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The Feasibility and the Economic Viability of Shipping LNG via the Northern Sea Route

By
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Abstract

The melting of the sea-ice in the Russian Arctic has lead to a stronger optimism than ever before as regards the supply of Norwegian LNG to Asia-Pacific via the Northern Sea Route (NSR). The successful completion of the world's first LNG supply via the NSR by the *Ob River* in 2012 has been to a large extent highlighted in the media. International oil & gas companies operating in northern Norway and Russia should see here promising opportunities to ship LNG via the NSR during the summer season.

The dissertation investigates the feasibility and the economics of the shipping of LNG via the NSR. The objective of the thesis is also to clarify and understand some crucial aspects, should shipping LNG on this new route occur one day.

The analysis presents a qualitative approach for the feasibility part. A more quantitative and numerical approach is carried out for the economic viability. The study evaluates the profitability for a trader of shipping LNG via the NSR compared to the Suez Canal route for a round trip Hammerfest-Yokohama. Further on, the economics of an annual regular service via the Suez Canal and a service via the NSR during summer with the Suez Canal for the rest of the year are compared. The models analyze also the advantage of operating a Triple-Fuel Diesel-Electric (TFDE) LNG carrier rather than a Steam Turbine (ST) vessel on these routes.

In a second part, an annual voyage plan is simulated in order to show how the trader can benefit from arbitrage opportunities on gas prices across the continents and to see how shipping via the NSR can be linked to exit strategies. The dissertation will also analyze the net present value of a 15-year LNG trading project and value an extension option of five years on a 15-year Time Charter contract.

Different comprehensive sensitivities on the results are carried out to deal with uncertainty, flexibility and to remedy with possible erroneous assumptions.

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Introduction

The increased Norwegian and Russian Barents Sea oil & gas offshore activity, as well as the onshore activity in Russia, have strengthened the attention paid to a deep-sea shipping route via the Northern Sea Route (NSR) in order to reach Asia-Pacific. The Arctic sea-ice is melting at an accelerated rate from year to year and light ice conditions from July to November on the NSR become more evident with time. The *Ob River's* NSR transit success in 2012 has marked the start of a new era for shipping LNG from Norway to Asia-Pacific during summer.

Since the NSR was officially opened to international commercial transit in 2009, the NSR Administration (NSRA), in collaboration with the Russian authorities and the icebreaking company Rosatomflot, has devoted considerable efforts to make the NSR a safe and reliable route for newcomers. Although the NSR will never be a replacement route to the Suez Canal, at least in the short to the medium term, the NSR has many positive aspects which can boost its competiveness with the Suez Canal during summer if the sea-ice continues melting at the current rate. A transit via the NSR requires however serious preliminary planning by the ship owner and the charterer and also a close cooperation with Rosatomflot and the NSRA, before and during the voyage. In fact, the presence of sea-ice and the unpredictable and frequent weather will not forgive if an accident should occur.

The importance of the NSR increases as the route can potentially save companies valuable time between Europe and Asia, with a shortened distance of approximately 40% compared to the Suez Canal route. However shortened distance is not always synonym of reduced costs by an equivalent percentage.

This dissertation has a first objective to argue for whether or not a transit via the NSR is feasible for a LNG tanker. The second objective is to answer the question whether or not it is economically viable to ship LNG on this route. The economic competitivenesses of the NSR and the Suez Canal will be compared.

I) The feasibility of shipping LNG via the Northern Sea Route

1.1 The LNG industry

1.1.1 Total E&P Norge's LNG activity in Norway

1.1.1.a) Definition of LNG

LNG stands for Liquefied Natural Gas and is a result of a liquefaction process of methane extracted from gas fields. The percentage volume of methane can vary depending on the origin of the gas. It can be superior to 95%, below 90% or in between 90% and 95% (Buhaug, 2011). The remaining percentages contain other hydrocarbons and gases such as carbon dioxide and nitrogen. The natural gas is liquefied in so called trains, compressors compressing the methane until it reaches a temperature of -163°C. At this temperature, the natural gas is in a liquid state and the volume is reduced by $1/630^{th}$ from its gaseous state at atmospheric pressure. It is then stored in refrigerated tanks before being loaded on LNG carriers ready to export (Stopford, 2009, pp.486). Although the process requires some extra costs, as for example capital costs, liquefaction and re-gasification costs and storage related costs, liquefying the gas is advantageous as it can be transported in much larger amounts before being re-gasified at the import terminal. Natural gas is regarded as an important source of energy for many countries since it provides basic needs such as heating and electricity. Furthermore, LNG is today seen as a clean source of energy and is becoming increasingly an alternative fuel for many shipping companies. LNG as bunker for ships for instance reduces carbon emissions by 20 to 30 percent and reduces sulfur oxide and nitrogen oxide discharges to significantly lower levels compared to traditional fuel oil (Advantage Environment, 2011).

1.1.1.b) Total E&P Norge, part of Total Group

Total Group is a French oil & gas company ranked as the fifth largest, based on market capitalization from December 2011. The Group has 96,000 employees spread across 130 different countries. With activities in both upstream (oil & gas exploration, development and production, LNG) and downstream operations (refining, marketing, and trading and shipping of crude oil and other products) Total has a well diversified portfolio of activities (Total, 2013a). The headquarters are located in Paris at La Défense. The group's center of research in exploration and development is located in the city of Pau in southern France (Total, 2013b).

Total is the world's fourth largest producer of natural gas and is among the top three LNG suppliers in the world. They are present in Yemen and Indonesia among many other countries. According to them, natural gas is expected to be the second largest fossil fuel in 2030. The LNG shipping will play a major role in meeting the global demand. To do so, the supply capacity will have to double in the next decade (Total, 2013c). Total is currently investing in two major projects in Australia, the Ichthys and Gladstone projects. Around 70% of the future LNG volumes extracted from Ichthys LNG will be sent to Japan. The first production should start by the end of 2016 (Robin & Demoury, 2012). According to Total, the LNG and the LNG shipping markets are respectively two perfect examples of innovative marketing and an efficient transportation mode. The group is chartering in partnerships around 70 of the total 370 LNG carriers across the world.

Total E&P Norge (TEPN) is a Norwegian wholly owned subsidiary of Total group and contributes to 12% of the company's oil & gas production. It is the biggest contributor of oil & gas among all the subsidiaries around the world (Total E&P Norge, 2013a). TEPN employs 375 employees and is located in the city of Stavanger (Laurent, 2013). TEPN has a solid portfolio of licenses with 90 in total of which they are operator in 27 of them (Total E&P Norge, 2013b).

1.1.1.c) Snøhvit, a major Norwegian gas production field

The gas field of Snøhvit is located in the Norwegian Barents Sea northwest from Hammerfest, at a water depth of 310-340 meters (Figure 1). It was discovered in 1984 and the development was approved the 7th March 2002 by the Norwegian Government. The operator of the gas field is Statoil Petroleum AS, the largest owner with a share of 36.79%. Other international oil & gas companies have licenses in the field which are Petoro AS (30.00%), TEPN (18.40%), GDF Suez E&P Norge AS (12%) and RWE Dea Norge AS (2.81%). The reservoirs contain gas, condensate and oil. The natural gas extracted from Snøhvit is sent to the liquefaction plant of Melkøya in Hammerfest through a 160-kilometer long pipeline (Figure 1). Arrived at the liquefaction facility, the gas enters a liquefaction process before it is shipped with LNG carriers to the international markets (Norwegian Ministry of Petroleum and Energy & Norwegian Petroleum Directorate, 2012). The liquefaction plant of Melkøya in Hammerfest is the only one in Europe (Robin & Demoury, 2012). The plant has recently increased its capacity to receive up to 210,000 m^3 LNG carriers, which up to now was limited to 160,000 m^3 (Laurent, 2013).

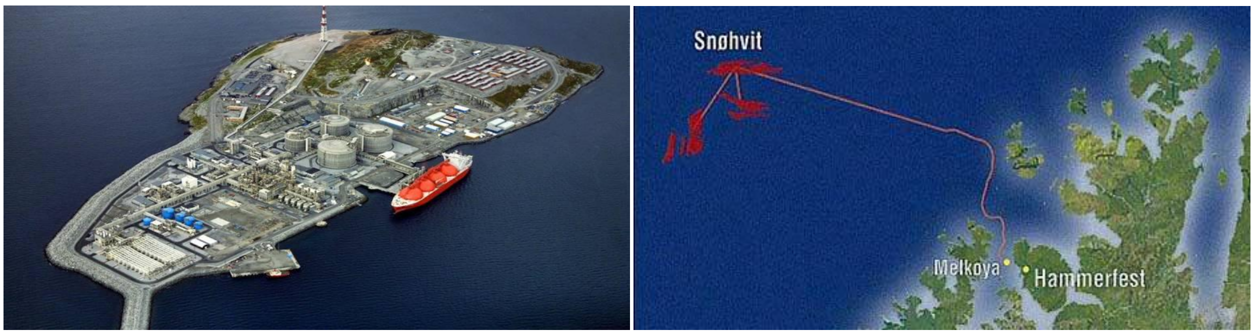

Figure 1: Statoil's LNG plant at Melkøya outside Hammerfest (left) and map of Snøhvit's location (right)

Source: (Aenergy , 2012)

1.1.1.d) TEPN's LNG fleet and nature of the charter agreement

TEPN operates two LNG carriers, the *Arctic Lady* and the *Meridian Spirit*, respectively owned by Høegh LNG and Teekay LNG Partners L.P. The specifications of the two vessels can be found in Appendix A for background information.

The *Arctic Lady* (Figure 2) entered into service for TEPN the 13th April 2006 on a long term Time Charter (TC) agreement of 20 years with an option of 5+5 years with Høegh LNG. The cargo tank containment system of the vessel is a 39.6 m diameter Moss sphere[1]. The spheres are suspended in the equator by a continuous skirt as we can see in Figure 3 (Laurent, 2013).

The *Meridian Spirit* (Figure 2), former *Maersk Meridian*, started a spot charter the 1st November 2010 with Maersk LNG, the former ship owner. The 9th December 2011, TEPN entered a long term TC of 18 years for the *Maersk Meridian* with an option of 5+4 years. In July 2012, Maersk LNG decided to sell the carrier to Teekay LNG Partners L.P; the name of the vessel was replaced by *Meridian Spirit*. This was made with the authorization from TEPN since they had the entire control of the vessel. The change in ship owner did not affect the time charter party (Laurent, 2013). The cargo tank containment system of the vessel is a Membrane type Mark III with a

[1] 35 mm aluminium tickness

primary 1.2 mm thickness corrugated stainless steel and secondary 0.6 mm thickness triplex (Figure 3) (Laurent, 2013).

Figure 2: The *Arctic Lady* (left) and the *Meridian Spirit* (right)

Source: (Skipsfoto, 2013) & (The Motorship, 2010)

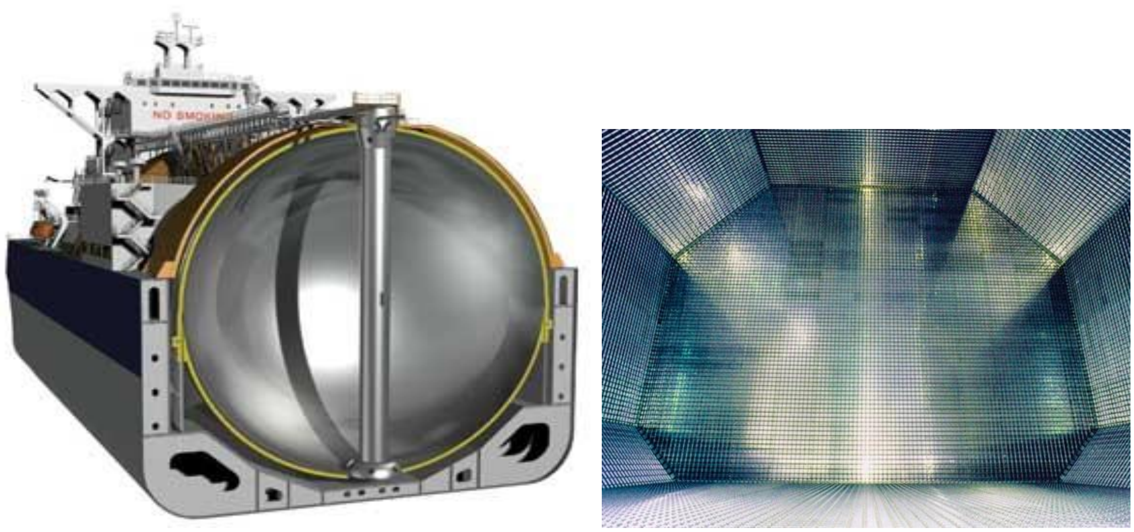

Figure 3: A typical Moss sphere tank (left) and inside view of a membrane tank (right)

Source: (Liquefied Gas Carrier, 2011) & (gCaptain, 2012)

Long term TCs are typically used for long-term finance of LNG tankers such as the *Arctic Lady* and the *Meridian Spirit*. They can be regarded as a long term leasing. The lessors, Høegh LNG and Teekay LNG, whose role is to finance the vessels, have little involvement with the asset beyond owning it. All operating responsibilities fall on TEPN, the lessee. The vessels are built to TEPN's specifications and are purchased by companies providing the finance, which can either be banks or large corporation companies for instance. The vessels are then leased under a long term agreement (Stopford, 2009, pp.308). For the *Arctic Lady* and the *Meridian Spirit*, the nature of the leasing agreement is a "Long Term Time Charter in Cost Pass through". The Time Charter Party (TCP) form used by TEPN is the Shell LNG Time Charter form. This charter form represents the LNG industry norm for chartering during long or shorter periods (Laurent, 2013).

Under "Long Term Time Charter in Cost Pass through", TEPN pays the daily long term time charter rate including the capital expenditures (CAPEX) and the operating expenditures (OPEX). Since TEPN controls the vessels, according to the charter form, they pay all voyage related costs, agency fees, canal dues, port charges, commissions for brokers and bunkering (Laurent, 2013). TEPN is marketing the LNG from the Snøhvit production facility to its London-based affiliate Total Gas and Power Limited (TGPL) on a long-term contract. The main destinations for this contract are the Gulf of Mexico, Spain and north-west Europe. For the North American market, TEPN exports LNG to the re-gasification terminals of Sabine Pass in the USA and Altamira in Mexico. In Spain, Snøhvit LNG has been shipped to Barcelona, Sagunto, Cartagena and Huelva. In 2012, LNG from Snøhvit has been delivered for the first time in the Fos-Cavaou re-gasification terminal in the south of France. Additionally to these main destinations, LNG from Snøhvit has also been delivered to Asian buyers (Terrade, 2013).

1.1.2 The LNG trade

1.1.2.a) The LNG supply and demand

From a supply perspective, the LNG production has been growing the last three decades. The growth has been accelerating since the early 2000s mainly due to the increased LNG demand from new emerging markets. Qatar is by far the world's largest producer and exporter of LNG. Their production reached 75.5 mt in 2011, representing a total share of 31% of world's production at that time (International Gas Union, 2011). In 2007, the country exported LNG to eight different countries while in 2011 23 countries imported LNG from Qatar. The strategic position of the country makes it well suited to export their gas to Asia-Pacific and Europe. Data from 2011 shows that 47% of their exports went to Asia-Pacific and 42% percent was sent to Europe (The Peninsula, 2012). With 18.7 mt of additional LNG volumes sold to the rest of the world, Qatar accounted for 67% of the global trade growth in 2011 (Robin & Demoury, 2012).

Malaysia is the second largest producer with around 2 million mt produced per month (Bakkelund, 2012). They overtook Indonesia's position in 2011 which now ranks third. Other countries such as Australia, Nigeria and Algeria are also major key actors in the world LNG supply (Figure 4). However, since 2000, the total world supply has been mainly driven by Qatar and Nigeria as the supply of LNG from the other countries has remained relatively stable. The LNG industry in Australia is still young, but the country has far more gas than it consumes internally. This has lead western oil & gas companies to enter the Australian market and invest heavily in new infrastructure and in LNG facilities. Australia's third LNG plant sent its first shipment to market in June 2012 (White, 2012).

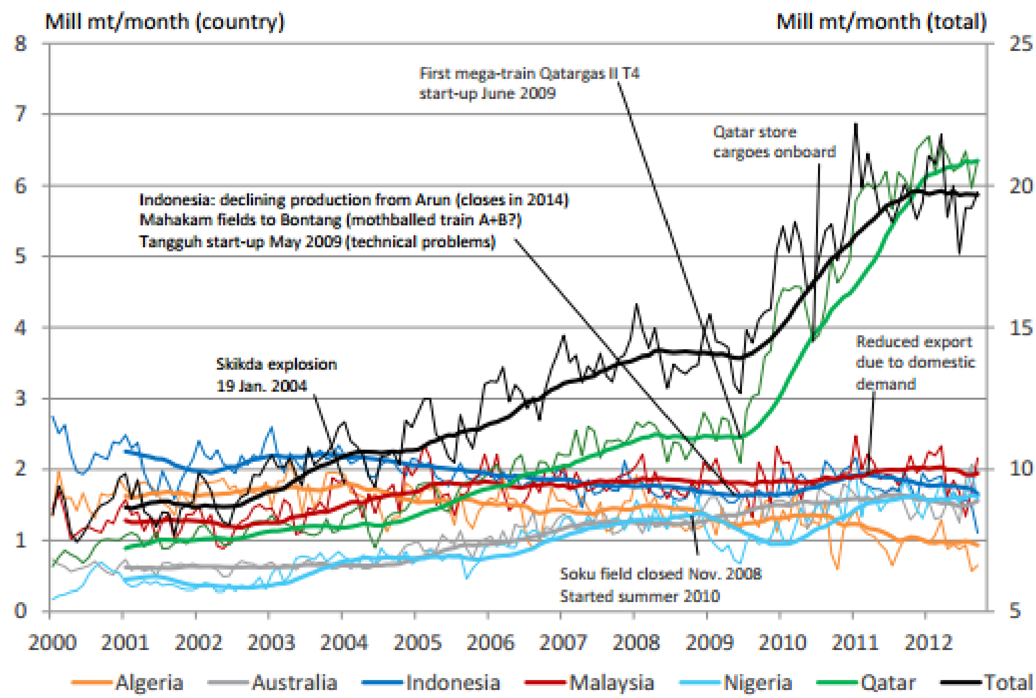

Figure 4: LNG production – monthly 1999 – 2012

Source: (Bakkelund, 2012)

As we have already mentioned, Total is investing massively in Australia with the Ichthys and Gladstone projects which are among the seven ongoing venture LNG projects in Australia (Paton, 2012). The country's LNG projects under way have reached an astonishing 170 billion dollars worth investments in 2012 (White, 2012). With this level of development, Australia is well placed to surpass Qatar as the largest exporter of LNG by the end of the decade. Total says that the country may produce as much as 100 million metric tons of LNG a year in the near future (Paton, 2012).

The world supply of LNG in 2012 declined by 1.9% compared to 2011, the first time ever in the past thirty years. Maintenance and unscheduled interruptions on existing liquefaction plants with only one new train coming into service for Pluto in Australia are the causes behind the reduced supply (Robin & Demoury, 2013).

Looking closely on the demand side, Japan is a central market today for LNG exporters and is by far the import leader of LNG in terms of annual volumes. The total imported volumes in 2011 were estimated to 78.8 mt (International Gas Union, 2011). Japan saw its LNG imports to increase dramatically after the Fukushima earthquake on 11th March 2011. Four of the 54 nuclear reactors in the country were severely damaged and 48 were shut down (Bakkelund, 2012). Consequently, alternative sources of energy had to be found and natural gas was one them. LNG demand from Japan during the second half of 2011 was on average 900,000 mt per month higher than the same period in 2010 (Hang, 2012). The country accounted for 41.6% of Asia's additional LNG imports and had a global LNG import share of 32.8% in 2011 (Robin & Demoury, 2012).

South Korea is the second larger importer of LNG and combined with Japan they consumed 48% of the LNG supplied in 2011. Recently, fast growing markets like China and India are seeing their LNG imports increasing remarkably as their appetite for more energy is greater (International Gas Union, 2011).

The LNG imports in Europe reached a peak in the first half of 2011. Over the second half of 2011, LNG imports have dropped by 8.7% year-on-year which was explained by the warmer weather and the lower utilization rates of the Spanish gas-fired power plants (Hang, 2012). The falling LNG imports into Spain started when the country shifted the Algerian imports from LNG to gas via pipelines. A new pipeline became operational in April 2011 (Hang, 2012). The decrease in LNG imports to Europe continued during the first half of 2012 and fell by 33% year-on-year over this period. This fall does not mean that the continent will remain undersupplied because they rely considerably on gas via pipelines coming from Norway and Russia. Furthermore, the price competitiveness relative to renewal energies and coal has been declining in the region. The negative trend should continue and supply of LNG to Europe should drop by 70% by 2015 from the August 2012 level (Gloystein, 2012). Figures for the first quarter of 2013 show that about 9 million tons of LNG has been delivered to Europe compared to 13.8 million for the first quarter in 2012. This negative trend is a combination of high prices in Asia causing diversions and also robust prices in Brazil and Argentina. Increased gas imports to the UK by pipelines in the first quarter 2013 from Norway and Holland have jumped around 10% compared to the last quarter in 2012, which in terms have pushed the LNG imports down (Meredith, 2013). Wood Mackenzie is predicting imports to drop until 2015. Beyond 2017, the imports should start rising again but it will take long time before we are back to the top level in 2011 (Meredith, 2013). In Figure 5, it is also worth to notice that the LNG imports in North America have flattened the last years and started to decrease since 2010. This trend is treated under section 1.1.2.b) below.

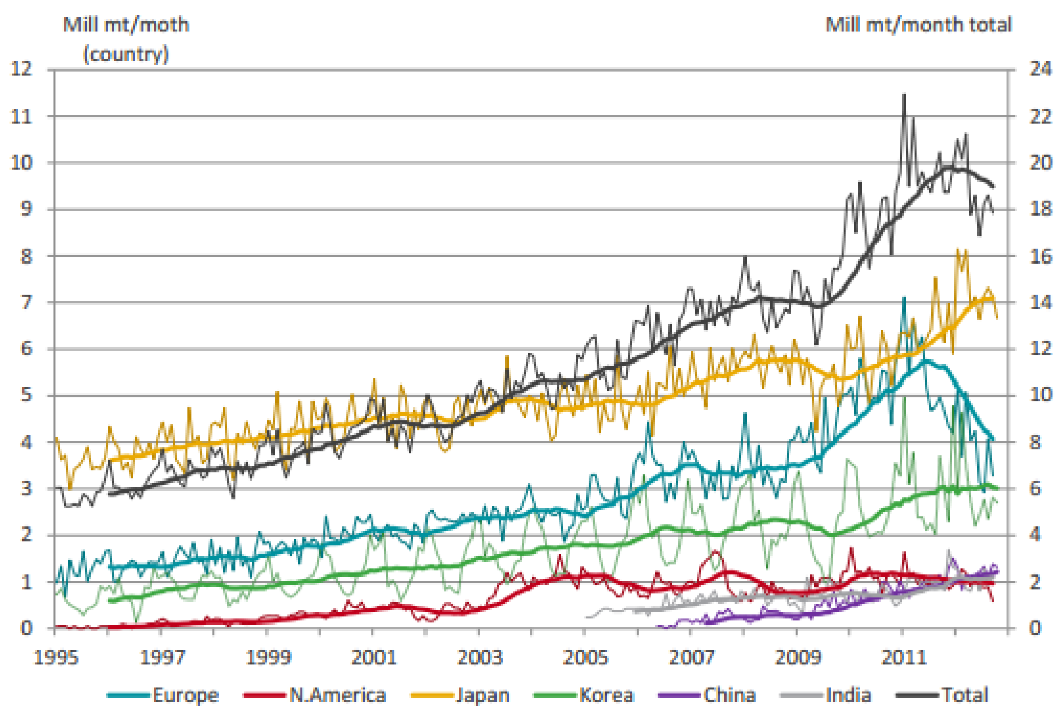

Figure 5: LNG import by region – monthly 1995 – 2012

Source: (Bakkelund, 2012)

The higher demand from Japan combined with the strong economic growth from the Asian countries has lengthen transport distances between the Atlantic basin and the Pacific basin. The higher volumes transported in addition to the longer distances have caused a strong growth in the inter-basin ton-mile supply of LNG. Figure 6 shows the average shipping distance evolution since 2002 and the inter-basin volume by country. We observe that the average distance has followed a positive trend since 2002. We also notice that the volume growth was particulary high between 2006 and 2008 just before the financial crisis hit. After a sharp fall in 2009 and 2010, the recovery of traded volumes started on the beginning of 2011, mainly driven by Japan (Bakkelund, 2012).

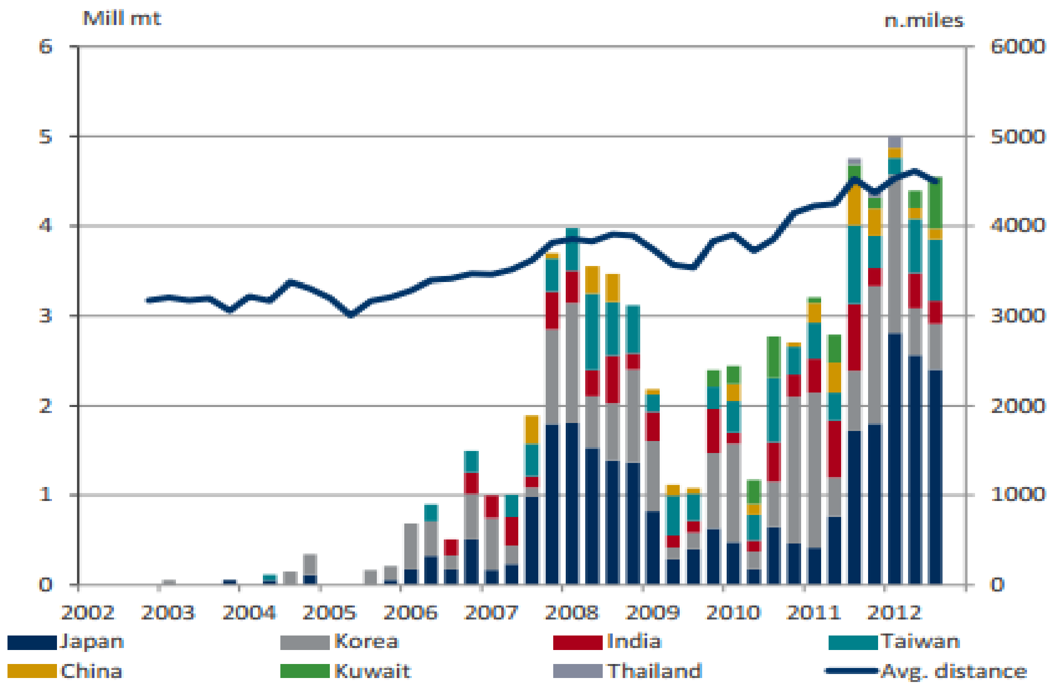

Figure 6: Inter-basin volume and transport distance - quarterly 2002-2012

Source: (Bakkelund, 2012)

1.1.2.b) A new era with the American shale gas

The American shale gas revolution has the last few years changed the world picture of the natural gas market. The growth in US gas production has been driven by the ability to extract unconventional gas at cheaper rates (International Gas Union, 2011). Seen as more affordable and easy to extract, the USA have a clear intention to promote and attract new investors for exploiting this unconventional source of energy on their own territory. The natural gas production has jumped to high levels recently. In 2000, shale gas represented only 2% of the American gas supply; by 2012 the share of shale gas has increased to 37% of the American supply (Mufson, 2012). The International Energy Agency says that if the trend continues, America could become self-sufficient in energy by 2035 (The Economist, 2012). While cheap and plentiful gas has its advantages to provide cheap electricity, which in term boosts the power-hungry North American industry, the gas revolution has created a new picture in terms of pricing we see across the world. Due to the recovery of the American shale gas, the US gas prices are expected to remain respectively 50 and 70 percent lower than prices in Europe and Japan (Mufson, 2012). At the end of October 2012, the Henry Hub (HH) gas price index averaged 2.64 USD/mmBtu which is 36% lower than the same period in 2011 (Federal Energy Regulatory Comission [FERC], 2013). The growth in shale gas production has emerged as a shock for two main reasons. Firstly, the Americans being gradually self sufficient with gas will see their imports of LNG to drop over the next decade. Furthermore, there is a growing uncertainty about whether other countries will be able to replicate the Americans by extracting shale gas on their own territory (International Gas Union, 2011). As an example, China seems already to be on the way to extract natural gas on its own territory. Several shale gas licensing rounds have been already carried out and the country is now planning a new round. The Chinese Ministry of Land Resources is willing to urge local government officials to select up to 20 shale gas blocks to offer to Chinese businesses (Yihe, 2013). The amount of shale gas China aims to produce by 2015 is evaluated to 6.5 billion m^3 (Yihe, 2013). Thirdly, one new development for the coming years will be the start of LNG export from the USA. The first American export project in Sabine Pass is due to start in late 2015. The US department of energy says that further project expansions of LNG exports will add value for the country (RS Platou, 2013). Despite a fall in gas imports to Europe, US exports could see their volumes to find home in Europe. The old continent is willing to diversify its supply sources of LNG and many European companies are considering US LNG as a potential supply source to not only relay principally on Qatari gas (Meredith, 2013).

From the Norwegian perspective, the development of the LNG plant in Melkøya was initially built with exports to the USA in mind. However, the recent recovery of shale gas on the American territory and the lower US imports of LNG has made the gas prices to drop and hence less interesting to ship LNG there. For the time being there is an increased interest for LNG in Asia for instance (McGrath, 2012). Consequently, the picture we observe today is the LNG flows moving east and not west anymore. The shale gas revolution has turned the market upside down (McGrath, 2012). However, TEPN has long term commitments of selling the gas from Snøhvit to the North American and European markets. The Group cannot decide to send instead all their shipment to Asia. The possibility of sending their LNG east of Suez can arise sometimes when the opportunity of benefiting from arbitrage is there (Laurent, 2013).

1.1.2.c) The LNG pricing and arbitrage opportunities

As the interest for natural gas is increasingly going global, the gas market is not global in terms of pricing (International Gas Union, 2011). Worldwide natural gas prices can be divided in three main categories:

1- For the North American market, we have the *Henry Hub (HH)* price index where spot and futures are being traded on the New York Mercantile Exchange (NYMEX).
2- In Europe, the main gas price reference is the *National Balancing Point (NBP)*.
3- For the Asian market, the *Japan/Korea Spot (JKS)* is the most common reference used.

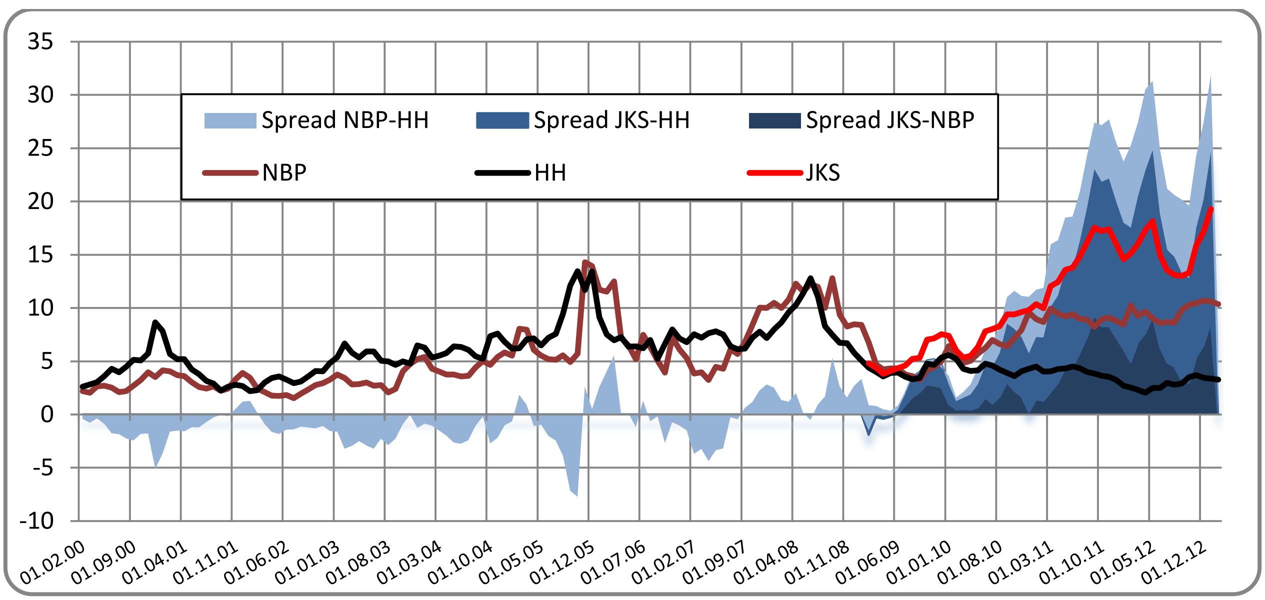

Figure 7: Natural gas prices and respective spreads in USD/mmBtu – monthly 2000 – 2013

Source: Data provided from TEPN (Laurent, 2013)

Figure 7 shows the gas pricing schemes as well as the price spreads which are source of arbitrage. For the NBP and HH prices references, the period starts form February 2000 and lasts to February 2013. The JKS reference starts from February 2009. All data are expressed in USD/mmBtu on a monthly basis.

As we already know, the shale gas effect has contributed to change significantly the price picture of the international gas market. The US gas imports have fallen sharply since the financial crisis in 2008 and the HH has stabilized to around 3-4 USD/mmBtu the last couple of years as we can see in Figure 7. Since March 2010, price spreads between the three continents are more evident. While the JKS prices are reaching all time high levels around 20 USD/mmBtu, the NBP is oscillating around the 10 USD/mmBtu level and the Henry Hub has recently fallen under 3 USD/mmBtu.

The correlation factor represented by "$p_{i/j}$", where i and j refer to two of the three price indexes, can give us a good idea of the degree in which the three curves from Figure 7 vary together or not[2].

The results give us the following

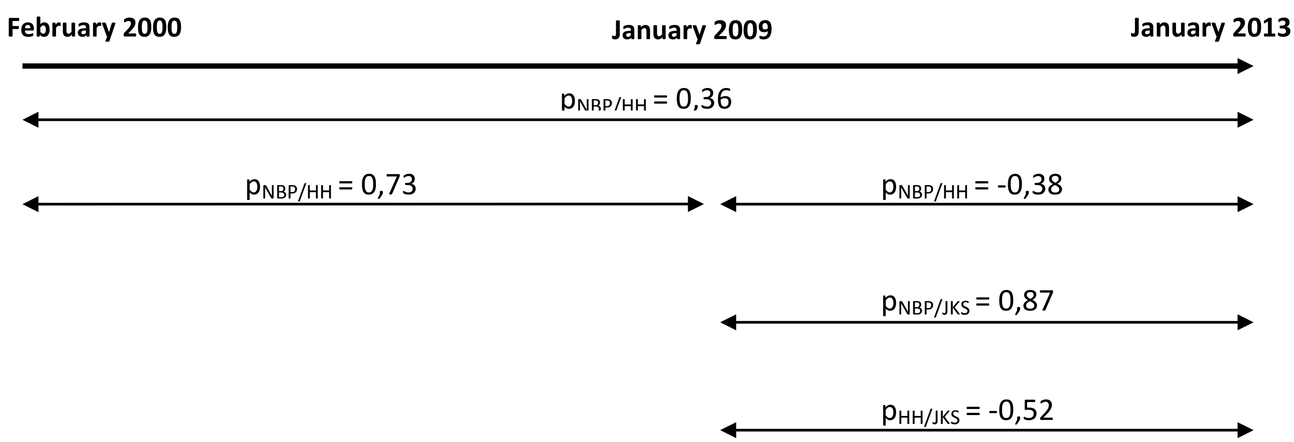

Figure 8: Correlation factors by periods

Source: Data provided from TEPN (Laurent, 2013)

NBP and HH have a positive but weak correlation of 0.36 from February 2000 to January 2013 meaning that the two price references tend to vary together over these 13 years. When dividing into two sub periods, we notice that the NBP and the HH have a relatively high degree of correlation of 0.73 between February 2000 and January 2009 and a negative correlation of -0.38 from January 2009 to January 2013. We can think of the US shale gas as the main explanation behind this shift of sign.

[2] Due to lack of information, data from February 2000 to January 2009 for the JKS are not represented in Figure 7

The NBP and JKS tend to vary much together with a positive correlation of 0.87 between January 2009 and January 2013. For the HH and JKS over the same period, the behavior seems to be the opposite with a negative correlation of -0.52.

The different gas price schemes across the markets and the covariance results give the possibility for oil & gas companies such as Total to arbitrage and sell gas at the best rate at the right time. The main strategic challenges for Total are meeting the needs for their customers and at the same time transporting the LNG at the lowest cost (Total, 2013d).

Total is one of the few having developed LNG trading capabilities (Total, 2013d). The Group's main trading offices are located in London at TGPL. When Total is going to ship LNG to Europe where the price is at 10 USD/mmBtu and the traders see a possibility to sell the gas in Japan for 20 USD/mmBtu, there is an arbitrage opportunity to get a 10 USD/mmBtu in additional revenue.

What would that mean in term of loss revenues if they did not transport the gas to Japan instead?

If you take a conventional 160,000 m^3 LNG cargo vessel, the loss in revenue, excluding cost transportation differences, would represent:

$$160{,}000\ (m^3) \times 23.2\ (mmBtu/m^3) \times 10\ (USD/mmBtu) = USD\ 37{,}120{,}000 \qquad (1.1)$$

This amount is too high to be ignored. Since the gas market is going global while price differences persist, the arbitrage opportunities across countries for the Group are increasing. The trading center in London enables the group to find the most profitable markets (Total, 2013d).

1.1.3 The LNG Shipping Market

1.1.3.a) The LNG Charter Market

In the LNG charter market, spot prices have been relatively high since the summer 2010. This increase can be explained by different reasons. The number of new vessel deliveries was low in 2012 which caused a shortage of available carriers in the market. This effect was combined, as we already know, with the earthquake in Japan in 2011 which led to a sharp increase in LNG demand. Higher Asian LNG demand from the Atlantic basin strengthened this effect and lengthened the inter-basin travel time which in term limited the short run transport supply

(Arnsdorf, 2011). The spot charter rates reached a historical peak during the spring 2012 of USD 150,000 per day (RS Platou, 2013). For a 138,000-145,000 m^3 LNG carrier, the east of Suez and west of Suez spot charter rates vary around 120,000 USD/day and the 1-year Time Charter (TC) rates are at 110,000 USD/day (Fearnley LNG, 2013). Figure 9 gives us the LNG shipping rates for a 155,000 m^3 LNG carrier back from the end of 2009.

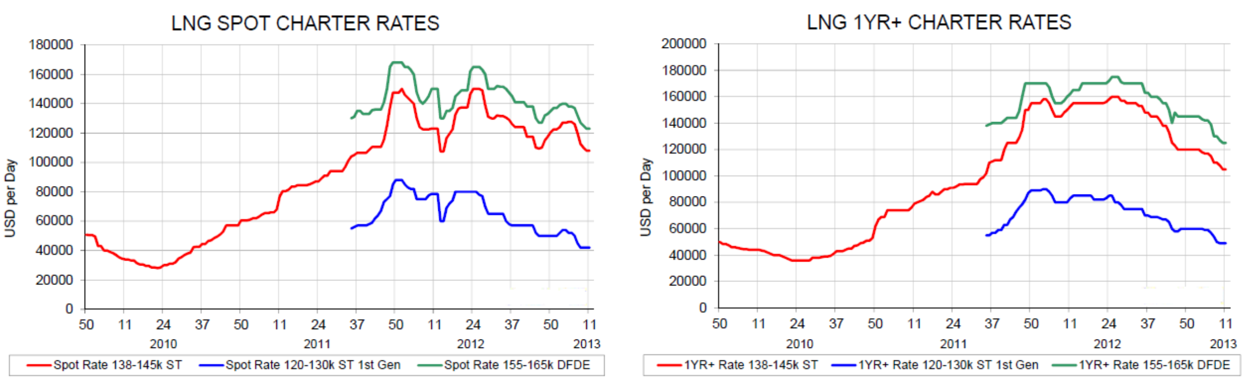

Figure 9: LNG Freight rates in USD/day

Source: (Fearnley LNG, 2013)

1.1.3.b) The world's LNG fleet and order book

The LNG shipping market is growing fast with a current world fleet of 380 vessels (big and smaller carriers combined) and a total of 102 carriers on order (RS Platou, 2013). In 2012, only two new vessels were delivered (RS Platou, 2012) so the world fleet has not changed dramatically from 2011. 2011 was also a strong year in terms of new orders. The cumulative number of outstanding orders in the order book was 67 at the end of 2011; these orders include Floating Storage Regasification Units, FSRUs (International Gas Union, 2011).

The number of carriers available in the spot market is low. With 3 to 4 carriers available in total, east and west of Suez combined; the spot market is still tight (Fearnley LNG, 2013). The few vessels available in spot and the high number of new orders are explained by the high LNG demand on a world basis. This has lead to high levels of spot and TC rates as we have observed the last months.

1.1.3.c) The LNG shipping perspectives for the coming years

Based on RS Platou's expectations, the transported volumes for 2013 should increase by 3% from

2012. Two new LNG projects are expected to start production, the Angola LNG and Sonatrach's Skikda project. Regarding the orderbook, there will be 23 vessels delivered from shipyards in 2013 and 35 vessels in 2014. These numbers are high compared to the 2 vessels delivered in 2012 (RS Platou, 2013). Many of the new uncommitted deliveries for 2013 and 2014 are highly speculative. The market holds its breath. According to an industry observer, if he was an owner, he would be scared. He would have fixed a contract as soon as possible he says (Hine, 2013a).

The development in transport distances are difficult to forecast but should decrease by 1% per year in 2013 and 2014 as the inter-basin trade will continue at a high level. Nevertheless, the increase in LNG supply from the Middle East is a fact and should continue the coming years. Most of these LNG volumes should be exported east of Suez shortening the average transport distances at the expense of the inter-basin trade (RS Platou, 2013).

In 2013, the LNG market will still be tight; the vessel utilization rate should increase slightly from 95% to 96%. For 2014, the high growth of new deliveries (8%) coupled with a lower demand growth should cause a fall in the vessel utilization rate to 91%. This should also have a repercussion on the short term TC rates. While the expectations for 2013 are USD 125,000 per day, for 2014 the rates are expected to fall to USD 82,000 per day (RS Platou, 2013). A Greek owner expects spot rates to fall down to the 90,000 USD/day range. Other predict a much more severe fall down to 50,000 USD/day for steam turbine vessels by the end of the year (Hine, 2013a).

1.2 The Northern Sea Route

1.2.1 Definition and historical background

The Northern Sea Route (NSR) can be defined in different ways when it comes to its start and end point, hence, regarding distances and borders. However, officially the NSR is defined as follows: *"The water area of the Northern Sea Route shall be considered as the water area adjacent to the northern coast of the Russian Federation, comprising the internal sea waters, the territorial sea, the adjacent zone and exclusive economic zone of the Russian Federation and confined in the east with the Line of Maritime Demarcation with the United States of America and Cape Dezhnev parallel in Bering Strait, with the meridian of Cape Mys Zhelania to the Novaya Zemlya Archipelago and the western borders of Matochkin Strait, Kara Strait and*

Yugorski Strait" (Balmasov, 2012a). In other words, the NSR region starts from the Novaya Zemlya Island in the west and ends at the Bering Strait in the east. As the definition suggests, the NSR cannot be seen as a single linear route, but should be thought of as a region or a whole sea area between Novaya Zemlya and the Bering Strait (Ragner, 2000). The distance of the NSR is generally considered to be from 2100 to 2900 nm (Liu & Kronbak, 2009). Consequently, actual distances can vary. Depending on the seasons and thus ice conditions, vessels will have to choose the most adapted route (Center for High North Logistics [CHNL], 2013a). A map of the NSR's geographic area with the different routes in blue is illustrated in Figure 10 (p25). From west to east, the NSR starts at the Kara strait and continues through the Kara Sea, the Laptev Sea, followed by the East Siberian Sea and the Chukchi Sea before ending at the Bering Strait.

The NSR was initially used for national purposes and foreign carriers were historically prevented from using the NSR (Liu & Kronbak, 2009). From the 1930's the Soviet Union developed the NSR as an internal Russian waterway in support of the industrial development in the Arctic resources (Ragner, 2000). They devoted considerable efforts to develop the whole Arctic region with ports, marine transportation and infrastructure in order to supply populated regions with natural resources (Mulherin, et al., 1996). In 1970, the NSR played a central role as the Soviet Union started to exploit vast amounts of natural resources, from oil to gas (Truc, 2013). However, since the end of the Soviet Union in 1991, the shutdowns of the military bases and the fall in mining activity in these regions reduced the shipping traffic by five (Truc, 2013). The activity in the NSR reached its peak in 1987 with 6.6 million tons of cargo transported. At that same time, in October, Gorbachev delivered a speech in Murmansk where he declared his willingness to open the NSR for international traffic.

The initiative was followed-up with the formal opening of the NSR to foreign vessels and the "Regulations for Navigation on the Seaways of the Northern Sea Route" were approved in 1990. From 1987 to 1999 the NSR cargo volumes dropped with 76% from the peak level which was mainly caused by the decline in industrial production and investment activity, and the shrinking population in the northern regions of Russia. Political issues were also responsible for this decline (Liu & Kronbak, 2009).

Since the early 2000s, we have seen almost a decade of neglect of the NSR from the Russian Federation which has caused the maritime freight to decrease, ports to fall into disrepair and nuclear icebreakers to age. Nevertheless, in 2008, Moscow decided to open the NSR for international transit during July and August. The route was officially open for international commercial transit in 2009. Since then, the navigation period hasn't stopped extending. Today the route is open during five months from July to November (Truc, 2013). In terms of transits via the NSR (without stops on the way), Russia claims that 46 vessels carrying 1.2 million tons of cargo utilized the NSR in 2012, between the 23rd June and the 18th November, of which 21 travelled in the westerly direction and 25 took the eastern direction (Hine, 2013b). This number of 46 transits is small when comparing it to the annual number of transits through the Suez Canal (Truc, 2013). However, the 46 transits via the NSR in 2012 represent an impressive increase from the 2 transits in 2009, the 4 ones in 2010 and the 34 ones in 2011. The positive trend for 2013 should continue and we should expect to see more commercial transits than in 2012 (Gunnarsson, 2013). Rosatomflot is expecting an increase in the NSR traffic for 2013 and should equal 1.5 million tons cargo, maybe more. This represents a 25% increase from the 2012 level (Belkin, 2013).

1.2.2 The evolution of the Arctic sea-ice coverage

The study of ice conditions is essential to understand the feasibility of a voyage via the NSR. The sea-ice extent is cyclical along the year which means that the covered ice area increases during the fall and winter period while it decreases during the spring and summer period. Every year the sea-ice extent cyclical curve has a peak and a trough that varies from year to year (Ragner, 2000).

There is no doubt that the Arctic sea-ice extent during summer has been diminishing the last couple of decades and that the phenomenon has been accelerating since the mid 2000s. As we observe in Figure 11 the September sea-ice coverage since 2006 has been decreasing and it is particularly evident from September 2009 to September 2012.

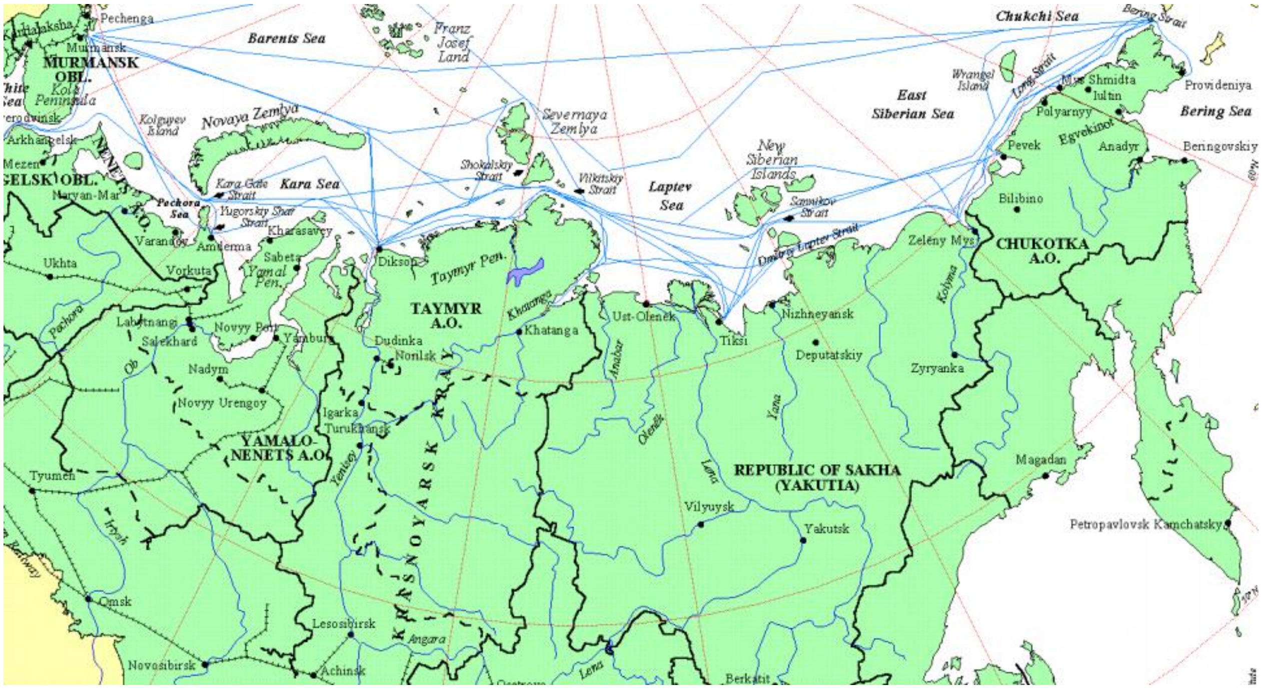

Figure 10: The Northern Sea Route

Source: (Ragner, 2000)

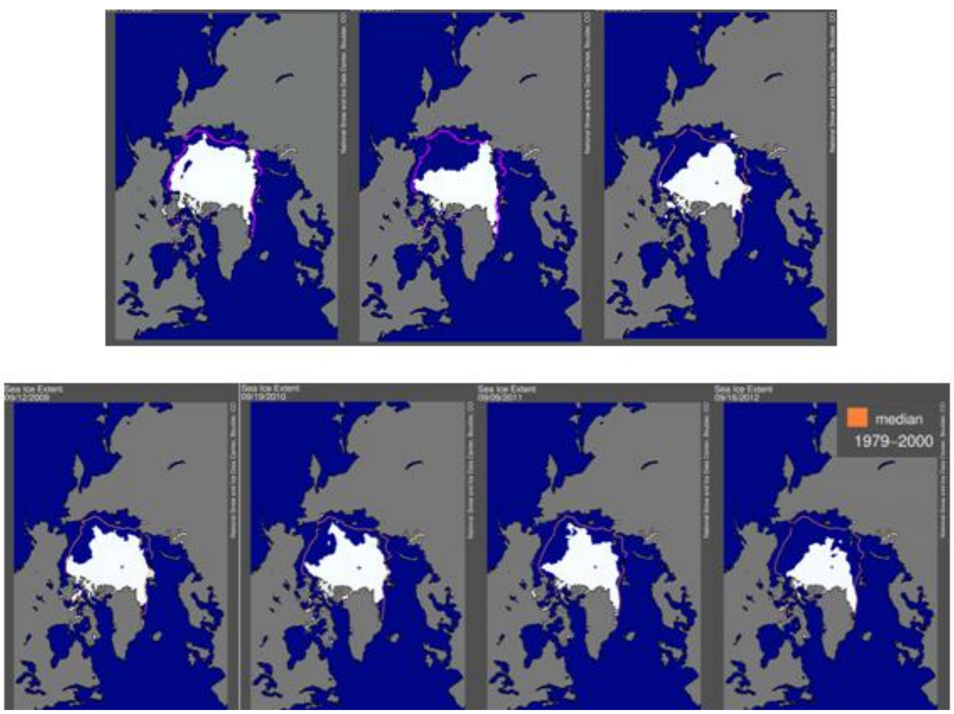

Figure 11: Arctic sea-ice extent evolution from 2006 to 2012 (from upper left to right)

Source: (National Snow & Ice Data Center, 2013)

The main factor influencing the navigation on the NSR is the presence of ice. The seasonal and annual variability of ice is typical for all areas on the NSR (CHNL, 2013b). However, the sea-ice extent varies from sea-to-sea. The south-western Kara Sea and the south-western Chukchi Sea for instance have historically the lightest ice conditions while the Laptev Sea and East Siberian Sea usually has more difficult ice conditions (Ragner, 2000). Under normal winter conditions, navigation along the NSR is not profitable and it is far to hazardous for commercial shipping due to the harsh climate conditions, the thick ice from the Laptev to the East Siberian Sea and the extreme low temperatures. However, the observable climate change trends indicate that the polar ice is shrinking at an impressive rate which should lead to good prospects for shipping during summer (Ragner, 2000). The navigation periods on the NSR starts theoretically at the beginning of July and can last up to the second half of November, again, depending on the years (CHNL, 2013b). The NSR seaways were open for navigation during 141 days in 2011 (CHNL, 2013b). Taking this number into account and if the conditions allow, TEPN could in theory make at least two round trips between Hammerfest and Yokohama through the NSR which would save the company valuable sailing time.

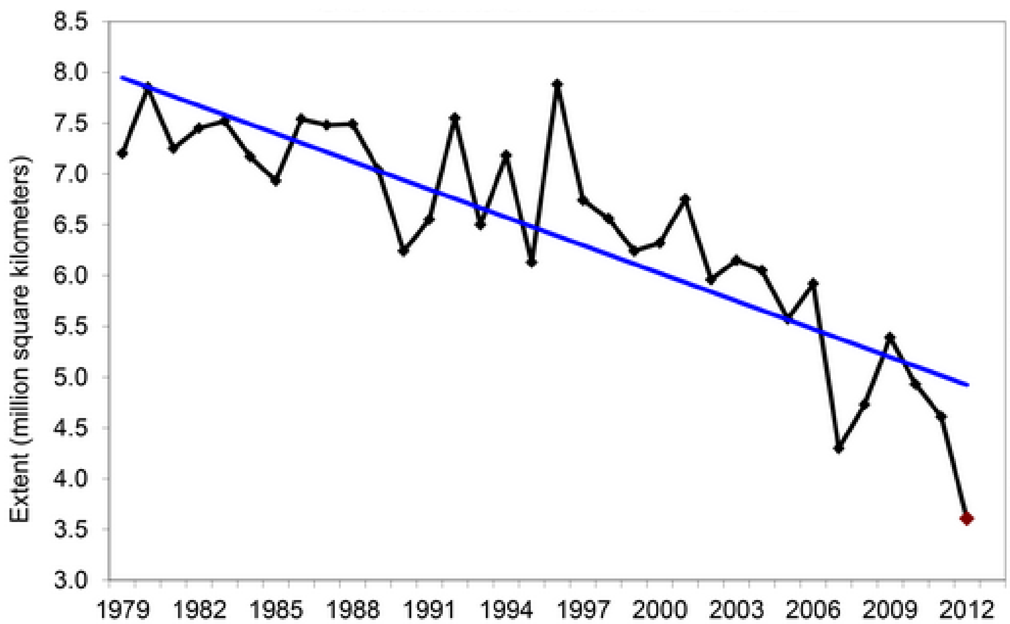

Figure 12: September Arctic sea-ice extent 1979-2012

Source: (National Snow & Ice Data Center, 2013)

The Arctic sea-ice in 2012 was at its lowest level ever recorded since the recording began nearly three decades ago (Matt, 2012). On September 2012, the National Snow and Ice Data Center registered the lowest number in million square kilometers of sea-ice coverage since 1979. It was estimated to 3.6 million km^2. For comparison, in 2009 and 2008, the registered data was respectively 5.4 and 4.9 million km^2 (National Snow & Ice Data Center, 2013). Figure 12 shows a negative trend of the sea-ice extent since 1979. One can notice the impressive drop in 2012. It is interesting to study September month since it is the period of the year where the Arctic sea-ice extent is at its lowest level (Figure 13) and where shipping transits are most likely to happen. This is good news for TEPN seeing the possibility to ship LNG through the NSR in order to reach the Asian-Pacific market.

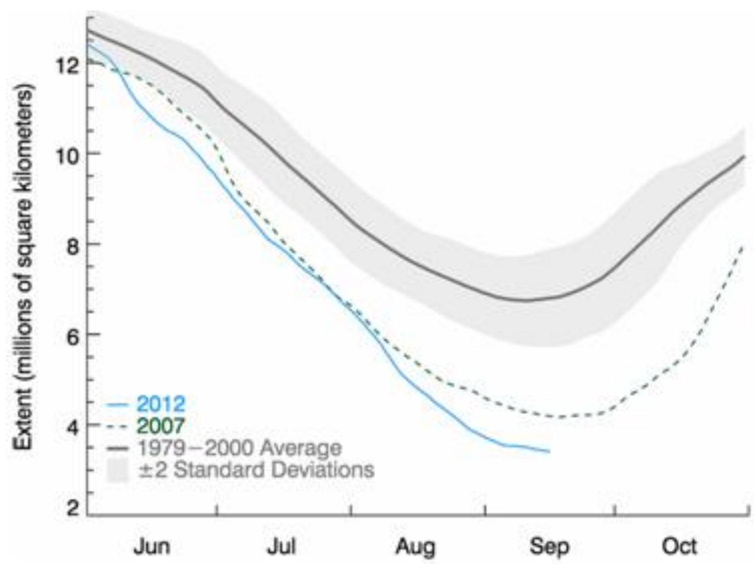

Figure 13: Arctic sea-ice extent (Area of ocean with at least 15% sea-ice)

Source: (National Snow & Ice Data Center, 2013)

1.2.3 The Economic Interest of the NSR

1.2.3.a) The main drivers

The NSR has recently attracted worldwide attention from cargo owners and ship owners seeing this route as strategically interesting for shipping goods between Europe and Asia (Ragner, 2000). Seen a unique opportunity, the distance saved from northern Europe to Asia-Pacific compared to the Suez Canal route can be up to 40% depending on the ports of departure and arrival (Liu & Kronbak, 2009).

The Eurasian Arctic presents a commercial opportunity for the shipping industry. The region is rich in hydrocarbons and other natural resources such as iron ore. Russia has the world's largest gas reserves and wishes to benefit from the development of the NSR to facilitate their exports. The example of the Yamal LNG project, which will be described later, will have a significant impact on the future of this route and should develop considerable growth in the whole region.

The Eurasian Arctic has changed from having a distance disadvantage to having a transport opportunity to reach the fast growing markets in Asia during the summer season (Gunnarsson, 2012a). The sea-ice reduction during summer and the national interest from Russia and other countries have led to more optimism then ever before (Gunnarsson, 2012a). President Vladimir Putin has expressed his wish to develop the NSR for international shipping. According to him, the NSR is becoming more cost-efficient for transporting goods from Europe to the Asia-Pacific area, as compared to the route via the Suez Canal (Hine, 2013b). Moscow has also announced that 35 billion Euros will be invested in Russia's "great north" within 2020 in order to modernize the ports, the infrastructure and the communication facilities (Truc, 2013).

The Russian icebreaking service company, Rosatomflot, wishes to attract international shipping companies and become more competitive with the traditional route through the Suez Canal (Belkin, 2013). Despite that, according to Laurence C. Smith, an American professor and researcher from UCLA in California, the shipping traffic via the Suez Canal will not be out of date at the first. Vyacheslav Ruksha, head of Rosatomflot, claims that the NSR will never be a replacement route to the Suez route, but an alternative route for shipments from the North Sea and Baltic Sea to northeast Asia (Truc, 2013). One will never see an all year long transit via the NSR in the short to the medium term (Lieungh, 2013).

To come back to the question of arbitrage mentioned under section 1.1.2.b), along with the arbitrage opportunity for TEPN follows also the strategic value of being able to supply LNG to Japan. A company such as TEPN loading its cargo in Hammerfest may not be able to supply Japan as the country is considered to distant via the Suez Canal. In addition, closer LNG suppliers to Japan exist as we already know like Indonesia, Malaysia and Australia. The shipping length will raise an additional risk as the vessel may not be back in time for its next cargo loading in Hammerfest. Consequently, the NSR has the advantage for TEPN and other companies to reach new markets without affecting considerably the overall shipping distance (Lauritzen, 2013).

1.2.3.b) A challenging route

Before entering the NSR, many seafarers onboard the vessels having experienced an NSR transit have been questioning themselves about many things. Is the route totally free of ice? What is the ice's size and density? Will we avoid the fog? Will the vessel be capable to follow the ice breaker's track? Are the crew members up to face an eventual emergency in such a hostile environment? (Truc, 2013).

The recent willingness from the Russian authorities to revive the NSR will require billions of dollars of investments in order to make the sea route competitive to the Suez route. Although the Russian authorities have plans to invest 35 billion Euros until 2020, the overall investment in the Arctic could reach $100 billion or more for the coming decade (Vukmanovic & Koranyi, 2013).

From an operational point of view, there are some challenges to take into consideration before planning to sail along the NSR. Long distances and the lack of infrastructure along the NSR coast line are a fact (Balmasov, 2012b). Differences in developed infrastructure between the northwest and northeast of Russia can cause problems. Adapted rescue centers along the coast are still missing and some ports are incapable to receive vessels with a draft exceeding 10 meters (Gunnarsson, 2013). This is especially the case along the Laptev and East Siberian Sea where we often find the most extreme weather conditions. On the other hand, the Russian authorities have plans to develop ten integrated emergency and rescue centers located along the coast. The expansion and progressive renewal of the ice breaker fleet from Rosatomflot has become a national concern (Gunnarsson, 2013). The Government is also planning to build floating terminals in order to receive the vessels with high drafts (Gunnarsson, 2013). According to Tore Henriksen, a law professor at the University of Tromsø, there is a whole series of obstacles: legal deficiencies, the irregularity of sea ice, lack of search and rescue, poor access to ports, communications and deficiencies in satellite coverage (Vukmanovic & Koranyi, 2013).

From an environmental point of view, ship owners may face some problems with fog reducing considerably the visibility (Balmasov, 2012b). This may in periods reduce the sailing speed which often is a synonym of lost time. Furthermore, pushing-off and pushing-to winds are source of a potential deviation of vessels which increase the total sailing distance. These violent winds on the NSR can represent a severe threat for the vessels since they can also push ice blocks into the vessels' hull. That explains why ice breakers are essential to avoid taking any unnecessary risk of meeting an iceberg, even during summer (Truc, 2013).

An unfavorable business environment in Russia, a high level of corruption and communication problems can reinforce this challenge. It is difficult and not safe to do business in Russia, despite the high growth level of the country (Browder, 2011). However, the willingness from the Russian government to develop the NSR should facilitate the procedure to get a permit of transit.

According to Gunnar Sander from Norsk Polarinstitutt, the difference in ice conditions during summer and winter will be a problem for many ship owners. A survey has shown that many of them consider the irregularity of the shipping traffic as a major problem. Extra logistics for sailing via the NSR during summer and via the Suez during winter will be required (Lieungh, 2013).

1.2.3.c) Evidence of a feasible transit

History has shown that there have been transits before and that there will be likely more of them in the future.

Tschudi Shipping Company AS, a Norwegian shipping company, made some calculations of the shipping time between Melkøya in Hammerfest and Yokohama via the NSR and the Suez Canal. They assumed a sailing speed of 13 knots for both routes. The distance between Melkøya-Suez-Yokohama is 12,510 nm and 5,827 nm for Melkøya-NSR-Yokohama. The voyage should last 40.1 days for the Suez route and 18.7 days for the NSR meaning that 21.4 days can in theory be saved (Tschudi, 2012). Those numbers should be taken with a degree of caution. The distances and speed may vary from time to time depending on the weather conditions but also on the nature of the vessel. Nothing can predict a constant sailing speed of 13 knots across the NSR and an exact distance of 5,827 nm. However, these numbers give a preliminary idea of the distance and time benefits for sailing through the NSR.

For a particular Ice Class 1A LNG tanker of 173,400 m^3 basic winterized, the Russian icebreaking service company, Rosatomflot, said that the vessel was accepted for a NSR transit and the most favorable period would be August to October. They could provide the average speed of 12 to 14 knots. The transit via the NSR (from Kara Strait to the Bering Strait) would take approximately 8 days given that the actual mentioned speed was maintained. They also expressed their willingness to go into further preliminary negotiations (Belkin, 2013). Ice Class ships have a strengthened hull which enables them to navigate through sea-ice. An Ice Class vessel is not necessarily an ice breaker (Table1).

The voyage simulation from Tschudi and the sentiments from Rosatomflot support the idea of a feasible transit via the NSR during summer.

DNV Class Notification	Equivalent Lloyd Register Notification	Vessel Type	Ice Conditions	Impact Limits
ICE-C	1D	All Ship Types	Very light ice conditions	No ramming
ICE-1C	1C		0.4 m ice thickness*	
ICE-1B	1B		0.6 m ice thickness*	
ICE-1A	1A		0.8 m ice thickness*	
ICE-1A*	1A Super		1.0 m ice thickness*	
*First year ice and broken channel				

Table 1: Classification of the most common Ice Classes in the market

Source: (Koren, 2007)

We are still in an early stage when it comes to having a regular transit via the NSR. The traffic along the NSR is much smaller than the traditional route via the Suez Canal. As mentioned before, 46 vessels transited the NSR in 2012; one of them only was a LNG carrier, (Hine, 2013b). These numbers are low compared to the 17,225 vessels having transited the Suez Canal in 2012 of which 800 were LNG carriers, in ballast and laden combined (Suez Canal Traffic Statistics, 2012). Nevertheless, the opportunity exists for ship owners.

Between the 7th November and the 5th December 2012, the 150,000 m^3 Ice Class 1A *Ob River*, built in 2007 and chartered by Gazprom, successfully achieved its trip from Hammerfest to Tobata in Japan via the NSR. Under the voyage planning, the ship owner Dynagas Ltd had collected and studied many observation data in order to be best prepared. They had daily ice reports and forecasts concerning the weather and ice conditions (Lauritzen, 2013). Some may wonder how the vessel could have sailed via the NSR so late during the year. As we already know, the Arctic sea-ice extent was at its lowest level ever registered in September 2012. This made the navigation during November possible since the ice recovery took longer time. With 134,066 m^3 LNG on board the *Ob River's* NSR transit started the 9th November and ended the 18th November 2012 (Laurent, 2013). The vessel was escorted by two ice breakers from Rosatomflot and led by two ice pilots (Gazprom, 2012). The average sailing speed via the NSR from the Kara Strait to the Bering Strait was claimed 15 knots according to Dynagas (Lauritzen, 2013). The voyage was perfectly completed in line with their expectation and Dynagas experienced neither positive nor negative surprises (Lauritzen, 2013).

Figure 14: The *Ob River* being loaded at Melkøya

Source: (Egholm, 2012)

1.2.3.d) The importance for Total and TEPN of the NSR in the near future

The *Ob River's* NSR transit accomplishment between Hammerfest and Tobata received a lot of attention from a couple of other oil & gas companies in Norway. TEPN is one of them and they take the successful transit of the *Ob River* seriously seeing big potentials in terms of distance savings, days saved, cost and emission reductions. The forecasts of growth in the scope of transportation in the Arctic are also related to the exploration of new fields and exportation of raw materials from the Arctic shelf (CHNL, 2013a).

Figure 15: View of the Russian icebreakers from the *Ob River* sailing on the NSR

Source: (Lauritzen, 2013)

Figure 16: View from the *Ob River* on the NSR

Source: (Lauritzen, 2013)

An example can be the "Yamal LNG megaproject" situated on the Yamal peninsula along the Kara Sea in northern Russia. The Yamal LNG project is developed by a joint venture of Novatek (80%) and Total Group (20%). The mission of the project is to exploit the vast natural gas reserves and build a three train gas liquefaction plant and export the LNG to the international market. By 2016, the first production train should be in operation, although some speculate that the project will be postponed to early 2017 (LNG World News, 2013). The project will alone boost Russia's production of LNG from 11 to 27.5 million tons and increase shipping volumes along the NSR to an estimated 20 million tons per year (Staalesen, 2012). This number corresponds to three times the record of 1987 of 6.6 million tons.

This megaproject will have undoubtedly a considerable impact on the shipping traffic in northern Russia. The LNG cargoes will be shipped out from the port of Sabetta to Asia and Europe. The plan is to send half of the LNG volumes east via the NSR during summer and the remaining half west. During winter, when the NSR is icebound, all the shipment will be sent west where the plan is to transship the gas in European waters to free up tonnage. In total, the partners are planning to build between 12 and 16 Arc-7[3] Ice Class LNG carriers. These vessels will be unique in their class since they will be icebreakers and the price per unit could pass the 300 million dollars (Hine, 2013c). Knowing that the market price for a conventional LNG carrier today is situated around 200 million dollars; the total investment in icebreakers for the Yamal project represents a considerable amount. Novatek wishes to have a year round export operation from Yamal LNG, even during the worst winter conditions, which explains why they will need icebreaking LNG carriers. According to them, the navigability to Asia via the NSR during the summer 2011 had given good results. Novatek shipped more than 600,000 tons via this route in 2011 which corresponded to 9 cargos (Selstad, 2012). The "Vladimir Tikhonov", a Suezmax gas condensate tanker carried 120,843 tons of cargo and sailed via the NSR in a record time of 7 days at an average speed of 14 knots (Gunnarsson, 2012b).

[3] Russian classification

Figure 17: The suezmax “Vladimir Tikhonov” escorted by a Russian nuclear icebreaker

Source: (The Maritime Executive, 2011)

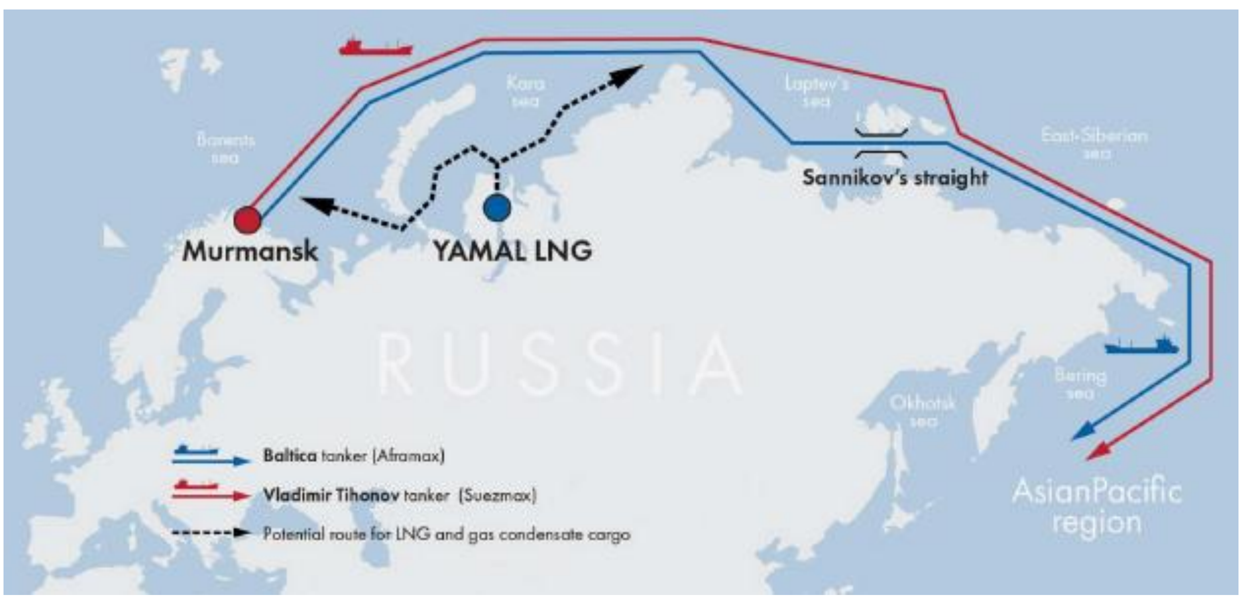

Figure 18: Location of Yamal LNG

Source: (Selstad, 2012)

1.3 The Russian NSR transit rules and regulations

1.3.1 The Northern Sea Route Administration

Before studying the economic viability for a NSR transit, it is important to understand what the latest Russian rules of navigation on the NSR tell us. New rules were approved by the Ministry of Transport of the Russian Federation the 17th January 2013 (Ministry of Transport of Russian Federation, 2013).

The overall supervision and arrangement of the NSR is controlled by the Northern Sea Route Administration (NSRA), established as a Federal State-owned Institution. The targets of the NSRA are preventing pollution, protecting the marine environment and ensuring a safe navigation in the NSR waters (Ministry of Transport of Russian Federation, 2013). The NSRA receives and considers all submitted applications and issues permissions for navigation through the NSR. They have department responsible for research within weather, ice and navigational conditions. Certificates of ice pilotage on the NSR are issued by the NSRA. Other main functions of the NSRA are to assist in eliminating the consequences of pollution from vessels, assist in the organization of search and rescue operations, coordinate the installation of navigational aids and make recommendations about development of routes of navigation in close cooperation with Rosatomflot (Ministry of Transport of Russian Federation, 2013).

1.3.2 Requirements for navigation through the NSR

The owner or the Master of a vessel wishing to transit the NSR should submit an application form to the NSRA. The application should indicate some core pieces of information of the vessel characteristics, name, flag, and IMO number. Documents as copies of the vessel ownership certificate; the classification certificate, the right to navigation certificate etc. have to be attached to the application. According to those regulations, the NSRA considers the application within ten working days and informs then the applicant about the decision. The application should be submitted to the NSRA not earlier than 120 calendar days and not later than 20 days before the expected date of the vessel’s entering into the NSR water area (Ministry of Transport of Russian Federation, 2013).

A permit can be refused from the NSRA for different reasons. Incorrect information can be specified on the application, a failure to provide all the necessary documents in attachments or the non-conformity of the vessel as safety requirements are often the main reasons. The shipmaster has to notify the NSRA of the expected time of entering the NSR at the eastern or western border and the time when the vessel is expected to have left the NSR after completion (Ministry of Transport of Russian Federation, 2013). More information about the latest rules for navigation can be found in the "*Rules of navigation on the water area of the Northern Sea Route*", approved by the Russian Ministry of Transport the 17th January 2013 (Ministry of Transport of Russian Federation, 2013).

Table 2 on page 38 shows the admittance criteria for navigation via the NSR water area based on the vessel's ice class. The navigation period is from July to November (Ministry of Transport of Russian Federation, 2013). Vessels with any ice reinforcement and with ice reinforcement 1D and 1C are not allowed to sail via the NSR water area in the periods from November to June. Vessels without ice reinforcement at all are only allowed to sail via the NSR on open blue water (Ministry of Transport of Russian Federation, 2013). The list in Table 3 (p39) shows the existing Ice Class LNG fleet in the market with the corresponding new buildings. It is interesting to notice that the capacity of the vessels on order (newbuildings) is superior to that of the existing ones.

If a gas cargo owner, such as TEPN, sees an arbitrage opportunity to transport LNG from Hammerfest to Japan via the NSR, it is unlikely that TEPN will easily find an Ice Class 1A, basic winterized, NSR approved LNG carrier with an experienced crew on board. The simple reason is that there are few Ice Class LNG carriers available in the market for a spot voyage. It would therefore be more interesting to enter into a long term TC agreement with a ship owner and make use of the arbitrage opportunity when it arises (Lauritzen, 2013).

1.3.3 Regulations for icebreaking and vessel guiding through the NSR

Icebreaker support ensures the safety of navigation of the ship on the NSR. The current shipping companies responsible for escort of vessels in the region are FSUE Atomflot, a state owned company, and Far East Shipping Company. The choice is dependent upon whether you are sailing west or east. FSUE Atomflot was part of the "Murmansk Shipping Company" until 1988.

Every carrier intending to sail via the NSR is subject to pay a tariff for icebreaking service, depending on the type of cargo and the amount of cargo (Rosatomflot, 2013).

Ice reinforcement class (Lloyd Register UK)	Ice Navigation mode (Independent Navigation - IN, with Icebreaker Support - IS)	The Kara Sea				The Laptev Sea				The East Siberian Sea				The Chukchi Sea			
		E	S	M	L	E	S	M	L	E	S	M	L	E	S	M	L
No	IN	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
	IS	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
1D	IN	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
	IS	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
1C	IN	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
	IS	-	-	+	+	-	-	-	+	-	-	-	+	-	-	-	+
1B	IN	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+
	IS	-	+	+	+	-	-	-	+	-	-	-	+	-	-	+	+
1A	IN	-	-	+	+	-	-	-	+	-	-	-	+	-	-	+	+
	IS	-	+	+	+	-	-	+	+	-	-	+	+	-	-	+	+
1A Super	IN	-	+	+	+	-	-	+	+	-	-	+	+	-	-	+	+
	IS	-	+	+	+	-	+	+	+	-	+	+	+	-	+	+	+

Table 2: Classification of the Ice Classes suitable for a NSR transit

Source: (CHNL, 2013c)

"E" Extreme ice conditions according to the Rosgidromet official information;

"S" Severe ice conditions according to the Rosgidromet official information;

"M" Moderate ice conditions according to the Rosgidromet official information;

"L" Easy ice conditions according to the Rosgidromet official information;

"+" Navigation is allowed

"-" Navigation is not allowed.

The NSRA indicates in the permit information on the need for icebreaker assistance in a heavy, medium and light ice conditions during navigation in the Northern Sea Route water area (CHNL, 2013d). Place and time of the commencement and completion of the icebreaker support shall be agreed by the shipowner with the organization providing icebreaker support services in the NSR water area. When approaching the point of formation of a group of vessels to follow the icebreakers, which are set up by the organization providing icebreaker support services, the vessel sets radio communication with an icebreaker and acts in accordance with the icebreaker instructions (CHNL, 2013d).

Name	ICE CLASS	Capacity (m3)	Year Built	Commercial Owner
ANNABELLA	1C	35 491	1975	Chemikalien Seatransport
ARCTIC SPIRIT	1C	89 089	1993	Teekay
CLEAN FORCE	1A	149 700	2008	Dynagas Ltd
CORAL METHANE	1B	7 350	2009	Veder A.
CYGNUS PASSAGE	Yes	145 000	2009	Tokyo Electric/NYK/Mitsubishi Corp
ENERGY ADVANCE	1D	147 624	2005	Tokyo Gas
ENERGY FRONTIER	1D	147 599	2003	Tokyo LNG/Mitsui OSK
ENERGY NAVIGATOR	1D	147 558	2008	Tokyo LNG/Mitsui OSK
GRACE BARLERIA	Yes	149 700	2007	NYK
GRAND ANIVA	1B	145 000	2008	Sovcomflot/NYK
GRAND ELENA	1B	145 580	2007	Sovcomflot/NYK
GRAND MEREYA	1B	145 963	2008	MOL/Primorsk
HYUNDAI ECOPIA	1C	145 000	2008	Hyundai Merchant Marine
K JASMINE	1C	151 800	2008	Korea Line
LNG DREAM	Yes	145 000	2006	Osaka Gas/NYK
LNG JUPITER	1C	155 999	2009	Osaka Gas/NYK
NORMAN LADY	1C	87 600	1973	Mitsui OSK/Hoegh LNG
OB RIVER	**1A**	**149 700**	**2007**	**Dynagas Ltd**
POLAR SPIRIT	1C	88 996	1993	Teekay
RIBERA DEL DUERO KNUTSEN	1A	173 400	2010	Knutsen O.A.S. Shipping
SCF ARCTIC	1C	71 651	1969	Sovcomflot
SCF POLAR	1C	71 650	1969	Sovcomflot
STENA BLUE SKY	1C	145 700	2006	Stena
STENA CLEAR SKY	1C	171 800	2011	Stena
STENA CRYSTAL SKY	1C	171 800	2011	Stena
SUN ARROWS	1B	19 176	2007	MOL/Hiroshima Gas
New Buildings				
DAEWOO 2289	1C	155 900	2013	Awilco LNG
DAEWOO 2290	1C	155 900	2013	Awilco LNG
KAWASAKI 1665	Yes	177 000	2013	NYK
PSKOV	1C	170 200	2014	Sovcomflot
SCF MELAMPUS	1C	170 200	2014	Sovcomflot
SCF MITRE	1C	170 200	2015	Sovcomflot
VELIKIY NOVGOROD	1C	170 200	2013	Sovcomflot
YENISEI RIVER	1A	155 000	2013	Dynagas Ltd
LENA RIVER	1A	155 000	2013	Dynagas Ltd
CLEAN WORLD	1A	155 000	2013	Dynagas Ltd
CLEAN OCEAN	1A	162 000	2014	Dynagas Ltd
CLEAN PLANET	1A	162 000	2014	Dynagas Ltd
HN 2566	1A	162 000	2015	On Offer
HN 2567	1A	162 000	2015	On Offer

Table 3: Overview of the current Ice Class LNG carrier fleet and new buildings

Source: (Laurent, 2013)

1.4 Preliminary conclusion on the feasibility

The aim of this part was to answer the question of whether sending an LNG shipment via the NSR is feasible. The approach used is a more qualitative than a quantitative one. I have come to a preliminary conclusion in this paper that shipping LNG via the NSR instead via the Suez Canal is feasible from July to November.

The Arctic sea-ice extent evolution the past years leads to new opportunities of sending shipments via the NSR. The Russian authorities' new measures for attracting shipments on this route follow its own path. The unexpected decision from Egyptian authorities to increase the Suez Canal toll by 2.5 to 5% from the 1st May 2013 (Tradewinds, 2013) could be a good opportunity for Russia to offer competitive icebreaking tariffs and hence attract newcomers on the NSR. The fact that Russia should allow Ice Class 1C and 1D vessels to transit via the NSR with icebreaking assistance from July to late November, as of before vessels should not be less than Ice Class 1A, reinforces new shipping opportunities. From Table 2 (p38) whenever the ice conditions are light, meaning that there is almost no ice at all, the new regulations allow also non-Ice Class vessels to transit with icebreaking escort with the permission from Rosatomflot.

Although a transit via the NSR is associated with extra risks, the NSRA's regulations are robust and strict. It should not be a problem to take advantage of sailing via the NSR. In addition, many seafarers and ship owners see the pirates along Somalia's and Vietnam's coasts and in the Strait of Malacca as a serious threat, and probably even more risky?. Consequently, the NSR could benefit from its more "pirate safe" image and attract new shipments in the future if the problem persists.

According to Viktor Olerski, Deputy Transport Minister of Russia, in the future, commercial attractiveness of transit navigation along the NSR will continue to grow with the development of the route's seaport infrastructure and with the implementation of projects for construction of large capacity vessels of Arctic Ice Class (Chernov, 2013). The progress of the Yamal project with the world's biggest Arctic port for gas export in Sabetta and the new buildings list of LNG Ice Class carriers from Table 3 (p39) are good indicators of this development. The questions remaining are how long it will take to develop this project and when will the first LNG cargo from Yamal happen. Will they meet financing problems? Will the project be further postponed?

The future of the gas market in Europe is uncertain. Nothing is indicating that the European gas prices will rise in the future; they should pursue their fall due to the sharp fall in demand (Figure 5) (p15). One of the main causes is the unexpected European rise in consumption of coal at a lower price than natural gas (Tollaksen, 2013). Terje Martin Halmø, a gas analyst from Terica AS, thinks that oil & gas companies such as Statoil in Norway are too focused on the European market. 95% of the Norwegian gas infrastructure is linked to European customers wishing to get the gas price down as low as possible. According to him, Norway should develop more its LNG infrastructure and send more of the gas shipment to Asia instead. He thinks that Norway should take advantage of the NSR and see it as a new opportunity to reach the Asian market. More LNG plants along the Norwegian coast should be considered to enable gas revenues to be less dependent on the European gas market. If nothing is done, Norway can probably lose NOK 20 billion in annual revenues in the near future (Tollaksen, 2013).

However, Statoil has recently announced its wish to re-enter the Shtokman project in the Barents Sea, in partnership with Gazprom and Total, if a new technology to extract and export the gas is envisaged. The most feasible and economic viable solution is to invest in a floating LNG terminal, a kind of "floating Melkøya" located over the gas field. With an uncertain gas market in Europe, Statoil is opposed to build a long gas pipeline to reach the European market. The cost would be too high to bear and there would be a risk to oversupply the continent with gas which would make the prices to fall even more from today's already low level (Helgesen, 2013).

According to Nikolai Grigoriev from Gazprom who succeeded with the *Ob River*, the NSR is not a highway, but an 'A' road. He also recommends for those wishing to sail via the NSR to plan in advance and take it seriously because the Arctic doesn't forgive, you have to treat it with respect. He is also ready to do it again; his group has planned and has the experience from 2012. When a new opportunities arise, he is ready to execute again he says (Hine, 2013d). Tschudi Shipping Company AS, which provides shipping and logistics services with special focus on Russia and the Baltic regions, were involved last year with the *Ob River's* transit through the NSR. They are now saying that they are in close cooperation with Rosatomflot and Dynagas Ltd, the *Ob River's* ship owner, to send a new LNG cargo for the coming 2013 season (Hagen, 2013).

II) A case study: the economic viability of the NSR

2.1 Purpose of the study

What I have studied so far is the feasibility of the NSR from a qualitative aspect. The aim of next part is to have a more quantitative approach by investigating whether it is economically viable or not to operate and send a LNG carrier via the NSR. The work will be performed by comparing two different shipping routes between Hammerfest in Norway and Yokohama in Japan. One of the routes will go via the Northern Sea Route while the other one will pass through the Suez Canal. The calculations will be made for two different LNG carriers. The study will be made from the LNG trader's point of view who charters the vessel.

2.2 Description of the study

2.2.1 A Voyage Cash Flow Analysis

I will start comparing the profitability of sailing via the NSR with the profitability of sailing through the Suez Canal for a single round trip Hammerfest-Yokohama.. The method used for each route will be the Voyage Cash Flow (VCF) analysis, again, from the trader's point of view (charterer). In order to better compare the results for each route, I will use an identical LNG tanker for each route and perform the calculation a second time using a different LNG tanker for both routes.

- The first one is a fictive Ice Class 1A 150,000 m^3 Steam Turbine (ST) basic winterized which I will name *Polar Bear* in the whole dissertation.
- The second LNG carrier will be a fictive one also; an 180,000 m^3 Triple-Fuel Diesel-Electric (TFDE) Ice Class 1A basic winterized. I will call it the *Northern Light* hereinafter.

It is interesting to choose these two vessels because of the difference of their engine (ST and TFDE), hence of the bunker consumption. Since they are of different size, they belong to different market segments; hence the charter rates will differ. The reason for choosing these vessels is to understand which of them would be more suitable and cost-effective to charter for the trader. Vessels like *Polar Bear* exist in today's LNG shipping market while the *Northern Light* does not but might exist in the near future.

In October 2012, the first NSR voyage of the *Ob River* started in ballast from Mizushima (Japan) and ended in Hammerfest. Arrived there, the *Ob River* loaded 134,066 m^3 LNG in Melkøya and performed the voyage back to Tobata in Japan (Lauritzen, 2013). In my case study, the NSR round trip will start from Hammerfest where the vessel will be fully loaded with LNG and will sail to Yokohama. The LNG cargo will be sold to the Japanese market at the Japan/Korea Spot (JKS) price. After unloading the cargo, the same voyage will be made back again to Hammerfest, in ballast this time.

The contract between Gazprom and Dynagas is a long term TC. As for the two LNG carriers chartered by TEPN[4], the TCP of the *Ob River* is a "*Shell LNG Time Charter*". Gazprom pays the long term daily TC rate (CAPEX and OPEX) and all voyage related costs (Lauritzen, 2013). For the VCF analysis in my case, I will consider a round trip voyage where the trader charters the vessel in the spot charter market.

To make the study more flexible, different sensitivity analyses will be made by varying important input variables as the LNG cargo price, the JKS sales price, the nature of the bunker and the sailing speed in order to see how these variations will influence the competitiveness of the NSR with Suez.

2.2.2 An Annual Cash Flow analysis

Once the VCF for a round trip has been studied and compared for each route, I will evaluate the trader's results from the Annual Cash Flows (ACFs). For the first ship service, the routine will be a simple round trip Hammerfest-Yokohama during the 365 navigable days a year. For the second service, the LNG carrier will sail via the NSR during the summer period and will sail via the Suez Canal during the rest of the year. The number of possible round trips along the two routes will depend on different variables as the shipping speed and the NSR's number of navigable days per year. The cargo lifting dates are scheduled from the number of round trips Hammerfest-Yokohama the vessel can complete during a year and hence from the expected dates at port. As for the VCF analysis, a sensitivity analysis will be carried out varying different input variables.

[4] The *Meridian Spirit* and the *Arctic Lady*

2.2.3 General distance and sailing speed assumptions

A distance Hammerfest-Suez-Yokohama of 12,500 nm will be assumed (Lauritzen, 2013). The Suez Canal scenario will be denominated "Suez". The guaranteed average speed for LNG carriers is usually situated between 18 and 20 knots. Because of winds, sometimes rough sea and other unpredictable weather conditions, the average sailing speed for "Suez" from Hammerfest to Yokohama will be assumed 18 knots, laden as in ballast.

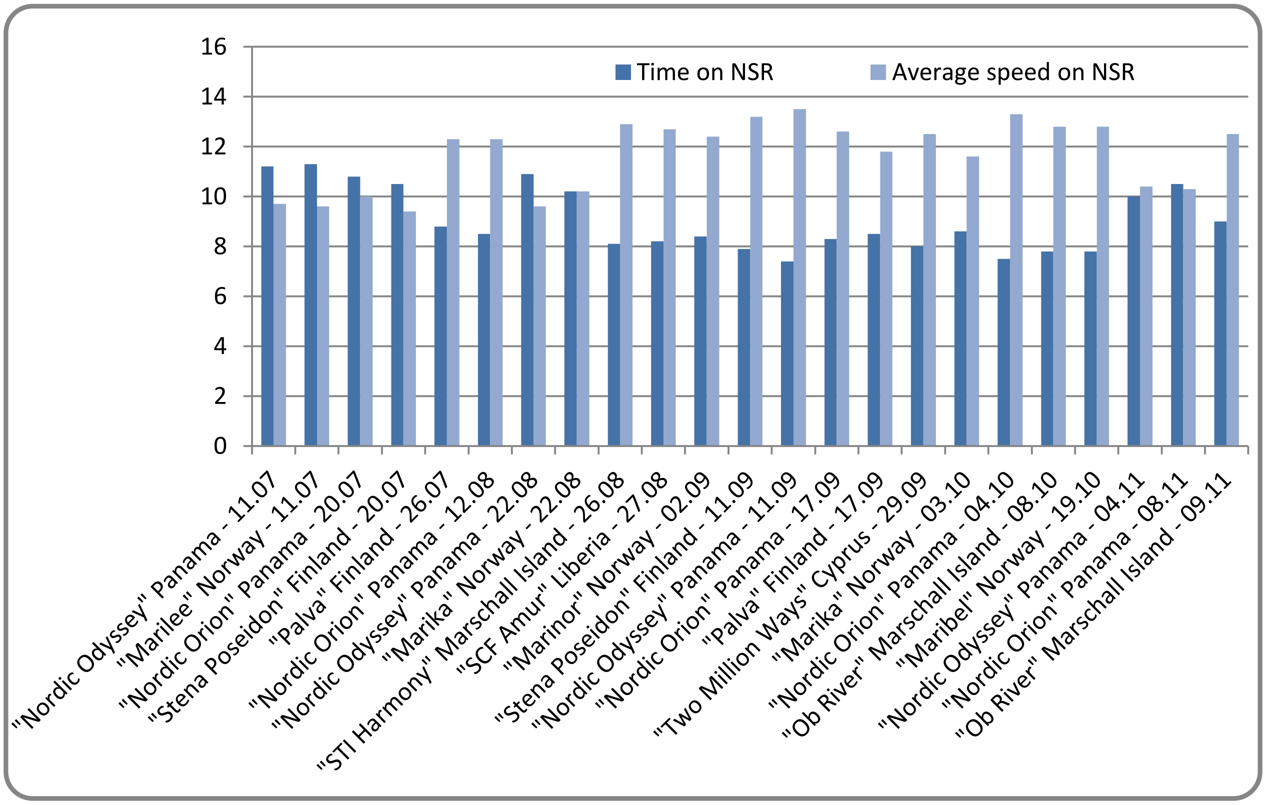

Figure 19: Largest vessels having entered the NSR in 2012 sorted by date of entrance

Source: (CHNL, 2012)

The sailing distance between Hammerfest and Yokohama via the NSR is 6,400 nm (Lauritzen, 2013). Since weather and ice conditions are often hard to predict on this route, the actual sailing distance may vary. For simplicity, in the study, the distance will be assumed constant. The NSR scenario will be denominated "NSR". In order to make the model more accurate and flexible, "NSR" will be divided into three sections:

- The first one goes from Hammerfest to the Kara Strait (section H/K) and the distance is 950 nm. On this route section we never see ice formations during summer (Belkin, 2013). Because of the Gulf Stream from Florida in the USA, the Barents Sea is guaranteed ice-free during all the year (Truc, 2013). Consequently, open blue water will be considered and the average speed assumed will be the same as for "Suez", 18 knots laden as in ballast.

- The second section is the NSR per definition which starts form the Kara Strait and ends at the Bering Strait and vice versa (section K/B). The sailing distance is 2,700 nm. There is typically young ice[5] during summer which is mainly present in the Laptev Sea, the East Siberian Sea and the Chukchi Sea. Again, the summer sea-ice extent in these regions varies with the years. Furthermore, it is usually on this route section the ice breaking escort lasts. The Arctic summer in 2012 was exceptional which enabled the *Ob River* escort to start from the Vilkitsky Strait. In the case study, I will assume the escort for the laden voyage to start at the Kara Strait, which is the most common, and end at the Bering Strait. For the ballast voyage back again, the ice breaking escort will start at the Bering Strait and end at the Kara Strait. The average assumed speed on this route section will be 12 knots laden as in ballast. This approximation is based on 2012 historical average sailing speeds on the NSR. In order to make the comparison more reliable, I have only taken into account the largest carriers (out of the total 46 in 2012) having transported at least 44,000 tons of cargo. These carriers are figured in Figure 19 (p44) and are sorted by the corresponding dates of entrance on the NSR. The graph shows the time spent on the NSR and the average sailing speed each vessel performed. It is interesting to observe that the average speed is at the highest from the end of August to the end of October, period in which it is optimal to transit as the sea-ice extent is at its lowest level (Figure 13) (p27).

- The third and last route section starts at the Bering Strait and ends in Yokohama (section B/Y) and the sailing distance is 2,750 nm. As for the H/K section, this sea is free of ice during summer (Belkin, 2013) and consequently the average sailing speed will be assumed 18 knots as well, laden as in ballast.

With the mentioned speed and distances in mind we can calculate the number of days it takes for a round trip Hammerfest-Yokohama under each scenario. I assume a direct service line without any stops along the route. The waiting and transit time combined for the Suez Canal is assumed

[5] Young ice refers to ice with a tickness varying generally from 10 cm to 30 cm

to be one day and the time necessary for planning a NSR transit is made preliminary to the voyage. The numbers of days at port are not taken into consideration as they are the same irrespective to the route taken. Table 4 gives us the results.

Route	**“Suez”**	**“NSR”**
Distance Hammerfest - Yokohama (nm)	*12,500*	*6,400*
Distance Hammerfest - Kara Strait (nm)	-	*950*
Distance Kara Strait - Bering Strait (nm)	-	*2,700*
Distance Bering Strait - Yokohama (nm)	-	*2,750*
Number of sailing days Hammerfest - Kara Strait (days)	-	*2.20*
Number of sailing days Kara Strait - Bering Strait (days)	-	*9.38*
Number of sailing days Bering Strait – Yokohama (days)	-	*6.37*
Waiting and transit time through the Suez Canal (days)	*1*	-
Total number of sailing days Hammerfest-Yokohama	29,94	17.94
Number of sailing days for a round trip*	**59,87**	**35.88**

Table 4: The number of sailing days

where

$$Number\ of\ sailing\ days = \frac{distance\ (nm)}{speed\ (knots) \times 24} + 1_{\{if\ "Suez"\}} \qquad (2.1)$$

$$Number\ of\ sailing\ days\ for\ a\ round\ trip = Number\ of\ sailing\ days \times 2 \qquad (2.2)$$

It is worth to notice that the number of sailing days on the NSR of 9.38 days (section K-B) is a good approximation. If we take the average from the numbers in Figure 19, we get an overall average sailing speed of 9.05 days for 2012.

2.3 The Voyage Cash Flow model

2.3.1 The vessels’ bunker consumption

Table 5 and Table 6 show respectively the bunker consumption for the *Northern Light* and the *Polar Bear*. The data for the *Northern Light* are taken from the 165,000 m^3 TFDE *Meridian Spirit* chartered by TEPN. There are several reasons for why these numbers represent a good approximation for the *Northern Light*. First of all, an 180,000 m^3 TFDE LNG carrier doesn’t exist in today's shipping market and bunker consumption numbers are hard to get. TEPN believes that the technology improvements rely today principally in more bunker efficient vessels. They believe that today's TFDE technology improvements would make a new 180,000 m^3 TFDE LNG carrier's bunker consumption comparable to the 2010 built 165,000 m^3 TFDE *Meridian Spirit*. The fact that the fictive *Northern Light* is Ice Class while the *Meridian Spirit* is not, will not affect the bunker consumption dramatically. It is wrong to think that Ice Class vessels are heavier than conventional ones, they are not ice breakers. The difference in bunker consumption relies principally in the form of the propellers and on the hull's hydrodynamics (Laurent, 2013). I will assume that the *Northern Light* is similar to the *Meridian Spirit* in terms hull design, hydrodynamics and propellers*;* although it can carry 15,000 m^3 more LNG. Consequently, for the reasons just mentioned, I will assume the bunker consumption of the *Northern Light* to be the same as of the *Meridian Spirit* in my model. For similar reasons, data for the *Polar Bear* are taken from the *Arctic Lady*.

A TFDE vessel can either burn marine gas oil, heavy fuel oil or LNG. The decision of choosing the nature of bunker will entirely depend on what is the cheapest for the trader. The consumption rates remain the key variable for traders contracting those vessels (Hine, 2013e). I will assume that the vessels run with LNG, expressed in BOG (Boil-Off-Gas). A case where the vessels run with fuel oil will also be studied later in order to see what would be the most cost efficient for the trader.

Northern Light	**Ballast**		**Laden**	
Speed (Knots)	**FOE/day mt**	**BOG/day m^3**	**FOE/day mt**	**BOG/day m^3**
19,5	137	263	142	273
19	134	257	136	261
18,5	127	244	126	242
18	120	230	117	224
17,5	114	219	109	210
17	109	209	101	195
16	99	190	88	168
15	89	171	79	151
14	82	158	69	132
13	76	145	63	120
12	70	135	57	110

Table 5: Overview of the *Northern Light's* bunker consumption volumes respective to speed

Source: (Laurent, 2013)

Polar Bear	Ballast		Laden	
Speed (Knots)	HFO/day	BOG/day	HFO/day	BOG/day
	mt	m^3	mt	m^3
19,5	180	360	195	390
19	165	330	180	360
18,5	150	300	165	330
18	135	270	150	300
17,5	130	260	145	290
17	125	250	140	280
16,5	120	240	135	270
16	115	230	130	260
15	105	210	120	240
14	95	190	110	220
13	85	170	100	200
12	75	150	90	180
11	65	130	80	160
10	55	110	70	140
8	53	105	55	110

Table 6: Overview of the *Polar Bear's* bunker consumption volumes respective to speed

Source: (Laurent, 2013)

In order to have a better overview of the consumption schemes, I drew the curves in Figure 20 representing the daily BOG as function of speed for the TFDE *Northern Light* and the ST *Polar Bear*.

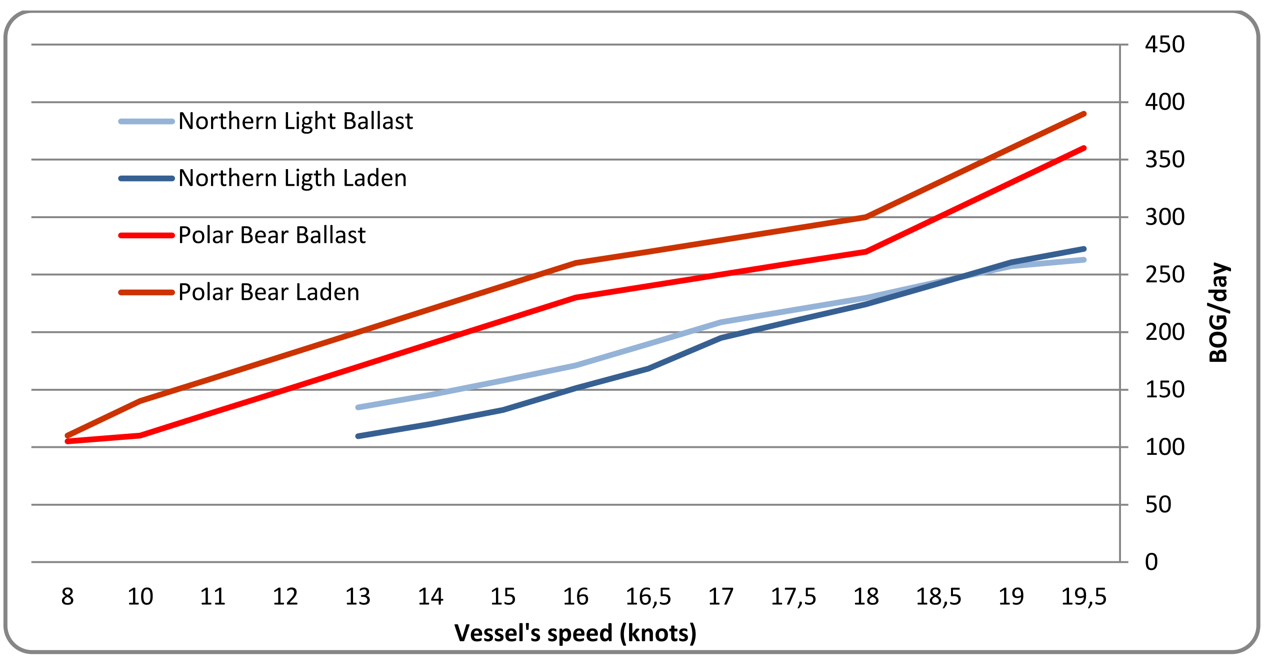

Figure 20: Representation of the LNG bunker consumption rates as function of sailing speed

HFO/day and FOE/day correspond to the daily "*Heavy Fuel Oil*" and "*Fuel Oil Equivalent*" expressed in metric tons (mt). The LNG bunker consumption expressed in m^3 is given by the daily BOG. TEPN uses 1 mt = 2 m^3 as a good approximation for converting HFO/day or FOE/day into BOG/day. For that reason, the same will be used in the calculations and I will not go into further details behind this equality.

The main reason for the atypical consumption characteristic of the *Northern Light* relies on the design of the ship´s hull, which has been optimized for the laden conditions and the TFDE propulsion at 18.5 knots. When the carrier is fully laden the vessel´s displacement makes the hull´s bulbous bow totally submerged and the hydrodynamics optimal at 18.5 knots. When the vessel is on ballast, the displacement is less, meaning that the hull´s bulbous bow is less efficient as well as the hydrodynamics, with an adverse effect resulting in an increase of consumption below 18.5 knots of speed. However below 18.5 knots, on ballast conditions, the hydrodynamics could be improved by trimming the vessel by ahead, but this action would also be detrimental to the ship´s propeller efficiency (Laurent, 2013).

For the *Polar Bear'*s case, we observe a more traditional shape of the curve with a vessel consuming more bunker laden than in ballast. We notice that all in all the 180,000 m^3 TFDE *Northern Light* is more bunker efficient than the 150,000 m^3 ST *Polar Bear*.

It is worth to point out that the incremental bunker consumption under ice conditions during summer can be disregarded. The main reason is that the vessels in my case will always be escorted by Russian ice breakers leading the route. Hence, the channel created by the ice breakers is made of broken sea-ice (Figure 15 & Figure 16, p33). It is also worth to emphasize on the fact that it will neither be the cargo owner's nor the ship owner's intention to break the ice. Secondly, the two players will always avoid taking unnecessary extra risk of breaking the ice. Lastly, an Ice Class vessel, whether it is 1C, 1B or 1A, is designed for first year ice and for broken sea-ice, not for breaking the sea-ice as it is specified in Table 1 (p31). The *Polar Bear* and the *Northern Light* are not ice breakers.

2.3.2 The shipping revenues

The *Polar Bear* has an exact LNG cargo capacity of 146,791 m^3. I know that the *Ob River* arrived in Tobata the 5th December 2012. The JKS price from the beginning of December 2012 was around 16 USD/mmBtu and I will be content myself with this value as a source of revenue for the trader (Laurent, 2013). The fact that the destination is Yokohama in the model has no impact on the JKS sales price.

Table 7 shows the trader's net shipping revenue for a fully laden vessel:

	ST *Polar Bear*		TFDE *Northern Light*	
Route	**"Suez"**	**"NSR"**	**"Suez"**	**"NSR"**
-LNG cargo volume (m^3)	*146,791*	*146,791*	*180,000*	*180,000*
-LNG burned during transport (m^3)	*17,063*	*7,976*	*13,595*	*6,178*
-Net LNG volume for sale (m^3)	*129,728*	*138,815*	*166,405*	*173,822*
*-Net LNG volume for sale (mmBtu)**	*3,009,688*	*3,220,515*	*3,860,605*	*4,032,662*
-JKS Gas sales price (USD/mmBtu)	*16*	*16*	*16*	*16*
Trader's Net Shipping Revenue (USD)	**48,155,013**	**51,528,241**	**61,769,683**	**64,522,600**

*Conversion factor 23.2 mmBtu/m^3.

Table 7: The shipping revenue

As already mentioned before, both vessels operate at the same speed laden as in ballast for the round trip, thus

$$LNG\ burned\ during\ transport\ (m^3)$$

$$= \frac{Laden\ (m^3/day) + Ballast\ (m^3/day)}{2} \times (\#\ of\ sailing\ days\ for\ a\ round\ trip) \qquad (2.3)$$

For the *Polar Bear's* NSR voyage round trip, the LNG bunker consumption is 7,976 m^3, given the speeds assumed of 18 knots on sections H-K and B-Y and 12 knots on K-B (NSR). This leads to a net cargo volume for sale in Yokohama of 138,815 m^3. For "Suez", since the sailing distance is approximately twice as long, of course more bunker will be consumed explaining the lower net LNG volumes for sale.

From the cargo owner's perspective, since the LNG is taken from the cargo volume transported, the marginal cost of burning LNG will depend on the LNG delivery price to Yokohama. Hence, the trader values the marginal LNG bunker cost via Suez as a cost of 16 USD/mmBtu since the marginal volume burned could have been sold to the Japanese market.

Given a same sales price of 16 USD/mmBtu, the *Northern Light* will generate more revenues than the *Polar Bear* since it has a higher cargo capacity and it is more bunker efficient.

2.3.3 The shipping costs

2.3.3.a) The hire cost

The *Polar Bear* is atypical in the LNG shipping market since the tanker is Ice Class 1A and there are few of them (Table 3, p 39). The *Northern Light* is even more out of the ordinary, since a vessel of this size and Ice Class 1A doesn't exist. We can find neither weekly nor monthly market reports given the spot charter rates for Ice Class LNG carriers. This can probably be explained by the fact that the number of Ice Class LNG carriers is small among conventional ones. There is not a clear defined market for those carriers. Whenever a vessel as the *Polar Bear* is available in the spot charter market for a short period of time, something rare since the vast majority of these vessels are in long term TC hire, the rate is often purely negotiated between the ship owner and the cargo owner. The spot rate is more than a simple supply and demand equilibrium. The ship owner will not hesitate to push the price up when bargaining with the charterer. This is especially true when the cargo owner wishes to charter the vessel for the NSR purpose. Since the ship owner sees there an additional risk and at the same time a cost advantage of sailing via the NSR instead via the Suez Canal, he will not hesitate to take a part of the profit by pushing the freight rate up (Laurent, 2013).

In the case study, an average spot charter rate of 122,000 USD/day will be considered for the *Polar Bear*, which is the average rate from August to November 2012 for a conventional 155,000 m^3 LNG (RS Platou, 2012).

For the *Northern Light*, reports on charter rates for 180,000 m^3 LNG carriers cannot be found, not to mention for Ice Class vessels. Despite that, it is possible to give rough estimates of the average spot charter rates for a 145,000 m^3 ST and 165,000 m^3 Dual-Fuel Diesel-Electric (DFDE) LNG vessels from August to November 2012. These were approximately respectively equal to 120,000 USD/day and 140,000 USD/day according to Fearnley LNG (2013). I will therefore assume that the spot charter rate difference between an 180,000 m^3 TFDE and the 165,000 m^3 DFDE is equal to the spot charter rate difference of USD 20,000 per day between the 165,000 m^3 DFDE and

145,000 m^3 ST. Hence, a good approximation of the spot charter rate for the *Northern Light* could have been 160,000 USD/day between August and November 2012.

Table 8 below shows the sum of the hire costs the trader would have to bear for a round trip spot voyage under each route.

	ST *Polar Bear*		**TFDE *Northern Light***	
Route	**"Suez"**	**"NSR"**	**"Suez"**	**"NSR"**
-Daily Spot Charter Rate (USD/day)	*122,000*	*122,000*	*160,000*	*160,000*
*-Number of sailing days for a round trip**	*59.87*	*35.88*	*59.87*	*35.88*
Sum trader's Hire Cost for a round trip (USD)	**7,304,185**	**4,377,315**	**9,579,259**	**5,740,741**

*The number of days at port is not taken into consideration

Table 8: The hire cost

2.3.3.b) The LNG cargo cost

Since the trader is assumed not to be a partner of Snøhvit, the LNG seller may charge him the NBP price plus a certain premium for the LNG. Thus, due to lack of information, I will assume the price paid by the charterer to be 12 USD/mmBtu which can be seen as a realistic approximation. This price takes into account the NBP price of 10 USD/mmBtu (Laurent, 2013) from November 2012 and a premium of 2 USD/mmBtu to the LNG seller. The table bellow gives an estimation of the LNG cargo cost for the trader, assuming a fully laden vessel.

	ST *Polar Bear*		**TFDE *Northern Light***	
Route	**"Suez"**	**"NSR"**	**"Suez"**	**"NSR"**
-LNG cargo volume (m^3)	*146,791*	*146,791*	*180,000*	*180,000*
-LNG cargo cost (USD/mmBtu)	*12*	*12*	*12*	*12*
Trader's total LNG cargo cost (USD)	**40,866,614**	**40,866,614**	**50,112,000**	**50,112,000**

Table 9: The LNG cargo cost

where

$$Trader's\ total\ LNG\ cargo\ cost\ (USD)$$
$$= LNG\ cargo\ volume\ (m^3) \times 23.2\ (m^3/mmBtu) \times LNG\ cargo\ cost (USD/mmBtu) \qquad (2.4)$$

2.3.3.c) *The Voyage costs*

For the Suez scenario, the Suez Canal costs involve channel dues, light dues, immigration clearance, mooring/unmooring, pilotage, port clearance fees and port sundries. The insurances take into account the Suez insurance, the extra risk insurance premiums related to the CTA (Conditional Trading Area) & IRTC (International Recommended Transit Corridor). For the NSR scenario the *Polar Bear* requires an extra LNG consumption of 4 mt per day for the winterization (Lauritzen, 2013). We will assume this rate to be the same for the *Northern Light.* As for the LNG bunker cost, the winterization cost is valued at the JKS price of 16 USD/mmBtu. The price is assumed to be the same for the laden and in ballast voyage. They are calculated only for the K/B route section with the following formula:

$$Extra\ LNG\ consumption\ for\ winterization$$

$$= 4\ (mt/day) \times 2(m^3/mt) \times 23{,}2(mmBtu/m^3) \times 16(USD/mmBtu) \times 9{,}38(days) \qquad (2.5)$$

$$= USD\ 27{,}840$$

The commercial agency costs include the approval cost from the NSRA, the support pre, during and post NSR voyage. For a first voyage along the NSR it costs USD 30,000. For subsequent voyages the cost is USD 15,000 (Lauritzen, 2013). They are assumed equal for both vessels.

For the *Polar Bear* and the *Northern Light*, I have assumed the 2013 Suez Canal tariffs to be equal to those for the *Arctic Lady* and the *Meridian Spirit.* They can be found in Appendix B & C.

The NSR tariff eastbound, when the *Polar Bear* is laden, is estimated from the cost Gazprom paid in November 2012 for the *Ob River*, which was approximately USD 325,000 (USD 5 per ton cargo according to Rosatomflot). Since the vessel at that time was not fully laden (134,066 m^3 given a max cargo capacity of 146,791 m^3), I have adjusted the NSR tariff since my study assumes a fully laden tanker. This gives us a NSR tariff of:

$$USD\ 325{,}000 \times \left(\frac{146{,}791(m^3)}{134{,}066(m^3)}\right) = USD\ 355{,}848 \qquad (2.6)$$

For the voyage back again in ballast, the *Polar Bear's* NSR tariff is based on the actual cost paid in 2012 by the Gazprom for the *Ob River;* a USD 2.5 per ton of displacement which gave a total of USD 222,500,

Regarding the *Northern Light*, the NSR tariff of the vessel laden is calculated from the 5 USD per ton cargo giving

$$\frac{180{,}000\ (m^3)}{2(m^3/mt)} \times 5(USD/mt) = USD\ 450{,}000 \qquad (2.7)$$

The NSR tariff for the *Northern Light* in ballast is based on the ton of displacement of 113,609 mt from the *Meridian Spirit* and the tariff of 2.5 USD per ton of displacement giving

$$113{,}609\ (mt) \times 2.5(USD/mt) = USD\ 284{,}023 \qquad (2.8)$$

The cost for anti-fouling afloat for the NSR scenario is considered in the voyage costs although it is not a requirement for every transit. For the *Polar Bear* purpose, they decided to carry out anti fouling on the vessel's hull due to the scraping of broken sea-ice. This was made afloat and did not require dry docking. It cost USD 15,000 (Lauritzen, 2013). Since the *Northern Light* is of higher volume, I assume a cost of USD 20,000 for the anti fouling afloat.

Port dues are based on data provided from TEPN for the *Arctic Lady* and the *Meridian Spirit* and are assumed to be the same for the *Polar Bear* and the *Northern Light.* The details behind the port dues can be found in Appendix B & C as I will not go into further details of the cost elements. The exchange rate taken into account to convert NOK into USD is 5.79 NOK/USD.

When the route goes via the Suez Canal, the insurance costs the trader USD 65,000. It takes into account the Suez Canal insurance, a crew bonus and war risk insurance. The insurance cost is the same for both vessels regardless if they transit the canal laden or in ballast. Whenever the vessels sail via the NSR, the trader pays the same amount of USD 65,000 as for Suez but including this time an insurance premium of USD 95,000; the approximated amount Gazprom paid in November 2012 for the *Ob River*. This gives a total NSR insurance of USD 160,000 laden as in ballast.

From Table 10, what we first observe is that the voyage costs for the *Polar Bear* (excluded LNG bunker costs) are somewhat higher for "Suez" than for "NSR" by USD 16,367. For the *Northern Light*, "NSR" is more costly than "Suez" given the assumptions taken.

	ST *Polar Bear*		**TFDE *Northern Light***	
Route	**"Suez"**	**"NSR"**	**"Suez"**	**"NSR"**
Extra LNG consumption for winterization Laden	-	*27,840*	-	*27,840*
Extra LNG consumption for winterization Ballast	-	*27,840*	-	*27,840*
Agent and Surveyor Load port Hammerfest	*219,859*	*219,859*	*206,450*	*206,450*
Transit fee Suez Canal Southbound laden	*502,591*	-	*439,068*	-
Transit fee Canal Northbound ballast	*433,304*	-	*380,018*	-
Commercial Agency cost (NSR approval and voyage support) Laden	-	*30,000*	-	*30,000*
Commercial Agency cost (NSR approval and voyage support) Ballast	-	*15,000*	-	*15,000*
*Ice pilotage Laden (2 pilots), USD 600 per pilot per day**	-	*11,250*	-	*11,250*
*Ice pilotage Ballast (2 pilots), USD 600 per pilot per day**	-	*11,250*	-	*11,250*
NSR Tariff Eastbound (Laden) 5 USD/ton of cargo	-	*355,848*	-	*450,000*
NSR Tariff Westbound (Ballast) 2.5 USD/ton of displacement	-	*222,500*	-	*284,023*
Cost for anti-fouling painting afloat	-	*15,000*	-	*20,000*
*Extra communication equipment for NSR (NBDP)***	-	*5,000*	-	*5,000*
*Cost for two sets of Russian charts***	-	*8,000*	-	*8,000*
Suez Insurance + War risk Insurance + Crew Bonus Laden	*65,000*	-	*65,000*	-
Suez Insurance + War risk Insurance + Crew Bonus Ballast	*65,000*	-	*65,000*	-
NSR Insurance Laden	-	*160,000*	-	*160,000*
NSR Insurance Ballast	-	*160,000*	-	*160,000*
*Agent and Surveyor Disch port Yokohama****	*108,831*	*108,831*	*105,378*	*105,378*
Sum Voyage Costs (USD)	**1,394,585**	**1,378,218**	**1,260,914**	**1,522,031**

*The cost does not take into account travel expenses for the pilots.
**The cost is only paid for the first voyage.
***The agent disch port costs are from the port of Futsu, assumed equivalent for Yokohama.

Table 10: The voyage costs

2.3.4 The Voyage Cash Flow results

2.3.4.a) Computing the results

Let's recall the assumptions I have made. I assumed a sailing speed is 18 knots on open blue water and 12 knots for the NSR (route section K/B) for both vessels, laden as in ballast. The freight rate is assumed to be USD 122,000 per day for the *Polar Bear* and USD 160,000 for the *Northern Light*. The cargo cost for the trader in Hammerfest is estimated to 12 USD/mmBtu and the JKS selling price in Yokohama is 16 USD/mmBtu. Given the distances of 12,500 nm via Suez and 6,400 nm through the NSR, and knowing the BOG rate is taken from the cargo volume and thus valued at the JKS price, I have come to the following results for each vessel:

	ST *Polar Bear*		**TFDE *Northern Light***	
Route	**"Suez"**	**"NSR"**	**"Suez"**	**"NSR"**
Trader's Net Shipping Revenue (USD)	48,155,013	51,528,241	61,769,683	64,522,600
-Sum Hire Cost for a round trip (USD)	*7,304,185*	*4,377,315*	*9,579,259*	*5,740,741*
-Trader's total LNG cargo cost (USD)	*40,866,614*	*40,866,614*	*50,112,000*	*50,112,000*
-Sum Voyage Cost (USD)	*1,394,585*	*1,378,218*	*1,260,914*	*1,522,031*
Trader's Voyage Cash Flow (USD)	**-1,410,372**	**4,906,095**	**817,510**	**7,147,828**
Net LNG volume for sale (mmBtu)	*3,009,688*	*3,220,515*	*3,860,605*	*4,032,662*
Trader's Voyage Cash Flow (USD/mmBtu)	-0.47	1.52	0.21	1.77
-Broker's Commission (USD/mmBtu)	*0.10*	*0.10*	*0.10*	*0.10*
Trader's Voyage Cash Flow (USD/mmBtu)	**-0.57**	**1.42**	**0.11**	**1.67**

Table 11: The Voyage Cash Flows with LNG as bunker

2.3.4.b) General comments

Given a commission to the broker of 0.10 USD/mmBtu, the Suez route would give a net loss of 0.57 USD/mmBtu for the charterer of the *Polar Bear* and a net profit of 0.11 USD/mmBtu for the charterer of the *Northern Light*. The NSR route would give a net profit of 1.42 USD/mmBtu for the *Polar Bear's* charterer and a net profit of 1.67 USD/mmBtu for the *Northern Light's* charterer. It would not be profitable to sail via the Suez Canal for the *Polar Bear* given that the assumptions I have taken are correct. All in all, it would be more profitable to take the NSR than sailing through the Suez Canal. The savings for the trader from sailing via the NSR when looking at these numbers cannot be ignored. We notice for both vessels that the savings from choosing the NSR instead of Suez rely principally in the hire cost and the bunker cost.

These preliminary results inform us also about the advantages of sailing with a Triple-Fuel Diesel-Electric LNG carrier. The main driver of the positive results for TFDE carriers is the lower bunker consumption rates relative to Steam Turbine carriers. The combination of higher transported volumes and the lower consumption leads to increased net shipping revenues. For the NSR, the *Northern Light* in my case would generate around USD 13 million in extra revenues for a single round trip compared to the *Polar Bear*. There is no doubt that oil & gas companies would care about economies of scale and the bunker consumption given these results. They would have rather chosen the TFDE *Northern Light* than the ST *Polar Bear* for both routes.

Typically, brokers compete and can accept a commission of USD 100,000 per voyage or sometimes USD 50,000. Some may accept even a negative commission for their first NSR voyage in hope of being better placed to gather future contracts on this strategic passage (Laurent, 2013).

2.3.4.c) A case with traditional fuel oil bunker

In the VCF model I have chosen LNG as bunker and valued the bunker cost to the JKS price in Japan at 16 USD/mmBtu. It is interesting to compare the cost if the *Northern Light* runs with Heavy Fuel Oil (HFO) instead. For an average speed between Hammerfest and Yokohama via the NSR approximated to 15 knots[6] and for a fully laden vessel, the daily BOG costs the trader:

$$151\ (m^3/day) \times 23.2(mmBtu/m^3) \times 16(USD/mmBtu) = USD\ 56{,}051\ per\ day \qquad (2.9)$$

If the vessel ran with HFO and the bunker price was 630 USD/mt, the daily bunker would cost the trader:

$$79(mt/day) \times 630(USD/mt) = USD\ 49{,}510\ per\ day \qquad (2.10)$$

It would have been more economical for trader of the *Northern Light* to run with traditional fuel oil in this case since the daily savings represent USD 6,521.

[6] The speed of 15 knots is estimated from the weighted average of 18 knots on sections H/K & B/Y and 12 knots on K/B, the NSR.

What should the bunker prices be for the trader in order to be indifferent between the two types of bunker? Keeping LNG bunker cost and other parameters constant, the break even HFO cost is 713.12 USD/mt. Keeping the fuel bunker cost and other parameters constant; the break even BOG cost is 14.13 USD/mmBtu.

For the *Polar Bear*'s case, supposing the same prices as before, a fully laden vessel, and an average speed of 15 knots between Hammerfest and Yokohama via the NSR, the daily BOG costs the trader:

$$240\ (m^3/day) \times 23.2(mmBtu/m^3) \times 16(USD/mmBtu) = USD\ 89{,}088\ per\ day \qquad (2.11)$$

If the vessel runs with HFO as bunker, taking a bunker price of 630 USD/tone, the daily bunker would cost him:

$$120(mt/day) \times 630(USD/mt) = USD\ 75{,}600\ per\ day \qquad (2.12)$$

This gives daily savings of USD 13,488 for the *Polar Bear*, even more than the *Northern Light*.

What would the VCF's be if the vessels ran with HFO instead?

We see in Table 12 that the trader increases the VCFs although the *Polar Bear* via the Suez Canal would have still generated a loss, but a slighter one than before.

	ST *Polar Bear*		**TFDE *Northern Light***	
Route	**"Suez"**	**"NSR"**	**"Suez"**	**"NSR"**
Trader's Shipping Revenue (USD)	54,488,819	54,488,819	66,816,000	66,816,000
-Bunker cost at 630 USD/mt	*5,374,829*	*2,542,995*	*4,462,051*	*1,894,249*
-Sum Hire Cost for a round trip (USD)	*7,304,185*	*4,377,315*	*9,579,259*	*5,740,741*
-Trader's total LNG cargo cost (USD)	*40,866,614*	*40,866,614*	*50,112,000*	*50,112,000*
-Sum Voyage Cost (USD)	*1,394,585*	*1,378,218*	*1,260,914*	*1,522,031*
Trader's Voyage Cash Flow (USD)	**-451,394**	**5,323,677**	**1,401,776**	**7,546,979**
LNG volume for sale (mmBtu)	3,405,551	3,405,551	4,176,000	4,176,000
Trader's Voyage Cash Flow (USD/mmBtu)	-0.13	1.56	0.34	1.81
-Broker's Commission (USD/mmBtu)	*0.10*	*0.10*	*0.10*	*0.10*
Trader's Voyage Cash Flow (USD/mmBtu)	**-0.23**	**1.46**	**0.24**	**1.71**

Table 12: The Voyage Cash Flows with fuel oil as bunker

This time the trader's shipping revenue is calculated from the full LNG capacity of the vessels (respectively 146.791 m^3 and 180,000 m^3).

The trader's bunker costs for a round trip Hammerfest-Yokohama are calculated as follows:

Polar Bear via Suez at 18 knots:	$630 \times 60 \times (135 + 150)/2 = USD\ 5{,}374{,}829$
Polar Bear via NSR at 15 knots:	$630 \times 36 \times (105 + 120)/2 = USD\ 2{,}542{,}995$
Northern Light via Suez at 18 knots:	$630 \times 60 \times (120 + 117)/2 = USD\ 4{,}462{,}051$
Northern Light via NSR at 15 knots:	$630 \times 36 \times (89 + 79)/2 = USD\ 1{,}894{,}249$

The voyage costs are assumed the same as before. For simplification, I did not adjust the extra cost for winterization via the NSR to 630 USD/mt since the adjustment would give little difference. I kept it as before at USD 27,840.

The results under BOG and fuel oil give us a preliminary idea of the potential savings that can be reached for the trader when conditions are ideal, which is not always the case. It is therefore important to do some sensitivity analysis by varying input variables as gas prices, speed and freight rates in order to see how the results will be affected.

2.3.5 A VCF sensitivity analysis

In this part, I will content myself with the BOG rate valued at the JKS price and disregard the fuel oil bunker case.

2.3.5.a) Varying the cargo cost and the JKS price

It is interesting to observe how the cargo cost and the JKS price can influence the results from Table 11 (p56). The following Table 13 to 16 show the USD/mmBtu VCFs by varying the cargo cost and JKS from one extreme to another. I have chosen an interval from 1 to 15 USD/mmBtu for the cargo cost and 1 from 20 USD/mmBtu for the JKS sales price. We have two kinds of LNG carriers and two different routes giving a total of four matrices. The numbers marked in red represent the results I found from the previous calculations in Table 11 (p56).

It is worth to point out that if the trader was partner of Snøhvit, the LNG cargo would cost him much less than 12 USD/mmBtu. If that was the case, the trader would generate a higher profit. Since the *Arctic Lady* and the *Meridian Spirit* are not Ice Class, the NSR can represent an interesting opportunity to TEPN for LNG exports to Asia if they charter an Ice Class vessel in the spot charter market for instance. The *Northern Light*, if it existed, could have been a good choice for them.

NSR Profit/Loss (USD/mmBtu)		LNG cargo price (USD/mmBtu)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
JKS Gas price (USD/mmBtu)	1	-1,93	-2,99	-4,04	-5,10	-6,16	-7,22	-8,27	-9,33	-10,39	-11,45	-12,50	-13,56	-14,62	-15,68	-16,73
	2	-0,93	-1,99	-3,04	-4,10	-5,16	-6,22	-7,27	-8,33	-9,39	-10,45	-11,50	-12,56	-13,62	-14,68	-15,73
	3	0,07	-0,99	-2,05	-3,10	-4,16	-5,22	-6,28	-7,33	-8,39	-9,45	-10,51	-11,56	-12,62	-13,68	-14,73
	4	1,07	0,01	-1,05	-2,10	-3,16	-4,22	-5,28	-6,33	-7,39	-8,45	-9,51	-10,56	-11,62	-12,68	-13,74
	5	2,07	1,01	-0,05	-1,11	-2,16	-3,22	-4,28	-5,33	-6,39	-7,45	-8,51	-9,56	-10,62	-11,68	-12,74
	6	3,07	2,01	0,95	-0,11	-1,16	-2,22	-3,28	-4,34	-5,39	-6,45	-7,51	-8,57	-9,62	-10,68	-11,74
	7	4,07	3,01	1,95	0,89	-0,16	-1,22	-2,28	-3,34	-4,39	-5,45	-6,51	-7,57	-8,62	-9,68	-10,74
	8	5,06	4,01	2,95	1,89	0,83	-0,22	-1,28	-2,34	-3,40	-4,45	-5,51	-6,57	-7,63	-8,68	-9,74
	9	6,06	5,01	3,95	2,89	1,83	0,78	-0,28	-1,34	-2,40	-3,45	-4,51	-5,57	-6,63	-7,68	-8,74
	10	7,06	6,00	4,95	3,89	2,83	1,77	0,72	-0,34	-1,40	-2,46	-3,51	-4,57	-5,63	-6,69	-7,74
	11	8,06	7,00	5,95	4,89	3,83	2,77	1,72	0,66	-0,40	-1,46	-2,51	-3,57	-4,63	-5,69	-6,74
	12	9,06	8,00	6,94	5,89	4,83	3,77	2,71	1,66	0,60	-0,46	-1,51	-2,57	-3,63	-4,69	-5,74
	13	10,06	9,00	7,94	6,89	5,83	4,77	3,71	2,66	1,60	0,54	-0,52	-1,57	-2,63	-3,69	-4,75
	14	11,06	10,00	8,94	7,89	6,83	5,77	4,71	3,66	2,60	1,54	0,48	-0,57	-1,63	-2,69	-3,75
	15	12,06	11,00	9,94	8,88	7,83	6,77	5,71	4,65	3,60	2,54	1,48	0,42	-0,63	-1,69	-2,75
	16	13,06	12,00	10,94	9,88	8,83	7,77	6,71	5,65	4,60	3,54	2,48	1,42	0,37	-0,69	-1,75
	17	14,05	13,00	11,94	10,88	9,82	8,77	7,71	6,65	5,59	4,54	3,48	2,42	1,36	0,31	-0,75
	18	15,05	14,00	12,94	11,88	10,82	9,77	8,71	7,65	6,59	5,54	4,48	3,42	2,36	1,31	0,25
	19	16,05	14,99	13,94	12,88	11,82	10,76	9,71	8,65	7,59	6,54	5,48	4,42	3,36	2,31	1,25
	20	17,05	15,99	14,94	13,88	12,82	11,76	10,71	9,65	8,59	7,53	6,48	5,42	4,36	3,30	2,25

Suez Profit/Loss (USD/mmBtu)		LNG Cargo price (USD/mmBtu)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
JKS Gas price (USD/mmBtu)	1	-3,12	-4,25	-5,38	-6,52	-7,65	-8,78	-9,91	-11,04	-12,17	-13,31	-14,44	-15,57	-16,70	-17,83	-18,96
	2	-2,12	-3,25	-4,38	-5,52	-6,65	-7,78	-8,91	-10,04	-11,17	-12,31	-13,44	-14,57	-15,70	-16,83	-17,96
	3	-1,12	-2,25	-3,38	-4,52	-5,65	-6,78	-7,91	-9,04	-10,17	-11,31	-12,44	-13,57	-14,70	-15,83	-16,96
	4	-0,12	-1,25	-2,38	-3,52	-4,65	-5,78	-6,91	-8,04	-9,17	-10,31	-11,44	-12,57	-13,70	-14,83	-15,96
	5	0,88	-0,25	-1,38	-2,52	-3,65	-4,78	-5,91	-7,04	-8,17	-9,31	-10,44	-11,57	-12,70	-13,83	-14,96
	6	1,88	0,75	-0,38	-1,52	-2,65	-3,78	-4,91	-6,04	-7,17	-8,31	-9,44	-10,57	-11,70	-12,83	-13,96
	7	2,88	1,75	0,62	-0,52	-1,65	-2,78	-3,91	-5,04	-6,17	-7,31	-8,44	-9,57	-10,70	-11,83	-12,96
	8	3,88	2,75	1,62	0,48	-0,65	-1,78	-2,91	-4,04	-5,17	-6,31	-7,44	-8,57	-9,70	-10,83	-11,96
	9	4,88	3,75	2,62	1,48	0,35	-0,78	-1,91	-3,04	-4,17	-5,31	-6,44	-7,57	-8,70	-9,83	-10,96
	10	5,88	4,75	3,62	2,48	1,35	0,22	-0,91	-2,04	-3,17	-4,31	-5,44	-6,57	-7,70	-8,83	-9,96
	11	6,88	5,75	4,62	3,48	2,35	1,22	0,09	-1,04	-2,17	-3,31	-4,44	-5,57	-6,70	-7,83	-8,96
	12	7,88	6,75	5,62	4,48	3,35	2,22	1,09	-0,04	-1,17	-2,31	-3,44	-4,57	-5,70	-6,83	-7,96
	13	8,88	7,75	6,62	5,48	4,35	3,22	2,09	0,96	-0,17	-1,31	-2,44	-3,57	-4,70	-5,83	-6,96
	14	9,88	8,75	7,62	6,48	5,35	4,22	3,09	1,96	0,83	-0,31	-1,44	-2,57	-3,70	-4,83	-5,96
	15	10,88	9,75	8,62	7,48	6,35	5,22	4,09	2,96	1,83	0,69	-0,44	-1,57	-2,70	-3,83	-4,96
	16	11,88	10,75	9,62	8,48	7,35	6,22	5,09	3,96	2,83	1,69	0,56	-0,57	-1,70	-2,83	-3,96
	17	12,88	11,75	10,62	9,48	8,35	7,22	6,09	4,96	3,83	2,69	1,56	0,43	-0,70	-1,83	-2,96
	18	13,88	12,75	11,62	10,48	9,35	8,22	7,09	5,96	4,83	3,69	2,56	1,43	0,30	-0,83	-1,96
	19	14,88	13,75	12,62	11,48	10,35	9,22	8,09	6,96	5,83	4,69	3,56	2,43	1,30	0,17	-0,96
	20	15,88	14,75	13,62	12,48	11,35	10,22	9,09	7,96	6,83	5,69	4,56	3,43	2,30	1,17	0,04

Table 13 (left) and Table 14 (right): Gas price sensitivities for the *Polar Bear*

NSR Profit/Loss (USD/mmBtu)		LNG cargo price (USD/mmBtu)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
JKS Gas price (USD/mmBtu)	1	-1,92	-2,96	-3,99	-5,03	-6,07	-7,10	-8,14	-9,17	-10,21	-11,24	-12,28	-13,31	-14,35	-15,39	-16,42
	2	-0,92	-1,96	-3,00	-4,03	-5,07	-6,10	-7,14	-8,17	-9,21	-10,24	-11,28	-12,32	-13,35	-14,39	-15,42
	3	0,07	-0,96	-2,00	-3,03	-4,07	-5,10	-6,14	-7,17	-8,21	-9,25	-10,28	-11,32	-12,35	-13,39	-14,42
	4	1,07	0,04	-1,00	-2,03	-3,07	-4,10	-5,14	-6,17	-7,21	-8,25	-9,28	-10,32	-11,35	-12,39	-13,42
	5	2,07	1,04	0,00	-1,03	-2,07	-3,10	-4,14	-5,18	-6,21	-7,25	-8,28	-9,32	-10,35	-11,39	-12,42
	6	3,07	2,04	1,00	-0,03	-1,07	-2,11	-3,14	-4,18	-5,21	-6,25	-7,28	-8,32	-9,35	-10,39	-11,43
	7	4,07	3,04	2,00	0,96	-0,07	-1,11	-2,14	-3,18	-4,21	-5,25	-6,28	-7,32	-8,36	-9,39	-10,43
	8	5,07	4,03	3,00	1,96	0,93	-0,11	-1,14	-2,18	-3,21	-4,25	-5,29	-6,32	-7,36	-8,39	-9,43
	9	6,07	5,03	4,00	2,96	1,93	0,89	-0,14	-1,18	-2,21	-3,25	-4,29	-5,32	-6,36	-7,39	-8,43
	10	7,07	6,03	5,00	3,96	2,93	1,89	0,86	-0,18	-1,22	-2,25	-3,29	-4,32	-5,36	-6,39	-7,43
	11	8,07	7,03	6,00	4,96	3,93	2,89	1,85	0,82	-0,22	-1,25	-2,29	-3,32	-4,36	-5,39	-6,43
	12	9,07	8,03	7,00	5,96	4,92	3,89	2,85	1,82	0,78	-0,25	-1,29	-2,32	-3,36	-4,40	-5,43
	13	10,07	9,03	7,99	6,96	5,92	4,89	3,85	2,82	1,78	0,75	-0,29	-1,32	-2,36	-3,40	-4,43
	14	11,07	10,03	8,99	7,96	6,92	5,89	4,85	3,82	2,78	1,75	0,71	-0,33	-1,36	-2,40	-3,43
	15	12,06	11,03	9,99	8,96	7,92	6,89	5,85	4,82	3,78	2,74	1,71	0,67	-0,36	-1,40	-2,43
	16	13,06	12,03	10,99	9,96	8,92	7,89	6,85	5,81	4,78	3,74	2,71	1,67	0,64	-0,40	-1,43
	17	14,06	13,03	11,99	10,96	9,92	8,88	7,85	6,81	5,78	4,74	3,71	2,67	1,64	0,60	-0,44
	18	15,06	14,03	12,99	11,96	10,92	9,88	8,85	7,81	6,78	5,74	4,71	3,67	2,64	1,60	0,56
	19	16,06	15,03	13,99	12,95	11,92	10,88	9,85	8,81	7,78	6,74	5,71	4,67	3,63	2,60	1,56
	20	17,06	16,02	14,99	13,95	12,92	11,88	10,85	9,81	8,78	7,74	6,70	5,67	4,63	3,60	2,56

Suez Profit/Loss (USD/mmBtu)		LNG Cargo price (USD/mmBtu)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
JKS Gas price (USD/mmBtu)	1	-2,99	-4,07	-5,15	-6,23	-7,32	-8,40	-9,48	-10,56	-11,64	-12,72	-13,81	-14,89	-15,97	-17,05	-18,13
	2	-1,99	-3,07	-4,15	-5,23	-6,32	-7,40	-8,48	-9,56	-10,64	-11,72	-12,81	-13,89	-14,97	-16,05	-17,13
	3	-0,99	-2,07	-3,15	-4,23	-5,32	-6,40	-7,48	-8,56	-9,64	-10,72	-11,81	-12,89	-13,97	-15,05	-16,13
	4	0,01	-1,07	-2,15	-3,23	-4,32	-5,40	-6,48	-7,56	-8,64	-9,72	-10,81	-11,89	-12,97	-14,05	-15,13
	5	1,01	-0,07	-1,15	-2,23	-3,32	-4,40	-5,48	-6,56	-7,64	-8,72	-9,81	-10,89	-11,97	-13,05	-14,13
	6	2,01	0,93	-0,15	-1,23	-2,32	-3,40	-4,48	-5,56	-6,64	-7,72	-8,81	-9,89	-10,97	-12,05	-13,13
	7	3,01	1,93	0,85	-0,23	-1,32	-2,40	-3,48	-4,56	-5,64	-6,72	-7,81	-8,89	-9,97	-11,05	-12,13
	8	4,01	2,93	1,85	0,77	-0,32	-1,40	-2,48	-3,56	-4,64	-5,72	-6,81	-7,89	-8,97	-10,05	-11,13
	9	5,01	3,93	2,85	1,77	0,68	-0,40	-1,48	-2,56	-3,64	-4,72	-5,81	-6,89	-7,97	-9,05	-10,13
	10	6,01	4,93	3,85	2,77	1,68	0,60	-0,48	-1,56	-2,64	-3,72	-4,81	-5,89	-6,97	-8,05	-9,13
	11	7,01	5,93	4,85	3,77	2,68	1,60	0,52	-0,56	-1,64	-2,72	-3,81	-4,89	-5,97	-7,05	-8,13
	12	8,01	6,93	5,85	4,77	3,68	2,60	1,52	0,44	-0,64	-1,72	-2,81	-3,89	-4,97	-6,05	-7,13
	13	9,01	7,93	6,85	5,77	4,68	3,60	2,52	1,44	0,36	-0,72	-1,81	-2,89	-3,97	-5,05	-6,13
	14	10,01	8,93	7,85	6,77	5,68	4,60	3,52	2,44	1,36	0,28	-0,81	-1,89	-2,97	-4,05	-5,13
	15	11,01	9,93	8,85	7,77	6,68	5,60	4,52	3,44	2,36	1,28	0,19	-0,89	-1,97	-3,05	-4,13
	16	12,01	10,93	9,85	8,77	7,68	6,60	5,52	4,44	3,36	2,28	1,19	0,11	-0,97	-2,05	-3,13
	17	13,01	11,93	10,85	9,77	8,68	7,60	6,52	5,44	4,36	3,28	2,19	1,11	0,03	-1,05	-2,13
	18	14,01	12,93	11,85	10,77	9,68	8,60	7,52	6,44	5,36	4,28	3,19	2,11	1,03	-0,05	-1,13
	19	15,01	13,93	12,85	11,77	10,68	9,60	8,52	7,44	6,36	5,28	4,19	3,11	2,03	0,95	-0,13
	20	16,01	14,93	13,85	12,77	11,68	10,60	9,52	8,44	7,36	6,28	5,19	4,11	3,03	1,95	0,87

Table 15 (left) and Table 16(right): Gas price sensitivities for the *Northern Light*

What we observe in Table 13 to 16 is that the numbers follow a linear path whether one is reading horizontally or vertically in the tables, which seems logical since the JKS and the cargo price are the only parameters allowed to vary.

According to the numbers, one thing for sure is that the NSR will always be more profitable than the Suez Canal route. With minimum risks during September month with almost ice free waters, a trader wishing to send a LNG shipment from Norway to Asia-Pacific should see the NSR as valuable in terms of savings compared to the Suez Canal route. The potential savings when comparing the results between “NSR” and “Suez” vary between 1 and 1.8 USD/mmBtu depending on where we place ourselves in the tables. Given that the *Northern Light* for instance delivers roughly 4 million mmBtus’ in a single voyage means that the potential extra revenues compared to Suez can represent an amount situated between USD 4 million and USD 7.2 million.

With these numbers, we can also say that a TFDE LNG carrier is more economical than a standard ST LNG carrier. Moreover it is interesting to observe that with a 4 USD/mmBtu margin between the JKS of 16 USD/mmBtu and the cargo cost of 12 USD/mmBtu, the results for the *Northern Light* are in the positive zone indeed, but close to the negative zone. A drop in the JKS price to 14 USD/mmBtu for instance knowing that the trader paid 12 USD/mmBtu for its cargo would have given a net loss of -1.89 USD/mmBtu for “Suez” and -0.33 USD/mmBtu for “NSR”. Hence, the question to ask ourselves is whether the trader/charterer would take the risk or not to ship the LNG at the price levels in red we have assumed.

When subtracting for each route the matrix table of the *Northern Light* with the corresponding table of the *Polar Bear*, we get a new table expressing the incremental profit of the *Northern Light* on the *Polar Bear*. Each line in the new tables will give the same results because of linearity. However, when having a look at the columns, we observe that the incremental profit of the *Northern Light* on the *Polar Bear* increases with the LNG cargo cost for both routes as we can see in Figure 21. The “Suez” curve increases faster than the “NSR” curve because of the longer sailing distance. What we can deduce from that is that the higher the LNG cargo price, the higher is the incremental profit of the *Northern Light* on the *Polar Bear*. The choice of the *Northern Light* for shipping becomes more evident the higher the incremental profit. The graph shows us a result of economies of scale.

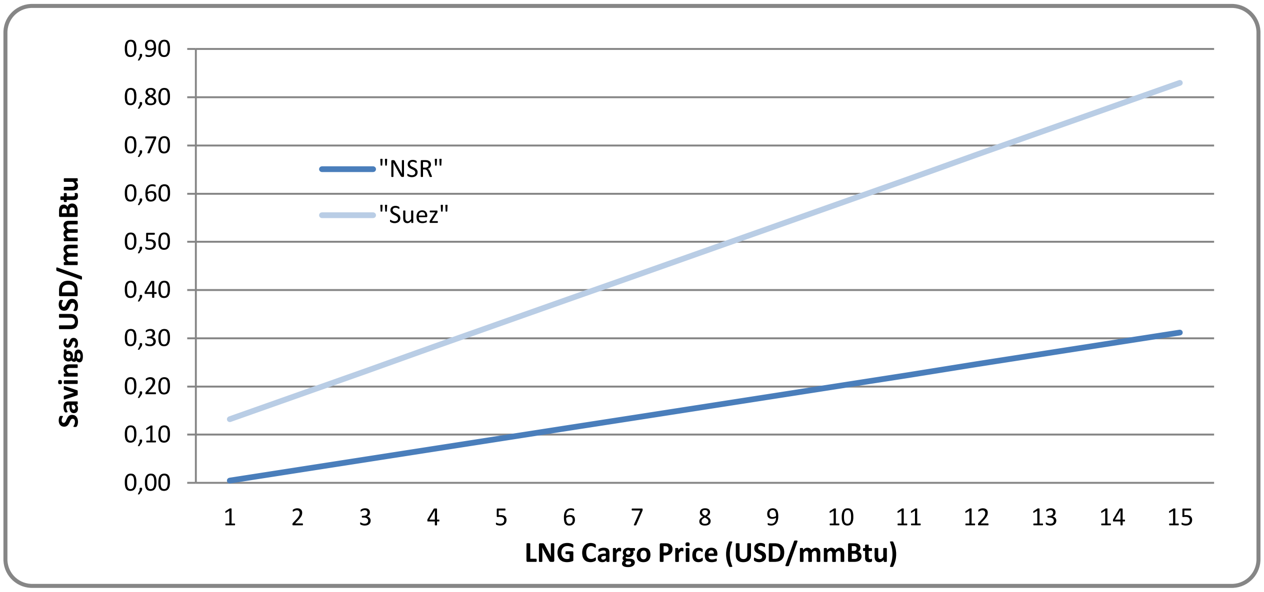

Figure 21: Incremental profit of the *Northern Light* on the *Polar Bear* as function of the LNG cargo price

2.3.5.b) Varying the average sailing speed on the NSR

In the following two tables, I have plotted the trader's VCFs (expressed in USD/mmBtu) for the "NSR" scenario by varying the two speed parameters and keeping the other parameters constant.

Polar Bear	Average sailing speed (knots) Kara Strait-Bering Strait (NSR)							
		8	**10**	**11**	**12**	**13**	**14**	**15**
Average sailing speed (knots) H/K and B/Y	**12**	0,81	1,05	1,11	1,17	1,21	1,25	1,28
	13	0,87	1,11	1,17	1,23	1,27	1,31	1,34
	14	0,92	1,16	1,22	1,28	1,32	1,36	1,39
	15	0,96	1,20	1,27	1,32	1,37	1,40	1,44
	16	1,00	1,24	1,31	1,36	1,40	1,44	1,48
	16,5	1,02	1,26	1,32	1,38	1,42	1,46	1,49
	17	1,03	1,28	1,34	1,39	1,44	1,48	1,51
	17,5	1,05	1,29	1,36	1,41	1,45	1,49	1,53
	18	1,06	1,31	1,37	**1,42**	1,47	1,51	1,54
	18,5	1,04	1,28	1,35	1,40	1,45	1,49	1,52
	19	1,02	1,26	1,33	1,38	1,43	1,47	1,50

Table 17: *Polar Bear* sensitivity analysis of the VCF in USD/mmBtu

Northern Light	Average sailing speed (knots) Kara Strait-Bering Strait (NSR)				
Average sailing speed (knots) H/K and B/Y		12	13	14	15
	12	1,40	1,45	1,50	1,54
	13	1,47	1,53	1,58	1,61
	14	1,54	1,59	1,64	1,68
	15	1,58	1,64	1,69	1,73
	16	1,62	1,68	1,73	1,77
	17	1,65	1,71	1,76	1,79
	17,5	1,66	1,72	1,77	1,80
	18	1,67	1,73	1,78	1,81
	18,5	1,68	1,74	1,78	1,82
	19	1,68	1,74	1,79	1,83

Table 18: *Northern Light* sensitivity analysis of the VCF in USD/mmBtu

It is particularly useful to study the curves' shape in order to see how the VCFs vary with speed. In Figure 22 below, I have chosen two columns from each table and figured the VCFs as function of average sailing speed on the sections H/K and B/Y. This is done for a given speed on route section K/B (Kara Strait to Bering Strait) that I have chosen to be 12 and 14 knots. It is worth to recall that H/K stands for route section "Hammerfest – Kara Strait" and B/Y for "Bering Strait-Yokohama"

The first thing we notice is the difference in the curves' shape between the two LNG carriers. The more bunker efficient *Northern Light* gives better results than the *Polar Bear* and the VCFs are maximized at a maximum speed of 19 knots, given that all other parameters are hold constant. However, for the *Polar Bear*, keeping all other parameters constant, the trader would maximize its VCF by maintaining a constant speed of 18 knots on sections H/K and B/Y. At a speed level above 18 knots, the trader would reach a lower VCF compared to the 18 knots level. This effect is due to the higher BOG rates the more you speed up. Although you are moving faster and taking fewer days to reach destination when speeding up, the bunker consumption rate, hence bunker cost, become too high which in terms will have a negative effect on the VCF.

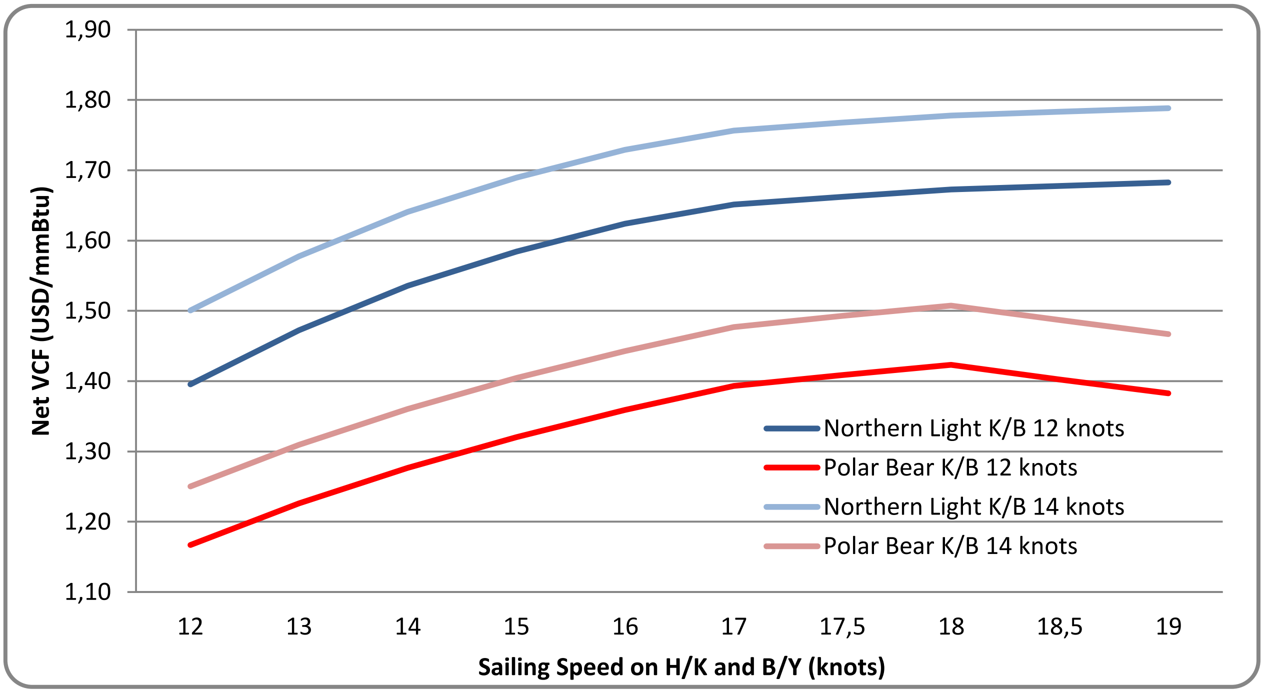

Figure 22: Trader's VCFs as function of sailing speed on H/K and B/Y

2.4 The Annual Cash Flow model

2.4.1 Preliminary assumptions

In this part, I will analyze the trader's cash flows on annual basis supposing that we have 365 sailing days a year. For the Suez Canal route, based on the sailing distance Hammerfest-Yokohama of 12,500 nm, the sailing speed and the number of days at port, I will be able to find the number of round trips that can be performed annually.

For "NSR", the voyages will be made via the NSR during summer and via the Suez Canal during the remaining days of the year. The word "summer" can be regarded as somewhat ambiguous in an Arctic context. We know for instance that the number of exact navigable days along the NSR varies over the years because of several factors such as temperature and the sea-ice extent. I will therefore study three different scenarios where the NSR is open for navigation during respectively 90 days per year under the worth case scenario, 120 days per year under base case and 150 days per year under the best case.

First and foremost, I will assume a constant sailing speed on the routes for every round trip. Speeds will be assumed equal as in the VCF model in section 2.2.3.

For every round trip, the number of days at port in Hammerfest and Yokohama are respectively 2 days, which gives a total number of 4 days at port per round trip.

I assume that the tankers have neither dry docking days nor stops along the routes during the year. The waiting and transit time combined through the Suez Canal is assumed to be one day as before. Given the distances we have, I have summed up the number of round trips in Table 19.

Route	**"Suez"**	**"NSR"**		
Navigable days per year	**365**	**365**		
NSR Navigable days per year	**N.A**	**90**	**120**	**150**
Number of round trips per year via NSR	-	*2.26*	*3.01*	*3,76*
Number of round trips per year via Suez	-	*4.31*	*3.84*	*3,37*
Number of round trips per year	**5.71**	**6.56**	**6.84**	**7,13**

Table 19: Number of sailing days

For "Suez" it is straight forward to find the theoretical number of round trips per year given the assumptions above:

$$Number\ of\ round\ trips\ per\ year = \frac{365(days)}{(\frac{12{,}500(nm)}{18(knots)\times 24}+1)\times 2+4(days)} \quad (2.13)$$

$$= \frac{365(days)}{59.87(days)+4(days)} = \mathbf{5.71}$$

For "NSR" when the NSR is open for 120 navigable days a year, the number of round trips per year can be found by following:

$$Number\ of\ round\ trips\ per\ year = \frac{120(days)}{35.88(days)+4(days)} + \frac{(365-120)(days)}{59.87(days)+4(days)} \quad (2.14)$$

$$= 3.01 + 3.84 = \mathbf{6.84}$$

The same calculations are done for 90 and 150 navigable days via the NSR. In the denominator, what I take is the number of days for a round trip without port days from section 2.2.3 and I add the 4 days at port since this will affect the number of round trips per year.

2.4.2 Costs assumptions

The main differences this time compared to the VCF analysis is the nature of the charter agreement. In the Voyage Cash Flow analysis, I supposed that the *Polar Bear* and *the Northern Light* were chartered for a spot voyage round trip at respectively 122,000 USD/day and 160,000 USD/day.

When analyzing the Annual Cash Flows (ACFs), I will assume that the LNG carriers are chartered in a long term Time Charter (TC) as the *Arctic Lady* and the *Meridian Spirit*. The long term TC rates include the capital expenditures (CAPEX) and the operating expenditures (OPEX). This time, I will not chose a fix rate for each vessel and do the calculations step by step again, as I did in the VCF model, to we find the ACFs. I will instead go directly to the sensitivities by choosing different rates. For the 150,000 m^3 ST *Polar Bear*, I have chosen three different TC rates (CAPEX+OPEX); respectively 100,000 USD/day, 130,000 USD/day and 160,000 USD/day. For the 180,000 m^3 TFDE *Northern Light*, since the vessel is of higher capacity and thus belongs to a different market segment, I have chosen three different charter rates; respectively 120,000 USD/day, 150,000 USD/day and 180,000 USD/day.

A sensitivity analysis will also be considered for the gas prices. Concerning the cargo cost of USD 12 per mmBtu and the JKS USD 16 per mmBtu from the previous VCF model, I will now choose three different prices in order to see how the ACFs will be affected. For the cargo cost, I have chosen the rates 7 USD/mmBtu, 10 USD/mmBtu and 13 USD/mmBtu. For the JKS sales price, I have chosen 11 USD/mmBtu, 14 USD/mmBtu and 16 USD/mmBtu.

2.4.3 The Annual Cash Flow results

I have computed the ACFs results from the Excel sheet in Table 20 and Table 21 for each LNG carrier. The numbers are calculated from the cash flows generated over a year divided by the net annual volumes sold in mmBtu. The sensitivity analysis is performed by varying the TC charter rate, the cargo price and the selling JKS price. The reference “130,000/10/16” for instance corresponds to the "TC rate/cargo cost/JKS price". I have also studied the cases where I take into account the broker's commission or not.

ST *Polar Bear* ACF	Without Broker's Commission				Commission 0,20 USD/mmBtu				Commission 0,50 USD/mmBtu			
Route	Suez	NSR			Suez	NSR			Suez	NSR		
NSR Navigable days	N.A	90	120	150	N.A	90	120	150	N.A	90	120	150
100,000/7/11	0,46	0,99	1,13	1,26	0,26	0,79	0,93	1,06	**-0,04**	0,49	0,63	0,76
100,000/7/14	3,46	3,99	4,13	4,26	3,26	3,79	3,93	4,06	2,96	3,49	3,63	3,76
100,000/7/16	5,46	5,99	6,13	6,26	5,26	5,79	5,93	6,06	4,96	5,49	5,63	5,76
130,000/7/11	**-0,17**	0,44	0,61	0,76	**-0,37**	0,24	0,41	0,56	**-0,67**	**-0,06**	0,11	0,26
130,000/7/14	2,83	3,44	3,61	3,76	2,63	3,24	3,41	3,56	2,33	2,94	3,11	3,26
130,000/7/16	4,83	5,44	5,61	5,76	4,63	5,24	5,41	5,56	4,33	4,94	5,11	5,26
160,000/7/11	**-0,81**	**-0,10**	0,09	0,27	**-1,01**	**-0,30**	**-0,11**	0,07	**-1,31**	**-0,60**	**-0,41**	**-0,23**
160,000/7/14	2,19	2,90	3,09	3,27	1,99	2,70	2,89	3,07	1,69	2,40	2,59	2,77
160,000/7/16	4,19	4,90	5,09	5,27	3,99	4,70	4,89	5,07	3,69	4,40	4,59	4,77
100,000/10/11	**-2,94**	**-2,34**	**-2,17**	**-2,03**	**-3,14**	**-2,54**	**-2,37**	**-2,23**	**-3,44**	**-2,84**	**-2,67**	**-2,53**
100,000/10/14	0,06	0,66	0,82	0,97	**-0,14**	0,46	0,62	0,77	**-0,44**	0,16	0,32	0,47
100,000/10/16	2,06	2,66	2,82	2,97	1,86	2,46	2,62	2,77	1,56	2,16	2,32	2,47
130,000/10/11	**-3,58**	**-2,88**	**-2,69**	**-2,52**	**-3,78**	**-3,08**	**-2,89**	**-2,72**	**-4,08**	**-3,38**	**-3,19**	**-3,02**
130,000/10/14	**-0,58**	0,12	0,31	0,48	**-0,78**	**-0,08**	0,11	0,28	**-1,08**	**-0,38**	**-0,19**	**-0,02**
130,000/10/16	1,42	2,12	2,31	2,48	1,22	1,92	2,11	2,28	0,92	1,62	1,81	1,98
160,000/10/11	**-4,22**	**-3,42**	**-3,21**	**-3,01**	**-4,42**	**-3,62**	**-3,41**	**-3,21**	**-4,72**	**-3,92**	**-3,71**	**-3,51**
160,000/10/14	**-1,22**	**-0,42**	**-0,21**	**-0,01**	**-1,42**	**-0,62**	**-0,41**	**-0,21**	**-1,72**	**-0,92**	**-0,71**	**-0,51**
160,000/10/16	0,78	1,58	1,79	1,99	0,58	1,38	1,59	1,79	0,28	1,08	1,29	1,49
100,000/13/14	**-3,34**	**-2,66**	**-2,48**	**-2,31**	**-3,54**	**-2,86**	**-2,68**	**-2,51**	**-3,84**	**-3,16**	**-2,98**	**-2,81**
100,000/13/16	**-1,34**	**-0,66**	**-0,48**	**-0,31**	**-1,54**	**-0,86**	**-0,68**	**-0,51**	**-1,84**	**-1,16**	**-0,98**	**-0,81**

Table 20: *Polar Bear* sensitivity analysis of the ACF in USD/mmBtu

Not surprising, the TFDE *Northern Light* will always be more profitable to charter for the trader than the *Polar Bear*, although he has to bear higher charter rates. In Table 20, for a given charter rate of 100,000 USD/day and a cargo price of 13 USD/mmBtu, if the JKS sales price is 14 USD/mmBtu or 16 USD/mmBtu, it will never be profitable for the charterer to trade with the *Polar Bear*. For the *Northern Light* in Table 21 however, it is interesting to observe that at a JKS price of 16 USD/mmBtu, given charter rate of 100,000 USD/day and a cargo price of 13 USD/mmBtu, the trader will be able to generate a positive ACF. For instance, if we ignore the broker's commission, it will be profitable to sail via the NSR but not through the Suez Canal with the *Northern Light*. Because of economies of scale, the trader of the *Northern light* can bear higher cargo cost than the trader of the *Polar Bear*.

When moving from left to the right in the columns, we can notice that the results are sensitive to the broker's commission. Many numbers drop from a net profit to a net loss (in fat) when increasing the commission rate from zero to 0.20 USD/mmBtu or 0.50 USD/mmBtu.

TFDE *Northern Light* ACF	Without Broker's Commission				Commission 0,20 USD/mmBtu				Commission 0,50 USD/mmBtu			
Route	**Suez**	**NSR**			**Suez**	**NSR**			**Suez**	**NSR**		
NSR Navigable days	**N.A**	**90**	**120**	**150**	**N.A**	**90**	**120**	**150**	**N.A**	**90**	**120**	**150**
120,000/7/11	1,09	1,48	1,58	1,68	0,89	1,28	1,38	1,48	0,59	0,98	1,08	1,18
120,000/7/14	4,09	4,48	4,58	4,68	3,89	4,28	4,38	4,48	3,59	3,98	4,08	4,18
120,000/7/16	6,09	6,48	6,58	6,68	5,89	6,28	6,38	6,48	5,59	5,98	6,08	6,18
150,000/7/11	0,60	1,05	1,18	1,29	0,40	0,85	0,98	1,09	0,10	0,55	0,68	0,79
150,000/7/14	3,60	4,05	4,18	4,29	3,40	3,85	3,98	4,09	3,10	3,55	3,68	3,79
150,000/7/16	5,60	6,05	6,18	6,29	5,40	5,85	5,98	6,09	5,10	5,55	5,68	5,79
180,000/7/11	0,10	0,62	0,77	0,90	**-0,10**	0,42	0,57	0,70	**-0,40**	0,12	0,27	0,40
180,000/7/14	3,10	3,62	3,77	3,90	2,90	3,42	3,57	3,70	2,60	3,12	3,27	3,40
180,000/7/16	5,10	5,62	5,77	5,90	4,90	5,42	5,57	5,70	4,60	5,12	5,27	5,40
120,000/10/11	**-2,16**	**-1,72**	**-1,61**	**-1,50**	**-2,36**	**-1,92**	**-1,81**	**-1,70**	**-2,66**	**-2,22**	**-2,11**	**-2,00**
120,000/10/14	0,84	1,28	1,39	1,50	0,64	1,08	1,19	1,30	0,34	0,78	0,89	1,00
120,000/10/16	2,84	3,28	3,39	3,50	2,64	3,08	3,19	3,30	2,34	2,78	2,89	3,00
150,000/10/11	**-2,65**	**-2,15**	**-2,01**	**-1,89**	**-2,85**	**-2,35**	**-2,21**	**-2,09**	**-3,15**	**-2,65**	**-2,51**	**-2,39**
150,000/10/14	0,35	0,85	0,99	1,11	0,15	0,65	0,79	0,91	**-0,15**	0,35	0,49	0,61
150,000/10/16	2,35	2,85	2,99	3,11	2,15	2,65	2,79	2,91	1,85	2,35	2,49	2,61
180,000/10/11	**-3,15**	**-2,58**	**-2,42**	**-2,28**	**-3,35**	**-2,78**	**-2,62**	**-2,48**	**-3,65**	**-3,08**	**-2,92**	**-2,78**
180,000/10/14	**-0,15**	0,42	0,58	0,72	**-0,35**	0,22	0,38	0,52	**-0,65**	**-0,08**	0,08	0,22
180,000/10/16	1,85	2,42	2,58	2,72	1,65	2,22	2,38	2,52	1,35	1,92	2,08	2,22
120,000/13/14	**-2,41**	**-1,93**	**-1,80**	**-1,68**	**-2,61**	**-2,13**	**-2,00**	**-1,88**	**-2,91**	**-2,43**	**-2,30**	**-2,18**
120,000/13/16	**-0,41**	0,07	0,20	0,32	**-0,61**	**-0,13**	0,00	0,12	**-0,91**	**-0,43**	**-0,30**	**-0,18**

Table 21: *Northern Light* sensitivity analysis of the ACF in USD/mmBtu

2.5 Preliminary conclusion on the economical viability

This part had two main purposes. The first one was to investigate the economic attractiveness of the NSR compared to the Suez Canal route for a LNG trader. The second purpose was to analyze the economic attractiveness of operating a TFDE LNG vessel rather than a ST LNG carrier. A case study with the *Polar Bear* and the *Northern Light* was carried out where I compared in a first part the VCFs for a round trip Hammerfest-Yokohama-Hammerfest and in a second part the ACFs generated by a routine service Hammerfest-Yokohama-Hammerfest via the Suez Canal all year long and a routine service via the NSR during summer and Suez for the rest of the year. I performed some sensitivities by varying key parameters such as the cargo cost, the JKS sales price, the sailing speed or the freight rates. These variables were found out to have a significant impact on the VCF and ACF results when varying them.

I can hereby say that the NSR has an economic potential as an alternative route to the Suez Canal. LNG traders operating in northern Norway and Russia should see this route as a new and unique opportunity for exporting their gas to Asia during summer. For the 2013 season, Rosatomflot, in collaboration with the NSRA in Moscow, has reviewed its icebreaking tariffs. According to Ulf Hagen (2013), the managing director of Tschudi Arctic Transit, the new tariffs valid from this year (unofficial) should be 4.50 USD/GRT laden and 3.50 USD/GRT in ballast for LNG carriers exclusively. We have always to keep in mind that Russia wishes to attract new shipments on the NSR and increase their competitive position with the Egypt and the Suez Canal. These new tariffs should be subject for negotiation between the icebreaking company and the ship owner. They should therefore be seen as a maximum tariff rate.

We have seen from the Ice Class newbuildings list in Table 3 (p39) that ship owners wish LNG tankers of higher capacity and at the same time bunker efficient vessels. The majority of the traders report that reduced fuel consumption and lowering consumption rates are the key priorities (Hine, 2013e). A TFDE LNG carrier, according to our model, should therefore be more interesting to opt for rather than a ST vessel.

III) Developing a LNG trading project

3.1 The objective

In this third and last part, I will make an annual voyage plan that a LNG trader could have typically chosen in 2012. As we will see, the voyage plan takes into account a way the NSR can be used during summer time in order to reach Asia-Pacific. This part is useful and important because a trader is unlikely to have a routine service Hammerfest-Yokohama-Hammerfest all year long, as we analyzed in part II. He will rather use the NSR as an opportunity whenever the conditions and time allow it. I will content this time myself with using only one LNG carrier, the *Polar Bear*. The simple reason is that similar vessels exist in the LNG shipping market and hence the data used will be more accurate. As before, to deal will flexibility, a sensitivity analysis will be carried out.

Based on the ACFs the trader of the *Polar Bear* will generate from his voyage plan, the second objective will be to analyze the present value of the project if the voyage plan is maintained and repeated over a 15-year period. Estimations of future gas prices, interest rates and inflation rates will be necessary in order to evaluate these future cash flows.

With the intention to "open" my dissertation, I have dedicated a last and third subpart in this section to the valuation of an extension option on the 15-year TC contract. As we will see later on, it is common for charterers in the LNG industry to enter long term TC contracts with ship owners, where they have the possibility to extend the TC contract by five more years.

3.2 Computing the cash flows

3.2.1 Description of the voyage plan

3.2.1.a) The sea routes

The 2012 voyage plan will have multi-leg-voyages starting and ending in Hammerfest. Each leg-voyage will be either performed laden or in ballast. The sales of LNG will be on a Free On Board (FOB) basis where per definition the LNG sellers deliver the goods on board and clear the goods for export. The buyer bears all costs and risks of loss or damage (Web Courier, 2013). Some traders will have to pay for the re-gasification process of their LNG when arriving at the import terminal. I will assume that this cost is not bared by our trader. The scheduled 2012 voyage plan is represented in Table 23 (p74).

As in part two, I assume the average speed to be 18 knots on open blue water routes and 15 knots on average between Hammerfest and Asia-Pacific via the NSR. It is implicitly assumed that the speed on the route on section K-B of the NSR is maintained as before to 12 knots. These speeds will be assumed equal for laden and in ballast voyages. However as before, the LNG bunker rate will differ according to Table 22. These numbers are taken from Table 6 in section 2.3.1.

Routes	Blue water	Routes via NSR
Average Speed (knots)	18	15
Ballast BOG (m^3/day)	*270*	*210*
Laden BOG (m^3/day)	*300*	*240*

Table 22: Corresponding BOG rates with speeds for laden and in ballast

I suppose that the 2012 voyage plan starts the 1st January 2012 and ends the 31st December 2012. With 365 navigable days a year, the *Polar Bear* will be able to finalize its voyages in time, given that the average speeds and the number of days at port are respected. One day for waiting and transit time through the Suez Canal is considered, as before.

It is not always easy to estimate port days precisely, but I will suppose that these port days take into account loading and discharging, documentation, waiting time for a berth and the transiting time via the Suez Canal (Stopford, 2009, pp.254). All laden trips will be assumed fully laden with 146,791 m^3 LNG on board and the BOG rate will be valued at the JKS gas sales price. The cargo loading ports for the *Polar Bear* are Hammerfest and Bonny Island in Nigeria. The other ports are discharging ports with re-gasification facilities which are Yokohama, Huelva, Fos-Cavaou and InChon. The numbers of days at port this time are assumed to be 3 days at loading ports and 2 days at discharging ports. This gives a total annual number of 47 days at port.

The first two routes between Hammerfest and Yokohama and the first route Hammerfest – InChon (marked in red in Table 23) go via the Suez Canal since it is still too early in the year to sail via the NSR according to the calendar year. However, as we can see in the table, the subsequent two routes between Norway and Japan/Korea will be performed via the NSR.

3.2.1.b) The voyage costs

Port dues are based on data provided from TEPN for the *Arctic Lady* and are assumed to be the same for the *Polar Bear*, as we did in part II. It is worth to mention that I have assumed the total port costs for Fos-Cavaou and Yokohama to be the same as for Fos-Sur-Mer and Futtsu. The costs can be found in Appendix B.

The exchange rates chosen to convert NOK and Euros into USD are respectively 5,79 NOK/USD and 0,77 Euro/USD.

Route	Country of Departure	Arrival Country	Nature of route	Distance (nm)	Ballast/ Laden	# of days	# of port days
Hammerfest - Yokohama	Norway	Japan	Suez Blue Water	12,500	Laden	29.94	2
Yokohama - Bonny	Japan	Nigeria	Blue Water	10,626	Ballast	24.60	3
Bonny - Huelva	Nigeria	Spain	Blue Water	3,359	Laden	7.78	2
Huelva - Hammerfest	Spain	Norway	Blue Water	2,594	Ballast	6.00	3
Hammerfest - Fos-Cavaou	Norway	France	Blue Water	3,349	Laden	7.75	2
Fos-Cavaou - Hammerfest	France	Norway	Blue Water	3,349	Ballast	7.75	3
Hammerfest - InChon	Norway	Korea	Suez Blue Water	12,214	Laden	29.27	2
InChon - Bonny	Korea	Nigeria	Blue Water	10,390	Ballast	24.05	3
Bonny - Yokohama	Nigeria	Japan	Blue Water	10,626	Laden	24.60	2
Yokohama - Hammerfest	Japan	Norway	Suez Blue Water	12,500	Ballast	29.94	3
Hammerfest - Yokohama	Norway	Japan	NSR	6,400	Laden	17.78	2
Yokohama - Bonny	Japan	Nigeria	Blue Water	10,626	Ballast	24.60	3
Bonny - Huelva	Nigeria	Spain	Blue Water	3,359	Laden	7.78	2
Huelva - Hammerfest	Spain	Norway	Blue Water	2,594	Ballast	6.00	3
Hammerfest - Fos-Cavaou	Norway	France	Blue Water	3,349	Laden	7.75	2
Fos-Cavaou - Hammerfest	France	Norway	Blue Water	3,349	Ballast	7.75	3
Hammerfest - InChon	Norway	Korea	NSR	6,500	Laden	18.06	2
InChon - Bonny	Korea	Nigeria	Blue Water	10,390	Ballast	24.05	3
Bonny - Hammerfest	Nigeria	Norway	Blue Water	6,100	Laden	14.12	2
					Sum	**320**	**47**
					Sum days	**~365**	

Table 23: The 2012 voyage plan

Source for distances: (Robin & Demoury, 2012)

The trader's insurance costs for the *Polar Bear* are the same as in Table 10 (p55). The Bonny loading insurance costs the trader USD 20,000 for the 2 days loading. The NSR tariff laden is USD 355,848 as before. The tariff in ballast of USD 222,500 can be disregarded as the tanker will never transit the NSR in ballast according to the voyage plan. The Suez Canal transit costs (laden and in ballast) are based on the *Arctic Lady's* values from Appendix B. The commercial agency cost is assumed USD 30,000 for each NSR transit. The extra communication equipment for the NSR and the cost for two sets of Russian charts are ignored. The ice pilotage is supposed constant at USD 11,250. Cost for anti-fouling afloat of USD 15,000 is valid for each NSR transit.

Summing up the voyage costs for each leg-voyage:

$$Voyage\ Costs\ (USD) = Port\ dues(USD) + Suez\ or\ NSR\ dues(USD) + Insurrance\ (USD) \qquad (3.1)$$

3.2.1.c) The charter rates

The 2012 voyage plan will be analyzed on a spot charter and on a 1-year TC.

The 1-year TC rate of 140,000 USD/day is from the date of signature of the contract, the 1st January 2012, and it is based on the "Assessed Term & Spot Rates" overview for a conventional Dual-Fuel Diesel-Electric (DFDE) LNG carrier (Clarksons, 2013).

I have taken the average spot charter rates corresponding to the period of time each leg-voyage takes place. The spot rates are based from a conventional 138,000-150,000 m^3 Steam Turbine LNG carrier (Bakkelund, 2013). The 2012 charter rates are figured in Figure 23.

Since the *Polar Bear* is not an ordinary vessel and a clear defined freight market for LNG Ice Class carriers doesn't exist, I am going to assume that these freight rates are also valid for the *Polar Bear*.

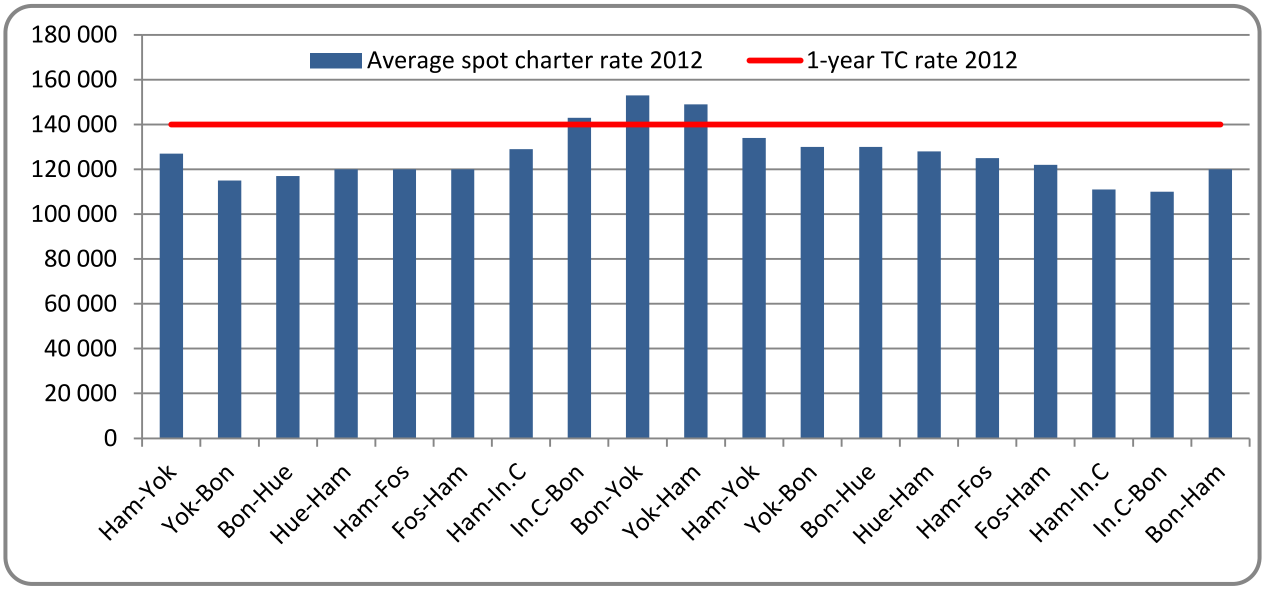

Figure 23: Overview of 2012 charter rates for each leg-voyage (USD/day)

Source: (Clarksons, 2013) & (Bakkelund, 2013)

3.2.1.d) Gas prices

The gas sales prices in Huelva, Fos-Cavaou, Yokohama, and InChon (and Hammerfest for the last leg-voyage) are based on real historical NBP and JKS prices from 2012. The rates are the same used to study the correlations in part I (p18-19).

I have contented myself with monthly rates for the gas price estimates having no access to daily rates. As an example, if the *Polar Bear* arrives at the discharging port of Huelva the 23rd March 2012, I choose the March 2012 NBP price as reference.

For the JKS price, I have also used monthly numbers; however, the numbers correspond to the end of the month prices, the 30th or the 31st day of the month for instance. I will use them as an average monthly reference. However, should the vessel arrive in InChon in the middle of April, I choose an average of the end of March and the end of April as reference and not the end of April price.

Since the trader does not have an ownership on the gas extracted from Hammerfest and Bonny, he will have to buy it at the market price and usually pay a premium to the operator of the LNG terminal. That is exactly what Gazprom did at Melkøya in November 2012.

The gas prices in Bonny will be assumed 11 USD/mmBtu, 9 USD/mmBtu or 8 USD/mmBtu depending on the sales price at the import country (ref Table 24 and 25).

For the gas bought in Hammerfest and sold to Japan and Korea at the JKS, the cost will be the monthly NBP price and I will add the premium of 2 USD/mmBtu as I did in part II.

LNG cargos to France (Fos-Cavaou) in provenance from Hammerfest are sold at the NBP price. Exceptionally for this particular route, the trader and the LNG seller in Hammerfest have agreed on a fair cargo price of 8 USD/mmBtu for the first voyage and 9 USD/mmBtu for the second one.

As before, LNG is used as bunker, hence the BOG cost for our trader is based on the market price (NBP or JKS). Since every laden voyage is followed by a voyage in ballast, the BOG cost during the voyage in ballast is taken into account in the laden voyage. Hence, the net LNG volume sold when the *Polar Bear* arrives at the import port is the cargo volume (146,791 m^3) minus the bunker consumption volume for the laden voyage and for the following voyage in ballast. When the *Polar Bear* is doing the voyage via the NSR, extra bunker consumption for winterization is considered. Extra bunker consumption in waters with summer sea-ice is negligible.

3.2.2 Finding the results

3.2.2.a) Voyage and Annual Cash Flows results

In the following tables, we will find the overview of the trader's ACFs resulting from his 2012 voyage plan. Table 24 illustrates the case where the *Polar Bear* has been chartered in the spot market for a year and the second one, Table 25, illustrates the 1-year TC case.

2012 Voyage Plan *Polar Bear*	Ham-Yok	Yok-Bon	Bon-Hue	Hue-Ham	Ham-Fos	Fos-Ham	Ham-In.C	In.C-Bon	Bon-Yok	Yok-Ham	Ham-Yok	Yok-Bon	Bon-Hue	Hue-Ham	Ham-Fos	Fos-Ham	Ham-In.C	In.C-Bon	Bon-Ham
Distance (nm)	12 500	10 626	3 359	2 594	3 349	3 349	12 214	10 390	10 626	12 500	6 400	10 626	3 359	2 594	3 349	3 349	6 500	10 390	6 100
Approx distance K-B (nm)											2 700						2 700		
# of days section K-B											9,38						9,38		
Total # of days	29,94	24,60	7,78	6,00	7,75	7,75	29,27	24,05	24,60	29,94	17,78	24,60	7,78	6,00	7,75	7,75	18,06	24,05	14,12
Port days loading and discharging	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2
Spot charter rate 2012 (USD/day)	127 000	115 000	117 000	120 000	120 000	120 000	129 000	143 000	153 000	149 000	134 000	130 000	130 000	128 000	125 000	122 000	111 000	110 000	120 000
Sum Hire Cost (USD)	**4 055 769**	**3 173 681**	**1 143 729**	**1 080 556**	**1 170 278**	**1 290 278**	**4 034 236**	**3 868 282**	**4 069 375**	**4 907 343**	**2 650 222**	**3 587 639**	**1 270 810**	**1 152 593**	**1 219 039**	**1 311 782**	**2 226 167**	**2 975 602**	**1 934 444**
LNG cargo cost (USD per mmBtu)	10,45		9,00		8,00		11,66		11,00		10,62		8,00		9,00		12,32		9,00
Δ% LNG cargo cost										0									
Estimated cost for the LNG cargo (USD)	**35 590 580**		**30 649 961**		**27 244 410**		**39 710 666**		**37 461 063**		**36 159 313**		**27 244 410**		**30 649 961**		**41 948 072**		**30 649 961**
Voyage Cost (USD)	**676 422**	**759 732**	**147 444**	**257 359**	**162 188**	**257 359**	**706 633**	**759 732**	**146 331**	**718 163**	**680 929**	**759 732**	**147 444**	**257 359**	**162 188**	**257 359**	**711 140**	**759 732**	**257 359**
Sum Exposure Costs (USD)	**40 322 770**	**3 933 413**	**31 941 134**	**1 337 915**	**28 576 875**	**1 547 637**	**44 451 535**	**4 628 014**	**41 676 769**	**5 625 506**	**39 490 464**	**4 347 371**	**28 662 664**	**1 409 952**	**32 031 188**	**1 569 141**	**44 885 378**	**3 735 334**	**32 841 764**
LNG volume transported (m3)	146 791		146 791		146 791		146 791		146 791		146 791		146 791		146 791		146 791		146 791
LNG burned during transport (m3)	16 074		4 406		4 871		15 728		15 914		11 435		4 406		4 871		11 354		4 417
Net LNG volume for sale (m3)	130 717		142 385		141 920		131 063		130 877		135 356		142 385		141 920		135 437		142 374
Net LNG volume for sale (mmBtu)	3 032 641		3 303 336		3 292 550		3 040 670		3 036 356		3 140 263		3 303 336		3 292 550		3 142 138		3 303 080
Gas price (USD/mmBtu)	14,60		10,25		9,30		17,50		15,20		13,30		9,80		10,30		14,10		10,70
Δ% Gas price										0									
Gas price +/- Δ% (USD/mmBtu)	14,60		10,25		9,30		17,50		15,20		13,30		9,80		10,30		14,10		**10,70**
Shipping Revenue (USD)	**44 276 554**		**33 859 198**		**30 620 715**		**53 211 733**		**46 152 610**		**41 765 497**		**32 372 696**		**33 913 265**		**44 304 149**		**35 342 951**
VCF (USD)	**3 953 784**	**-3 933 413**	**1 918 064**	**-1 337 915**	**2 043 840**	**-1 547 637**	**8 760 198**	**-4 628 014**	**4 475 841**	**-5 625 506**	**2 275 033**	**-4 347 371**	**3 710 033**	**-1 409 952**	**1 882 077**	**-1 569 141**	**-581 229**	**-3 735 334**	**2 501 187**
																		ACF (USD)	**2 804 545**
																		Total vol. sold (mmBtu)	**31 886 921**
																		ACF (USD/mmBtu)	**0,088**

2012 Voyage Plan *Polar Bear*	Ham-Yok	Yok-Bon	Bon-Hue	Hue-Ham	Ham-Fos	Fos-Ham	Ham-In.C	In.C-Bon	Bon-Yok	Yok-Ham	Ham-Yok	Yok-Bon	Bon-Hue	Hue-Ham	Ham-Fos	Fos-Ham	Ham-In.C	In.C-Bon	Bon-Ham
Distance (nm)	12 500	10 626	3 359	2 594	3 349	3 349	12 214	10 390	10 626	12 500	6 400	10 626	3 359	2 594	3 349	3 349	6 500	10 390	6 100
Approx distance K-B (nm)											2 700						2 700		
# of days section K-B											9,38						9,38		
Total # of days	29,94	24,60	7,78	6,00	7,75	7,75	29,27	24,05	24,60	29,94	17,78	24,60	7,78	6,00	7,75	7,75	18,06	24,05	14,12
Port days loading and discharging	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2
1-year TC rate January 2012 (USD/day)	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000
Sum Hire Cost (USD)	**4 470 926**	**3 863 611**	**1 368 565**	**1 260 648**	**1 365 324**	**1 505 324**	**4 378 241**	**3 787 130**	**3 723 611**	**4 610 926**	**2 768 889**	**3 863 611**	**1 368 565**	**1 260 648**	**1 365 324**	**1 505 324**	**2 807 778**	**3 787 130**	**2 256 852**
LNG cargo cost (USD per mmBtu)	10,45		9,00		8,00		11,66		11,00		10,62		8,00		9,00		12,32		9,00
Δ% LNG cargo cost										0									
Estimated cost for the LNG cargo (USD)	**35 590 580**		**30 649 961**		**27 244 410**		**39 710 666**		**37 461 063**		**36 159 313**		**27 244 410**		**30 649 961**		**41 948 072**		**30 649 961**
Voyage Cost (USD)	**676 422**	**759 732**	**147 444**	**257 359**	**162 188**	**257 359**	**706 633**	**759 732**	**146 331**	**718 163**	**680 929**	**759 732**	**147 444**	**257 359**	**162 188**	**257 359**	**711 140**	**759 732**	**257 359**
Sum Exposure Costs (USD)	**40 737 928**	**4 623 343**	**32 165 970**	**1 518 007**	**28 771 921**	**1 762 683**	**44 795 540**	**4 546 862**	**41 331 005**	**5 329 089**	**39 609 130**	**4 623 343**	**28 760 418**	**1 518 007**	**32 177 473**	**1 762 683**	**45 466 989**	**4 546 862**	**33 164 172**
LNG volume transported (m3)	146 791		146 791		146 791		146 791		146 791		146 791		146 791		146 791		146 791		146 791
LNG burned during transport (m3)	16 074		4 406		4 871		15 728		15 914		11 435		4 406		4 871		11 354		4 417
Net LNG volume for sale (m3)	130 717		142 385		141 920		131 063		130 877		135 356		142 385		141 920		135 437		142 374
Net LNG volume for sale (mmBtu)	3 032 641		3 303 336		3 292 550		3 040 670		3 036 356		3 140 263		3 303 336		3 292 550		3 142 138		3 303 080
Gas price (USD/mmBtu)	14,60		10,25		9,30		17,50		15,20		13,30		9,80		10,30		14,10		10,70
Δ% Gas price										0									
Gas price +/- Δ% (USD/mmBtu)	14,60		10,25		9,30		17,50		15,20		13,30		9,80		10,30		14,10		10,70
Shipping Revenue (USD)	**44 276 554**		**33 859 198**		**30 620 715**		**53 211 733**		**46 152 610**		**41 765 497**		**32 372 696**		**33 913 265**		**44 304 149**		**35 342 951**
VCF (USD)	**3 538 626**	**-4 623 343**	**1 693 228**	**-1 518 007**	**1 848 793**	**-1 762 683**	**8 416 193**	**-4 546 862**	**4 821 605**	**-5 329 089**	**2 156 367**	**-4 623 343**	**3 612 278**	**-1 518 007**	**1 735 792**	**-1 762 683**	**-1 162 840**	**-4 546 862**	**2 178 780**
																		ACF (USD)	**-1 392 057**
																		Total vol. sold (mmBtu)	**31 886 921**
																		ACF (USD/mmBtu)	**-0,044**

Table 24 (left) and Table 25 (right): Trader's ACF analysis in a spot charter (left) and in a 1-year TC (right)

3.2.2.b) Comments and implications

The ACFs are calculated before tax and I do not take into account the broker's commission. The total net LNG volumes sold during 2012 was 31,886,921 mmBtu or 1,374,436 m^3. Under a spot charter, the results give the trader an ACF of USD 2,804,545 or 0.088 USD/mmBtu. For the 1-year TC voyage, the trader has a loss of USD 1,392,057 or 0.044 USD/mmBtu. The 2012 voyage plan in the spot charter market would have given the trader an incremental profit of 0.132 USD/mmBtu compared to the 1-year TC voyage.

It is worth to notice that the trader would have earned money in almost all the laden leg-voyages, excepted the last leg Hammerfest-InChon via the NSR where he would have generated a loss of USD 581,229 under spot and a loss of USD 1,162,840 under a 1-year TC. The main reason is that the margin between the LNG he buys at 12.32 USD/mmBtu and the price he sells it for (14.10 USD/mmBtu) is too small to generate a surplus on this route given the exposure costs. The two voyages via the NSR in 2012 saves the charterer valuable time and has probably enabled him to make an extra voyage or two in 2012 than if he had taken the Suez Canal.

3.2.3 Sensitivity analysis

3.2.3.a) Varying the hire rate

If there were few Ice Class 1A LNG carriers available for a 1-year spot charter the 1st January 2012, the ship owner would have probably required a higher freight rate. Let's suppose he required an additional 10% on the 2012 spot market rates, if that was the case, the trader would have generated a loss of 0,060 USD/mmBtu.

If the trader had paid 10% less than the 2012 spot market rates, due to plenty of Ice Class 1A LNG carriers available in the market for instance, the trader would have generated a surplus of 0.236 USD/mmBtu.

In Table 26 I have listed the ACFs expressed in USD/mmBtu by varying the 1-year TC rate from 80,000 USD/day to 195,000 USD/day. Giving that all the other parameters are hold constant, we notice that the trader of the *Polar Bear* would have reached the break even for a 1-year TC rate between 135,000 USD/day and 140,000 USD/day.

1-Yr TC rate Jan 2012	80,000	85,000	90,000	95,000	100,000	105,000	110,000	115,000
ACF (USD/mmBtu)	*0,646*	*0,589*	*0,531*	*0,474*	*0,416*	*0,359*	*0,301*	*0,244*
1-Yr TC rate Jan 2012	**120,000**	**125,000**	**130,000**	**135,000**	**140 000**	**145,000**	**150,000**	**155,000**
ACF (USD/mmBtu)	*0,186*	*0,129*	*0,071*	*0,014*	*-0,044*	*-0,101*	*-0,159*	*-0,216*
1-Yr TC rate Jan 2012	**160,000**	**165,000**	**170,000**	**175,000**	**180,000**	**185,000**	**190,000**	**195,000**
ACF (USD/mmBtu)	*-0,274*	*-0,331*	*-0,389*	*-0,446*	*-0,503*	*-0,561*	*-0,618*	*-0,676*

Table 26: ACFs sensitivities by varying the 1-year TC rate

3.2.3.b) Varying the sailing speed

Holding all parameters constant, if we vary the sailing speed it is interesting to study how the cash flows will be affected. Table 27 and 28 give us an overview of the ACFs for a range of different speeds. I have delimited with a fat line the positive numbers from the negative ones. It is important to mention that we do not take into consideration the Natural Boil of Gas (NBOG) of 192 m^3 (Lauritzen, 2013). Typically for low speeds, when the BOG rate is lower than the NBOG, the vessel is consuming less than the NBOG level which leads to a net loss of LNG volumes during transport, especially when low speed is maintained over long periods. The *Polar Bear* should therefore rather keep an average speed higher than 14 knots in ballast and 12.5 knots laden (ref Table 6 p48).

Under a spot charter in Table 27, we can observe that there is room for the trader to increase his ACF slightly by increasing its sailing speed on routes via the NSR. An average sailing speed of 16.5 knots on routes via the NSR keeping the average speed on normal routes the same at 18 knots would have increased his ACF from 0.088 USD/mmBtu to 0.099 USD/mmBtu, a slight increase though.

Under a 1-year TC in Table 28, we notice that it wouldn't have helped to increase the *Polar Bear's* sailing speed in order to generate a positive ACF, neither on normal routes or on routes via the NSR. The table shows only negative values of ACFs.

In Figure 24 and Figure 25 bellow I have figured from Table 27 and 28 the ACFs as function of speed on normal routes (blue water) for different speed level ranges on routes via the NSR. We notice again from the curves the maximum point achieved at a sailing speed of 18 knots on normal routes.

Spot charter		Average speed on normal routes (knots)													
		8	10	11	12	13	14	15	16	16,5	17	17,5	18	18,5	19
Average speed on routes via NSR (knots)	8	-1,308	-0,743	-0,597	-0,474	-0,369	-0,280	-0,202	-0,134	-0,103	-0,074	-0,046	-0,020	-0,052	-0,082
	10	-1,258	-0,694	-0,547	-0,424	-0,320	-0,230	-0,152	-0,084	-0,053	-0,024	0,004	0,030	-0,002	-0,032
	11	-1,243	-0,678	-0,531	-0,408	-0,304	-0,214	-0,136	-0,068	-0,037	-0,008	0,020	0,046	0,014	-0,016
	12	-1,230	-0,665	-0,518	-0,395	-0,291	-0,201	-0,123	-0,055	-0,024	0,005	0,033	0,059	0,028	-0,002
	13	-1,219	-0,655	-0,507	-0,384	-0,280	-0,190	-0,112	-0,044	-0,013	0,016	0,044	0,070	0,039	0,009
	14	-1,210	-0,645	-0,498	-0,375	-0,270	-0,181	-0,103	-0,034	-0,003	0,026	0,054	0,080	0,048	0,019
	15	-1,202	-0,637	-0,490	-0,367	-0,262	-0,172	-0,094	-0,026	0,005	0,034	0,062	**0,088**	0,057	0,027
	16	-1,194	-0,630	-0,483	-0,359	-0,255	-0,165	-0,087	-0,019	0,012	0,042	0,069	0,095	0,064	0,034
	16,5	-1,191	-0,627	-0,479	-0,356	-0,252	-0,162	-0,084	-0,016	0,016	0,045	0,072	0,099	0,067	0,038
	17	-1,188	-0,624	-0,476	-0,353	-0,249	-0,159	-0,081	-0,012	0,019	0,048	0,076	0,102	0,071	0,041

1 year TC rate 140,000 USD/day		Average speed on normal routes (knots)													
		8	10	11	12	13	14	15	16	16,5	17	17,5	18	18,5	19
Average speed on routes via NSR (knots)	8	-1,568	-0,962	-0,801	-0,667	-0,552	-0,454	-0,369	-0,294	-0,260	-0,228	-0,198	-0,169	-0,199	-0,227
	10	-1,511	-0,906	-0,744	-0,609	-0,495	-0,397	-0,311	-0,236	-0,202	-0,170	-0,140	-0,112	-0,141	-0,169
	11	-1,493	-0,888	-0,726	-0,591	-0,477	-0,378	-0,293	-0,218	-0,184	-0,152	-0,122	-0,093	-0,122	-0,151
	12	-1,478	-0,872	-0,711	-0,576	-0,461	-0,363	-0,278	-0,203	-0,169	-0,136	-0,106	-0,078	-0,107	-0,135
	13	-1,466	-0,860	-0,698	-0,563	-0,449	-0,350	-0,265	-0,190	-0,156	-0,123	-0,093	-0,065	-0,094	-0,122
	14	-1,455	-0,849	-0,687	-0,552	-0,437	-0,339	-0,253	-0,178	-0,144	-0,112	-0,082	-0,053	-0,083	-0,111
	15	-1,445	-0,839	-0,678	-0,543	-0,428	-0,329	-0,244	-0,169	-0,135	-0,103	-0,072	**-0,044**	-0,073	-0,101
	16	-1,437	-0,831	-0,669	-0,534	-0,419	-0,321	-0,235	-0,160	-0,126	-0,094	-0,064	-0,035	-0,064	-0,092
	16,5	-1,433	-0,827	-0,666	-0,530	-0,416	-0,317	-0,231	-0,156	-0,122	-0,090	-0,060	-0,031	-0,061	-0,088
	17,0	-1,430	-0,824	-0,662	-0,527	-0,412	-0,313	-0,228	-0,153	-0,119	-0,087	-0,056	-0,028	-0,057	-0,085

Table 27 (upper) and Table 28 (under): ACF sensitivities by varying the sailing speeds

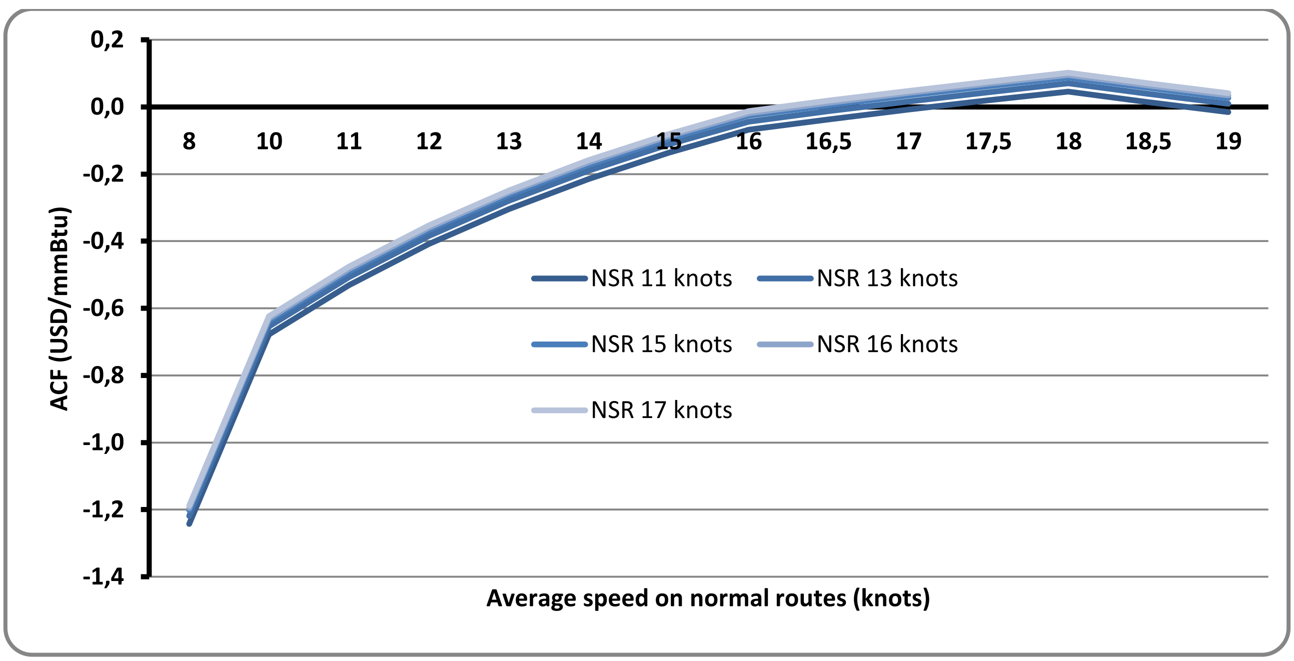

Figure 24: ACFs as function of average sailing speed on normal routes in a spot charter

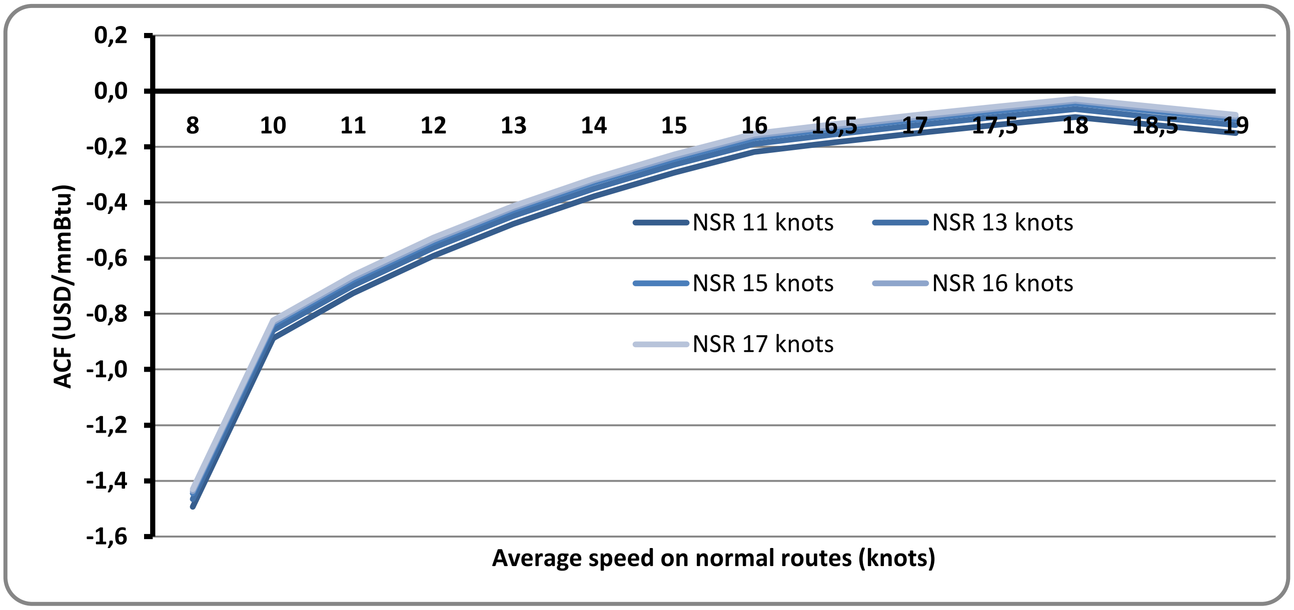

Figure 25: ACFs as function of average sailing speed on normal routes in a 1-year TC charter

Remember that "NSR 15 knots" doesn't refer to the average speed on the NSR from the Kara Strait to the Bering Strait. This time, the speed refers to the average speed from Hammerfest to Japan or Korea via the NSR.

The maximums on both figures are reached at a speed of 18 knots on normal (blue water) routes. At this level, supposing that the average speed on routes via the NSR is 16 knots in the spot charter market, the trader would have reached a maximum of 0.095 USD/mmBtu according to tables and figures. In the TC market, the maximum reached would have been a loss of 0.035 USD/mmBtu. The curves are concave meaning that we have a decreasing but positive marginal ACF up to the maximum at 18 knots. From 18 knots and onwards, the marginal ACF is negative.

3.2.3.c) Varying the gas prices

What happens this time with the results when we vary the gas prices by a delta (Δ) factor, supposing that all other parameters are hold constant? In Table 29 and Table 30, I have figured in red the results from Table 24 and Table 25 (p78) with the 2012 gas prices. I have varied the gas sales price and the cargo cost from -40% to +40%. I have delimited in the tables the positive results from the negative ones with a fat line.

Spot charter		Δ Gas selling price (USD/mmBtu)																
		-40 %	-35 %	-30 %	-25 %	-20 %	-15 %	-10 %	-5 %	0 %	5 %	10 %	15 %	20 %	25 %	30 %	35 %	40 %
Δ Cargo cost (USD/mmBtu)	-40 %	-0,646	-0,116	0,414	0,944	1,473	2,003	2,533	3,063	3,593	4,123	4,653	5,183	5,713	6,242	6,772	7,302	7,832
	-35 %	-1,084	-0,554	-0,024	0,505	1,035	1,565	2,095	2,625	3,155	3,685	4,215	4,745	5,274	5,804	6,334	6,864	7,394
	-30 %	-1,522	-0,992	-0,463	0,067	0,597	1,127	1,657	2,187	2,717	3,247	3,777	4,306	4,836	5,366	5,896	6,426	6,956
	-25 %	-1,960	-1,431	-0,901	-0,371	0,159	0,689	1,219	1,749	2,279	2,808	3,338	3,868	4,398	4,928	5,458	5,988	6,518
	-20 %	-2,399	-1,869	-1,339	-0,809	-0,279	0,251	0,781	1,311	1,840	2,370	2,900	3,430	3,960	4,490	5,020	5,550	6,080
	-15 %	-2,837	-2,307	-1,777	-1,247	-0,717	-0,187	0,343	0,872	1,402	1,932	2,462	2,992	3,522	4,052	4,582	5,112	5,641
	-10 %	-3,275	-2,745	-2,215	-1,685	-1,155	-0,625	-0,096	0,434	0,964	1,494	2,024	2,554	3,084	3,614	4,143	4,673	5,203
	-5 %	-3,713	-3,183	-2,653	-2,123	-1,593	-1,064	-0,534	-0,004	0,526	1,056	1,586	2,116	2,646	3,175	3,705	4,235	4,765
	0 %	-4,151	-3,621	-3,091	-2,561	-2,032	-1,502	-0,972	-0,442	0,088	0,618	1,148	1,678	2,207	2,737	3,267	3,797	4,327
	5 %	-4,589	-4,059	-3,529	-3,000	-2,470	-1,940	-1,410	-0,880	-0,350	0,180	0,710	1,239	1,769	2,299	2,829	3,359	3,889
	10 %	-5,027	-4,497	-3,968	-3,438	-2,908	-2,378	-1,848	-1,318	-0,788	-0,258	0,271	0,801	1,331	1,861	2,391	2,921	3,451
	15 %	-5,465	-4,936	-4,406	-3,876	-3,346	-2,816	-2,286	-1,756	-1,226	-0,697	-0,167	0,363	0,893	1,423	1,953	2,483	3,013
	20 %	-5,904	-5,374	-4,844	-4,314	-3,784	-3,254	-2,724	-2,194	-1,665	-1,135	-0,605	-0,075	0,455	0,985	1,515	2,045	2,574
	25 %	-6,342	-5,812	-5,282	-4,752	-4,222	-3,692	-3,162	-2,633	-2,103	-1,573	-1,043	-0,513	0,017	0,547	1,077	1,606	2,136
	30 %	-6,780	-6,250	-5,720	-5,190	-4,660	-4,130	-3,601	-3,071	-2,541	-2,011	-1,481	-0,951	-0,421	0,109	0,638	1,168	1,698
	35 %	-7,218	-6,688	-6,158	-5,628	-5,098	-4,569	-4,039	-3,509	-2,979	-2,449	-1,919	-1,389	-0,859	-0,330	0,200	0,730	1,260
	40 %	-7,656	-7,126	-6,596	-6,067	-5,537	-5,007	-4,477	-3,947	-3,417	-2,887	-2,357	-1,827	-1,298	-0,768	-0,238	0,292	0,822

1 year TC rate 140,000		Δ Gas selling price (USD/mmBtu)																
		-40 %	-35 %	-30 %	-25 %	-20 %	-15 %	-10 %	-5 %	0 %	5 %	10 %	15 %	20 %	25 %	30 %	35 %	40 %
Δ Cargo cost (USD/mmBtu)	-40 %	-0,778	-0,248	0,282	0,812	1,342	1,872	2,402	2,932	3,461	3,991	4,521	5,051	5,581	6,111	6,641	7,171	7,700
	-35 %	-1,216	-0,686	-0,156	0,374	0,904	1,434	1,964	2,493	3,023	3,553	4,083	4,613	5,143	5,673	6,203	6,732	7,262
	-30 %	-1,654	-1,124	-0,594	-0,064	0,466	0,995	1,525	2,055	2,585	3,115	3,645	4,175	4,705	5,235	5,764	6,294	6,824
	-25 %	-2,092	-1,562	-1,032	-0,502	0,027	0,557	1,087	1,617	2,147	2,677	3,207	3,737	4,267	4,796	5,326	5,856	6,386
	-20 %	-2,530	-2,000	-1,470	-0,941	-0,411	0,119	0,649	1,179	1,709	2,239	2,769	3,299	3,828	4,358	4,888	5,418	5,948
	-15 %	-2,968	-2,438	-1,909	-1,379	-0,849	-0,319	0,211	0,741	1,271	1,801	2,331	2,860	3,390	3,920	4,450	4,980	5,510
	-10 %	-3,406	-2,877	-2,347	-1,817	-1,287	-0,757	-0,227	0,303	0,833	1,362	1,892	2,422	2,952	3,482	4,012	4,542	5,072
	-5 %	-3,845	-3,315	-2,785	-2,255	-1,725	-1,195	-0,665	-0,135	0,394	0,924	1,454	1,984	2,514	3,044	3,574	4,104	4,634
	0 %	-4,283	-3,753	-3,223	-2,693	-2,163	-1,633	-1,103	-0,574	-0,044	0,486	1,016	1,546	2,076	2,606	3,136	3,666	4,195
	5 %	-4,721	-4,191	-3,661	-3,131	-2,601	-2,071	-1,542	-1,012	-0,482	0,048	0,578	1,108	1,638	2,168	2,697	3,227	3,757
	10 %	-5,159	-4,629	-4,099	-3,569	-3,039	-2,510	-1,980	-1,450	-0,920	-0,390	0,140	0,670	1,200	1,729	2,259	2,789	3,319
	15 %	-5,597	-5,067	-4,537	-4,007	-3,478	-2,948	-2,418	-1,888	-1,358	-0,828	-0,298	0,232	0,761	1,291	1,821	2,351	2,881
	20 %	-6,035	-5,505	-4,975	-4,446	-3,916	-3,386	-2,856	-2,326	-1,796	-1,266	-0,736	-0,207	0,323	0,853	1,383	1,913	2,443
	25 %	-6,473	-5,943	-5,414	-4,884	-4,354	-3,824	-3,294	-2,764	-2,234	-1,704	-1,175	-0,645	-0,115	0,415	0,945	1,475	2,005
	30 %	-6,911	-6,382	-5,852	-5,322	-4,792	-4,262	-3,732	-3,202	-2,672	-2,143	-1,613	-1,083	-0,553	-0,023	0,507	1,037	1,567
	35 %	-7,350	-6,820	-6,290	-5,760	-5,230	-4,700	-4,170	-3,640	-3,111	-2,581	-2,051	-1,521	-0,991	-0,461	0,069	0,599	1,128
	40 %	-7,788	-7,258	-6,728	-6,198	-5,668	-5,138	-4,608	-4,079	-3,549	-3,019	-2,489	-1,959	-1,429	-0,899	-0,369	0,160	0,690

Table 29 (left) and Table 30 (right): ACFs sensitivities by varying the gas prices

The ACF of 0.088 USD/mmBtu we found for the spot charter case (marked in red) is positive. However, we can observe that the number is not far away from the negative zone in the table. A slight increase of 5% in the cargo cost, given the same sales prices, would have generated the LNG trader a loss 0.350 USD/mmBtu in 2012. Given a total of 31,866,921 mmBtu LNG sold in 2012, this would represent a loss of USD 11,153,422 for the trader; a considerable amount. On the other way round, if the sales prices had increased by 5% given constant costs, the trader would have generated a profit of 0.618 USD/mmBtu or 19,693,757 USD in total, before tax though.

Under the 1-year TC hire, we know that the trader makes a slight loss of 0.044 USD/mmBtu. According to Table 30, a decrease of 5% in the cargo costs or an increase of 5% of the sales prices would have been enough for the trader to switch from a loss to a profit.

What can be said is that the trader's cash flows are sensitive to changes of the gas prices. Small variations in gas prices have large variation effects on the ACFs. Traders should be aware of that. A 5% increase or decrease in prices seems not so much in fact, but it is enough to make a big difference for the trader.

3.3 A Net Present Value Analysis

3.3.1 Setting the limits

I will assume that the trader's 2012 voyage plan is maintained and repeated every year from 2012 until the beginning of 2027. Since it is a long term contract, the 15-year TC rate paid by the trader (charterer) to the ship owner depends this time on the delivered newbuilding price of the vessel, on its lifetime and on the required rate of return (cost of capital) to the ship owner. The new building price for a conventional 150,000 m^3 LNG carrier at the beginning of 2012 was at USD 205 million. By adding 5%, we get a delivered newbuilding cost of USD 215 million. Assuming a required rate of return of 8% to the ship owner and a lifetime of 25 years for the vessel, the daily CAPEX paid by the trader to the ship owner during 15 years is USD 55,181 per day (Bakkelund, 2013). This number can be found from the following annuity formula.

$$A = \frac{i}{(1-(1+i)^{-n})} \times P_0 \qquad (3.2)$$

$$\begin{aligned}&where\\&A = Annual\ CAPEX\\&i = Shipowner's\ cost\ of\ capital\\&n = The\ vessel's\ lifetime\\&P_0 = The\ delivered\ newbuilding\ cost\\&which\ gives\end{aligned}$$

$$A = \frac{0.08}{(1-(1+0.08)^{-25})} \times 215{,}000{,}000$$

$$A = 20{,}140{,}938\ USD/year$$

Assuming 365 days of operation per year

$$CAPEX = 55{,}181\ USD/day$$

In addition, as the *Polar Bear* is Ice Class 1A, the trader chartering this vessel has to pay usually the ship owner a premium of 2,567 USD/day. This number is based on an incremental delivered newbuilding cost of USD 10 million for an Ice Class 1A and an 8% required rate of return for the ship owner over 25 years (Bakkelund, 2013). Generally, for long term contracts lasting 15 years, the ship owner would charge the charterer a fix daily OPEX rate. If we assume an OPEX of 20,000 USD/day (Bakkelund, 2013), this gives us a total daily 15-year TC rate of $55{,}181 + 2{,}567 + 20{,}000 = 77{,}748\ USD/day$

All information in terms of distances, destinations, speed, cargo volumes will be held as before. The only variables that will differ from year to year will be the market gas prices.

3.3.2 Forecasting the data

3.3.2.a) The gas prices

The gas prices for 2012 will be held the same as before. The average annual gas prices forecast for 2013 until 2026 included are based on expectations from Wood Mackenzie (2013). Sales to France receive a price in nominal terms of 12.68 USD/mmBtu in 2013, 11.88 USD/mmBtu in 2014, 11.41 USD/mmBtu in 2015 and 10.97 USD/mmBtu in 2016 remaining flat thereafter.

Sales to Spain will receive a price in nominal terms of 10.82 USD/mmBtu in 2013, 10.15 USD/mmBtu in 2014, 9.76 USD/mmBtu in 2015 and 9.39 USD/mmBtu in 2016 remaining flat thereafter.

I assume that sales prices in nominal terms to Hammerfest (last leg-voyage from Bonny to Hammerfest) are the average of the French and Spanish prices.

Sales prices to Korea and Japan will be assumed 1 USD/mmBtu higher than the Malaysian prices, the only reference I have access to from Wood Mackenzie. The simple reason behind this is that Japan demands high volumes of LNG. Thus, sales will receive a price, 14.90 USD/mmBtu in 2013, 13.81 USD/mmBtu in 2014, 13.15 USD/mmBtu in 2015 and 12.52 USD/mmBtu in 2016 remaining flat thereafter.

The cost for the LNG cargo in Hammerfest and Bonny will be based on the NBP spot. I will assume this cost to be 9.50 USD/mmBtu in 2013. The year to year change in the price will be based on the percentage change of the year to year change of the sales price in France. Consequently, the price will be 8.90 USD/mmBtu in 2014, 8.55 USD/mmBtu in 2015 and 8.22 USD/mmBtu in 2016 remaining flat thereafter. The following graph gives a summary of the estimated pricing schemes from 2013 to 2026 just mentioned.

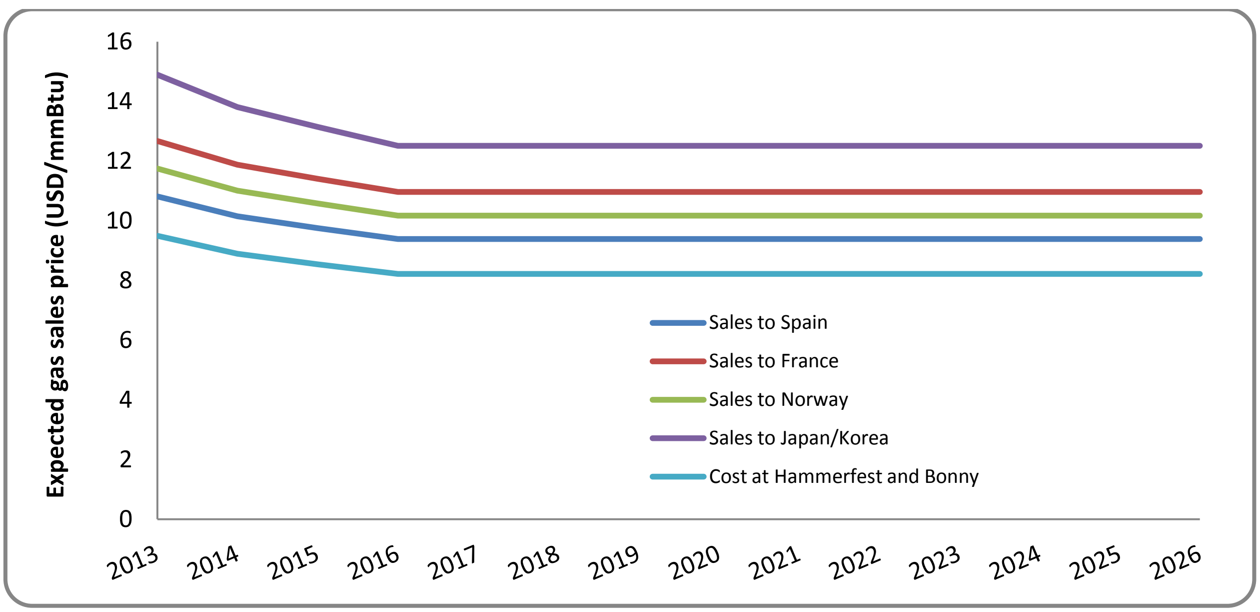

Figure 26: Forecasted gas prices for 2013 until 2026

Source: (Wood Mackenzie, 2013)

3.3.2.b) General economic assumptions

The 15-year TC rate is a function of the ship owner's cost of capital. Assuming a required rate of return to the ship owner of 6%, 7%, 8%, 9% or 10%, I have come to the following results for the 15-year TC rate paid by the trader.

Required rate of return to ship owner	**6%**	**7%**	**8%**	**9%**	**10%**
CAPEX (USD/day)	*46,078*	*50,546*	*55,181*	*59,968*	*64,894*
CAPEX Premium for Ice Class 1A (USD/day)	*2,143*	*2,351*	*2,567*	*2,789*	*3,018*
OPEX (USD/day)	*20,000*	*20,000*	*20,000*	*20,000*	*20,000*
15-year TC rate (USD/day)	**68,221**	**72,897**	**77,748**	**82,757**	**87,912**

Table 31: Effect of the required rate of return to the ship owner on the 15-year TC rate paid by the trader

3.3.2.c) The Present Value of the trader's 15-year project

With the five 15-year TC rates scenarios in place (Table 31) and the expected gas prices from Figure 26, I computed the trader's Annual Cash Flows (ACFs) for the 15-year project in Excel and I calculated the Net Present Value NPV of the project at 1st January 2012 based on the Discounted Cash Flow model (DCF). The NPV (Investopedia, 2013) is generally defined[7] as

$$NPV_0 = \sum_{t=1}^{n} \frac{ACF_t}{(1+r)^t} \qquad (3.3)$$

where

$$NPV_0 = Net\ Present\ Value\ at\ year\ 0$$
$$ACF_t = Annual\ Cash\ Flow\ at\ year\ t$$
$$r = trader's\ required\ rate\ of\ return$$
$$n = the\ lifetime\ of\ the\ project$$

In our particular case we will have

$$NPV_{2012} = \sum_{t=1}^{15} \frac{ACF_t}{(1+r)^t} \qquad (3.4)$$

[7] There is no initial investment cost I_0 for the trader since the ship owner invests in the vessel

3.3.2.d) Result of the Net Present Value

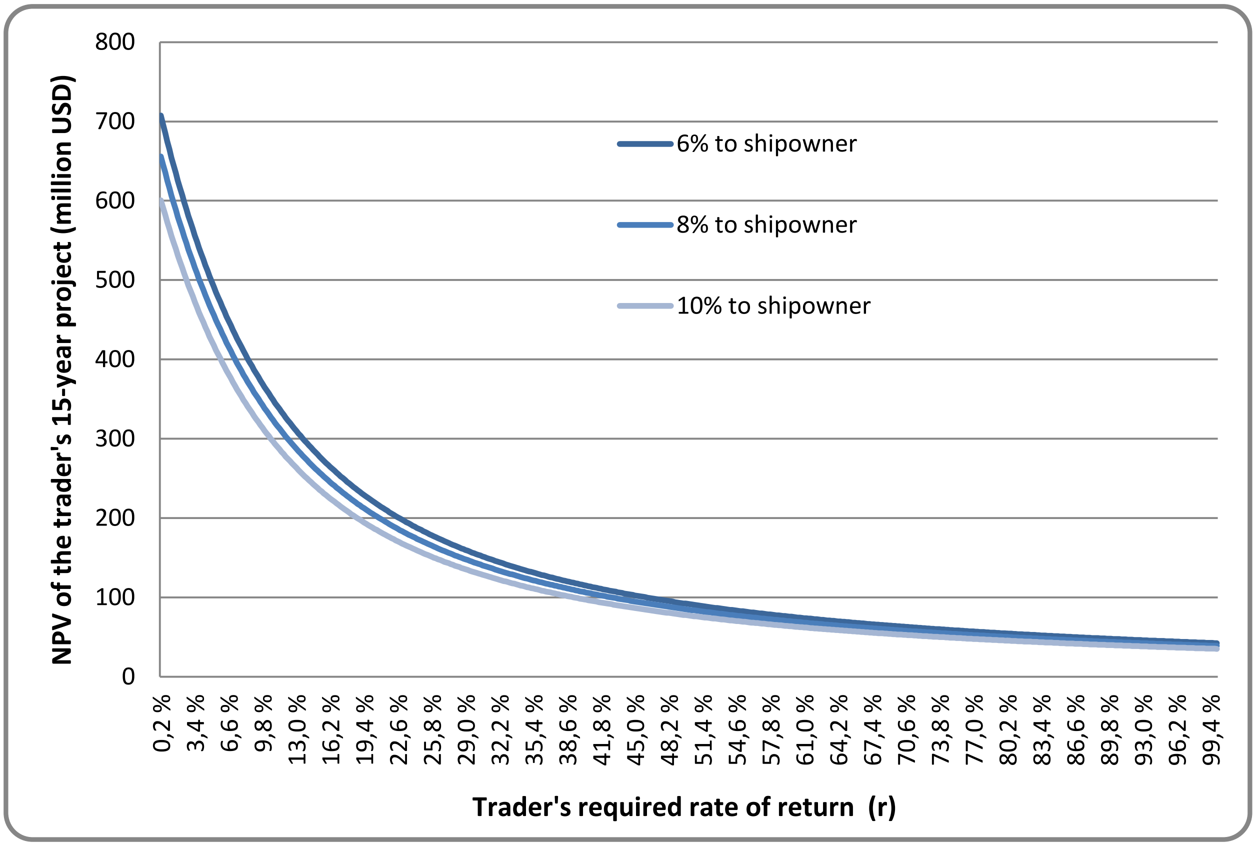

Figure 27: Trader's NPV of the 15-year project as function of his required rate of return

I have only represented in the above figure three of the five cases regarding the ship owner's cost of capital. We notice that for low values of the trader's required rate of return r, the differences in NPVs are evident when varying the ship owner's required rate of return. If r was equal to 6%, the trader would have an NPV of USD 466 million, USD 432 million or USD 396 million depending on the ship owner's cost of capital. The higher the value of r, the lower becomes the spreads of NPVs as the curves are converging to a same limit. The trader should go into this 15-year project according to Figure 27 since the NPVs are positive.

3.4 Valuing a five year extension option on the 15-year TC contract

3.4.1 Real options

3.4.1.a) Definitions

An option is defined as a right but not an obligation to undertake an action at a predetermined cost (exercise price) for a predetermined period (option's lifetime). In finance, there are mainly two categories of options: "call options" and "put options". A call option gives a person the right but not the obligation to buy an underlying asset from the option writer (seller) at a predetermined price at a certain point in time in the future. A put option gives the option holder the right to sell an underlying asset at a predetermined price at a certain point in time in the future. The buyer of the option is often said to have a long position. The writer of the option has a short position and is obliged to follow the option holder's decision (Alizadeh & Nikos, 2009).

A call (put) option is said to be *in-the-money* when the exercise price is under (above) the price of the underlying asset. In the other way round, the option is said to be *out-of-money*. Whenever the exercise price is equal to the price of the underlying asset, the option is said to be *at-the-money*. There are many different types of options; the most common ones are the European option and the American option. A European option gives the possibility for the option holder to exercise only at maturity date $t = T$. For an American one, the option holder can decide to exercise at any time before maturity date T (Alizadeh & Nikos, 2009).

Real options refer to options when the underlying asset is a physical asset, also known as tangible asset (De Giovanni & Jørgensen, 2009). LNG carriers for instance are regarded as tangible assets. Real options capture the value of managerial flexibility to adapt decisions in response to unexpected market developments, giving the manager of the option the right to defer, expand, contract or abandon a project when more information becomes available (Bendall, 2010). Real options in the LNG shipping industry are common.

3.4.1.b) Real options in the LNG shipping industry

Two main parties are involved in the charter market, the charterer (our trader) and the ship owner. Whenever a charterer enters a long term TC contract with the ship owner, it is usually common in the LNG shipping industry that the charterer enters the contract where he has the option to extend the duration of it. The usual extension period consists of two periods of five years, which is the case for the *Arctic Lady* for instance as we already know. Indeed, TEPN opted for a 20-year TC for the *Arctic Lady* with and option of 5+5 years. This contract was signed with Høegh LNG, the ship owner (Laurent, 2013).

Some charterers can have the option to purchase the vessel at the end of the long term TC. These types of options are better known as TC-POPs. Under a European TC-POP, the charterer has the opportunity to purchase the vessel at the end of the charter period at a predetermined price (Bendall, 2010).

Real options are important to understand in the LNG shipping industry as they are common for long term TC contracts. They may have a substantial value, but they are often given away by the ship owner (Strandenes, 2011). In my dissertation, I will only content myself with a value analysis of an extension option.

3.4.1.c) Advantages of extending the DCF method

The trader of the *Polar Bear* entered a 15-year contract with the ship owner the 1st January 2012 ("today"). Next, I will analyze the value "today" of a 5 year extension option taking place at the end of the 15-year TC contract (1st January 2027). The option will be a European call option, giving the trader the right but not the obligation to exercise the option only at maturity date T. The exercise date T will be two years before the end of the 15-year TC contract. Knowing that the 15-year TC contract comes to an end the 1st January 2027, the exercise date takes than place the 1st January 2025.

When analyzing the net present value of a TC project, the most common method used is the DCF model. However, it has the weakness to not take into account the managerial flexibility under the project's lifetime and can be regarded as to static. When a charterer enters a long term TC contract with a ship owner, the decision to enter the contract can be regarded as a large scale capital evaluation problem within the context of a great number of volatile parameters (Bendall, 2010). Volatile parameters are synonym of risk for the charterer. He will always be glad for having some flexibility when entering a contract. An extension option adds such flexibility to the charterer. The Real Option Analysis (ROA) is an extension of the DCF adding the value of flexibility (Bendall, 2010). The extension option can be of high substantial value for the *Polar*

Bear's ship owner but are often given away to the charterer as mentioned before. In the case where the option is given away to the charterer (trader), the only thing we know is that the value of the option by accepting it is not negative for the trader. Whenever the trader wishes to "buy" such an option, it will represent an extra exposure cost for him. However, he can benefit from this option if the 5-year TC market rate at expiration date turns out to be higher than the agreed option rate. In this way he will be protected against rising freight rates in the future. With an extension option, he will also be able to generate revenues from LNG trade during five more years. Thus

$$Value\ of\ project\ with\ flexibility = Value\ of\ project\ without\ flexibility + Value\ of\ flexibility$$

where $Value\ of\ project\ without\ flexibility = Value\ of\ the\ 15\ year\ TC\ contract$

$$Value\ of\ flexibility = Value\ of\ an\ extension\ option\ of\ 5\ years$$

By *value*, I refer to the "*value today*", the value at the date of signature of the long term TC contract the 1st January 2012.

Figure 28 captures the chronology of the important dates to have in mind.

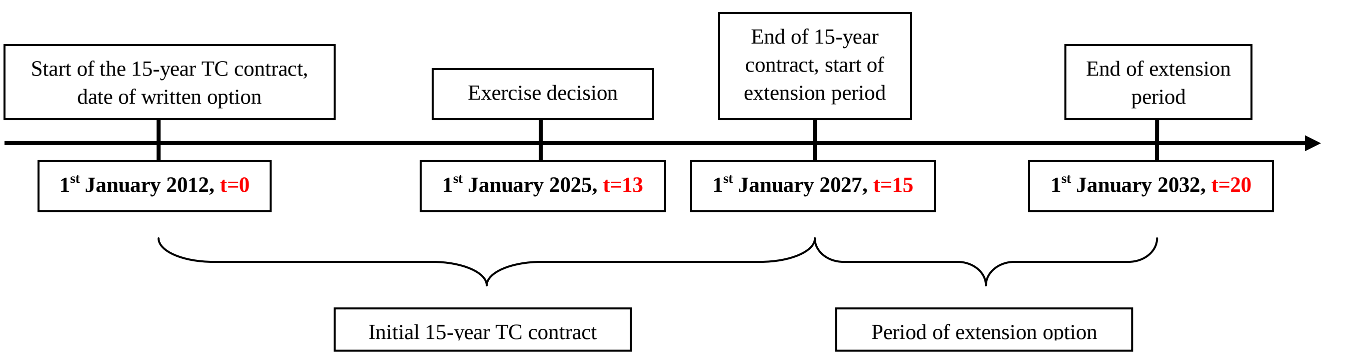

Figure 28: The structure of the project including a 5-year extension option

3.4.1.d) Methodology

The methodology used in the dissertation to value the 5-year extension option will be the Black-Scholes-Merton (BSM) model. It is the most common model used for financial options and can also be used for real options as we will see next.

For a dividend paying stock, the value of a European call option at date t according to Hull (2012) is given by

$$C(X_t, t) = X_t N(d_1) e^{-\delta(T-t)} - K e^{-r(T-t)} N(d_2) \qquad (3.5)$$

where $d_1 = \frac{\ln\left(\frac{X_t}{K}\right) + \left(r - \delta + \frac{\sigma^2}{2}\right)(T-t)}{\sigma\sqrt{(T-t)}}$ and $d_2 = d_1 - \sigma\sqrt{(T-t)}$

$X_t = Value\ of\ the\ underlying\ security\ at\ date\ t$

$K = The\ exercise\ price$

$T - t = Time\ to\ maturity$

$\sigma = Volatility\ of\ returns\ of\ the\ underlying\ asset$

$\delta = Continous\ payout\ of\ the\ underlying\ asset\ (dividend\ yield)$

$r = Continiously\ compounded\ risk\ free\ interest\ rate$

$N(d) = Cumulative\ distribution\ function\ of\ the\ standard\ normal\ distribution$

Some important assumptions behind this BSM formula are to be taken into account.

- The continuously compounded return on the underlying asset is assumed to be normally distributed and independent over time. In our case, the 5-year TC rate will be the underlying asset and is assumed to follow a random walk over time leading to a normal return distribution. Thus, the TC rate follows a stochastic process over time.

- The volatility expressed with the standard deviation σ will be based on historical fluctuations and will be assumed constant during the five years of the extension.

- There are no transaction and tax costs. Real options are not traded in the market and have no transaction costs.

- The formula for the call option shows how we can replicate a portfolio by going short in the underlying asset and borrowing at the risk free rate. For real options in our case, the replicating portfolio and the question of arbitrage opportunities has little sense. $N(d_1)$ and $N(d_2)$ correspond to probabilities in a risk neutral world; this is important to have in mind for later on. For instance, $N(d_2)$ is the probability that the option will be exercised in a risk-neutral world (Hull, 2012).

- A real option does not pay out dividends δ, however the factor exists. For real assets, it is often more difficult to estimate this factor than for financial assets since the asset is not openly traded. Many real options analysts assume it to be zero or use an arbitrary value and test the option's value sensitivity (Davis, 1998). Over the time, the dividend yield δ is simply the difference between the total expected rate of return μ on the underlying asset and the expected growth rate or capital gain rate α (Triantis, 2003).

-The time to expiration T is 13 years if we place ourselves at t=0. The decision to exercise is done two years before the end of the 15-year contract.

3.4.2 Valuating the trader's extension option

3.4.2.a) Applying the methodology

When substituting the convenience yield δ with $r - g_{13}$ in the BSM formula and X_t with $X_{2012} = X_0$, we get

$$C_0 = C(X_0, 0) = N(d_1)X_0 e^{-(r-g_{13})T} - Ke^{-rT}N(d_2) \qquad (3.6)$$

where $d_1 = \frac{\ln\left(\frac{X_0}{K}\right)+\left(g_{13}+\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$ $\quad d_2 = d_1 - \sigma\sqrt{T}$ and $T = 13$

In our case, we have an uncertainty on the development of the TC rates; hence the value of the extension option must be adjusted for this uncertainty. Usually, when developing the BSM differential equation, the equation is independent of risk preferences; we are in a risk neutral world and the expected return on all investment assets is the risk free rate r (Hull, 2012). The risk free interest rate r used will be assumed equal to the yield of a 20-year US treasury bill of 2.50% per year. Parameter g_{13} refers to the risk adjusted annual growth rate of the underlying asset for a thirteen years perspective (time to expiration T). The factor δ is replaced by $r - g_{13}$. The way we calculate g_{13} is described later.

The daily TC rate paid during the 5-year extension period from 1st January 2027 to 1st January 2032 will be denominated η. The charterer will have an incentive to exercise the extension option if and only if η is lower than the equivalent market TC rate at the time of exercise. However, in order to value the 5-year extension option, η is not exactly the exercise price used in the BSM model. The exercise price K is the date t=15 present value of the daily η paid between the beginning and the end of the five year extension period, discounted back by two years since the decision to exercise is done two years previously to the start of the extension period at t=13 (ref Figure 28) (Dahr, 2007). Hence, considering 365 days of operation a year, the exercise price

$$K = \frac{1}{(1+r)^2} \times [\eta \times 365] \times \frac{1}{r}\left[1 - \frac{1}{(1+r)^{T_0}}\right] \qquad (3.7)$$

There is no uncertainty regarding the contracted rate η because the rate is settled 1st January 2012 between both parties; the charterer and the ship owner. Hence the risk free rate r can be used in this case. T_0 corresponds to the number of annuities (option's duration) and is equal to five ($T_0 \neq T$). The last term represents the Present Value of an Annuity (PVA) formula (Bodie, Kan & Marcus, 2011).

Today's value of the underlying asset X_0 in the BSM formula refers to the present value of the daily TC freight rate ϕ observed in the market the 1st January 2012 for an equivalent five year period (Dahr, 2007). It is given by

$$X_0 = [\phi \times 365] \times \frac{1}{(r - g_5)}\left[1 - \frac{(1+g_5)^{T_0}}{(1+r)^{T_0}}\right] \qquad (3.8)$$

Parameter g_5 refers to the risk adjusted annual growth rate of the TC rate ϕ for a five year perspective. Remember that I assumed the TC freight rate ϕ to follow stochastic process. This is because the TC rate ϕ observed the 1st January 2012 has an uncertain five year development. Thus, the risk free interest rate r must be adjusted for g_5. The last term this time is the Present Value of a Growing Annuity (PVGA) formula (Finance Formulas, 2013).

We know that the BSM formula uses the risk free interest rate r as discounting factor because of the risk neutral world. The probabilities used in the BSM model are risk neutral hence the uncertain development of the underlying asset is neutralized.

In our case, we have uncertainty regarding the development of the TC rates and thus the value of the extension option must be adjusted for this uncertainty. The TC freight rate can be regarded as non-traded asset. How can it be adjusted for systematic risk? The method used is presented in the course of “Principles of Derivatives Pricing and Risk Management” at NHH taught by Haug (2012).

The risk adjusted annual growth rate, also called risk neutral drift, can be defined as

$$g = \mu - \lambda\sigma \qquad (3.9)$$

In our case, we have to differentiate the risk adjusted growth rate g_{13} in the BSM formula from the growth rate g_5 employed for X_0. μ refers to the drift term or the expected annual growth rate in the underlying asset. Since the two calculations refer to different time perspectives, different μ will be used since the expected annual growth rates for a five year perspective is different from a thirteen year perspective. Parameter σ represents the standard deviation of the TC rate and is assumed constant. The market price per unit of asset risk is denominated by λ, better known as Equivalent Martingale Measure restriction or Sharpe ratio here.

We know that

$$\mu - r = \lambda\sigma \qquad (3.10)$$

For the continuous-time version of the Capital Asset Pricing Model (CAPM),

$$\mu - r = \frac{\rho\sigma}{\sigma_m}(\mu_m - r) \qquad (3.11)$$

It follows from substituting $\mu - r$ with (3.10) that

$$\lambda\sigma = \frac{\rho\sigma}{\sigma_m}(\mu_m - r) \qquad (3.12)$$

Hence the risk adjusted annual growth rate

$$g = \mu - \lambda\sigma = \mu - \frac{\rho\sigma}{\sigma_m}(\mu_m - r) \qquad (3.13)$$

The coefficient ρ is the instantaneous correlation between the percentage change in the underlying asset and the return on a market index. A typical market index could be the S&P 500, which will be the one considered in my case. The expected return and volatility of the S&P 500 are represented by μ_m and σ_m.

3.4.2.b) Computing the results

The expected annual market rate of return for the S&P 500 is assumed $\mu_m = 7.5\,\%$ and the volatility $\sigma_m = 15\%$. We have supposed the risk free interest rate to be $r = 2.5\%$ which gives a market risk premium of 5%. The volatility σ is set to 10%.

In LNG shipping, the spot charter market went liquid as late as 2005 (Bakkelund, 2013). The correlation coefficient between the TC freight rate and the S&P index is based on historical values back from February 2008 in Appendix D. The coefficient gives a slight positive value of $\rho = 0.16$. The fact that the number is closer to zero than one is not surprising. We expect freight rates to be positive correlated to the S&P 500. However freight rates are sensitive to LNG shipping specific indicators in addition to general macroeconomic indicators that influence the S&P 500's behavior. These LNG shipping industry specific indicators can be the supply and demand conditions in natural gas, the availability of vessels, the overcapacity or under capacity, speculative orders and newbuilding prices.

Now, what are the values of μ_5 and μ_{13} in order to find g_5 and g_{13}?

Let's assume that we are the 1st January 2012 (t=0). On a 5-year horizon, we may have expected the TC rates to continue rising in 2012 as a consequence of the Fukushima earthquake in Japan in 2011 and the expected low number of new built vessel deliveries for 2012. After a likely peak in the freight rates for 2012, let's assume the freight rates were predicted to gradually fall to normal levels again during 2013, 2014, 2015 and 2016. An expected annual growth in freight rate of $\mu_5 = -1\%$ for the five coming years is thus assumed here.

For the 13-year perspective it is even harder to predict the expected annual growth rate in freight rates. The longer the time horizon is, the more difficult it is to forecast the balance between supply and demand of tonnage for instance. We can suppose that the American shale gas will continue having a positive impact on the US LNG export volumes. We know that the first US LNG shipment for export is due to start from Sabine Pass soon. Emerging markets should continue to have a growth in their imported LNG volumes. China and India may probably be the biggest importers over time. However it is difficult to estimate with certainty an expected annual growth rate over thirteen years. I will thus assume the annual growth in the TC freight rates over thirteen years to be zero, thus $\mu_{13} = 0\%$.

Given the above numbers

$$g_5 = \mu_5 - \frac{\rho\sigma}{\sigma_m}(\mu_m - r) = -0.01 - \frac{0.16 \times 0.10}{0.15}(0.075 - 0.025) = -1.5\% \, per \, year \quad (3.14)$$

$$g_{13} = \mu_{13} - \frac{\rho\sigma}{\sigma_m}(\mu_m - r) = 0.00 - \frac{0.16 \times 0.10}{0.15}(0.075 - 0.025) = -0.5\% \, per \, year \quad (3.15)$$

The daily TC-rate η agreed the 1st January 2012 for the extension period is assumed equal to the rate paid in the 15-year contract before exercise, meaning USD 77,748 per day. The TC rate ϕ for a five years perspective on 1st January 2012 was around USD 120,000 USD/day. We thus get

$$K = \frac{1}{(1+0.025)^2} \times [77{,}748 \times 365] \times \frac{1}{0.025}\left[1 - \frac{1}{(1+0.025)^5}\right] = \boldsymbol{USD\ 125{,}486{,}642} \quad (3.16)$$

$$X_0 = [120{,}000 \times 365] \times \frac{1}{(0.025 + 0.015)}\left[1 - \frac{(1-0.015)^5}{(1+0.025)^5}\right] = \boldsymbol{USD\ 197{,}492{,}522} \quad (3.17)$$

From the BSM formula

$$d_1 = \frac{\ln\left(\frac{197{,}492{,}522}{125{,}486{,}642}\right) + \left[-0.005 + \frac{1}{2} \times 0.10^2\right] \times 13}{0.10\sqrt{13}} = 1.2458 \quad (3.18)$$

$$d_2 = 1{,}2412 - 0.10\sqrt{13} = 0.8852 \quad (3.19)$$

From the cumulative normal distribution function in Excel, we find

$$N(d_1) = 0.8936 \quad (3.20)$$

$$N(d_2) = 0.8120 \quad (3.21)$$

We can finally find the value at t=0 of the extension option by computing the numbers in the BSM formula. We thus get

$$C_0 = \left(0.8936 \times 197{,}492{,}522 \times e^{-(0.025+0.005)\times 13}\right) - (125{,}486{,}652 \times e^{-0.025\times 13} \times 0.8120)$$

$$\boldsymbol{C_0 = USD\ 45{,}346{,}435} \qquad (3.22)$$

The option to extend the 15-year TC contract by five more years from the 1st January 2027 has a present value of USD 45 million. This number corresponds to the value of flexibility observed the 1st January 2012 (t=0), a substantial value that the ship owner should not ignore.

What is the value of the project without flexibility?

Recall that the value without flexibility is the value today of the 15-year TC contract. Knowing that the trader pays USD 77,748 per day for chartering the *Polar Bear* during 15 years, we get

$$Value\ of\ the\ 15\ year\ TC\ contract = [77{,}748 \times 365] \times \frac{1}{0.025}\left[1 - \frac{1}{(1+0.025)^{15}}\right] \qquad (3.23)$$

$$Value\ of\ the\ 15\ year\ TC\ contract = \boldsymbol{USD\ 351{,}358{,}985}$$

We can use the risk less interest rate r of 2.5% as discounting factor since there is no uncertainty regarding the daily TC rate paid by the charterer during the 15 years.

Thus, the total value today of the project is given by

$$Value\ of\ project\ with\ flexibility = USD\ 351{,}358{,}985 + USD\ 45{,}346{,}435 = \boldsymbol{USD\ 396{,}705{,}420}$$

This value of USD 396,705,420 represents the total price a rational trader would have paid for chartering the *Polar Bear* on a 15-year TC with an extension option of five years.

Some sensitivities can be carried out by varying some key parameters in the BSM model. I have chosen three parameters having an important impact on the real option's value.

The TC freight rate η

The daily TC rate η contracted the 1st January 2012 for the extension period of five years appears in the option's strike price K, which is the present value of the stream of η (equation 3.7 at p94). The first intuition says that the higher η is, the higher is K, the lower are the chances to end up *in-the-money* for the trader and thus the lower is the value of the call option as one can observe in Figure 29. The curve is convex meaning that the higher η is, the lower is the fall in value of the extension option. The reason for the convexity lays in the fact that η appears indirectly in the probability $N(d_2)$ that the option will be exercised in a risk-neutral world. The higher η is, the lower becomes d_2 and thus the lower is $N(d_2)$. So a higher η decreases in fact the probability for exercise explaining why we have this convexity of the curve.

Figure 29: Option's value as function of parameter η

The annual growth in TC rates μ_{13} and μ_5

These factors are of highly importance in order to determine the risk adjusted growth rates g_{13} and g_5 calculated before. I took some assumption based on market expectations and are thus to some extent uncertain. It is therefore worth to vary them in order to deal with flexibility and see how the value of the extension option will be affected. I have represented in Figure 30 the value of the extension option as function of the annual growth in TC rates, μ_{13} in blue and μ_5 in red, for an interval $[-3\%; +3\%]$. Notice that I let only one of the two variables to vary at the time. Varying μ_{13} keeping μ_5 constant at -1% leads to the blue curve. Varying μ_5 keeping μ_{13} constant at 0% leads to the red curve. All other parameters are held constant.

What can be said first of all is that both curves have a positive trend. The higher the expected growths in the TC rates μ_{13} and μ_5, the higher are the risk adjusted growths rates g_{13} and g_5, and thus the higher are the chances to be *in-the-money* at expiration. Consequently, the higher the chances are to be *in-the-money* at expiration, the higher is the value of the extension option.

We notice that changes in μ_{13}, and hence g_{13}, has a stronger effect than changes in μ_5 because μ_{13} appears indirectly in the exponential factor of the BSM formula, thus having a stronger impact on the option's value. The higher g_5 has a positive impact on the underlying asset $X_0$of the real option. Recall that the underlying asset is the present value of the 5-year TC rate observed in today's market (equation 3.8 at p94). Thus the higher the value of X_0, the higher becomes the option's value keeping all other parameters unchanged.

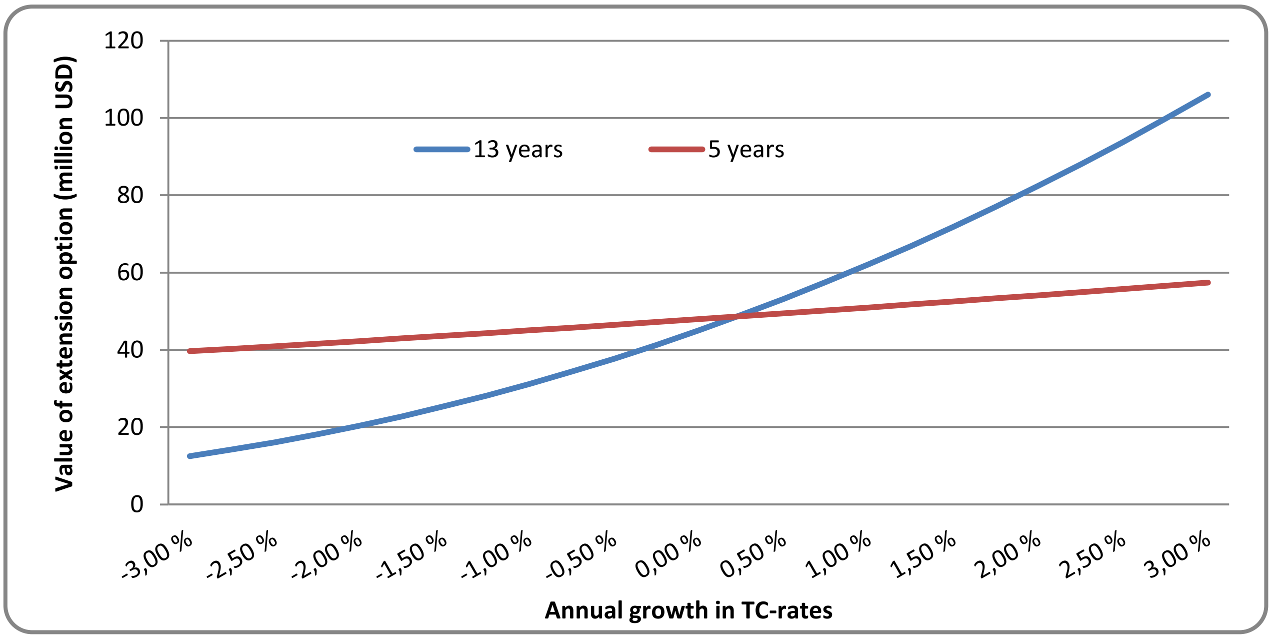

Figure 30: Option's value as function of annual growth in TC-rates

The five year expected growth rate is somewhat easier to predict than the 13 year growth rate. If we have a closer look to the blue curve, it is highly improbable that we may see a growth rate of 3% or -3% over 13 consecutive years. If that was the case, the LNG shipping business would have attracted newcomers (ship owners) increasing the degree in competition. This effect would have brought back the growth rate to less extreme levels, as -0.5% to +0.5% for instance. For the 5-year perspective, the annual growth rate μ_5 is more influenced by the short to medium run supply and demand forces in the LNG shipping market. It is therefore more probable to observe for instance a growth rate of 2% over five consecutive years than over 13 years.

Further sensitivities could have been carried out by varying key parameters as the volatility σ or the correlation coefficient ρ among others, but I will not go into further details in this dissertation.

3.5 Concluding remarks

The message in this third and last part was to show an example of a specific annual voyage plan carried out by a LNG trader. The liquefaction and re-gasification plants across the world are many; I have chosen some of them that could fit into the trader's voyage plan in 2012. The goal with this was to study the different exit strategies and analyze in what way the trader can benefit from arbitrage opportunities on gas prices across the continents. Indeed, as already mentioned, trading LNG between northern Norway and Asia-Pacific all year long, combining the NSR during summer and the Suez Canal for the rest of the year cannot be seen as a realistic scenario.

The trader would have benefited to follow its 2012 voyage plan in the spot charter market and not in a 1-year TC. Indeed, the trader would have generated a positive ACF of 0.088 USD/mmBtu in spot and a negative ACF of -0.044 USD/mmBtu in a 1-year TC. Some sensitivities by varying sailing speed and gas prices were carried out where we saw that the trader's ACFs can increase.

Further one, I studied a net present value of a project where the trader maintains and repeats the 2012 voyage plan over 15 years. Future gas prices where estimated from data by Wood Mackenzie. I performed some sensitivities by varying the trader's required rate of return and the ship owner's capital cost involved in the freight rates. Given a required rate of return of 6% to the trader and a freight rate of USD 77,748 per day, the NPV of the trader's 15-year project would have been USD 432 million. The 15-year LNG trading project would have been profitable for him.

Lastly, I decided to analyze the value of an extension option of five years on the 15-year TC contract using the Black-Scholes-Merton formula and I came to the conclusion that such an option has a substantial value, often ignored by the ship owner and therefore sometimes given away. The value found for the 5-year extension option was USD 45 million, a considerable amount. Sensitivities were done in order to analyze the behavior of the option's value. Key variables as the expected annual growth rate of the 13-year TC rate have a significant impact on the option's value. Other methods could have been used for valuating this real option. Monte-Carlo simulations, writing done the Euler schemes by discretisizing the stochastic differential equation of the TC rates, could have been also possible. This could have been done by simulating random walks factors ξ_t assumed normally distributed $N(0,1)$.

General Conclusion

The aim of the thesis was to argue for the feasibility and the economic viability of shipping LNG via the NSR. Based on History, on the effects of global warming and on the measures taken from the Russian authorities to facilitate the NSR transit procedures, there is no doubt that this route to Asia-Pacific has a bright future for the Norwegian and Russian LNG shipping industry. The location of Melkøya couldn't be better for commercial LNG shipping to benefit of this new gateway to Asia-Pacific during summer. TEPN, in collaboration with TGPL, wishes to take advantage of the NSR by sending LNG shipments to Asia from Melkøya during summer in the near future. Since Gazprom's NSR success in 2012 with the *Ob River*, the Total headquarters in Paris claim that they may send their first share of LNG produced in Melkøya via the NSR the summer 2013 (Vukmanovic, 2013). TEPN guess that an extra vessel chartered for a spot voyage will be envisaged since neither the *Arctic Lady* nor the *Meridian Spirit* accomplishes the requirements for transiting the NSR. However, TEPN finds hard to see how a transit in 2013 will be possible with the repeated problems and shutdowns affecting the LNG plant at Melkøya (Endresen, 2013). Despite that, as mentioned in the preliminary conclusion of part I, we should expect to see at least one new LNG shipping transit in 2013 according to Tschudi Shipping Company AS (Hagen, 2013).

Samsung Heavy industries in Korea have confirmed an order for two new LNG carriers of 180,000 m^3 for charter to Total with planned delivery in January and October 2017. The vessels will be placed on a 30-year charter contracts with TGPL in London (Almeida, 2013). The contract will be subject to final decision the summer 2013 of whether the Ice Class option will be chosen or not. TEPN expect that the option on Ice Class will be chosen. There is no information regarding the nature of the engines on these future vessels. According to Laurent (2013), the most likely to be installed are TFDE engines. This is not surprising as we have showed and argued that, indeed, TFDE LNG carriers are more fuel efficient than Steam Turbine carriers.

It would be much more profitable for TEPN and TGPL to export LNG to Japan via the NSR instead of sailing through the Suez Canal. The subsidiary TGPL has a cost advantage by owning a share of gas from Snøhvit. Gas extracted at a low cost and sold to Japan at a high price by choosing the NSR is tempting. There are good reasons to believe that other companies think about to do the same. However, it is worth to recall that TGPL has long term contracts and is commited to sell its LNG cargos to Europe and to the Gulf of Mexico. Each of the two new 180,000 m^3 vessels will be engaged in the transportation of LNG for the Australian Ichthys LNG project in which some other Japanese corporations participate and the Sabine Pass Liquefaction Project where the American shale-gas will be transformed into LNG for the first time (Almeida, 2013). Melkøya would be the third plant in which the new vessels would also be engaged in (Laurent, 2013). Thus, with three cargo lifting places spread across three continents, TGPL will be able to deliver the LNG to a worldwide client base which they have long term contracts with. The NSR is not the main explanation or the reason behind the two new orders. The NSR is perceived as an important route for Total that can be used when time is optimal. For instance, Total's Ichthys project in Australian will have Korea as the main importer of the LNG. Whenever one of the new vessels is scheduled to be at Melkøya in the middle of August for instance, a shipment to the clients in Korea via the NSR can be envisaged.

The NSR will increase in popularity with the years and attract newcomers wishing to send their shipment from Europe to Asia-Pacific or the other way round. This recent "A" way should see its commercial traffic to increase sharply with the years as long as Russia continues to put enough resources to develop the sea route, the region and their ice breaking fleet. Although it will never be an alternative highway to the Suez Canal route, at least in the short to the medium term, the possibility to choose the NSR with Asia-Pacific as destination seems promising for TEPN. Total's oil & gas activities in Norway and Russia will continue to progress. The Group should benefit from the mega project of Yamal in Russia and the Stockman project in the Russian Barents Sea in addition to the existing Snøhvit gas field in Norway. The NSR has a big potential.

Abbreviations and Acronyms

ACF	Annual Cash Flow
BOG	Boil Off Gas
BSM	Black-Scholes-Merton
CAPEX	Capital Expenditure
CAPM	Capital Asset Pricing Model
CHNL	Center for High North Logistics
CTA	Conditional Trading Area
DAP	Delivered At Place
DCF	Discounted Cash Flow
DFDE	Dual-Fuel Diesel-Electric
FOB	Free On Board
FOE	Fuel Oil Equivalent
FSRU	Floating Storage Regasification Unit
GRT	Gross Registered Tonnage
HFO	Heavy Fuel Oil
HH	Henry Hub
IMO	International Maritime Organization
IRTC	International Recommended Transit Corridor
JKS	Japan Korea Spot
LNG	Liquefied Natural Gas
MHO	Marine Operations Headquarter
NBDP	Narrow Band Direct Printing
NBOG	Natural Boil Off Gas
NBP	National Balancing Point
NPV	Net Present Value
NSR	Northern Sea Route
NSRA	Northern Sea Route Administration
NYMEX	New York Mercantile Exchange
OPEX	Operating Expenditure
PV	Present Value
PVA	Present Value of an Annuity
PVGA	Present Value of a Growing Annuity
ST	Steam Turbine
TC	Time Charter
TCP	Time Charter Party
TC-POP	Time Charter with Purchase Option
TEPN	Total E&P Norge

TFDE	Triple-Fuel Diesel-Electric
TGPL	Total Gas & Power Limited (UK)
VC	Voyage Cost
VCF	Voyage Cash Flow

km^2	Square kilometer
m^3	Cubic meter
mmBtu	Million Metric British Thermal Units (1m3 of LNG = 23.2 mmBtu)
mt	Metric Ton
nm	Nautical Mile

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Appendices

Appendix A

Source: (Laurent, 2013)

MERIDIAN SPIRIT	DATA	ARCTIC LADY
Meridian Spirit Aps (Teekay)	Owner	Leif Hoegh
286	L.O.A (Length overall) in m	288
43,4	Breadth in m	49
52	Keel to mast head in m	70,8
31 680	Light Ship in mt	34 020
113 608	Summer Displacement in mt	118 898
12,123	Summer Draft in m	12,329
Denmark International	Flag	NIS (Norwegian International Shipregister)
Bureau Veritas	Class	DNV
North	P&I	Gard
Samsung (Korea)	Shipyard	Mitsubishi (Japan)
15 January 2010	Delivery date	April 2006
8,6	Propeller Diameter in m	8,8
5	Propeller Blade number	6
7,619	Propeller Pitch in m	7,886
Diesel Electric Wartsila 3x 12V50DF + 1 6L50DF	Main Engine	2 Mitsubishi Boilers 60 bars / 60 mt steam - superheated 525 Deg C
ABB Electric Motor	Propelling Machinery	Steam Turbine Kawasaki & Reduction gir
26 200 @ 86 RPM	Propulsion in KW	27 600 @ 81 RPM
Fuel Oil, MGO, BOG (Natural and Forced)	Propulsion Fuel	Fuel Oil/MGO, BOG (Natural and Forced)
21,5	Max Speed in knots	20,5
128,5 mt per day 148,2 mt per day	Consumption @ 18,5 knots	165 mt per day
4	Number of cargo tanks	4
24 529,300	# 1	36 394,195
46 269,900	# 2	36 391,263
46 237,000	# 3	36 398,257
46 249,200	# 4	36 397,150
163 285,400	Total volume @ 98 / 98,5 % in m3	145 580,865
Membrane Type Mark III System - Primary 1,2 millimeter Thickness Corrugated Stainless Steel - Secondary 0,6 millimeter Thickness Triplex	Cargo tank Containment System	39,6 m Diameter Moss Sphere Type System 35 millimeter Aluminum Thickness suspended in the equator by a continuous skirt
Reinforced Polyurethane Foam	Cargo Tank insulation Type	Self Extinguishing extrusion expanded
270 millimeter	Cargo Tank Insulation Thickness	225 millimeter
0,15	BOG Max per day in cargo %	0,15
98 %	Filling Limits	98,5 %
Filling levels between 2 m and 70% of height of the tank are not allowed	Filling Levels	Nil
Yes	Bow thruster	Yes

Appendix B Source: (Laurent, 2013)

Port dues *Arctic Lady* 2013	Fos Sur Mer France	Huelva Spain	Hammerfest Norway	Suez Laden Egypt	Suez Ballast Egypt	Futtsu Japan	In-Chon South Korea	Bonny Nigeria
Berth hire		7 296	426 816				8 217	
Channel Dues				456 037	387 750			
Immigration Clearance				25	25			
Light dues		1 064		12 126	12 126			
Mooring/ Unmooring	3 220	5 574	25 000	2 353	2 353	5 756	7 500	
Pilotage	8 200	14 576	441 886	398	398	10 951	14 423	
Port clearance fee				50	50			
Port sundries				24 800	24 800			
Towage/ Tugs	29 484	53 847	218 000			33 854	89 957	
Oil Pollution Cess							794	
Harbor Dues	54 355		50 944	3 578	2 578	3 465	15 550	
Tonnage dues						14 969		
Garbage Collection		2 400						
Miscellaneous		120		3 224	3 224			
Watchman	1 000							
Harbor pilotage						6 793		
Escort boat charges			111 000			23 219		
Buoy charges						818		
Fire fighting boat fee						9 005	2 600	
Cargo dues								240 120
Carrier dues								144 700
5% VAT on carrier dues								7 235
Sea Protection Levy								36 479
Port piers								7 178
Hire of tugs								68 976
5% contingency on cargo dues								12 006
NMA Freight Levy								205 538
TOTAL	**96 259 Euros**	**84 877 Euros**	**1 273 646 NOK**	**502 591 USD**	**433 304 USD**	**108 831 USD**	**139 042 USD**	**722 232 USD**

Appendix C

Source: (Laurent, 2013)

Port dues *Meridian Spirit* 2013	Fos Sur Mer France	Huelva Spain	Hammerfest Norway	Suez Laden Egypt	Suez Ballast Egypt	Futtsu Japan	In-Chon South Korea	Bonny Nigeria
Berth hire		6250	380 683				7 060	
Channel Dues				395 076	336 026			
Immigration Clearance				25	25			
Light dues		911		10 292	10 292			
Mooring/ Unmooring	2 700	4 650	25 000	2 353	2 353	5 756	7500	
Pilotage	7 500	12 536	417 486	398	398	10 181	14 423	
Port clearance fee				50	50			
Towage/ Tugs	24 900	46 314	218 000	24 800	24 800	33 854	89 957	
Oil Pollution Cess							681	
Harbor Dues	48 685		43 798	3 028	3 028	2 968	13 322	
Tonnage dues						13 351		
Garbage Collection		2 400						
Miscellaneous		120		3 046	3 046			
Watchman	1 000							
Harbor pilotage						6 226		
Escort boat charges			111 000			23 219		
Buoy charges						818		
Fire fighting boat fee						9 005	2 600	
Cargo dues								273 240
Carrier dues								123 961
5% VAT on carrier dues								6 198
Sea Protection Levy								31 250
Port piers								8 167
Hire of tugs								68 976
5% contingency on cargo dues								13 662
NMA Freight Levy								233 887
TOTAL	**84 785 Euros**	**73 182 Euros**	**1 195 967 NOK**	**439 068 USD**	**380 018 USD**	**105 378 USD**	**135 542 USD**	**759 343 USD**

Appendix D

Source: (Bakkelund, 2013)