwegian gas is the main contributor to the individual countries' domestic gas consumption.

As demand for gas in Europe was initially believed to increase substantially from only a decade ago's point of view, LNG re-gasification terminals were planned and put in operation in order to relieve some of the predicted forth coming surges in natural gas demand.

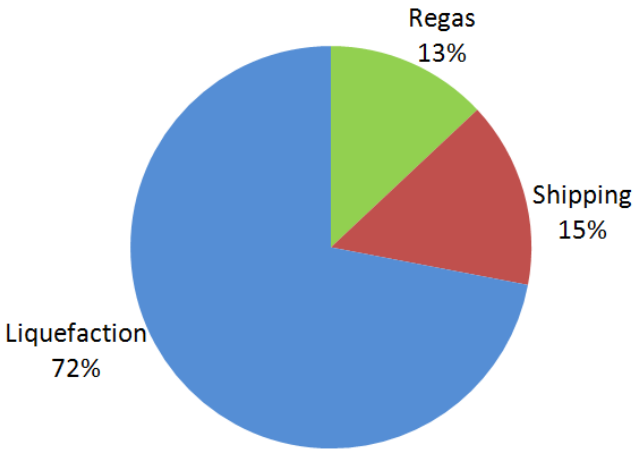
Figure 3-47 Supplying LNG to Europe (Stream, 2012)

As the figure above shows, southern Europe is heavily overrepresented in LNG Re-gasification plants, mostly due to high oil indexed pipelined gas prices and lack of limiting interconnections to Europe. Especially Portugal and Spain rely heavily on LNG (over 50% dependency)(Stream, 2012).

Although predictions previously of seemed to point towards a rise in European LNG, the contrary seems to be the case. According to new predictions by Barclays Capital, European LNG imports is anticipated to drop almost 70 percent up to 2015, where the heightened Asian demand diverts supply elsewhere. In addition, lower gas pipeline prices will contribute in weakening European LNG demand.

The bank's predictions have already begun. European LNG imports have fallen 33 percent year-on-year in the first half of 2012, where Asian LNG imports have risen by 16 percent. The drop towards 2015 is anticipated to be pushed back to current levels due to increased Australian and U.S LNG exports along with further LNG development, such as floating LNG's are introduced (Gloystein, 2012).

Floating LNG ship, are basically facilities in vessel form, anchored up above a gas field, where it processes the gas, liquefies it, and offloads it directly to an LNG carrier which transports the gas directly to the market. Should the field deplete or become economically unviable, the ship/facility merely relocates and starts up production elsewhere. The worlds' first such floating facility will be located of Western Australia and has a planned start of production in 2017, delivering 4.7 bcm/year (IEA, 2011). As it seems, the short term limited supply of LNG to Europe may have been a factor in Norway's record exports in 2012.



As LNG introduces a new means to transport natural gas to the market, it has certain disadvantage and advantages when competing with Norwegian pipeline gas. Cost wise, the true threat in LNG lies within its low transportation costs. Thus the length of distance to where the gas is transported does not largely affect the sales cost. This allows markets from the other side of the world to be able to compete and affect local gas pipeline markets.

One advantage from a Norwegian point of view, as seen in 2012, many LNG shipments were diverted to other markets with higher demand corresponding to higher sales prices, giving incentives for LNG sellers to divert the gas to other regions than Europe. In this respect, LNG becomes less reliable source due to globalization. But on the other hand, if demand is high enough in Europe, LNG vessels will sell here. In general, LNG provides Europe with a flexible and adaptable solution to the European gas market in times with fluctuating natural gas demand. In high demand, vessels supply the market, in low demand, vessels supply other global markets.

A sudden surge in natural shale gas from the US may affect local European prices; some buyers may diverge away from long term pipelined contracts and opt for LNG instead (long or short term).

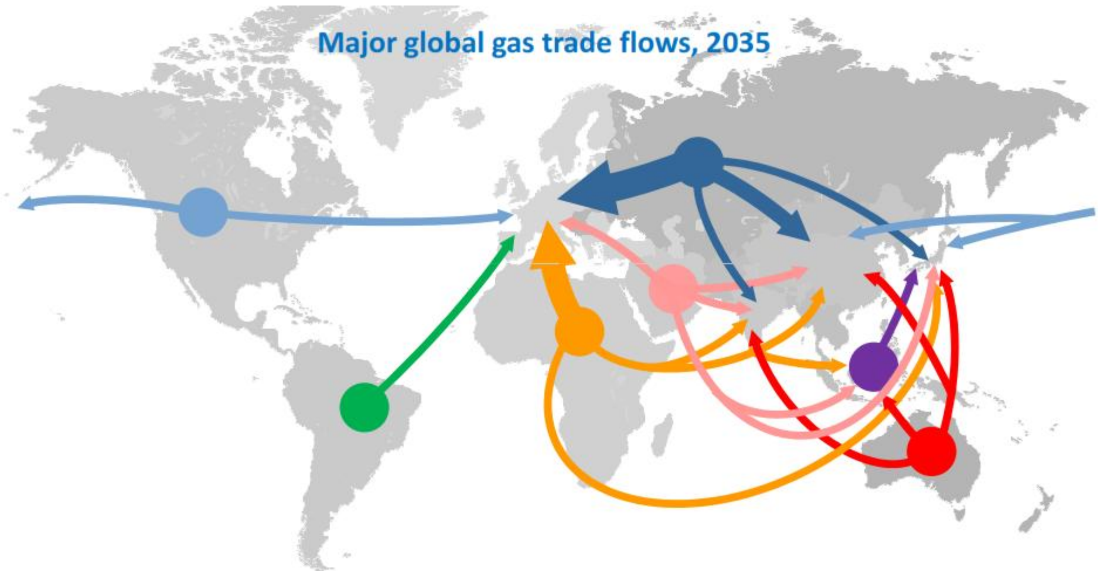


Figure 3-49 European gas markets in a global context both LNG and Pipeline (Gould, 2013)

The International Energy Agency predicted recently in a European conference that as rising supplies of unconventional gas & LNG towards 2035 will help diversify trade flows, an added pressure on conventional gas suppliers will be felt, especially those linked to oil-indexed pricing. In its essence, LNG poses a volatile threat, where it is the fastest growing and least predictable competitor to pipelined gas.

The predicted amount of European LNG import is according to WoodMackenzie a world energy analysis company, is as shown in Figure 3-50, anticipating to slightly slow its growth beyond 2020.

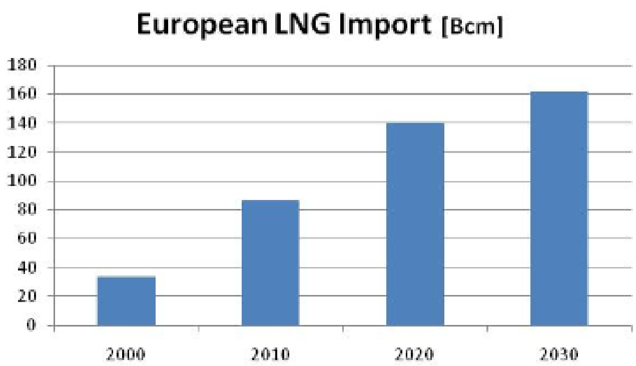


Figure 3-50 European LNG imports (Nysæter and Wottrich, 2012) WoodMackenzie

Regarding usage of energy commodities within its energy mix as a whole, political will and political motives are often seen as the backbone in steering which commodities are preferred within its borders and regions. By implementing subsidiaries, extra costs and research funds, a nation’s consumption of various energy sources can radically change if there is enough political and often public will to do so.

3.3.4 Politics

As Europe stands at a road cross regarding its energy policies, the members which are Norway's main gas importers have never been more diverse in their local energy politics (UK, Germany, France etc.) (Figure 3-51). Therefore, gaining consensus for mutual energy and climate policies within the EU is becoming ever complex.

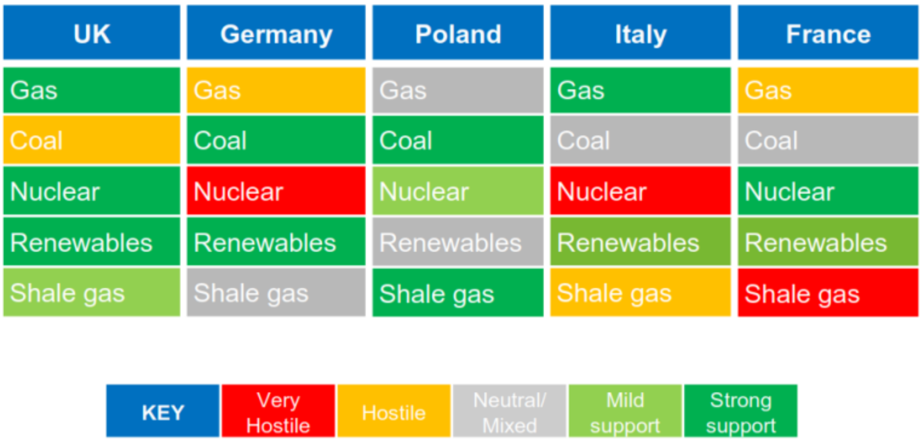


Figure 3-51 Energy policies are diverging (Bjørnson, 2013)

The cumulative number of climate and energy policies has increased over the past years, where objectives are grounded in sustainability, security and affordability (Bjørnson 2013) in order to ensure that the EU reaches its long term target of an 80% reduction in green house gas emission by 2050. In addition, short term targets towards 2020 involve 20% cuts in carbon emissions and energy use, along with increasing the share of renewable energy consumption from 8.5 to 20 percent. As the targets are clear, the means in getting there is becoming increasingly complicated as the EU is experiencing large financial trouble in the wake of the financial crisis, and as global energy commodities become ever more globalized (LNG, coal etc.)

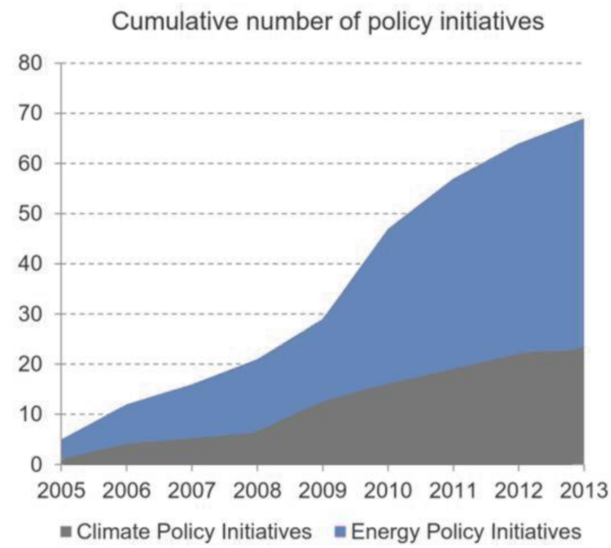


Figure 3-52 Cumulative number of EU policy initiatives (Bjørnson, 2013)

What is certain is that an energy transition within Europe is on its way, where renewable energy will stand as the energy choice of the future. The question is, what role is natural gas anticipated to play in EU's decarbonisation agenda? The outcome in this transition period lies within the European politicians in how they subsidize or add taxes and extra costs to various energy commodities.

As policy makers in EU are the key players in deciding the future magnitude of Norwegian gas to the EU, the Norwegian Ministry of Petroleum and Energy initiated a conference between them and European Commission along with key players within the energy sector in March 2013. The aim of the conference was to address the issues of how to further implement Norwegian natural gas in Europe and aid transforming the European energy systems towards their 2050 goals.
The conference was to focus on innovation along the value chain and competitiveness.

European Energy Policy Leader at GE, Simon Ashwell, foresaw natural gas posing a critical role in EU's plan on delivering a sustainable energy system, painting a picture of EU gas consumption increasing by 40-50%. Ashwell further detailed that by bringing together gas and renewable energy in the transition period, the two would complement each other in energy systems where a robust gas market and feasible, clear EU policies, would create a solid framework towards 2030.

Gas	Renewables
Central and distributed	Distributed
Flexible supply to grid	Intermittent supply to grid
Co-dispatch with renewables	Zero margin production cost
Proven technology	Strong social and local acceptance
Large installed base	Rapidly growing installed based
Lowest carbon footprint of all fossil fuels	Zero carbon emission
	Reduction of fuel dependence

Figure 3-53 Bringing together complementary capabilities (Ashwell, 2013)

Wintershall, Germany's largest crude and gas producer also indicated an increased need for natural gas towards 2020, but predicted a negative import amount from Norway, where Russian and LNG gas would be the two largest suppliers in meeting this demand.

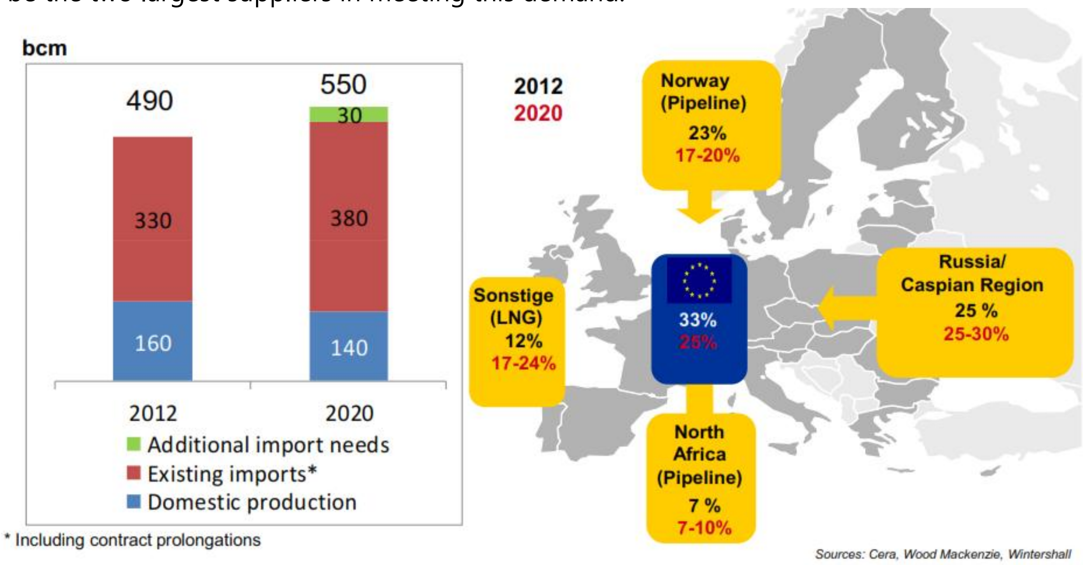


Figure 3-54 Rising import needs to EU, predictions towards 2020 (Bachmann, 2013)

As the conference was explicitly on how to ensure Norwegian gas for future European demand, Norway's energy minister Ola Borten Moe was clear in his words: Norway wants to supply Europe with up to 150bcm/ yr (currently 107bcm), but in order to plan future investments they need EU to fully implement its Emission Trading Scheme, something which it is at the moment failing at doing (Heren, 2013).

Note: In contradiction to Ola Borton Moe's proclamation, Chief executive of Gassco Brian Bjordal has stated that Norway's export capacity is slightly below 120bcm/yr (Adomaitis¸ 2012b), Bjordal most likely referring to the realistic capacity rather than the theoretical capacity.

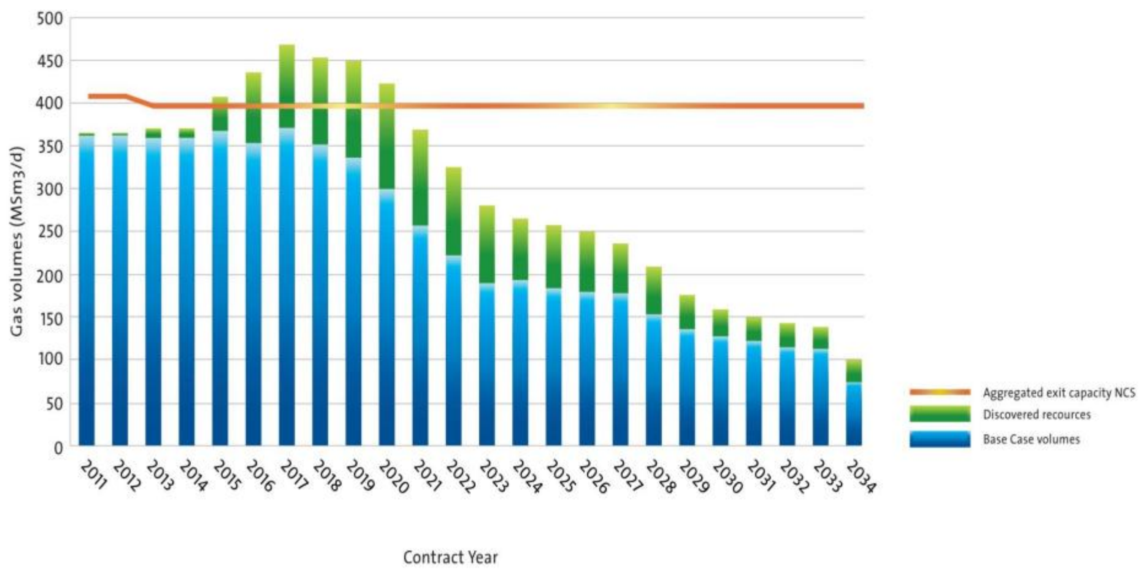


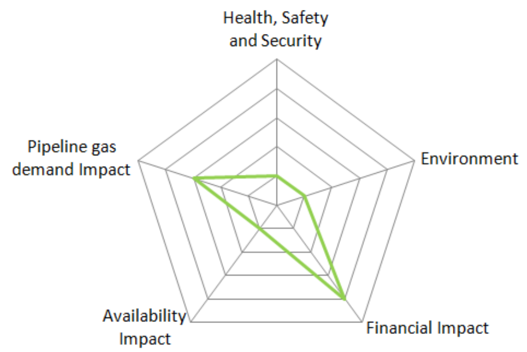
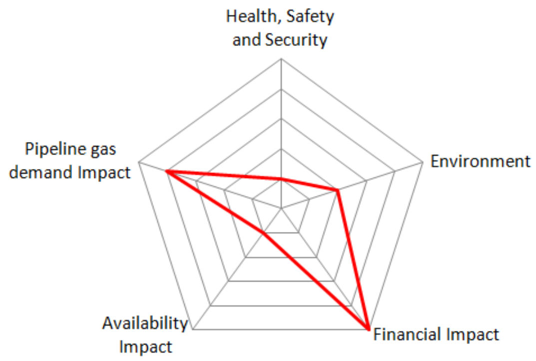
Figure 3-55 Norwegian future gas volume predictions based on known volumes (Bjordal, 2011)

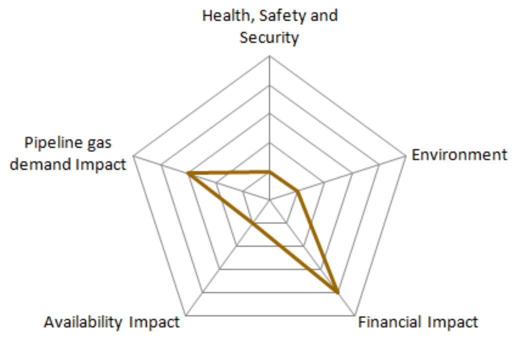
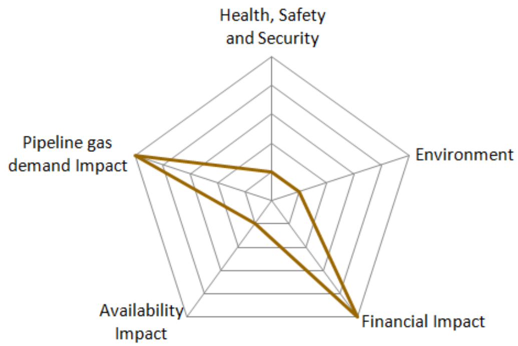
Currently Norwegian export capacity is almost fully utilized, without future investements, this will not last. The future investments which Moe is referring to, are most likely tied directly to investments in not only developing discovered resources and infrastructures, but also searching for more gas in order to sustain the aspiration of maximum pipeline utilization (Figure 3-55).

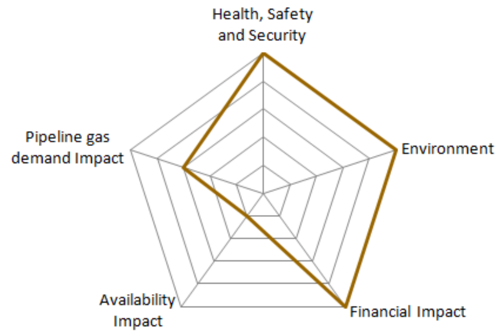
As Norway tries to gain traction in the European gas market, where international natural gas supply is forecasted to be abundant, UK's extra cost within carbon floor prices (taking effect in April 2013) will ensure UK electric utilities having to the pay GBP 16 per tonne of carbon emitted, set to rise to GBP 30 towards 2020 will according to Robert Minsaas, founder of analysis group Eclipse energy. An effect of this raise is that Norwegian gas spot prices are set to increase by 15-16 percent due to pipeline linking UK markets to European. Minsaas in addition recons that Norway will undoubtedly feel the effects of heightened competition in the market from Russia and LNG, especially in their core market segments. Norwegian gas has in the past been accustom to high profit margins and long term customers, but times are possibly turning. The pressure to compete with not only competitors within the natural gas market, but also competing energy sources, whilst in addition balancing the compliance to political policies (like the British carbon floor price points) and internal costs, all of which affects the value and demand for natural gas, increases complexity of the situation.

3.3.5 Quantify Market and Political Threats

This section will act as a summary of performed risk quantification (ref. chapter9).

Hazard	Hazard Description / Result	Ultimate Event	Threat Spider Diagram
Russian competition	Russia decreases gas prices substantially	Export shares taken from Norway	
Russian competition	The Russian Gas export pipeline Nord Stream increases our main competitors' supply capacity.	Lower demand for Norwegian gas	

LNG competition	LNG introduces a heightened supply of gas to Europe from distant markets	Reduction in European spot prices of gas, forcing local supplier's gas prices down.	
European politicians	Not prioritizing gas as a clean energy source. Renewable energy sources heavily subsidized.	Natural gas becoming too expensive compared to other energy sources. Decrease in export.	

European politicians	European politicians unwilling to implement enough environmental policies limiting the amount of cheap coal being burnt.	Natural gas becomes too expensive compared to cheap coal.	

3.4 ADDITIONAL THREATS

Although the main threat groups have previously been quantified, there are numerous other threats which can pose as challenges to the operation and well being of the GNG pipeline as an asset, a few of which hold relevance according to author are given below.

3.4.1 European Shale Gas

As shale gas has transferred US energy sustainability within a short period of time, Europe has hopes to replicate the US gas boom, but reality is somewhat different. With the exception of Poland and Spain, many European countries if which are believed to have large quantities of the unconventional gas resource, are reluctant to develop the technology and needed facilities, due to environmental issues, such as contamination of ground water etc.. France and the Netherlands have even implemented bans on hydraulic fracturing (Collins, 2013).

According to the European Resource Centre for Shale Gas, the countries in which are first most viable for indigenous production (resource wise) are the UK, France, Germany, Spain, Poland, Romania and Bulgaria. Most of which contain a vast majority of public opposition against the use of fracking, leading to amongst other the possibility of drinking water contamination.

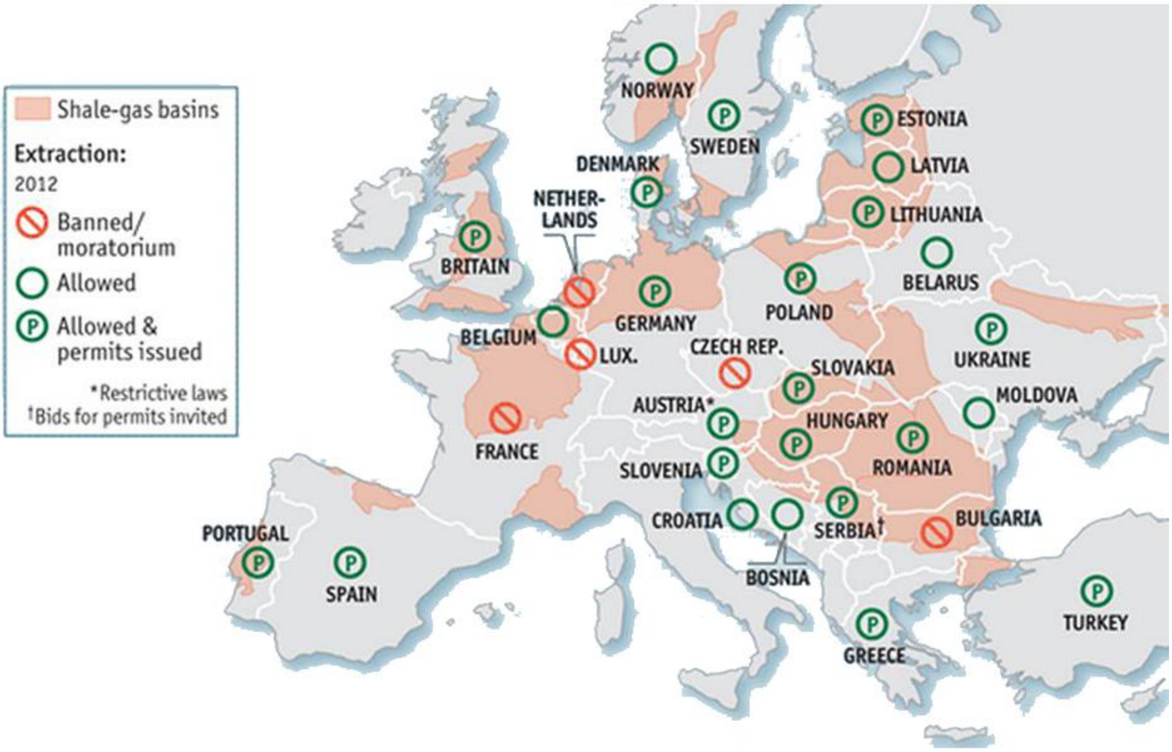


Figure 3-56 European Shale gas (The Economist, 2013c)

As of now, only a handful of test wells have been sunk in Europe, but even still, huge amounts of sums are being invested, especially in eastern European countries where public disapproval is not as severe, and more importantly the mitigation of Russian gas reliance is a fierce topic. As Germany suspended fracking in September 2012, Shell is currently probing the Ukraine for viable wells. As reserves are often in place, especially in Poland (187 trillion cubic feet according to U.S Energy Dperatment in 2011), they are often uneconomical. Gianna Ber, founder of Brookshire Advisory & Research said in regards to the polish shale-gas basins *"Shale exploration is a very high-cost and high-risk business and the Polish shale market is still in its infancy.. It's early in the game for Poland, and they have significant potential reserves over there."* (The Economist, 2013c). ExxonMobile, who largely missed out on the shale-gas boom in the US, is eager to join the new wave. Multiple test wells in Poland have given poor results, giving insufficient flow from the well, resulting in many companies such as ExxonMobile pulling out of Poland .

Even if Europe begins to produce its own shale gas, the quantities in the short term future will be minor in comparison to both US production and what amounts of natural gas is already delivered from Norway, Russia and LNG. It is reckoned that it may take five years to evaluate if the shale gas exists in commercial quantities, five more years before the resource start production and an additional few more years before providing a significant amount of gas to the markets (The Economist, 2013c).

According to world energy analytical company WoodMackenzie, the European gas market is not expected to be affected by shale gas until before 2020-2025

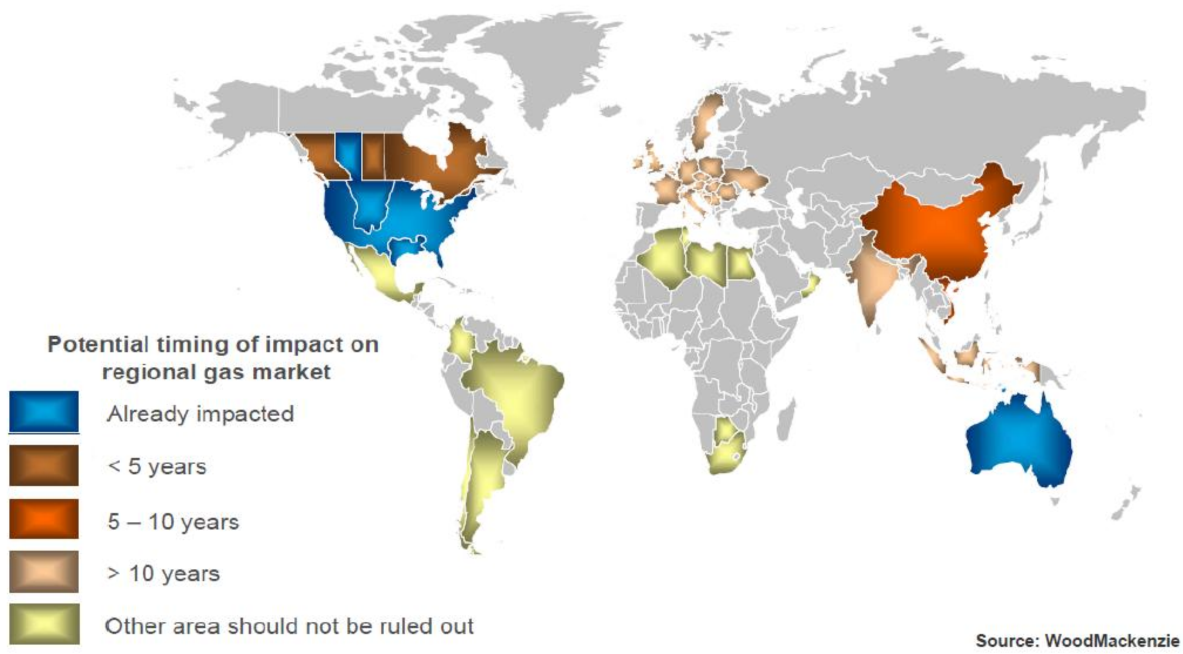


Figure 3-57 Impact of Shale gas on regional markets (Nysæter and Wottrich, 2012)

3.4.2 Terrorism

There are two main types of terrorism in which would pose a threat to the GNG pipeline, namely physical (i.e. bombs), or cyber-attack through for example Gassco's control systems.
Websters dictionary describes terrorism as "*a systematic use of violence to create a general climate of fear in a population and thereby to bring about a particular political objective.*" (Merriam-Webster, 2013).

3.4.2.1 Cyber terrorism

As technology hardware and competence spreads throughout the world, the likelihood of terrorists utilizing these new technological tools in order to inflict damage increases for each year that passes by. Just a decade ago the threat of cyber terrorism on critical infrastructures was believed to be low, almost non-existent (Shea, 2003). Diane Van de Hei, executive director of the Association of Metropolitan Water Agencies and point person for the Information Sharing and Analysis Center (SAC) for the US water utilities, stated that "If we had so many dollars to spend on a water system, most of it would go to physical security" (Lemos, 2002), signifying the weight in which terror threat was towards physical, rather than cyber at that time.

Today, a decade later, opinion has shifted. In an analysis of a report by CNN, the number of cyber attack claims on United State's essential infrastructural sectors grew by 52% in 2012 compared to 2011.
The US department of homeland security has an industrial control systems cyber emergency response team (ICS-CERT) who works to reduce risks within and across all critical infrastructure sectors in the US. Mostly all cyber threat incidents are reported to the ICS-CERT team. In 2012 they identified 198 incidents compared to only 9 in 2009 (RT, 2013).

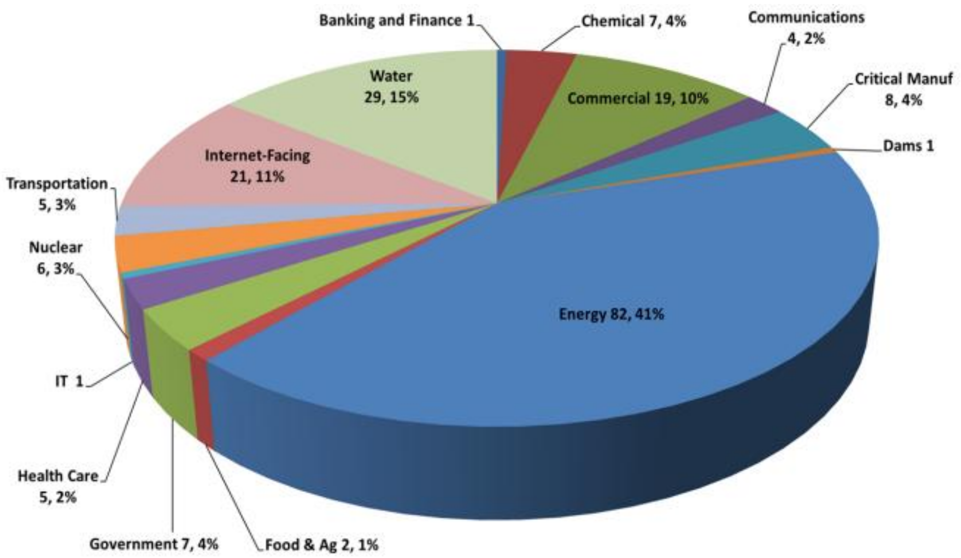


Figure 3-58 Incidents by sector - 198 Total in Fiscal Year (within US) 2012 (ICS-Cert, 2012)

As the cyber attack frequency increases, intelligence, industry and media reporting has shown an increasing trend in targeting energy and pipeline infrastructures around the world, many of which target Industrial Control Systems (ICS) such as SCADA (supervisory control and data acquisition).

Note: Gassco utilizes a typical SCADA system from ABB as a base system with additional integrated system alongside it within their control room in day to day activities (Atmos, 2013).

Attacks on SCADA systems are abundant, but few are publicly disclosed. In 1982 a Trojan was inserted in to a SCADA system causing a massive natural gas explosion along the Trans-Siberian pipeline. The cause of the incident was kept under wraps until 2004 (Dickman, 2009).

One of the easiest techniques in which hackers can gain access to an infrastructure is by "Spearphishing", a method which sends a misleading malicious email concealed as a trusted source, which contains a link which the receiver perceives as trustworthy. As the user clicks the link, spyware or malicious programming is downloaded without his/her knowledge, and thus the hacker would then have the ability to observe all actions on that computer.
According TrendMicro, a computer security firm, 91 percent of all targeted attacks originate via this method (Perloth, 2013).
In a presentation held at the S4 computer security conference in Miama in 2013, the threat from spearphishing in specifically regards to large infrastructural pipeline networks was shown. Tyler Klingler, a security researcher at Critical Intelligence dug up e-mail addresses for control room supervisors, pipeline controllers etc. of an oil pipeline infrastructure.
He then sent them all e-mail, of which seemingly originating from colleagues and contacts regarding job opportunities or software training for known industrial control systems.
26 percent of the employees clicked the link, some of which were control room supervisors, pipeline controllers, automation technicians, process controls engineer and a senior vice president for operations and maintenance (Perloth, 2013). By observing their activities, passwords, sensitive information and dialogs between colleagues could be attained, often extending the hackers reach within the system.
This was not a onetime affair either. The same method was applied to two different companies working with vital industrial control systems. Mr. Klinger's team identified 49 out of 300 employees who had worked with critical systems, 11 of whom clicked the link.

As such methods are increasingly being used by malicious hackers, the question then arises: who are these hackers? Most obviously, the attacks have some intention of inflicting damage to a nation's wellbeing. A common problem is that the real locations of a majority of attacks are somewhat hard to locate, since signals can be rerouted through multiple countries before reaching its source of origin. And even if the source of origin is found, knowing if the attack is coming from a known terrorist group, country or even "haktivist" groups such as Anonymous fighting for their own individual causes can often be hard to discover.
Jason Lewis, chief scientist of Lookingglass Cyber Solutions, a cyber security company says that it " doesn't take much to establish a cyberwarefare capability" (Edwards, 2012) signifying that basically that any enemy feeling unfairly treated or has a strong motive can within reason gain the ability to affect large infrastructures.
US intelligence chief Clapper told the US congress in 2013 that advanced cyber-actors like Russia and China are unlikely to target critical infrastructures unless they are threatened by conflict (Dozier, 2013)

(although cyber espionage is increasingly relevant from said nations (Holmes, 2013)). Cyber attacks aimed at Norwegian interests have along with US statistics doubled in 2012 to 50 attacks compared to the previous year according to the Norwegian national security Authority (NSM) (Thorvaldsen and Rafaelsen, 2013). Mandiat, an internet security company, recently uncovered that numerous international attacks can be tracked to Shanghai in China.

As both the ICS-CERT and the Norwegian national security authority hold relevant information, (in which reports have for instance concluded that cyber attacks have been able to infiltrate Norwegian infrastructures (Thorvaldsen and Rafaelsen, 2013), there have not been many well documented cases of large infrastructures being *directly* impacted by an attack, but many believe that there are bound to be large dark figures.
"There have been a few things that have been shady, but no one has definitively said this was cyber," said Dave Aitel, a former computer scientist at the National Security Agency and currently CEO of Immunity. "Unexplained is always code for: it could be cyber." (Egan, 2013).
According to Marie Moe, Section Chief of the Norwegian NSM, it would be fatal for a large infrastructural company subjected to cyber infiltration to go publically regarding their compromisation (Thorvaldsen and Rafaelsen, 2013).
Many therefore believe that IT professionals dealing with such matters are a secluded few who keep their lips tightly sealed (Egan, 2013).

A destructive attack would be picked up and reported by news agencies, authorities and the likes. But non-destructive scenarios are a different story. A breach of the system may be virtualy untraceable, where any tampering to pipeline data streams such as slight fiddling with temperature compensations, varying the amount of flow delivered or blends to customers would pose economic damages reaching millions of dollars per hour. If news spread, or investors and buyers lost confidence in the transport system, the losses would be in the billions (Dickman, 2009).

Although the energy sector is often highlighted as one of hacker's main targets, the true threat lies in the ability to form barriers against them.
According to Scott Register, director of marketing strategy at cyber security solutions company Ixia, the infrastructure sectors are lagging way behind other industries such as financing services and defense contractors regarding cyber threats.
Even as infiltrations such as the Stuxnet worm disrupting Iranian nuclear facilities, especially governmental entities seem to downplay the threat to national infrastructures.
Pat McGrary, principle systems engineer at Ixia does not understand the sectors unwillingness to invest in either security talents or acquiring advanced systems. Ixia amongst others sell sophisticated systems which simulates cyber attacks on client's networks in order to future risks. Of his knowledge, all of the companies within critical infrastructures expressed their concern and prioritization of their security, but none actually bought anything from either him or his competitors (Egan, 2013) signaling that the companies only nodded and put their wallets back in their pocket.

In order for the US infrastructure sectors to keep up with the times, Dave Aitel, a former computer scientist at the National Security Agency and currently CEO of Immunity, believes that the sector needs a push in the form of governmental policies. As technology often evolves faster than policies, such cyber security standards may be hard to implement and even harder to actually ensure that they prevent any major infiltration. Aitel and other security professionals believe that the best way to raise security is to increase transparency and information-sharing of attacks. In such a way, not only infrastructural companies will be aware of what is going on out there, but also the public.

"I believe that people will not truly get this until they see the physical implications of a cyberattack," former FBI cybercrime official Shawn Henry said last year, as quoted by CNN. "*We knew about Osama bin Laden in the early '90s. After 9/11, it was a worldwide name. I believe that type of thing can and will happen in the cyber environment.*"
"*We have had our 9/11 warning. Are we going to wait for the cyber equivalent of the collapse of the World Trade Centers?*" McConnell told Financial Times in an interview published in late 2012(RT, 2013).

3.4.2.2 Physical terrorism

As terrorism has always posed a threat to civilization, terrorist cells have often target "soft targets" rather than "hard". Hard targets are for example military bases, political organizations or high ranking people such as presidents. Soft targets are easier to hit, such as shopping malls, infrastructures. A normal point of view has been that the higher the number of casualties, the higher the media focus, thus further highlighting the terrorist groups' agenda (Pointon, 2005).

Terrorists targeting humans is changing. In 2004 then Al Qaeda leader, Osama bin Laden called upon followers to target oil and gas energy lines to the west, describing the pipeline as the Achilles heel of the west. A new chapter of terror has been predicted, with primary targets such oil and gas pipelines.

Attacks on pipeline have been abundant in politically unstable countries and regions for decades. But since January 2011, pipelines and energy facilities have been frequently attacked in Egypt, Syria, Yemen, and Libya (INED, 2012). Such disruptions in energy supplies to a nation can impact not only the local energy prices, but also regional. Examining trends of attack frequencies and locations have been a task in which the Energy Infrastructure Attack Database (EIAD) is currently working on (INED, 2012). The project plans on releasing the gathered analyzed data from 1933 to 2011 to the public within short time (as of January 2013).
Their initial findings on the basis of multiple factors such as correlation to armed conflicts, clusters, national stability where that in essence infrastructural targeting is increasing and clustering in key energy (oil & gas regions). 80% of the attacks are found to be correlated with armed conflicts, but regarding the last 20%, any correlations are at this point unsure (Giroux, 2013).

The fact remains, that any one individual with a strong enough belief can impact the society at large if he chooses to do so. Examples that terrorism can touch Norwegian soil need not look further than the gruesome acts of Ander Behring Breivik killing 77 people in 2011. As terrorists are moving away from humans as soft targets, big infrastructural pipelines transporting a large portion of Europe's energy demand may pose a relevant soft target for such terrorists, especially pipelines on shore or at or near landfall.

A Study performed by Brown et al. "*Analyzing the Vulnerability of Critical Infrastructure to Attack and Planning Defenses*" in cooperation with the US department of Homeland Security, utilizes statistical models and case study mapping in order to highlight how to best defend critical infrastructures such as airports, pipelines, electricity grids etc. The study concludes with the following (Brown, 2005):

- Certain infrastructures such as roads are naturally robust to sudden attacks, whilst other systems such as oil pipelines (ie. Energy pipelines in general) are a lot more fragile.

- Critical infrastructure has been built on being "cost-effective" with little concern for coordinated, aggressive attacks. Even as certain infrastructures have been designed to withstand extreme random acts of nature such as hurricanes or earthquakes, a skillful, pin pointed, small scale terrorist attack can inflict a greater amount of damage.
  Natural disasters are often based on random events and coincidences (location wise), terrorists are actively seeking out and planning their specific target.
- This leads to the fact that the attacker has the advantage since the defender (pipeline operator) has to protect a large, dispersed target set, whilst the attacker need only focus on a specific target.
- Hardening the robustness of infrastructures is a costly affair. But if you can evaluate which elements are high risk elements within the infrastructure, improvements within a given budget should be possible.
- Private owners of infrastructures have few economic incentives to spend money on making an already functioning system further robust. Therefore governmental subsidiaries should be introduced in order to mitigate the possibility of attackers affecting a nation's critical needs (i.e. energy demand)
- Many infrastructure owners believe that a reliable system which rarely fails due to random events, is categorized as a robust system, and is therefore also robust in the face of a malicious attack. This is not the case. As normal reliability structures dictates, backing up the least critical component ensures high overall reliability, this is the opposite case for terrorist attacks. An attacker will concentrate on the highest reliable components, since these are most likely increasingly critical for systems operations.

The study recommends the subsequent points (Brown, 2005):

- Redundancy may be the answer. By adding a few alternative supply routes one limits the overall dependency on the one single route, and thus mitigates the impact of a full blown downtime period.
- Secrecy and deception. By hiding the location of critical components and deceiving an attacker in to targeting a low critical component which is essentially invulnerable, an eventual attack may less of a threat to the infrastructure.
- Standard reliability analysis cannot be utilized in uncovering critical threat scenarios, since we cannot assume attacks occur randomly. One must assume attackers are intelligent, and adaptable enemies who are determined to maximize harm.

In Norway the physical barriers regarding an on-shore pipeline terrorist attack is practically absent compared to certain other receiving terminals in Western Europe.

	St. Fergus Terminal (Scotland)	**Kollsnes Terminal (Norway)**
Fencing	Solid metal fencing	1st barrier: 1 meter fence 2nd barrier: 3 meter fencing (Both of which can be breached relatively easy)
Guards	Armed Military police stationed around the terminal.	No visible guards
Dog patrol	Yes	None
Continues seaside surveillance	Armed guards with dogs	Unknown (unlikely)
Estimated response time	Guaranteed 10min	45min or more (no guarantee)

Table 3-15 St. Fergus - Kollsnes Securty comparison (Tidende, 2013)

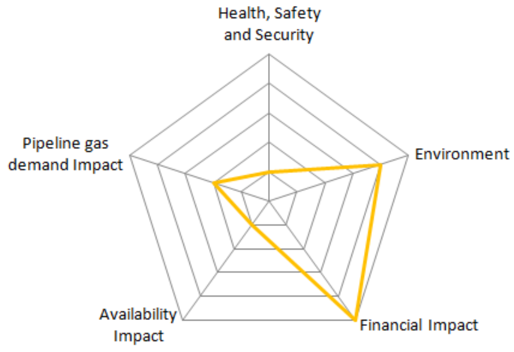
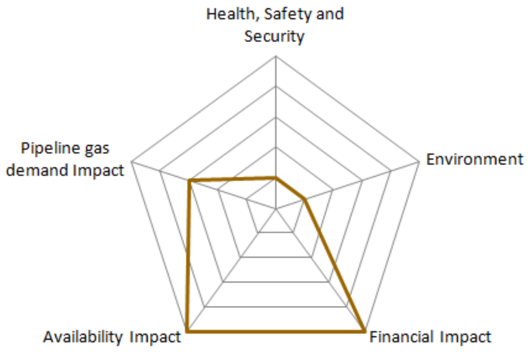
As no terminal can fully withstand a full armed attack, the main focus of any security is to delay the attackers until the authorities can get to location and intervene. In St. Fergus, their barriers with armed forces, dogs and solid fencing will hopefully stall attackers for at least 10min before a full strength backup force (most likely anti terrorism squad) is present.
In Kollsnes, the lack of barriers can be explained by the fact that the response time is so long. Even if they implemented armed guards, they will most likely not be able delay attackers the 45min or more until authorities arrive (Tidende, 2013). Norwegian authorities response time to terrorist attacks has been heavily securitized following the 22 July terrorist attack, where the aftermath commission were extremely critical of Norwegian preparedness in large parts of the country (Torve, 2012). As such, there is a lack of willingness from infrastructural owners to pay for an increased amount of security which will basically have minor affect in an event of an attack.

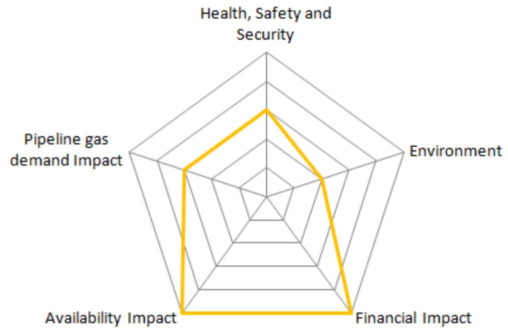
Basically, it seems that the lack of a central European attack on a main infrastructural assets has meant a lack of investments in mitigating such threats. As most often is the case in today's industries, it takes a onetime event (as previously referred to the 9/11 attack) to act as a catalyst for further mitigation implementations within the sector. It does not seem that the attacks on Russian gas pipelines (in 2009 which failed) or the attacks on Algerian (in 2013), both of which are major suppliers gas to European, affect the security levels in Norway.

The question then arises, can the attacks be directly correlated to political instability in the region as with Algeria and Russia? According to the Energy Infrastructure Attack Database 80% can, but then the question remains, what about the remaining last 20%?

3.4.3 Quantify Additional Threats

This section will act as a summary of performed risk quantification (ref. chapter9).

Hazard	Hazard Description / Result	Ultimate Event	Threat Spider Diagram
European Shale Gas	European Shale gas gains traction in European market	Lower demand for Norwegian gas	
Terror attack	Cyber terrorism aimed towards SCADA system or other flow management tools	Vary parameters of flow, limit flow or even stopping flow.	

Terror attack	Extremists targeting main infrastructural elements in order to gain public attention towards their cause.	Damage to pipeline, causing down time. The threat of repeatability.	

3.5 RISK MATRIX ELEMENTS SUMMARY

A holistic risk evaluation based on DNV recommended practice RP-F116 has been performed. Fully probabilistic models of the threats at hand have not been holistically based on author's estimations due to the complexity and time consuming matter of such calculations. According to the recommended practice: "*More simple qualitative assessments may be used and generally considered to be, sufficient in the context of submarine pipeline integrity management*."

The following breakdown of threats with their corresponding threat level based on parameters such as Health Safety and Security, Environment, Financial Impact, Availability Impact, Pipeline gas demand impact and probability, is derived from the risk quantification (Chapter 9 – Appendices).

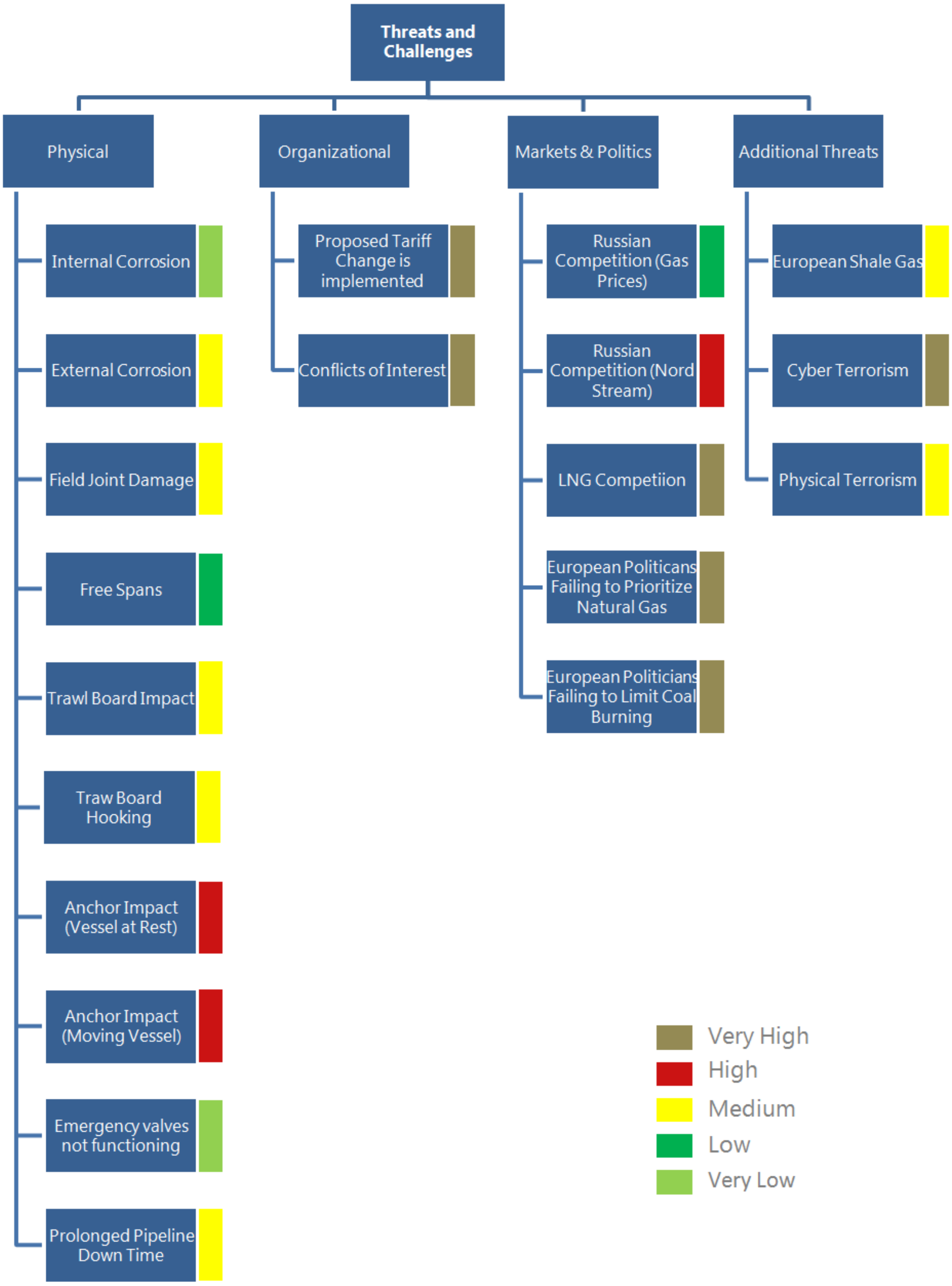


Figure 3-59 Threats and Challenges Breakdown

The threat break-down acts as part of the foundation for an asset management strategy. According to the institute of asset management, in order to create an asset strategy, future uncertainties must be associated and highlighted in regards to long-term planning, where their implications and likely impact on cost, risk and service etc. is evaluated.

4. Asset Management Strategy

Setting Direction, Ensuring Sustainability

An asset management strategy is a high level document in which acts as guidance for overall management activities within an organization. Its purpose is to explore long term issues, ensuring optimal asset availability in future years to come. Starting by restating organizational visions, goals and objectives, the strategy picks up by describing in macro terms, how they can be achieved (IGAM, 2013).

The term "organization" can be applied widely, from partnerships, governments to corporations. The American Heritage Dictionary of English Language describes an organization as "*Something made up of elements with varied functions that contribute to the whole and to collective function*". Within the thesis from this point on, the term "organization" will encompass the corporate entities Gassled and Gassco, along with the Norwegian government, all of which are coupled tightly together through the GNG pipeline.
In accordance to the thesis' scope, the main focus of the strategy will be limited to ensuring optimal future performance of the GNG pipeline within Gassled's natural gas infrastructure.

The past decade has seen a huge shift in how organizations create value. Kaplan and Norton opened the eyes of businesses who once where fixed focused on traditional accounting systems which failed at implementing intangible assets in an optimal manner. Kaplan and Norton introduced the fact that more than 75% of a firm's market value is derived from intangible assets, and therefore new ways of capturing these values were possible through their balanced scorecards.
As organizations implemented Kaplan and Norton's balanced scorecards, they saw a further need for a more powerful way of implementing their strategies in an optimal fashion.
The playing field was changing, where new competitors came from nowhere, new stakeholders were introduced, and in general new organizational strategies where required in order to react to the challenges. What most organizations experienced, was that they failed to implement their new strategies within the organization. Employees would read the strategy statements and visions, but would fail and implementing them within their work place. In fact, 70 to 90 percent of organizations failed to realize success through their newfound strategies (Kaplan and Norton, 2004).

Strategies have often been narrow, one-dimensional described by individuals with specific backgrounds. Human resource leaders focused on employee growth, top leaders on financial perspectives and so on, strategies were deep within their segment, but they were hard to convey to others outside their segment. There was no consistent way to represent their strategy allowing alignment and a shared understands on all levels.

Kaplan and Norton saw that businesses adopting to the balanced scorecards, utilizing them to their fullest extent, intuitively started to redesign their methods of implementing and communicating their strategy.
Kaplan and Norton investigated further and by tracking companies who where seeing great improvements, asked them to state their two typical keywords describing their individual success. More than often than not these two words where: alignment and focus.
Through further investigations and numerous data collection, Kaplan and Norton introduced in 2004

their new tool: Strategy maps, which has been receiving rave critics, being described as innovative and important as the balanced scorecards.
"The strategy map provides the missing link between strategy formulation and strategy execution" (Kaplan and Norton, 2004)

4.1 ORGANIZATIONAL GOALS AND VISIONS

In order for an asset management strategy to be optimally implemented, alignment to current goals and visions within the organization is set as base.

Gassco's visions and goals (Gassco, 2012):

- Norwegian gas transport to Europe - reliable and forward looking.
- Achieve personal development in a healthy business culture and a good social environment.
- Conduct business in an ethical, sustainable and socially responsible manner.

Norwegian government through Norwegian Petroleum Directorate's main visions and goals (NPD, 2011):

- Contribute to creating the greatest possible values for society from the oil and gas activities by means of prudent resource management based on safety, emergency preparedness and safeguarding of the external environment.
- Realizing the resource potential by emphasizing long-term solutions, upside opportunities, economies of scale and joint operations, as well as ensuring that time-critical resources are not lost.

Prominent visions and goals amongst Gassled joint ventures:

- Deliver risk-adjusted returns to investors.
- Aim to ensure Gassled customers world-class and cost-efficient service, while maintaining Gassled system integrity and reliability (NJORD, 2013).
- Ensure the highest possible value creation for society from the SDFI (Petoro, 2013).

As overall visions dictate, adopting strategies in which further facilitates a controlled and manageable continuous organizational improvement, resulting in organizational competitiveness in future markets is one of the top priorities.

According to The Business Dictionary an organization "should internally have collective goals" in order to exist, or even be termed an organization. Seeing as there has been a recent development of an impending major conflict between major stakeholders due to contradictory high levels goals and visions, the following asset strategy will utilize elements from Kaplan and Norton's Strategy map, in order to create an organizational strategy based on a well known framework.

4.2 STRATEGY MAP

According to Kaplan and Norton, customer satisfaction is the main source for sustainable value creation, and therefore, the main essence of implementing a strategy map is to visually depict the elements in which facilitate long term satisfaction for customers of the GNG pipeline, ultimately resulting in long term shareholder value through customer acquisition , satisfaction, retention, loyalty and growth.

The road to get there is built upon cause and effect layers, where elements within each consecutive layer must be fully aligned and able to support layer above in order to attain overall strategies. The layers in which encompass a strategy map consists of: the learning and growth perspective, internal perspective, customer perspective and financial perspective. Kaplan and Norton believe that only by aligning objectives within these segments, will yield proper value creation and thus a truly internally consistent strategy to take form.

It is important to realize that a strategy is not just limited within management processes, but rather is and should be, a route in which top mission statements are moved to the frontline and back-office of the organization. By mapping a strategy map, one creates a solid foundation to which measureable balanced scorecards, targets and initiatives and personal objectives can be tailored to fit the strategy.

Figure 4-1 Example of Strategy Map (source: Kaplan and Norton, 2004)

Micheal Porter, a founder and leader within the field of strategy, argues that strategy is about creating a sustainable difference in the marketplace by selecting a set of organizational activities. Such differences can be by delivering greater values to customers (Kaplan and Norton, 2004) or in this case, high availability, organizational stability and market competitive prices.

Financial Perspective

In creating a strategy map, one starts by highlighting the financial perspectives of the map. The financial performance of the asset GNG pipeline can be measured by operating income and return on investments, where basically one gains financial value by selling more and/or by spending less, hopefully both.
Kaplan and Norton therefore segregate the financial perspective between productivity strategy and growth strategy in order to further achieve long-term financial value.

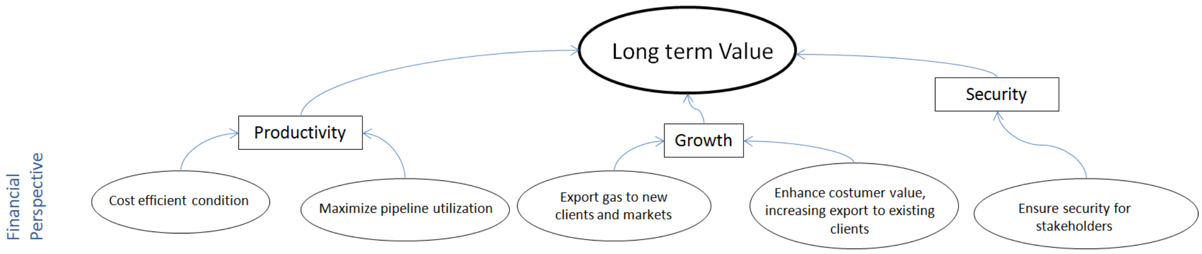


Figure 4-2 Strategy map: Financial Perspective

By *growth*, the GNG pipeline can basically sell more by increasing its annual gas flows, in the means of improving customer relations, or by attaining new clients within energy markets. By focusing specifically on these two elements the strategy involves long term growth aspects focused towards the external aspects of the system.

Another way of creating long term value is by increasing inspection efficiency, thereby reducing costs and at the same time increasing the quality of inspections. This in turn reduces unscheduled pipeline downtime, ensuring overall high asset utilization. Striving for maximum pipeline utilization as individual aspect utilization ensures the highest value creation within the limitations of the pipeline through other disciplines such as flow management.
By improving productivity through such means, cost structures can be reduced, thereby increasing the asset's profit margin.

As productivity improvements are often seen as attainable within short term time spans, growth improvement are attained by long term commitments and focus. By starting the strategy map within the financial perspective layer, Kaplan and Norton forces the organization to balance their strategy on both short term (productivity) and long term (growth) issues in order to sustain overall long term values.

One of the main criticisms Kaplan and Norton have received in light of their balanced scorecards (in which strategy maps is based on), is the fact that they have a too narrow stakeholder focus (Flak and Dertz, n.d.), thus devaluating other relevant stakeholders within the strategy. This fact became especially criticized by stakeholder theorists who believe that there are other important parties other than the immediate needs of shareholders and stockholders in which focus should be directed towards in gaining long term value.

By incorporating a third segregation called "security", elements such as financial security, environmental security and social security become objectives in which facilitate long term value. For example: Ensuring long term environmental security for local inhabitants will yield positive public opinion, resulting in consent from the masses. Public opinion should not be underestimated, and the power of the masses has on multiple occasions throughout history changed the courses of large financial investments.

Another example from within the security segment, could be the ensuring of social security in the form of taxes in which goes to the government and hence the public. By adding stakeholder "security" as an objective, the strategy incorporates long term stakeholders in which then again ensures long term sustainability within not only the financial setting, but also settings where other relevant stakeholders act within.

One important social aspect is that by investing in the gas industry, ripple effects spreads, such as affecting employment rates, further stimulating economic growth and prosperity in the region. By favoring expansion of the infrastructure to for example further north, not only does one unlock an increase in revenue for the organization, but also wealth to society.

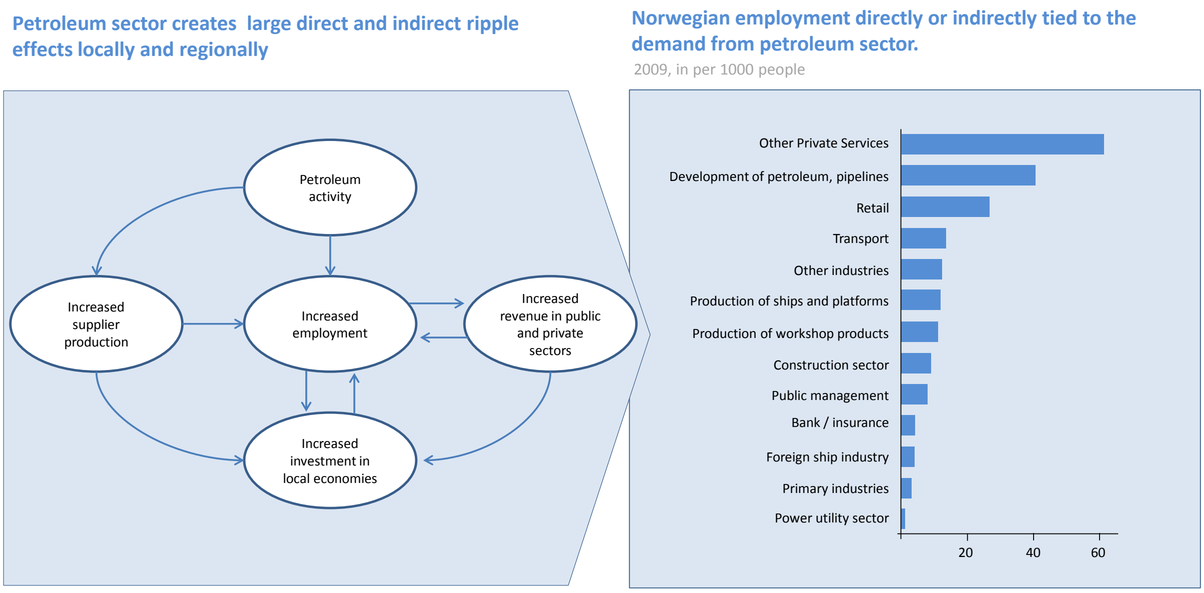


Figure 4-3 Employment in Norway related to demand from the petroleum sector. Source: (Gassco, 2012)

Customer Perspective

In order to strive for increases in productivity and growth, a strategy should identify specific customer segments which are anticipated to yield such results (Kaplan and Norton, 2004). By segmenting and focusing, customer retention and satisfaction can be targeted and achieved. These segments should reflect the needs and desires for their targeted group of customers, and thus supply such, in a better or different manner than its competitors. Customers of the pipeline, who are foreign gas buyers via NCS shippers, value high availability, reflected by impeccable reliability in order to sustain their own individual energy demands. At the same time, the price of Norwegian gas (therein including tariff) sold under various forms in the primary and secondary market become key factors when competing with not only natural gas competitors (Russia, LNG etc.), but also alternative energy sources such as coal and renewables.

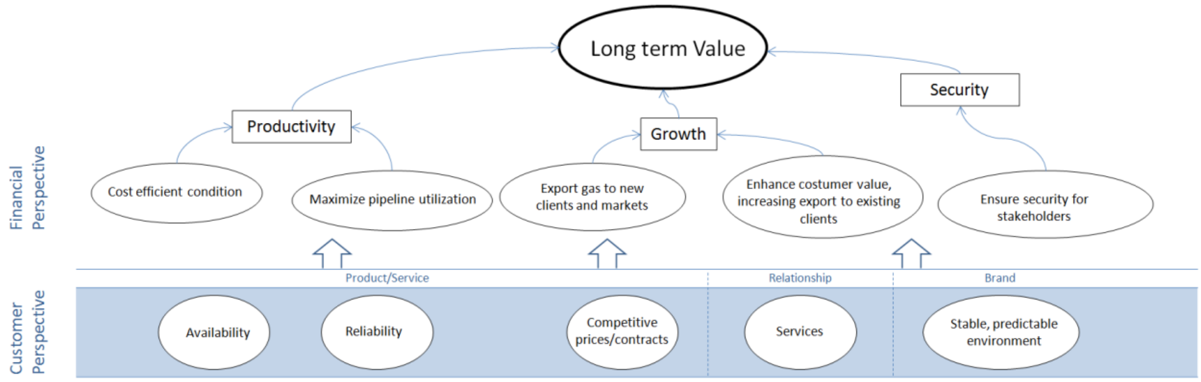


Figure 4-4 Strategy map: Customer Perspective

Other customer needs are tied to services provided in the likes of for example booking environment within GasViaGasledd or any additional services. By providing services in which clients benefit from, like for instance being able to sell booked capacity from the primary market to other buyers in secondary market gives flexibility for the shippers, whilst also ensuring a more flexible purchase milieu for downstream buyers. All such services build up around the relationship and trust within the localized gas system.

Today's world markets are unstable, and highly volatile. Within the energy sector (therein also politics), commodity investors often seek stable, predictable environments in which to do business. Providing such a setting for customers will be one of the largest future factors for Norwegian gas, creating a strong brand, in which future financial and energy investors are willing to participate heavily in.

Seeing as value comes from customers, creating a strategy in which encompasses all segmented elements within "customer perspective", will ensure increases in the financial perspectives. An example would be that by improving and facilitating customer perspectives, customer retention will be high, but should also through word of mouth, customer acquisitions should thrive.

Internal Perspective

As financial and customer objectives have been targeted, the below levels in the map further describes and facilitates the necessary objectives in order to accomplish the strategy. The internal perspective accomplishes two vital components of the strategy at hand: they deliver value to the customer, and improves processes and reduces costs for the productivity component of the financial perspective (Kaplan and Norton, 2004). *Operation Management* processes involve day-to-day activities in which the organization performs in order to facilitate existing products, services and customer needs. These are processes in which are specifically targeted in order to ensure short term value and customer retention. *Customer management* are objectives in which further deepens the relationship between targeted customers and organization. By knowing what your customers' wants and needs are, the organization can adapt and seize opportunities within the market.

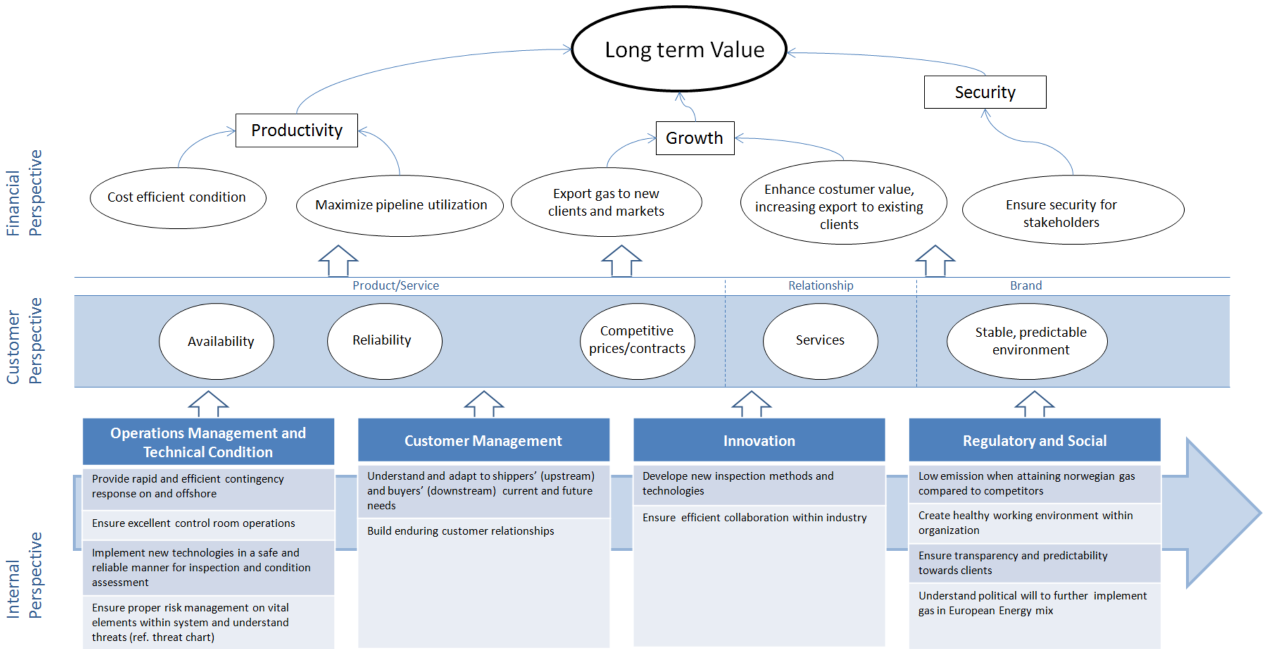


Figure 4-5 Strategy Map: Internal Perspective

Building within this cluster ensures branding through goodwill and faith by showing oneself as a reliable and forthcoming supplier of natural gas.

Innovation processes hold objectives in which give value in medium to long term settings gaining value through increased productivity and growth. Seeing as future gas uncertainties are predicted to be large, being cost/utilization efficient in a wide specter of disciplines in either a downward or upward gas trend will be increasingly important in order to achieve long term value.

Regulatory and social processes involve objectives in which support a large group of stakeholders, in order to sustain long term stability in a wide range of aspects.

Seeing as the four clusters within the internal processes are often tied to various time frames of when value is received, it becomes important that the strategy focuses on multiple objectives within all clusters in order to sustain a balanced value creation between the short- and long-term values. As there is a myriad of processes taking place throughout the organization, all contributing to value, it becomes crucial in targeting a collected few, in which the organization specifically strives for and prioritizes in order to facilitate value in the predefined customer objectives.

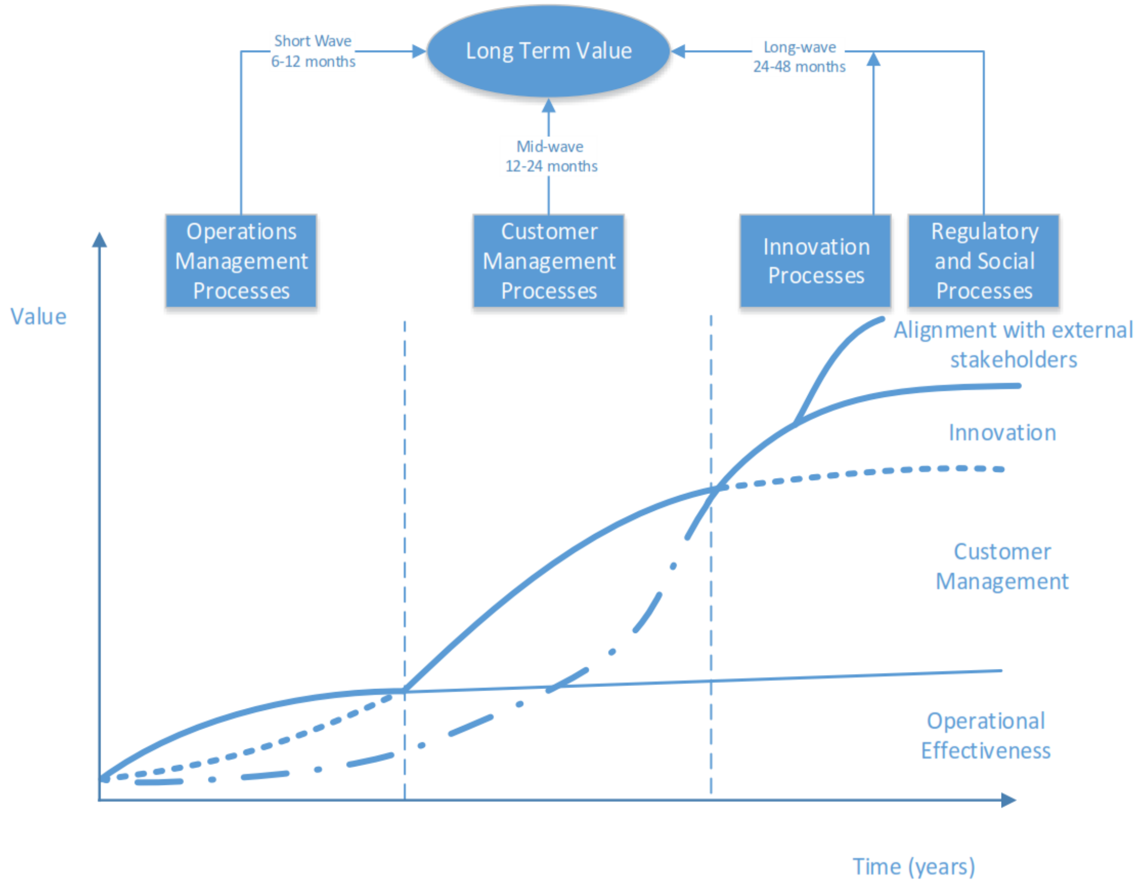


Figure 4-6 Internal Processes Deliver value over different time horizons
(original Source: Kaplan & Norton, 2004)

Learning and Growth Perspective

The founding stones when building up a strategy map are its intangible assets. As previously stated, estimates show that 75% of an organizations value is through its intangible assets, thus including these elements within the map is the largest contributor towards the success of a strategy. Kaplan and Norton segregate the segment in to:
- Human Capital, the skills and talent within the organization, ranging from valve checkers to third party companies hired to do specific tasks.
-Information Capital, which are the systems, networks and infrastructures in place in order to support the Human Capital. These could be routines, infrastructural IT systems etc.
- Organization Capital, the primary driver of any organization in which ensures that the execution of the strategy is implemented, followed through and continuously monitored.

Common theory dictates that the three intangible asset groups are interconnected and must together complement and be mutually supportive to one another in order to attain success. Changing a factor in one of the three will affect the two others, thereby requiring mutual strategic attention towards all of the three segmentations. Focus towards all three requires diligent awareness in regards to trade-offs and compromises being made between them, in order to attain the overall strategy (Perrow, 1999).

A note to be aware of is that seeing as the three are inherently interconnected, inevitable trade-offs can cause conflicts amongst humans across and within the segmentations.
Such conflicts must be dealt with as inevitable when striving for a well defined strategy.

By utilizing the previously found threats and challenges, each intangible asset segment is given its own set of objectives in which should be included with the overall strategy. Together, through their interconnections and interdependencies, they act as a foundation in order for the overall strategy to be effectively implemented.

Consequently, a complete strategy map starting from its intangible assets and building up towards long term value is presented in the figure below.

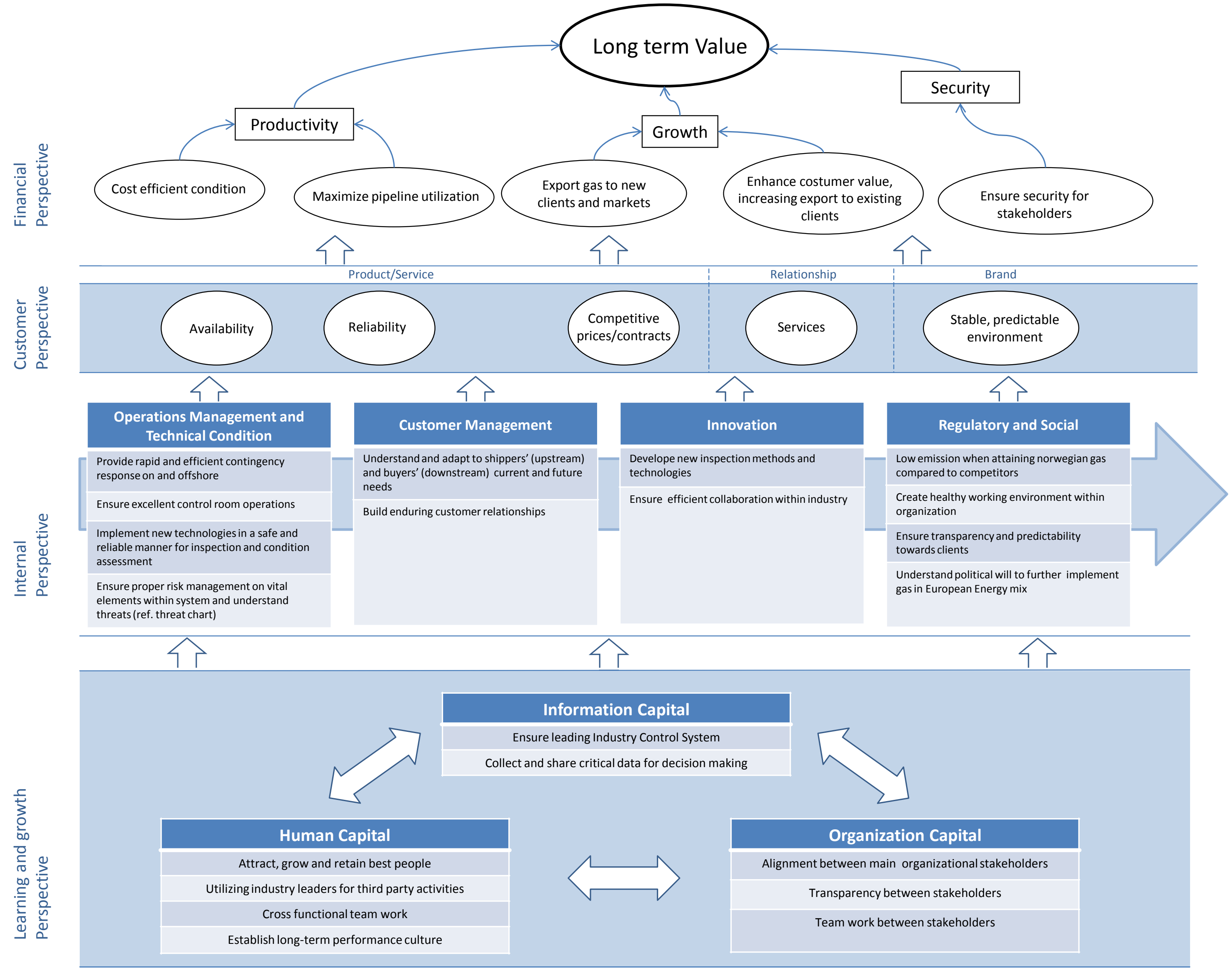


Figure 4-7 GNG pipeline Strategy Map

The strategy map is mainly applied from a stand point from the GNG pipeline itself and its localized wellbeing.
Since the term Long-term value implies an increase in gas flow, all stakeholders within the organization in essence strive towards the same basic parameter, but with somewhat different agendas and ways in reaching its target. In relation to the strategy map, priorities to certain objectives within the strategy map may differ from stakeholder to stakeholder, but as stated, the overall goal remains the same. This implies that due to long term interdependencies, the base building blocks for the mutual goals therefore also become shared amongst the entities within the organization (i.e. government, Gassled, Gassco)
As such there are certain aspects especially within the organization capital that must be overcome in order for the strategy to become a tool when striving for long term optimal flow.

The following sections delve in slight more detail in to the problems and challenges highlighted in chapter 3 which should/must be dealt with in order for the strategy to fully be optimized.

4.2.1 Learning and Growth Perspective:

4.2.1.1 Organization Capital

Organizational change in itself is a double edged sword, which on one hand can pave the way for optimal performance and excellent management, but on the other can also act as a catalyst for an uncontrollable fall in all aspects within an organization's business. Seeing as the organizational capital is at the core of an organization's wellbeing, any positive or negative factors will produce ripple effects spanning out to all corners of the business, and more importantly affecting the efficiency of any long term strategy set.

According to McKinsey & Company, an advanced analytical firm, roughly 70% of all changes within or to an organization fail. This has been statistically proven the past decades, and the numbers aren't diminishing. On the contrary, according to 2008 IBM research, an organization's ability to succeed during change is becoming increasingly complicated (Maurer, 2013). One of the main reasons being is that as companies become larger, they have an increasingly interconnected dependency to multiple stakeholders.
Such interconnections are not always easy to predict, before, or even during changes are set in motion. Due to tight dependencies, not only within said organization, but the industry in general, alignment and cooperation between all involved parties (especially within an organization) is crucial before trying to optimize lower level issues.

As one of the three founding blocks of the strategy map, namely the organizational capital (i.e. ownership composition of Gassled) has recently changed substantially over a relatively short period of time, certain elementary alterations have occurred.
Within the segmented organizational capital, the ownership change has resulted in an additional new vision being introduced in the organization, namely delivering risk-adjusted returns to its owners through revenue gained from tariff.
As previously discussed, the main returns from within Gassled's joint venture owners before the ownership change was in upstream interests, namely at the oil & gas fields and the sales of the actual gas. This ROI was aligned also with the government and thus subsequently Gassco.
By changing the composition of Gassled (approved by government), the majority of investors are now paid on the amount of revenue gathered from the tariff (set by government) and not the actual gas sold from upstream, a crucial common alignment is broken.

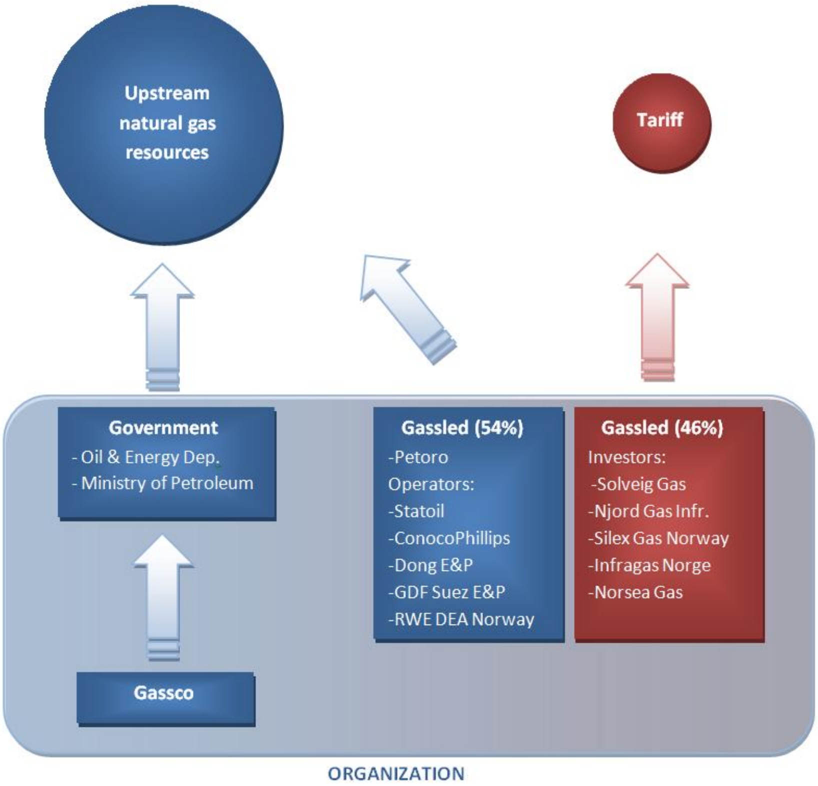


Figure 4-8 Gassled ownership with direct ties to upstream sector (in blue

Note: Even though Gassco receives its revenue through tariffs, Gassco still is owned by the government, and therefore hold the somewhat same vision.

Figure 4-8 shows where the different entities within the organization see their largest future earnings. The misalignment within the organization becomes evident, and any solution must uphold the fact that half of Gassled is solely dependent on the tariff level set by government. The "red" non-users of the system would like to see a high tariff to maximize yield, whilst the "blue" users of the system would prefer a low tariff, reducing their overall costs and increasing demand for their gas.
As the transition of ownership occurred, one of the main ties between the organizational stakeholders, ensuring organizational alignment (i.e. investors and government), was that of long term ROI through trust and predictability.

At the moment the Norwegian gas industry is set on supplying cheap reliable Norwegian gas to the Europe. Do to this, prices need to be cut somewhere, and at the moment it seems, this is partially in the form of a reduction in tariff levels, affecting Gassled.
According to Alexander Engh, consultant in Deloitte, the enormous purchase sums paid by investors are based on pure trust to the Norwegian Oil and Energy department (OED). Their purchase is based on that the OED acts in a predictable manner, where the owner's anticipated yearly projected income is more or less unchanged over time (Lewis, 2011).

Proposed governmental tariff cuts, if implemented, will definitely undermine internal ties, most likely ensuring long term instability within the organization affecting its ability to implement an efficient organizational strategy. Even though the cuts are not implemented, trust and predictability will still be challenged within the organization.

Many of the owners of the new Gassled joint venture have expressed deep distrust in how the Norwegian government has merely “tricked” them in to buying stakes in what was told to be a low risk, steady paying asset, which it still is, should the cuts be introduced, but the revenue gained from the asset is substantially less than what the investors utilized in their investment analysis’. Some might even say, that the tariff cuts, come very “conveniently” for the state owned Statoil who sold most of its ownership in Gassled at high prices where buyers were anticipating average returns over 7% not long before the consultation paper discussing a proposed cut was released. Had they sold their stake (and the other gas operators for that matter) after the paper was released, they would most likely have received lower sales value due to higher uncertainty for future return on investments.

As is now, the organization environment surrounding the GNG pipeline and the whole Norwegian gas infrastructure has shortfalls: conflicts of interest have arisen, where Norwegian government (and most likely 54% of Gassled) wants to increase demand for their gas by decreasing the tariffs on behalf of Gassleds’ new investor companies.

The fact is, that today’s gas infrastructure regulations are made in such a way that they restrict the investment companies in investing in new pipeline infrastructure, where if any new pipelines are to be built, oil and gas companies will build them (being coordinated by Gassco), and then acquire yet again, a stake in Gassled if the pipeline is to be included in Gassled’s infrastructure, diluting the current ownership stakes.

The way in which regulations and tariff system is set, creates too much of a diversion to create long-term growth and sustainability within the organization. Even if investors do invest in what segments they are allowed, they need healthy incentives. At the moment, investors have no risk tied to their cost. Since they are not users, any extra investments allowable within the regulations are to be compensated by an increase in tariff elements I and O in order to comply with the fact that returns on investments are to be an expected average of at least 7% (at least if the new tariff cuts fail to be implemented).

Still if the tariff cuts are implemented, an increased amount of investments may be relevant in order to be reimbursed some of their lost income due to the cuts.

The way the regulatory system is made up today, all priorities are towards oil and gas companies along with the government. They have full control, and investor companies are not prioritized. This must change.

In order to try and solve the conflicts between the “blue” and the “red” stakeholders, **alignment**, trust, cooperation, **transparency** and **team work** through new structures must be established. As a specific example regarding the tariff issue, Thor Magnus Rovik and Kenneth Fossøy from Rovik Energy, believe that the proposed suggestion should be abandoned, and instead they should initiate a process which culminates in industry consensus within a complex value chain, further aiming to facilitate optimal future resource management. In addition, an extensive revision of the Gassleds’ system is due, in light of new owners introducing new interests, in order to create stable clear and concise rules and regulations within the natural gas value chain (Rovik and Fossøy, 2013) for all stakeholders.
This need for alignment will pose especially crucial, as Norwegian gas resources are becoming depleted towards 2020 and new resource investments along with high pipeline cost efficiency is required in order to sustain the amount of reliable gas supplied to Europe at market competitive prices.
Only then, can one efficiently build add the remaining blocks encompassed in the strategy map in order to accomplish the financial long term values.

4.2.1.2 Information Capital

Computers and workforces are becoming ever more integrated, where the sheer power of a single entity is far overrun by the collective efficiency of a group of entities sharing information in a network.

As collaboration and teamwork between interdependent companies such as Gassco-TSP-third-party entities, information sharing and transparency is often crucial in order for critical decisions to be prepared optimally. Consequently, cross company information systems via information hubs should be strived for when sharing critical information within the GNG pipeline environment.

Consequently, as technologies, systems and information sharing evolve, they introduce elements and linkages which increases efficiency and data flow throughout not only the organization, but the whole industry. Likewise, as the system expands, the vulnerabilities in which hackers can gain access through, increases to a point where there are so many weak links, that a heightened focus on security almost becomes inevitable in order for crucial infrastructural systems to become robust enough in order to ensure its long term integrity.
As previously discussed, cyber attacks are on the rise, and will likely continue to do so in the years to come. Being aware of this growing threat and mitigating its presence by ensuring sufficient robustness within SCADA and information capital systems is most likely to become crucial in the years to come.

4.2.2 Internal Perspective:

4.2.2.1 Market & Politics Strategies

As European politicians struggle to align themselves behind their means of attaining emission goals, the GNG pipeline organization must yet again show that they are a reliable and stable supplier with a transparent organization (therein regulation regime), supporting long term stability at competitive prices. An organization's reputation takes years to build, but can be tarnished within a short period of time. Retaining and further improving such reputation over longer time will be one of the largest aims throughout the GNG pipeline's life cycle.

At the moment it seems that the Norwegian government is tarnishing the branding, by limiting transparency and avoiding team work with the industry when suggesting tax and tariff changes. Another case showing this, besides the newfound natural gas tariff cut proposition, is the introduction of increasing petroleum taxes on NCS in order to finance the reduction of mainland non-oil related industry taxes. Both propositions have met sharp criticism from many industries, documenting that because of the government's unpredictability and unwillingness to find solutions together with the industry a higher risk for financial investors is imposed, due to the unpredictability of the Norwegian government. 15 of the top oil and gas leaders stated in relation to the tax change, that it takes decades to build credibility, but all it takes is one bad decision to tear it all down again (Lorentzen and Hessevik, 2013).

As Russia has been seen as an unreliable and unpredictable supplier of gas, Norway has to be the firm rock in which its organizations are stable and aligned towards supplying reliable natural gas to Europe. If Europe sees two of its most prominent supplies as unstable and unpredictable, gas may further lose its role as a transitional energy commodity in favor of for example coal.

By internally aligning its stakeholders and ensuring optimal conditions for future investments, Norway can continue to grow as a main supplier of natural gas to Europe, creating long term value.

4.2.2.2 Operation Management - Pipeline objectives

Implement new technologies in a safe and reliable manner

To ensure on-going sustainability of the services provided through the GNG pipeline, world class diligent infrastructural inspection and maintenance levels should be a top priority in order to sustain the mutual vision of reliable supply of natural gas. In order to uphold such levels in the future, research in improved methods of maintenance and inspection will be increasingly important as the asset ages and the significance of high availability in a volatile market with an increasing amount of competitors such as LNG, renewable resources, Russian gas etc. show their presence in the market.

As the most prominent inherent risks of the GNG pipeline is from third party factors, such inflictions are steered somewhat of randomness. Therefore, one of the most important aspects in ensuring optimal asset performance level is to gain detailed information of the current pipeline status. One factor is monitoring the actual rate at which impacts occur over time, acting as a crucial step towards gaining a full understanding of the actual yearly risks at hand. The optimal process to integrate risk based inspections is to include real life data in to the analysis. As ship traffic and ship sizes are increasing, analyzing such data through impact and industry trends is an important step in deciding the true risk from such entities.

One of the issues at hand is that as new technology has been implemented in 2012 in order to lessen the cost by utilizing acoustic vessel based inspection rather than ROV, the data captured within such an inspection is reduced. Previous GNG pipeline inspections have been focused on:

- Lay comfort
- Freespans
- Pipeline damages
- Debris
- Anodes and cathodic protection
- Seabed features and targets
- Pipeline and cable crossings

New GNG inspection methods have withheld “pipeline damages” from their list of focus for their inspection. It is assumed that any major pipeline damages will be found due either major deformation and/or localized movement from original lay position.

Inspection data by acoustic measurements from vessel hull where extensive, there was however given no detail to the amount of registered pipeline impacts, CP measurements or damages to field joints (shown in blue in Figure 4-9), suggesting and implying that hull based acoustic inspections are not able to pick up such information.

As new data always supersedes old data in the report for specific pipeline legs, the old status of impacts where now not available. In the new 2012 rev03 report from TSP there was no mention of any field joint or pipe coating damages regarding the section covered by the new acoustic measurements (in blue).

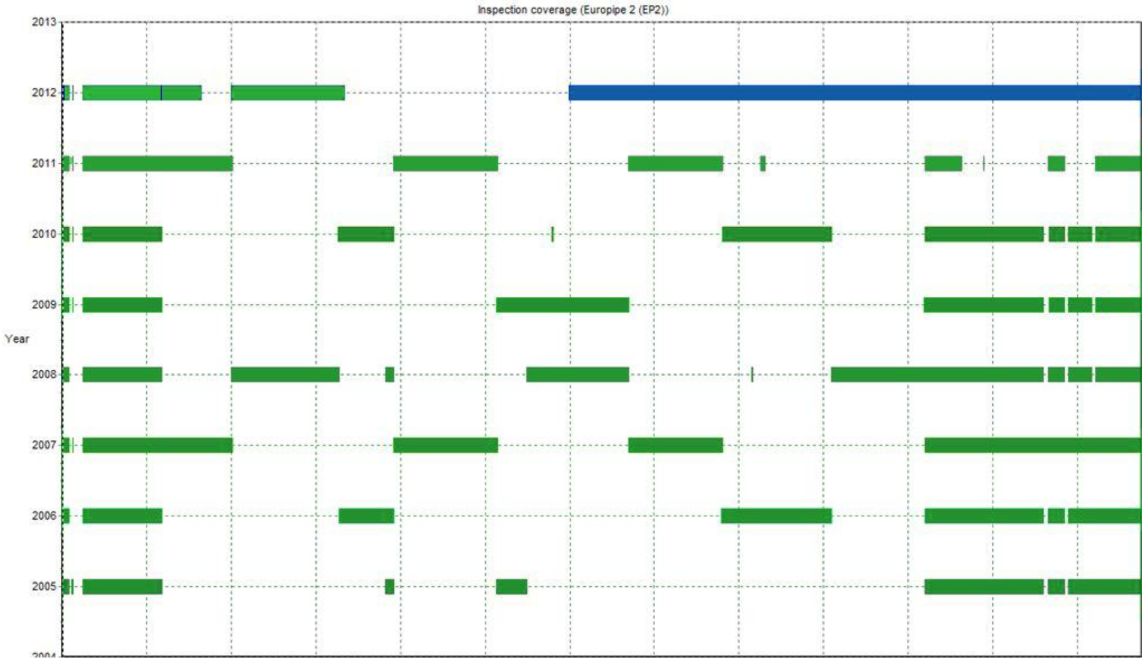


Figure 4-9 Yearly inspection coverage of GNG pipeline (Green = includes pipeline damages in focus area, Blue = does not include pipeline damages as focus area)

As current Gassco strategies strive to implement new technologies (AUV, Hull based acoustics & Acoustic resonance technology pigs) in order to optimize their inspection regime through cost effectiveness and lessening environment impact, being aware of inherent limitations within such technologies can pose a huge benefit when further striving to optimize inspection routines.

As previous incidents such as Kvitebjørn and CATS have shown, detecting pipeline damage before further development saves costs in the form of minimizing implications caused by full pipeline rupture. As such, cost effectiveness increases the amount of distance covered in annual inspections, thus reducing the likelihood of dormant damages occurring.

According to GNG pipeline's annual report, the beginning and end locations of the pipeline seem to have been given high priority regarding inspection. But by layering the annual pipeline inspections over pipeline profile and large vessel traffic, one can see that certain inspections intervals do not coincide optimally with regards to ship traffic who's anchors can affect the pipeline (Figure 4-11).

This can further be shown in Figure 4-10, where the two areas with large tonnage weight traffic has relatively high amounts of impacts to the pipeline, whilst only being inspected every somewhat 4 years.
As vessels posing a threat to the GNG pipeline would have to be traveling at 9 knots or below in order for a fully released anchor to reach depths of 275 meters (see Figure 3-14), the threat itself from anchors may not be all that large for deep water.
But looking at the Kvitebjørn incident, repair below 180 meter depths can take a long time to repair due to a heightened technical level of operations required.
Even though, there are still sections of relatively shallow water where the inspection interval does not match the risk posed by heavy traffic, underlined by the increased amount of pipeline damages due to third parties in the segment. Consequently, there may be a lack of convergence between the inspection intervals and the risk of anchor damage at various sections of the pipeline length.

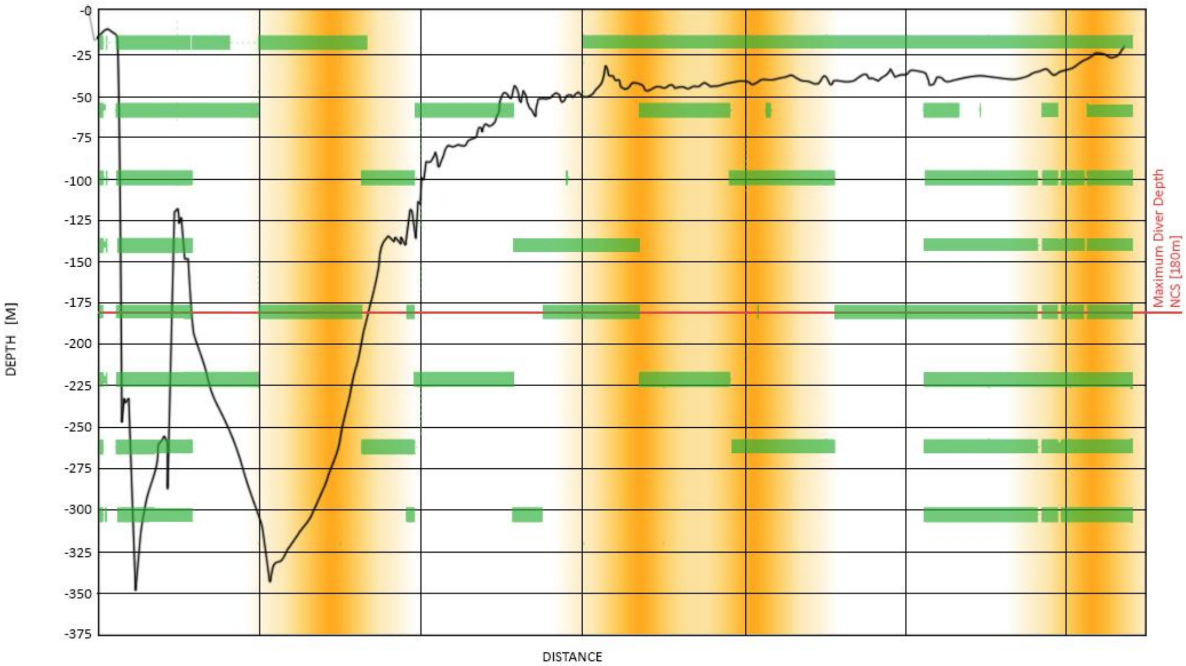


Figure 4-11 GNG pipeline profile plotted against diver depth, annual inspection coverage intervals and ship traffic

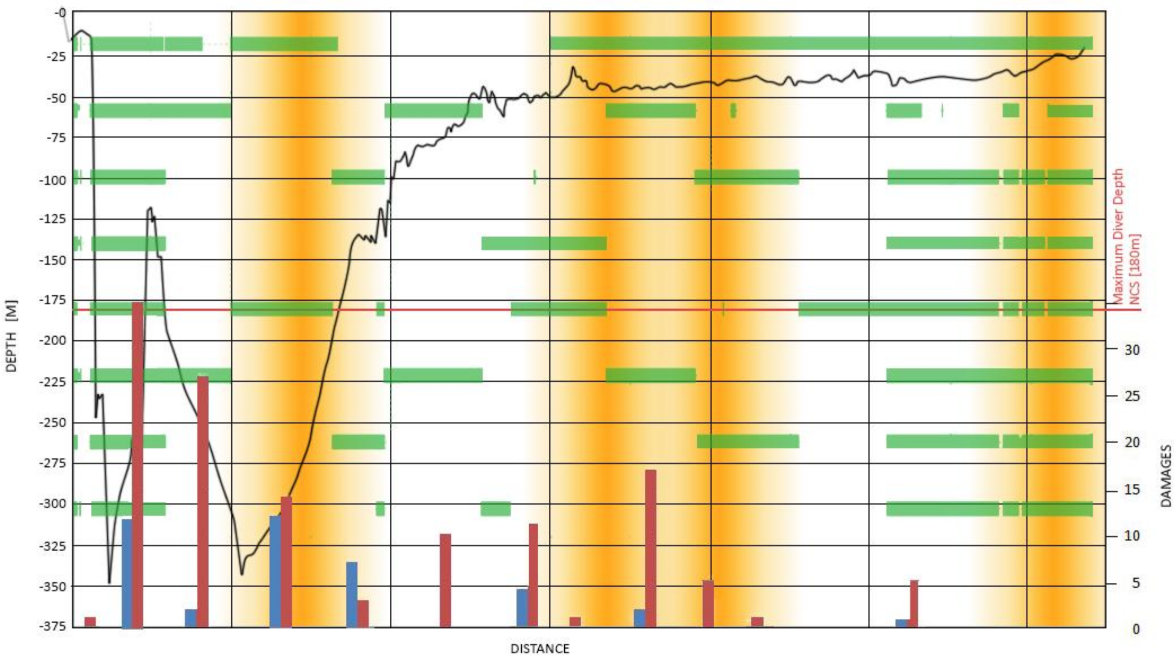


Figure 4-10 GNG pipeline profile plotted against diver depth, annual inspection coverage intervals , ship traffic and pipeline impact quantities and type.

5. Multiple Future Scenarios

In a region which is troubled by large uncertainty, the GNG pipeline and its corresponding aspects must be adaptable to a wide variety of future scenarios. The following sub section briefly discusses the multiple scenarios in which could take place in the near distant future.

5.1 LOW FUTURE GAS PRICES

In any event of what Europe demands from Norway as a gas supplier, there is still a predicted large amount of untapped resources which can yield profit and regional benefits for all stakeholders

A problem though, is that due to competition from ever-growing influx of foreign LNG gas (US shale for example), coal and highly subsidized renewable energy, natural gas prices might become lower than today's prices. An effect of lower natural gas prices through either an over-saturated gas market or a reduced demand for gas, is that smaller gas fields which typically have a higher production cost per unit than larger fields, would become less economically viable. Consequently fewer NCS fields would contribute to the overall gas production, possibly resulting in a lower utilized infrastructure (Gassco, 2012). A report by Gassco in 2012 states that the Norwegian infrastructure is relatively robust, and that first when gas prices fall beneath 1,20 NOK/Sm^3 will a significant amount of gas fields not be developed (in comparison, spot prices in 2012 was set at approximately 2,1 NOK/Sm^3). At such low levels, most other natural gas suppliers will also have problems in getting their ends to meet (Gassco, 2012), especially Russia, with their newly invested pipelines Nordstream, Southstream etc. In such a scenario, Norway may have a competitive advantage due to their assumed already paid for pipeline infrastructure, thus possibly gaining an edge through lower costs. The only negative aspect, is that as Norway is coming close to its maximum capability of 120Bcm per year, Russia has a lot of extra capacity within its export infrastructure.

In such a scenario, it becomes imperative that all stakeholders within the organization encompassing the GNG pipeline are aligned towards the same goals. As marginal profits are less, future investments in the NCS will most likely suffer and operating the infrastructure (therein the GNG pipeline) in a cost effective manner resulting in low tariff levels, will ensure future production at fields in which are sensitive to price changes.

5.2 HIGH FUTURE GAS DEMAND

If European politicians implement emission initiatives, increasing the cost for high emission fossil fuels such as coal, demand for foreign natural gas may increase whilst indigenous conventional natural gas resources depletes. Norway on its side may not be able to transport any more gas due to both export limitations and possibly low resources found further north in the Norwegian sea, Barents sea. Should the resource picture on the NCS turn out to be high, due to high gas demands, incentives for further large scale expansion development of the infrastructure may be present. In such a case, pipelines stretching further north and a new export pipeline may be constructed.

The result of such a new export pipeline to the EU continent, would according to Gassco, reduce the utilization of the transmission terminal of amongst others the GNG pipeline. This becomes increasingly present after 2030, due to flow dispersion towards export pipelines that receive flow directly from pipelines leading directly north.

A localized result towards 2030 and beyond will be an underutilized GNG pipeline, consequently leading to less economic loss should shut down due to damage or any other potential threat occur. Consequently, this could in turn lead to an increasing focus being directed towards the wellbeing of the major pipelines which are highly utilized and not the GNG pipeline, since they hold higher economic risk should an incident occur.

6. Discussion

In setting out on this thesis, it quickly became evident that appointing own personal evaluations of when to stop researching further in to an issue (threats: anchor, organizational, political etc.) was a strenuous task, as the drive for further knowledge had to be subdued in favor of achieving overall thesis goals set in the scope and objectives.
Consequently, the largest challenges have been with dealing with the sheer size and complexity of the issues at hand, especially prominent due to the lack of previous knowledge and experience often required to perform judgment and conclude on within such large and intricate interconnecting issues. Many such isolated opinions where often derived from assumed "professionals", each within multiple fields, in order for the author to gain a fuller understanding of the overall situation. Consequently, due to the nature of the thesis, there will always be a certain uncertainty related to the statements of assumed "professionals", where their statements may not only be biased, but may also hold inherent industrial uncertainty.
Overall, the uncertainties within, should not pose a large threat towards the thesis's overall conclusions, as research has as often as possible been spread across multiple sources all indicating more or less the same isolated issues.

Certain limitations also became evident due to the confidential nature of the GNG pipeline, where the classified location of the pipeline meant that certain deeper issues could not be highlighted in further detail than what presented in the thesis.
In author's opinion, the limitations set, did not distort or affect the overall conclusions.

A general feeling when looking at the final thesis presented, is a wish of further, deeper understanding of all aspects and problems highlighted in order to present a thesis with ever greater magnitude. Due to the inherent timescale boundaries and set limitations, this was not achievable, and would probably not even be attainable due to personal lack of experience and knowledge in such a range of disciplines and fields.

Future Work

Subsequently, the author believes that a future study, further delving in to the details in which has been presented in this thesis in order to gain an even deeper understanding of the Norwegian infrastructure's threats and interdependencies is due. Such a study is essential in order to optimally manage the infrastructure at all levels, currently and in the future, from an asset management perspective in order for best utilization of the resources available within Norwegian territory, optimizing value creation for all stakeholders.

7. Conclusion

As Norway's main pipeline competitor, Russia, amps up their new north stream pipelines (1,2, with 3 and 4 possibly on the way) and south stream comes on the grid along with strategies to increase supply to Germany and United Kingdom, other international gas suppliers will also most likely try and increase the supply of natural gas via LNG to the European market. Such surging LNG imports will mostly occur from unconventional gas resources which where until recently, unattainable, are now feeding the markets. The expanding US shale gas production and the ever increasing supply from Qatar, along with further planned LNG thermals, are examples in which further shift the previously monopolistic supply of pipelined gas, to a more liberalized European natural gas market.
In that respect, as energy markets desire stable, reliable suppliers, providing market competitive prices, Norway should ensure its internal stability and provide market focused contracts on the basis of its stability, predictability, and reliability. As such, pipeline stakeholders ought to align themselves especially towards their core markets, UK and Germany, whom which are experiencing a surge of Russian willingness to supply more.

At the moment it seems important for natural gas as an energy source in Europe, that natural gas suppliers adapt to European energy power needs, before coal gets a too large of a foothold within the energy mix. By providing what the market demands, through an increase in natural gas price contracts unlinked to high oil prices, and proving to be a reliable and stable source of clean energy, Europe may see Norwegian gas as a viable transition supplier in its mission towards increasing their renewable energy within their mix.

Consequently, providing a strategy in which encompasses and deals with a variety of threats, both internally and externally has been created in order to provide long term growth within all sectors and segments in which the GNG pipeline exists in. The strategy in addition aligns itself with the bullet points made by the IAM for good asset management.

Regarding the strategy, specifically for the financial investment owners in Gassled, their incentives may be solely towards gaining as much profit as possible for its confined shareholders through the tariff. According to Kaplan and Norton, long term values are target to be just this, namely value to its shareholders. But by in addition, introducing a "security" element within its top value gaining elements, they are for example indirectly forced to think of what investments they make could gain social security within Norway, thus aligning the strategy to other beliefs and values extending past the internal local stakeholders within an organization, in order to fully stimulation long term growth. By focusing on such matters, they involve themselves to a higher degree within upstream planning which could lead to an increase in wealth for not only them, but the nation in general through, by providing job security, further employment, basically aligning themselves with the government and upstream owners within Gassled. If it the security element was not present within the strategy, the investment companies may possibly overinvest in the infrastructure, shifting its increased cost to the users (oil and gas companies) through an increase in tariff. This would in turn reduce the profit margin for these companies, thus stagnating future investments, negatively affecting social benefits, like jobs, profits through future find petroleum taxes etc.

8. References

Adomaitis, N., 2012a. Norway challenges Russia with new European gas pricing. [online] Available at: http://www.theglobeandmail.com/report-on-business/international-business/european-business/norway-challenges-russia-with-new-european-gas-pricing/article5472474/ [accessed 09/04/2013]

Adomaitis,, N., 2012b. Norway is near its maximum gas exports. [online] Available at: http://www.reuters.com/article/2012/12/07/norway-gas-idUSL5E8N6E1920121207 [accessed 03/05/2013]

Andrea, C., Machado, M., and Skouras. S., 2012. *Presentation* Gas Quality – From reservoir to market. [online] Available at: http://www.ipt.ntnu.no/~jsg/undervisning/naturgass/lysark/LysarkMachadoSkouras2012.pdf [accessed 09/04/2013]

Andresen, T., 2012. EON Loses as RWE's Coal Plants Win Germany's Green Shift: Energy. [online] Available at: http://www.bloomberg.com/news/2012-12-07/eon-loses-as-rwe-s-coal-plants-win-germany-s-green-shift-energy.htm [accessed 30/01/2013]

Appert, O., 1998. Gas Market: Forecast and Challenge. Available through: OnePetro website: http://www.onepetro.org/mslib/servlet/onepetropreview?id=WPC-28217 [accessed 10/04/2013]

ASRO Eqiupment and Supply, 2009. Pipeline Field Joint Infill, [online] Available at: http://myasro.blogspot.no/2009/07/pipeline-field-joint-infill.html [accessed 09/05/2013]

Atmost, 2013. Gassco Pipeline Management System. [online] Available at: http://www.atmosi.com/english/company/experience-case-studies/gassco-pipeline-management-system [accessed 18/04/2013]

Bachmann, M., 2013 Security of Supply Starts at the Well Head - Presentation during 1st EU Norway energy conference. Available through: European commission website: http://ec.europa.eu/energy/gas_electricity/events/20130305_norway_energy_conference_en.htm [accessed 13/04/2013]

Bailey, S., 2009. Map of the major existing and proposed Russian natural gas transportation pipelines to Europe.

BarentsObserver, 2009. Gazprom shows interest in Norwegian pipeline grid. [online] Available at: http://barentsobserver.com/en/node/20249 [accessed 19/05/2013]

Berge, J.O., 2012. Remote Hyperbaric Welding presentation

Bjerke, E., 2011. Venter tidenes høyeste oljeinvesteringer. [online] Available at: http://www.dn.no/energi/article2213817.ece [accessed 03/05/2012[

Bjordal, B., 2011. Norwegian gas to Europe – reflections and views. [online] Available at: http://www.gassco.no/wps/wcm/connect/1e1ee880472d43dd848984bb467833c3/Brian+Bjordal+EGC+final.pdf?MOD=AJPERES [accessed 15/04/2013]

Bjørnson, R.,2013. Natural gas- key to transform Europe's energy system – Presentation during 1st EU Norway energy conference. Available through: European commission website: http://ec.europa.eu/energy/gas_electricity/events/20130305_norway_energy_conference_en.htm [accessed 13/04/2013]

Bloomberg, 2012. Merkel's Green Shift Forces Germany to Burn More Coal. [online] Available at: http://www.bloomberg.com/news/2012-08-19/merkel-s-green-shift-forces-germany-to-burn-more-coal-energy.html [accessed 30/01/2013]

Bothe, D. and Lochner, S., 2007. From Russia with Gas, An analysis of the Nord Stream pipeline's impact on the European Gas Transmission System with the Tiger-Model. [online] Available at: http://www.ewi.uni-koeln.de/fileadmin/user_upload/Publikationen/Working_Paper/EWI_WP_07-02_Nord-Stream-Impact.pdf [accessed 30/03/2013]

BP, 2013. Energy Outlook 2030

BP, 2012. BP Statistical Review of World Energy June 2012

Brown, G.G., Carlyle, W.M. and Salmeron J. Wood K., 2005. Analyzing the vulnerability of critical infrastructure to attack and planning defenses. [online] Available at: http://faculty.nps.edu/kwood/docs/DefendingCIBrownEtAlTutorialDraft.pdf [accessed 04/04/2013]

Burgess, J., 2012. Coal Consumption Increases in the EU: Is the Carbon Trading Scheme a Failure?. [online] Available at: http://oilprice.com/Energy/Coal/Coal-Consumption-Increases-in-the-EU-Is-the-Carbon-Trading-Scheme-a-Failure.html [accessed 15/04/2013]

Chazan, G. and Wiesmann, G., 2013. Shale gas boom sparks EU coal revival. [online] Available at: http://www.ft.com/cms/s/0/d41c2e8a-6c8d-11e2-953f-00144feab49a.html#axzz2JxgH3eOC [accessed 20/05/2013]

Collins, G., 2013. Russia: Can the Gas Empire Strike Back?. [online] Available at: https://thediplomat.com/2013/05/27/russia-can-the-gas-empire-strike-back/ [accessed 10/05/2013]

Crome, T., 2012. Technip – Building solutions for the energy industry. [online] Available at: http://media.corporate-ir.net/media_files/IROL/11/110877/Norway_Barclays_Investor_Presentation_June8_2010.pdf [accessed 03/04/2013]

DeepOcean, 2013. Pipeline Repair System. [online] Available at: http://www.do.deepoceangroup.com/pipeline-repair-system.php [accessed 14/03/2013]

Der Spiegel, 2007. Warning Sign on the Ocean floor. [online] Available at: http://www.spiegel.de/international/world/warning-signs-on-the-ocean-floor-china-and-india-exploit-icy-energy-reserves-a-523178.html [accessed 18/05/2013]

DG Energy, 2012. Quarterly Report on European Gas Markets. Volume 5, issue 4

Dickman, F., 2009. Hacking the industrial SCADA network. [online] Available at: http://pipelineandgasjournal.com/hacking-industrial-scada-network [accessed 29/04/2013]

DNV, 2009. DNV-RP-F116 - Integrity Management of Submarine Pipeline Systems. October 2009

DNV, 2010a. Optimum speed – from a shipper's perspective. [online] Available at: http://www.dnv.com/industry/maritime/publicationsanddownloads/publications/updates/container/2010/2-2010/optimumspeedfromashippersperspective.asp [accessed 19/03/2013[

DNV, 2010b, DNV RP-F111 "Interference between trawl gear and pipelines" October 2010

Dozier, K., 2013. US intelligence chief Clapper says cyberterror, al-Qaida lead threats to US security in 2013. [online] Available at: http://ics-cert.us-cert.gov/pdf/ICS-CERT_Monthly_Monitor_Oct-Dec2012.pdf [accessed 18/04/2013]

Edwards, J., 2012. 2012: Year one in global cyber ware. [online] Available at: http://defensesystems.com/articles/2012/11/15/cyber-defense-year-in-review.aspx [accessed 18/04/2013]

Egan, M., 2013. America's Cyber Achilles Heel: Aging Critical Infrastructure, [online] Available at: http://www.foxbusiness.com/technology/2013/02/12/americas-cyber-achilles-heel-aging-critical-infrastructure/ [accessed 18/04/2013]

EIA, 2012a. Annual Energy Outlook 2012 with Projections to 2035

EIA, 2012b. World Energy Outlook 2011 – Are we entering a golden age of gas?

EIA, 2012c. Norway. [online] Available at: http://www.eia.gov/countries/cab.cfm?fips=NO [accessed 15/04/2013]

Enerdata, 2013. 2,2% drop in European gas consumption in 2012. [online] Available at: http://www.enerdata.net/enerdatauk/press-and-publication/energy-news-001/22-drop-european-gas-consumption-2012_17554.html [accessed 04/06/2013]

Eurostat, 2011. EU-27 imports of natural gas. [online] Available at: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:EU-27_imports_of_natural_gas_-_percentage_of_extra-EU_imports_by_country_of_origin,_2011.png&filetimestamp=20120604085013 [accessed 01/02/2013]

Eurostat, 2012. Gross inland consumption in EU-27. [online] Available at: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Gross_inland_consumption_in_EU-27,_2011,_in_million_tonnes_of_oil_equivalent_(Gross_Calorific_Value).png&filetimestamp=20120529132738 [accessed 04/02/2013]

European Union, 2012. EU energy in figures – statistical pocketbook 2012

Exxon, 2013. The Outlook For Energy: A view to 2040

Espiner, R., Kaye, D., Goodfellow, G. and Hopkins, P., 2008. Inspection & Assessment of damaged subsea pipelines: a Case study. [online] Available at: http://www.penspenintegrity.com/downloads/virtual-library/inspection-and-assessment-of-damaged-subsea-pipelines.pdf [accessed 05/03/2013]

Farrier, R., n.d. Does Australia really need a pipeline Repair Club.. or are we really "the lucky country"?. [online] Available at: : http://www.slideshare.net/EngineersAustralia/does-australia-really-need-a-pipeline-repair-club-or-are-we-the-lucky-country-by-ray-ferrier [accessed 23/05/2013]

FishSafe.eu, n.d. Pipelines. [online] Available at: http://fishsafe.eu/en/offshore-structures/pipelines.aspx [accessed 09/05/2013]

Flak, L.S. and Dertz, W., n.d. Stakeholder Theory and Balanced Scorecard to Improve IS strategy Development in Public Sector. [online] Available at: http://web.bsru.ac.th/~thanarat/IRIS2028-1109.pdf [accessed 05/05/2013]

Fristedt, T. and Silferduk, F., 2009. R&D work –improved model based pipetracker system. [online] Available at: http://www.tekna.no/ikbViewer/Content/750067/Fristed%20-%20Pipetracking.pdf [accessed 16/04/2013]

Førde, T, 2013. Eksportrekord for gass. [online] Available at: http://www.aftenbladet.no/energi/Eksportrekord-for-gass-3100715.html#.UVBTDRymgs4 [accessed 25/03/2013]

Gartland, P.O. and Bich, N.N., 2004, Internal Corrosion of dry gas Pipelines during upsets. Available through: OnePetro website: http://www.onepetro.org/mslib/servlet/onepetropreview?id=NACE-04199 [accessed 20/03/2013]

Gassco, n.da, Gassco – Norwegian gas to Europe

Gassco, n.db, Extreme pipeline inspection

Gassco, 2007, Research and development summary report 2003-2007

Gassco, 2010. Secondary market for capacity in Gassled. [online] Available at: http://www.energy-regulators.eu/portal/page/portal/EER_HOME/EER_ACTIVITIES/EER_INITIATIVES/GRI/North_West/Priorities1/Capacity/Secondary%20markets/Tab/2nd%20meeting%20-%2022%20Jan.%202010 [accessed 23/04/2013]

Gassco, 2011a. Gassco Annual report 2011

Gassco, 2011b. Annual report 2011- research and development.

Gassco, 2012. NCS2020 – En studie av fremtidens gassinfrastruktur.

Gassco, 2012. Vision and values. [online] Available at: http://www.gassco.no/wps/wcm/connect/Gassco-EN/Gassco/Home/om-gassco/visjonogverdier/ [accessed 26/04/2013]

Gassco, 2013. Infrastructure development, [online] Available at: http://www.gassco.no/wps/wcm/connect/Gassco-EN/Gassco/Home/var-virksomhet/utviklingavinfrastruktur/ [accessed 16/04/2013]

Gazprom, 2012. Gazprom to continue reinforcing its standing in Europe. [online] Available at: http://www.gazprom.com/press/news/2012/april/article134112/ [accessed 18/05/2013]

Giroux, J., 2013. Energy infrastructure attack database complete. [online] Available at: http://trackingenergyattacks.com/update-energy-infrastructure-attack-database [accessed 18/04/2013]

Gjertveit, E., Berge, J.O. and Opheim B.S., 2010. The Kvitebjørn Pipeline Repair. Available through: OnePetro website: http://www.onepetro.org/mslib/servlet/onepetropreview?id=OTC-20814-MS [accessed 15/03/2013]

Gloystein, H. 2012. Europe's LNG supplies to drop 70 pct by 2015 –Barclays. [online] Available at: http://in.reuters.com/article/2012/08/09/energy-lng-idINL6E8J9CA820120809 [accessed 07/04/2013]

Gould, T., 2013. European gas markets in a global context Presentation during 1st EU Norway energy conference. Available through: European commission website: http://ec.europa.eu/energy/gas_electricity/events/20130305_norway_energy_conference_en.htm [accessed 13/04/2013]

Government, 2013. Consultation paper, Suggestion of tariff changes. [online] Available at: http://www.regjeringen.no/upload/OED/pdf%20filer/H%C3%B8ringer/Hoeringsnotat150113.pdf [accessed 04/04/2013]

Gurkov, A., 2012. Nordstream – Supply without demand. [online] Available at: http://www.dw.de/nord-stream-supply-without-demand/a-16288908 [accessed 03/04/2013]

Hafner, M., 2012. Russian Strategy on Infrastructure and Gas Flows to Europe. [online] Available at: http://www.polinares.eu/docs/d5-1/polinares_wp5_chapter5_2.pdf [accessed 27/04/2013]

Harbo, H., 2013. Investorer uten tillit til Norge. [online] Available at: http://www.aftenbladet.no/energi/Investorer-uten-tillit-til-Norge-3131621.html#.UVp5nxziks6 [accessed 04/04/2013]

Hawaiianattols.org, 201 Painting the seafloor: Why and how we map, [online] Available at: http://www.hawaiianatolls.org/research/June2006/painting_seafloor.php [accessed 17/04/2013]

Health & Safety Executive, 2009. Guidelines for pipeline operators on pipeline anchor hazards. [online] Available at: http://www.hse.gov.uk/pipelines/pipeline-anchor-hazards.pdf [accessed 07/04/2013]

Hendricks, P. 2012. Gassco: Norwegian gas to Europe. [online] Available at: http://www.gassco.no/wps/wcm/connect/eebc5c8046ff4108b441b4bb467833c3/11771-Gassco_hovedbrosjyre2011_engelsk_WEB.pdf?MOD=AJPERES [accessed 05/04/2013]

Heren, P., 2013. How to sell more Norwegian gas to Europe. [online] Available at: http://energiogklima.no/nyhetsblogg/patrick-heren/how-to-sell-more-norwegian-gas-to-europe/ [accessed 10/04/2013]

Holmes, K.R., 2013. Staying one step ahead of cyber attacks. [online] Available at: http://www.washingtontimes.com/news/2013/apr/17/holmes-staying-one-step-ahead-of-cyberattacks/ [accessed 18/04/2013]

HSE, 2009. Guidelines for pipeline operators on pipeline anchor hazards. [online] Available at: http://www.hse.gov.uk/pipelines/pipeline-anchor-hazards.pdf [accessed 12/04/2013]

Hynne H., 2007, Optimal arbeidsdeling mellom aktører I en verdikjede for gass transport. [online] Available at: http://www.magma.no/optimal-arbeidsdeling-mellom-aktoerer-i-en-verdikjede-forgasstransport [accessed 13/04/2013]

IAM, 2012. Asset Management – an anatomy. Available through: The Institute of Asset Management website: http://theiam.org/what-is-asset-management/anatomy-asset-management [accessed 20/01/2013]

ICS-CERT, 2012. ICS-Cert Monitor October/November/December 2012, [online] Available at: http://ics-cert.us-cert.gov/pdf/ICS-CERT_Monthly_Monitor_Oct-Dec2012.pdf [accessed 18/04/2013]

IEA, 2011. World Energy Outlook 2011 – are we entering a golden age of gas?. [online] Available at: http://www.worldenergyoutlook.org/media/weowebsite/2011/WEO2011_GoldenAgeofGasReport.pdf [accessed 05/03/2013]

IGAM, 2013. Asset Management Strategy, [online] Available at: http://Igam.wikidot.com/asset-management-strategy [accessed 23/04/2013]

Johnsen, E., n.d.. Gas transportation system presentation. [online] Available at: http://www.regjeringen.no/Upload/OED/Vedlegg/Norwegian%20model/Norwegian_model_ERIK_JOHNSEN.pdf [accessed 12/02/2013]

Jones, R.P., Paterson, G. and Nespeca, G.A., 2011. IBP1033_22 The Flexible Grouted Clamp – A Novel Approach to Mergency Pipeline Repair. [online] Available at: http://www.penspenintegrity.com/downloads/virtual-library/flexible-grouted-clamp.pdf [accessed 06/03/2013]

Kaplan R.S. and Norton D. P., 2004. Strategy Maps: Converting Intangible Assets Into Tangible Outcomes. Harvard Business Press.

Kramer, W., 2013. How much bigger can container ships get?, [online] Available at: http://www.bbc.co.uk/news/magazine-21432226 [accessed 14/03/2013]

Kystverket, 2010. Helhetlig forvaltningsplan for Nordsjøen og Skagerrak - Statusbeskrivelse for skipstrafikk. [online] Available at: http://www.klif.no/publikasjoner/2666/ta2666.pdf [accessed 10/04/2013]

Landre, E., 2012. EU nedjusterer vekstutsiktene. [online] Available at: http://e24.no/makro-og-politikk/eu-nedjusterer-vekstutsiktene/20365096 [accessed 03/05/2013]

Lefranc, J.M., 2013. *Documentary:* Killer drones and secret wars

Lemos, R., 2002. What are the real risks of cyber terrorism. [online] Available at: http://www.zdnet.com/news/what-are-the-real-risks-of-cyberterrorism/124765 [accessed 18/04/2013]

Lewis, H.Ø., 2011. Må legge til rette for nye Gassled-eiere. [online] Available at: http://www.aftenbladet.no/energi/Ma-legge-til-rette-for-nye-Gassled-eiere-2894849.html#.UV1MQxziks4 [accessed 04/04/2013]

LNG world news, 2013. [online] Available at: http://www.lngworldnews.com/japan-december-lng-imports-climb-7-4-percent/ [accessed 30/01/2012]

Lorentzen, M. and Hessevik, J., 2013. Statoil utsetter oljeprosjekt etter skatteskjerpelse. [online] Available at: http://e24.no/olje-og-raavarer/statoil-utsetter-johan-castberg-prosjektet/20377639 [accessed 05/06/2013]

Løvås, J., 2011, Finansaktører I gassrør – Er regulering av gasseksportsystemet robust? [online] Available at: https://www.duo.uio.no/handle/10852/16997 [accessed 30/04/2012]

Maurer, R, 2013. Why 70% of changes fail, [online] Available at: http://www.reply-mc.com/2010/09/19/why-70-of-changes-fail-by-rick-maurer/ [accessed 26/04/2013]

MacArtney, 2013. Precision stability for excellent survey results. [online] Available at: http://legacy.macartney.info/default.asp?objtype=mnews&ilanguage=dansk&func=showdetail&id=2531&menuItem=menuItemA_a_1911_a_&curMenu=A [accessed 16/04/2013]

MacDonald, M., 2001. Parloc 2001: The Update of Loss of Containment Data for Offshore Pipelines. [online] Available at: http://www.hse.gov.uk/pipelines/parloc-2001-report.pdf [accessed 30/03/2013]

Mann, C.C., 2013. What if We Never Run Out of Oil?, [online] Available at: http://www.theatlantic.com/magazine/archive/2013/05/what-if-we-never-run-out-of-oil/309294/3/ [accessed 18/05/2013]

Marine Accident Investigation Branch,2008. Report on the investigation of young Lady, dragging anchor. [online] Available at: http://www.maib.gov.uk/cms_resources.cfm?file=/Young_Lady.pdf accessed 19/03/2013

MBARI, 2009. The sonar system. [online] Available at: http://www.mbari.org/auv/MappingAUV/sonars.htm [accessed 16/04/2013]

McLeod, N.J. and Kelly, R.T., 2007. Identifying and Filling Western Europe's Natural-Gas Storage Needs for the Next Decade, SPE 110320. Available through: OnePetro website: http://www.onepetro.org/mslib/servlet/onepetropreview?id=SPE-110320-MS [accessed 11/04/2013]

Melling, A.J. , 2010, Natural Gas Pricing and Its Future – Europe as the Battleground. Washington D.C., Carnegie Endowment for International Peace.

Merriam-webster, 2013, Terrorism, [online] Available at: http://www.merriam-webster.com/dictionary/terrorism accessed 18/04/2013

Mesh, 2013. Suites of acoustic techniques. [online] Available at: http://www.searchmesh.net/default.aspx?page=1834 accessed 16/04/2013

Ministry of Petroleum and Energy, 2011. Meld. St. 28 sct.4.6.1. [online] Available at: http://www.regjeringen.no/nb/dep/oed/dok/regpubl/stmeld/2010-2011/meld-st-28-2010-2011/4/6.html?id=649761 [accessed 04/04/2013]

Morgrip, 2006, Morgrip News, issue 1 September. [online] Available at: http://www.hydratight.com/sites/default/files/downloads/media/hydratight-morgrip-newsletter-092006.pdf [accessed 13/04/2013]

Nash, I., 2011. Inspection, Maintenance and Repair of Deepwater Pipelines. [online] Available at: http://www.peritusint.com/docs/UDP2011-IRM.pdf [accessed 20/04/2013]

Nikl, H. and Pennington-Bick, D., 2010, Role of Gas Markets in Gas Monetization. Case Study: Europe Gas Market Development. Available through: OnePetro website: http://www.onepetro.org/mslib/servlet/onepetropreview?id=SPE-131660-MS [accessed 21/04/2013]

Nord stream, 2013. Images. [online] Available at: http://www.nord-stream.com/press-info/images/welding-habitat-3403/ [accessed 2013]

NPD, 2011. The Norwegian Petroleum Directorate. [online] Available at: http://www.npd.no/en/About-us/ [accessed 26/04/2013]

NPD, 2012a. NPD facts 2012

NPD, 2012b. Positive signs in a complex picture, [online] Available at: http://www.npd.no/en/Publications/Norwegian-Continental-Shelf/No1-2012/Positive-signs-in-a-complex-picture/ accessed 10/04/2013

NPD, 2012c. Framework and organization, [online] Available at: http://www.npd.no/en/Publications/Facts/Facts-2012/Chapter-2/ accessed 06/05/2013

Nysæter, J.B. and Wottrich V., 2012. Gas Markets 101. [online] Available at: http://www.ipt.ntnu.no/~jsg/undervisning/naturgass/lysark/LysarkNysaeter2012.pdf [accessed 03/05/2013]

Odland J., 2011, MOK 120 Offshore field development compendium held at the University of Stavanger

OGP, 2010. OGP Risk Assessment Data Directory – Riser & Pipeline release frequencies *Report No. 434-4 March 2010.* [online] Available at: http://www.ogp.org.uk/pubs/434-04.pdf [accessed 29/03/2013]

Orsolato, R., Fabbri, S. and Cherubini, P., 2011. Transmediterranean Pipelines Repair. Available through: OnePetro website: http://www.onepetro.org/mslib/app/Preview.do?paperNumber=OMC-2011-121&societyCode=OMC [accessed 06/04/2013]

Oskarsson, O., 2012. Acoustic pipeline inspection – Dream or reality? Field experiences 2011-2012

Pennwellnet, 2013. images, [online] Available at: http://images.pennwellnet.com/ogj/images/ogj3/9722jrh02.gif [accessed 17/04/2013]

Regjeringen, 2013. Petoro AS. [online] Available at: http://www.regjeringen.no/en/dep/oed/Subject/state-participation-in-the-petroleum-sec/petoro-as-2.html?id=445747 [accessed 27/03/2013]

Perlroth, N., 2013 . Critical Infrastructure Systems Seen as Vulnerable to Attack. [online] Available at: http://bits.blogs.nytimes.com/2013/01/17/critical-infrastructure-systems-seen-as-vulnerable-to-attack/ [accessed 18/04/2013]

Perrow, C., 1999. Normal accidents: Living with high-risk technologies, Chapter -3: Complexity, Coupling , and Catastrophe

Petoro, 2013. About Petoro. [online] Available at: http://www.petoro.no/about-petoro [accessed 26/04/2013]

Pointon, D., 2005. Terrorist Targets,.[online] Available at: http://www.historyofwar.org/articles/concepts_terrortargets.html [accessed 18/04/2013]

Prodhan, G. 2012. IEA head sees no golden age soon for European gas. [online] Available at: http://www.reuters.com/article/2012/10/04/us-oil-reserves-iea-idUSBRE8930TQ20121004 [accessed 14/04/2013]

Rovik, T.M. and Fossøy, K., 2013. Fra stabilitet til statlig opportunisme, Stavanger Aftenblad 24/05/2013

RT.com, 2012. BP wants Russia's Nord Stream gas pipeline to reach UK. [online] Available at: http://rt.com/business/bp-nord-stream-pipeline-uk-601/ [accessed 08/04/2013]

Ruppel, C., 2011, Methane Hydrates and the Future of Natural Gas . [online] Available at: http://mitei.mit.edu/system/files/Supplementary_Paper_SP_2_4_Hydrates.pdf accessed [15/05/2013]

Schultz, S. and Bidder, B., 2013. Under Pressure: Once Mighty Gazrom Loses Its Clout. [online] Available at: http://www.spiegel.de/international/world/gazprom-gas-giant-is-running-into-trouble-a-881024.html [accessed 06/02/2013]

Schwab, K., 2013. The Global Competitiveness Report 2012-2013. [online] Available at: http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2012-13.pdf accessed [18/04/2013]

Shalegas-europe, 2013. Map over shale gas in Europe. [online] Available at: http://www.shalegas-europe.eu/en/ [accessed 27/05/2013]

Shea, D.A., 2003. Critical Infrastructure: Control Systems and Terrorist Threat. . [online] Available at:http://www.fas.org/irp/crs/RL31534.pdf [accessed 13/05/2013]

S.L. Ross, Environmental Research Ltd, SINTEF and Well flow Dynamics, 2009. Assessing Risk and Modeling a Sudden Gas Release Due to Gas Pipeline Ruptures.

Sotra.net, 2013. Speck anchors. [online] Available at: http://www.sotra.net/index.php?mapping=44 [accessed 17/04/2013]

Stream Repsol –natural LNG, 2012. Image, Supplying LNG to Europe

Technip, 2013. Technip awarded two-year extension of frame contract for pipeline repair services. [online] Available at: http://www.technip.com/en/press/technip-awarded-two-year-extension-frame-contract-pipeline-repair-services [accessed 14/03/2013]

Torvaldsen, L. and Rafaelsen, L., 2013. Norge har ikke oversikt over hvem som hacker. [online] Available at: http://www.dagbladet.no/2013/02/25/nyheter/hacking/datasikkerhet/informasjonsteknologi/hackere/25935409/ [accessed 18/04/2013]

Torve, T., 2012. Politiets responstid. [online] Available at: http://tovelise.mittap.no/-/bulletin/show/749900_politiets-responstid [accessed 19/04/2013]

The Economist, 2013a. Europe's dirty secret – The unwelcome renaissance. [online] Available at: http://www.economist.com/news/briefing/21569039-europes-energy-policy-delivers-worst-all-possible-worlds-unwelcome-renaissance [accessed 05/02/2012]

The Economist, 2013b. Gazprom - Russia's wounded giant. [online] Available at: http://www.economist.com/news/business/21573975-worlds-biggest-gas-producer-ailing-it-should-be-broken-up-russias-wounded-giant [accessed 07/04/2013]

The Economist, 2013c. Unconvential gas in Europe – Frack to the future. [online] Available at: http://www.economist.com/news/business/21571171-extracting-europes-shale-gas-and-oil-will-be-slow-and-difficult-business-frack-future [accessed 29/05/2013]

Tidende, B., 2013. Væpnede vakter i Skottland, to gjerder i Norge. [online] Available at: http://www.aftenbladet.no/energi/Vapnede-vakter-i-Skottland_-to-gjerder-i-Norge-3109472.html#.UXD5krXiks4 [accessed 19/04/2013]

Treloar, S. and Holter, M., 2013. Norway Plans 90% Gas Tariff Cut in Blow to Gassled Investors. [online] Available at: http://www.bloomberg.com/news/2013-01-15/norway-proposes-gassled-tariff-cut-to-boost-exploration-1-.html [accessed 11/02/2013]

Valdemarsen, J.W., 1994. Overtråling av rørledninger gir lite skader og slitasje. [online] Available at: http://brage.bibsys.no/imr/bitstream/URN:NBN:no-bibsys_brage_3265/1/199413.pdf [accessed 02/04/2013]

Vermulen, U., Feasey, G. and Rottenberg, J., 2011. Economic Comission for Europe Committee on Sutainable Energy – Chapter 3: Competition between LNG and pipeline gas. [online] Available at:

http://www.unece.org/fileadmin/DAM/energy/se/pp/wpgas/21wpg_2011/18Jan2011/Rottenberg_Suez.pdf [accessed 04/04/2013]

Vervik, S., 2011. Pipeline Accidental Load Analysis. [online] Available at: http://ntnu.diva-portal.org/smash/record.jsf?pid=diva2:490903 [accessed 02/04/2013]

Wenman, T. and Dim, J., 2012. Pipeline Integrity Management SPE 161948. Available through: OnePetro website: http://www.onepetro.org/mslib/servlet/onepetropreview?id=SPE-161948-MS [accessed 01/04/2013]

Wyatts, 2005. Bathtub curve, [online] Available at: http://en.wikipedia.org/wiki/File:Bathtub_curve.svg [accessed 22/05/2013]

9. Appendices

GNG Pipeline Risk Quantification

Scope

The purpose of this document is to highlight the possible risks and challenges identified in which could pose a threat or challenge to the GNG pipeline in current or future scenarios. The risks and challenges will be evaluated on the basis of topics and industry issues described in the thesis. As such, a large degree of personal opinion established from researched material is present within the evaluation.

The risk quantification shall identify potential unacceptable high (VH and H) risks. They shall be systemized and graded according to consequence and severity. Mitigating barriers/measures shall be described in order to reduce unacceptable risks to an acceptable level.

The risks are organized with respect to consequence categories:

- Human safety risks.
- Environmental risks.
- Economical risks.
- Availability Impact risks.
- Pipeline Gas Demand risks.

The input to the risks has been provided by:

- Information presented throughout the thesis' chapters 1,2 and 3.

Risk assessment is based upon DNV-RP-F116 Integrity Management of Submarine Pipelines (October 2009).

Putting all risks into the Risk Acceptance Matrix makes it possible to see whether or not each risk is Acceptable or Unacceptable.

Methodology

The first step is to identify possible threats and challenges. Broad research within multiple fields (physical, political, etc.) is to be conducted and evaluated on the basis of said research.

By quantifying each finding according to all consequence categories, the nature of the risk becomes evident. Accordingly, the likely probability of the event from occurring is thereafter introduced to the isolated event.

As risk can be defined as Risk = Probability x Consequence (DNV, 2009), the overall risk acceptance level can be found and categorized as shown in Table 9-1.

In addition, mitigating measures/barriers, in which have already or should be implemented in order to control the majority of risks, are presented. A second evaluation of risks at hand after the implementations of barriers could have been conducted, but due to lack of specialized knowledge and a large degree of uncertainty in the field, the impact of some of the proposed barriers are somewhat ensure.

Risk	Description
VH - Very High	Unacceptable region - Immediate action to be taken
H - High	Unacceptable region - Action to be taken
M - Medium	ALARP region - Action to reduce risk may be evaluated
L - Low	Acceptable region - Low
VL - Very Low	Acceptable region - Insignificant

Table 9-1 Risk Acceptance Definitions (DNV, 2009)

Summary & Findings

21 findings were identified. Quantity of findings were divided into risk levels as listed below as well as illustrated in Table 9-2.

- 6 VH risks
- 4 H risks
- 7 M risks
- 2 L risks
- 2 VL risks

Consequence Scale	Health, Safety and Security	Environment	Financial Impact	Availability Impact	Pipeline gas demand Impact	Increasing Probability				
						P1	P2	P3	P4	P5
						Very unlikely 0 to 1%	Unlikely 1 to 5%	Less likely 5 to 25%	Likely 25 to 50%	Very likely 50 to 100%
C5	Several fatalities on workforce or fatalities to public. Serious illness, psychological stress or chronic exposure resulting in significant life shortening effects / death to public.	Adverse permanent impacts on key ecosystem functions and services in larger natural habitats (e.g. Restitution time > 10 years).	> 500 million	Major unplanned down time	Huge effects on amount of flow	3	4	4	1	0
C4	1-2 fatalities on workforce. Serious illness, psych. stress or chronic exposure resulting in significant life shortening effects / death to workforce.	Adverse long term impact on ecologically valuable natural habitats (e.g. Restitution time 3-10 years).	200 - 500 million	Minor unplanned down time	Major effects	1	1	0	1	0
C3	Serious injury, psychological stress or illness with possible permanent effects.	Adverse medium or long term impacts on a significant part of habitats (e.g. Restitution time 1-3 years). impact on natural habitats.	50 - 200 million	Extended planned down time	Moderate effects	1	0	0	0	0
C2	Medical treatment injury or occupational illness or short term psychological stress.	Adverse short term impact on natural habitats.	10 - 50 million	Minor extended planned down time	Minor effects	0	1	0	1	0
C1	First aid injury or occupational illness / effect with minor impact on health and ability to function.	No or very limited impact on natural habitats. No impact on population level, only on individual organism level.	0 - 10 million	No affect to pipeline availability.	None	0	0	0	1	2

Table 9-2 Quantity - Risk Acceptance Matrix with Risks Plotted

Table 9-3 shows the whole performed risk quantification. Summaries on the basis of the table is given as spider diagrams showing the extent of each consequence group along corresponding to the inherent issues discussed in the previous section (example section 3.1.4). The color of the spider diagram shows the overall risk acceptance level according to Table 9-1.

On the basis of these findings, chapter 4 (Asset Management Strategy) delves further in to the main issues and how to further mitigate such factors.

	Consequence Scale	Consequence Categories					Increasing Probability				
		Health, Safety and Security	Environment	Financial Impact	Availability Impact	Pipeline gas demand Impact	P1 Very unlikely	P2 Unlikely	P3 Less likely	P4 Likely	P5 Very likely
	C5	Several fatalities on workforce or fatalities to public. Serious illness, psychological stress or chronic exposure resulting in significant life shortening effects / death to public.	Adverse permanent impacts on key ecosystem functions and services in larger natural habitats (e.g. Restitution time > 10 years).	> 500 million NOK	Major unplanned down time	Huge effects on amount of gas demand	M	H	VH	VH	VH
	C4	1-2 fatalities on workforce. Serious illness, psych. stress or chronic exposure resulting in significant life shortening effects / death to workforce.	Adverse long term impact on ecologically valuable natural habitats (e.g. Restitution time 3-10 years).	200 - 500 million NOK	Minor unplanned down time	Major effects	L	M	H	VH	VH
	C3	Serious injury, psychological stress or illness with possible permanent effects.	Adverse medium or long term impacts on a significant part of habitats (e.g. Restitution time 1-3 years). impact on natural habitats.	50 - 200 million NOK	Extended planned down time	Moderate effects	VL	L	M	H	VH
	C2	Medical treatment injury or occupational illness or short term psychological stress.	Adverse short term impact on natural habitats.	10 - 50 million NOK	Minor extended planned down time	Minor effects	VL	VL	L	M	H
	C1	First aid injury or occupational illness / effect with minor impact on health and ability to function.	No or very limited impact on natural habitats. No impact on population level, only on individual organism level.	0 - 10 million NOK	No affect to pipeline availability.	None	VL	VL	VL	L	M

Haz. No.	Risk Category	System / Location	Hazard	Hazard Description / Result	Ultimate Event	Consequence: Health, Safety and Security	Consequence: Environment	Consequence: Financial Impact	Consequence: Availability Impact	Consequence: Pipeline gas demand Impact	Probability	Manageability Scale	Consequence: Health, Safety and Security	Consequence: Environment	Consequence: Financial Impact	Consequence: Availability Impact	Consequence: Pipeline gas demand Impact	Risk Category	Maximum Consequence	Risk Ranking	Barrier
1	Physical	GNP Pipeline	Internal corrosion	Upset in gas processing facility allowing unwanted water content in to gas flow, increasing the possibility of internal corrosion to develop.	Reduced pipeline wall thickness, leading to a possibly overstressed pipeline.	C1	C1	C2	C1	C1	P2	VL	1	1	2	1	1	Financial Impact	C2	4	Utilized advanced flow measurement capabilities in order to ensure propper gas composition.
2			External corrosion	Outer corrosive protection layer is damaged, along with insufficient sacrificial anode capabilities.	Reduced pipeline wall thickness, leading to a possibly overstressed pipeline.	C1	C1	C4	C1	C1	P2	M	1	1	4	1	1	Financial Impact	C4	8	Inspect pipeline and sacrificial anodes anually and check the electric potential at bare metal points to ensure that no reduction takes place on the pipeline.
3			Field Joint damage	Third party impact causes field joint to lose its integrity.	Outer protective concrete layer is damaged, and provides insufficient protection against further impact at specific location.	C1	C1	C2	C1	C1	P4	M	1	1	2	1	1	Financial Impact	C2	8	Inspect pipeline and sacrificial anodes anually .Rock dump if in prone vessel activity area.
4			Free Spans developing	Long free spans can cause the pipeline to become over utilized	Overstressing pipeline	C1	C1	C1	C1	C1	P4	L	1	1	1	1	1	Health, Safety and Security	C1	4	Inspect pipeline annually to identify large pipeline spans. Rock dump before the span becomes a threat, or alternatively recalculate design limit at the isolated location.
5			Trawl Board impact	Trawl board hits pipeline	Trawl board inflicts damage to pipeline concrete coating, revealing bare metal.	C1	C1	C1	C1	C1	P5	M	1	1	1	1	1	Health, Safety and Security	C1	5	None
6			Trawl Board Hooking	Trawl board hooks to pipeline on seabed, or on freespanning pipeline	Trawlboard inflicting damage to concrete coating and getting stuck under it.	C1	C1	C1	C1	C1	P5	M	1	1	1	1	1	Health, Safety and Security	C1	5	Rock dump large freespans.
7			Anchor impact	Planned anchor drop. Vessel at rest.	Anchor hits pipeline on its descent causing damage to the concrete coating. Worst case causing local derformation and down time.	C1	C1	C5	C5	C5	P2	H	1	1	5	5	5	Financial Impact	C5	10	Predefined safe anchorage locations.
8			Anchor impact	Anchored vessel is dragged in storm, causing anchor to hit pipeline.	Damage to pipeline coating or possibly local bending/deformation, which could cause failure.	C1	C1	C5	C5	C5	P2	H	1	1	5	5	5	Financial Impact	C5	10	None
9			Anchor impact	Accidentally dropped anchor hooks on to the pipeline during transit	Moving pipeline off original lay position, causing severe pipeline damage and/or causing a rupture leading to leakage. Downtime	C2	C2	C5	C5	C5	P2	H	2	2	5	5	5	Financial Impact	C5	10	Possibly lessening the risk by burrying pipeline in highly trafficated areas.
10			Emergency valves not functioning properly	Valves not functioning during an incident	Leakage at end points	C2	C1	C3	C1	C1	P1	VL	2	1	3	1	1	Financial Impact	C3	3	Annual valve function tests to ensure full functionality
11			Extended pipeline do wn time due to unexpected incident	Reduced reputation	May result in reduced gas sales price in long term contracts	C1	C1	C5	C1	C3	P1	M	1	1	5	1	3	Financial Impact	C5	5	Ensure contigency plans are always ready, both regarding physical pipleine, and possibly rerouting gas through other available pipelines.
12	Gassled Ownership		Tariff is changed by government	Gassled owners not recieving anticipated revenues from investments.	Gassled has less incentives to ensure optimal perfomance.	C1	C2	C5	C1	C2	P4	VH	1	2	5	1	2	Financial Impact	C5	20	Formal complaint to the government regarding their imposed change of tariff.
13			Conflicts of Interest	Conflicts of interest between major stakeholders	Inefficient system at stakeholder level.	C1	C1	C5	C1	C3	P3	VH	1	1	5	1	3	Financial Impact	C5	15	Ensure alignment between all stakeholders (Gassco, Gassled, TSP, Government)
14	Market & Politics		Russian competition	Russia decreases gas prices substantially	Export shares taken from Norway	C1	C1	C4	C1	C3	P1	L	1	1	4	1	3	Financial Impact	C4	4	Increase Norwegian gas demand by either further moving to spot pricing, or lowering prices.
15			Russian competition	The Russian Gas export pipeline Nord Stream increases our main competitors' supply capacity.	Lower demand for Norwegian gas	C1	C2	C5	C1	C4	P2	H	1	2	5	1	4	Financial Impact	C5	10	Increase Norwegian gas demand by either further moving to spot pricing, or lowering prices.
16			LNG competition	LNG introduces a heightened supply of gas to Europe from distant markets	Reduction in European spot prices of gas, forcing local supplier's gas prices down.	C1	C1	C4	C1	C3	P4	VH	1	1	4	1	3	Financial Impact	C4	16	Effectivising production and lowering gas prices to adjust to market prices.

Table 9-3 Risk Acceptance Matrix with Risks Plotted

	Consequence Scale	Consequence Categories					Increasing Probability				
		Health, Safety and Security	Environment	Financial Impact	Availability Impact	Pipeline gas demand Impact	P1	P2	P3	P4	P5
							Very unlikely	Unlikely	Less likely	Likely	Very likely
	C5	Several fatalities on workforce or fatalities to public. Serious illness, psychological stress or chronic exposure resulting in significant life shortening effects / death to public.	Adverse permanent impacts on key ecosystem functions and services in larger natural habitats (e.g. Restitution time > 10 years).	> 500 million NOK	Major unplanned down time	Huge effects on amount of gas demand	M	H	VH	VH	VH
	C4	1-2 fatalities on workforce. Serious illness, psych. stress or chronic exposure resulting in significant life shortening effects / death to workforce.	Adverse long term impact on ecologically valuable natural habitats (e.g. Restitution time 3-10 years).	200 - 500 million NOK	Minor unplanned down time	Major effects	L	M	H	VH	VH
	C3	Serious injury, psychological stress or illness with possible permanent effects.	Adverse medium or long term impacts on a significant part of habitats (e.g. Restitution time 1-3 years). impact on natural habitats.	50 - 200 million NOK	Extended planned down time	Moderate effects	VL	L	M	H	VH
	C2	Medical treatment injury or occupational illness or short term psychological stress.	Adverse short term impact on natural habitats.	10 - 50 million NOK	Minor extended planned down time	Minor effects	VL	VL	L	M	H
	C1	First aid injury or occupational illness / effect with minor impact on health and ability to function.	No or very limited impact on natural habitats. No impact on population level, only on individual organism level.	0 - 10 million NOK	No affect to pipeline availability.	None	VL	VL	VL	L	M

Haz. No.	Risk Category	System / Location	Hazard	Hazard Description / Result	Ultimate Event	Consequence					Probability	Manageability Scale	Consequence					Risk Category	Maximum Consequence	Risk Ranking	Barrier
						Health, Safety and Security	Environment	Financial Impact	Availability Impact	Pipeline gas demand Impact			Health, Safety and Security	Environment	Financial Impact	Availability Impact	Pipeline gas demand Impact				
17			European politicians	Not prioritizing gas as a clean energy source.Renewable energy sources heavily subsidized.	Natural gas becoming too expensive compared to other energy sources. Decrease in export.	C1	C1	C5	C1	C5	P3	VH	1	1	5	1	5	Financial Impact	C5	15	No main barriers
18			European politicians	European politicians unwilling to implement enough environmental policies limiting the amount of cheap coal being burnt.	Natural gas becomes too expensive compared to cheap coal.	C5	C5	C5	C1	C3	P3	VH	5	5	5	1	3	Health, Safety and Security	C5	15	No main barriers
19	Shale		European Shale gas	European Shale gas gains traction in European market	Less demand for Norwegian gas	C1	C4	C5	C1	C2	p1	M	1	4	5	1	2	Financial Impact	C5	5	Ensuring that Norwegian gas becomes attractive due to: increased spot market contracts, low prices, high availibility and reliability.
20	Terror		Terror attack	Cyber terrorism aimed towards SCADA system or other flow management tools	Vary parameters of flow, limit flow or even stopping flow.	C1	C1	C5	C5	C3	P3	VH	1	1	5	5	3	Financial Impact	C5	15	Implement security measures to systems.
21			Terror attack	Extremists targeting main infrastructural elements in order to gain public attention towards their cause.	Damage to pipeline, causing down time. The threat of repeatablility.	C3	C2	C5	C5	C3	P1	M	3	2	5	5	3	Financial Impact	C5	5	Security and govenrment intelligence