

A Trans-Korean Natural Gas Pipeline: Feasibility Study

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I. Executive Summary

The objective of this report is to assess the feasibility of a 3200 kilometer Trans-Korean natural gas pipeline. This project would run from the urban center of Vladivostok in the Russian Far East, through the Democratic People's Republic of Korea (DPRK), with a final destination of Seoul, the capital city of the Republic of Korea (ROK) (App. F. 2.).

To begin, South Korea, The Russian Federation, and North Korea are evaluated in respect to their current energy situations, political climate, and level of interest in an international energy scheme. Although this report recommends that the pipeline proposal be undertaken by firms, the national agendas of these countries cannot be ignored. There are several reasons for this. First, energy policy is of primary importance to all three nations. For Russia, energy exports are the cornerstone of both economic and political power. In South Korea, energy security is integral for continuing growth while in North Korea it is the lack of such energy that has been one of the primary reasons for economic stagnation. The second reason is the traditional involvement that all states have played in their energy sectors. Moreover, the firms most appropriate for undertaking this project are both controlled by state governments.

While the two firms in question are state controlled, Gazprom in the Russian Federation and the Korean Gas Corporation (KOGAS) in South Korea, a strong understanding of their fundamentals is necessary for comprehending this proposal. Thus, the next section of this paper is devoted to analyzing the suitability of Gazprom and KOGAS for this project.

Following the analysis of Gazprom and KOGAS is a detailed analysis of the project from three perspectives. The first is financial, explaining the most likely sources of capital for this proposal. Second, this report assesses how this project could be marketed to key decision makers in each country. Finally, the actual construction of the line is discussed. Along with these concerns, this paper also addresses steps that the ROK and Russia could take to mitigate the substantial political risk the DPRK presents.

This reports ends with a cost/benefit analysis, estimating an NPV of \$13,216,653,480.23. Despite the complications involved in constructing this pipeline, a careful analysis illustrates how lucrative this pipeline could be and suggests practical methods of risk minimization.

II. Pipeline Proposal

This report recommends the joint construction of a 3200 kilometer Trans-Korean natural gas pipeline. This project would run from the urban center of Vladivostok in the Russian Far East, through the Democratic People's Republic of Korea (DPRK), with a final destination of Seoul, the capital city of the Republic of Korea (ROK) (App. F. 2.).

With the anticipated growth in South Korea energy demand and Russia's untapped resources in the Far East a natural gas pipeline would be beneficial to both parties. Since the 1960's, companies, governments, and research institutions have continually revisited the possibility of

several Russian pipelines running into Northeast Asia.¹ However, many of the previously studied routes have been mired in complications, as they would have to traverse long distances and, in many cases, be laid under large bodies of water.²

This proposal seeks to circumvent these difficulties by laying a pipeline that would run from the Russian Province of Sakhalin, down through Russia's Southeastern provinces, and directly through the DPRK. While this plan does expose the pipeline to significant political risk, it also avoids the technological complications of having to construct undersea routes. Costs for constructing the main line of this project range from 10 billion to 14 billion USD, estimated from the projected costs of other similar initiatives that have been abandoned in the past.³

In addition, this project would call for the construction of eight 250 megawatt gas fired power stations within North Korea.⁴ These stations would be positioned in locations that would allow them to easily access the main pipeline and would conceivably power small local power grids by siphoning off a set portion of the gas running through the line. This element of the project would cost an estimated additional 1.4 billion USD and would be funded through a combination of international aid donations to the state of North Korea.⁵ This would both give North Korea a

¹ "Russia S. Korea to Sign New Gas Pipeline Deal," *The Economic Times*, (September 29th, 2008) http://economictimes.indiatimes.com/News/PoliticsNation/Russia_S_Korea_to_sign_new_gas_pipeline_deal/articleshow/3541341.cms

² Cabalu Helen, "Indicators of Security of Natural Gas Supply in Asia," *Energy Policy*, Vol. 38 iss. 1 pp. 218-225 (January 2010) http://www.sciencedirect.com.proxyau.wrlc.org/science?_ob=ArticleURL&_udi=B6V2W-4XDFDPX-1&_user=986260&_coverDate=01%2F31%2F2010&_rdoc=1&_fmt=high&_orig=gateway&_origin=gateway&_sort=d&_docanchor=&view=c&_acct=C000049872&_version=1&_urlVersion=0&_userid=986260&md5=af62cc672ffb7f09dde519cc6d4df23f&searctype=a

³ "South Korea and Russia Agree to Pursue Natural Gas Pipeline," *The Hankyoreh*, http://english.hani.co.kr/arti/english_edition/e_international/313141.html

⁴ Calder Kent, "The Geopolitics of Energy In Northeast Asia," *Korea Institute for Energy Economics SAIS John Hopkins*, (March 2004) http://www.iea.org/work/2004/seoul/Kent_Calder.pdf

⁵ Ibid 12

vested interest in the continued operation of the pipeline and begin a sustainable solution to the energy shortages that have plagued the DPRK in the past.

III. National Background

A. Republic of Korea

The Republic of South Korea is currently the world's 10th largest consumer of oil and energy in the world.⁶ It is also the most resource deficient country in all of Northeast Asia, importing 98% of all energy supplies.⁷ With a population growth rate ranked 179th in the world, at .266%, South Korea's future will include both an aging population and increased energy demands.⁸

Historically, South Korea has demonstrated staggering growth rates due to mass mobilization of its populace and clear government strategies focused on the development of key industries.

During the time period 1960 – 1996 South Korea averaged a growth rate of more than 8% per annum.⁹ This trend was briefly interrupted due to the Asian Financial Crisis which sent GDP plummeting by 6.9%. However, South Korea quickly experienced a “V-Shaped” Recovery which sent its GDP growth rate soaring to 9% during the year of 1999-2000. Since 2003, South Korea has averaged more modest increases of 4-5% per annum.¹⁰(App. F. 4)

⁶ Korea, South” *The CIA World Factbook* <https://www.cia.gov/library/publications/the-world-factbook/geos/ks.html>

⁷ Calder 2

⁸ CIA

⁹ Ibid

¹⁰ Lee Kon Seong, Gento Mogi and Jong Wook Kim, “Energy Technology Roadmap for the Next 10 Years: The Case of Korea,” *Energy Policy* Vol 37. Issue 2 588-596 (February 2009)

As South Korea's economy continues to grow its demand for energy is rising in tandem. In 2008 it was estimated that South Korea imported 2.982 million barrels of oil per day, consumed 440 billion Kwh of electricity, and 34 billion cubic meters of natural gas. With these figures South Korea is the world's 10th largest oil consumer and 25th in natural gas consumption.¹¹

Furthermore, although South Korea is anticipated to utilize much less natural gas than Japan in the next twenty years, its growth rates are more than double that of its larger neighbor (App. F.7).¹²

Compounding the ROK's growing need for energy is its deficit of natural resource endowments. In 2005 South Korea was recorded to have no proven reserves of oil, and a miniscule amount of exploitable natural gas reserves.¹³ Its coal endowment amounts to only 82 Megatons. By comparison, Russia has an estimated 200,580 megatons and even Japan holds 785 megatons of natural coal deposits.¹⁴ Taking into account oil, natural gas, and coal South Korea is the most resource deficient country in Northeast Asia, falling 742 megatons behind Japan in total potential energy production and 512 megatons behind North Korea (App. F.3.).¹⁵

Currently, Korea imports an estimated 81% of its oil from the Persian Gulf, a provider that is both geographically distant and subject to supply disruptions due to regional instability.¹⁶

Furthermore, not just South Korea but all of Asia is subject to what has been called the "Asian

¹¹ Calder 4

¹² Xiaojun Ma, "East Asian Energy Strategy: Conflict or Cooperation?" *International Strategies Research Institute* CCPS pp 1-10
http://www.aei.org/docLib/20050512_MaArticle.pdf

¹³ Cabelu 220

¹⁴ Calder 4

¹⁵ Calder 4

¹⁶ Choi Hyun Jin, "Fueling Crisis or Cooperation? The Geopolitics of Energy Security in Northeast Asia," *Asian Affairs and American Review*, vol. 36 iss. 1 (Spring 2009) PAIS International Database
<http://search.proquest.com.proxyau.wrlc.org/pais/docview/197418836/fulltextPDF?accountid=8285>

Premium,” or a historically higher average cost of energy resources when compared to other regions of the world. After accounting for shipping, storage, and risk premiums, it has been estimated that, on average, East Asia pays 1.5 USD more for each barrel of imported oil than the U.S. or Europe.¹⁷ This is assumed to be due to the high dependency that Asian countries have on energy rich regions; a result of their lack of domestic assets.¹⁸ While China has historically been able to mitigate some of this energy demand its high growth rate has caused China to switch from an energy exporter to that of a net importer since 1993.¹⁹ With China’s demand anticipated to outpace even its current suppliers by 2020 it is almost unthinkable that China will return to its role as an energy supplier in the future.²⁰

B. Russian Federation

Since the collapse of the Soviet Union in 1991 the Russian Federation has shifted its focus from an isolated centrally planned economy to one that is more open and market based.²¹ Possessing the 9th largest population base, the 7th largest world economy, and the endowed with the majority of natural resources on the Asian continent, Russia is poised to play a pivotal role in the energy market of both East Asian and the world in the coming decades.²² The International Energy Agency (IEA) predicts that Russia’s influence on the global price of oil and natural gas will increase dramatically in the next two decades.²³

¹⁷ Xiaojun 2

¹⁸ Ibid

¹⁹ Ibid 4

²⁰ Hyun-Jae Doh, “Energy Cooperation in Northeast Asia: Prospects and Challenges,” *East Asian Review* vol. 15 no. 3 Autumn 2003 pp. 85-110 http://www.ieas.or.kr/vol15_3/15_3_5.pdf

²¹ “Russia,” *CIA World Factbook*, <https://www.cia.gov/library/publications/the-world-factbook/geos/rs.html>

²² Ibid

²³ Thorton, Judith “Sakhalin Energy; Problems and Prospects,” *University of Washington, Seattle*, <http://www.econ.washington.edu/user/thornj/SakhProbRev4.25.00.pdf>

Since the 1998 Russian Financial Crisis, Russia has averaged a 7% growth rate per annum.²⁴ (App. F. 5.) This has resulted in a doubling of discretionary income for the average Russian citizen and the rise of a sizable middle class. Although Russia was heavily affected by the 2008 financial crisis, the country quickly rebounded by 2010; posting an estimated 3.8% GDP increase.²⁵ Despite continuing issues with weak property laws, regulatory complexity, and state interference prospects for continued Russian growth remain positive largely due to the expected rise in energy costs for the foreseeable future.²⁶

Since the collapse of the Soviet Union, Russia's economy has been dependent on the energy resources it possesses. In particular growth from 2000-2008 was driven by the spike in oil and gas prices resulting from the instability in the Middle East.²⁷ In 2009, Russia was the world's largest exporter of natural gas and the second largest exporter of petroleum. With the world's largest estimated reserves of natural gas, at 47.57 trillion cubic meters, Russia's importance in this industry will only continue to grow.²⁸ (App. F. 6) It was estimated by the IEA that if Russia were to construct a robust pipeline infrastructure with Northeast Asia it could easily meet the region's growing demand for energy resources in the next half century.²⁹

²⁴ "IMF Data Mapper," *International Monetary Fund*, <http://www.imf.org/external/datamapper/index.php>

²⁵ CIA

²⁶ Godzmirski Jakub and Nina Poussenkova, "Russia's New Gas Projects," *Center for Strategic Studies and Conflict Research*, Swiss Federal Institute of Technology (April 21 2009)

²⁷ Ibid 3

²⁸ The Economic Times

²⁹ "Russian Energy Survey," *International Energy Agency*, (2002)
http://www.iea.org/textbase/nppdf/free/archives/russia_energy_survey.pdf

Russia is also looking to diversify the market for its energy products. Currently, 63% of all Russian gas is exported to the European Union.³⁰ Because of this, 45% of all the EU's gas consumption is supplied by the Russian Federation, or more specifically, Gazprom as it is the only company that is authorized to export Russian natural gas.³¹ Furthermore, in the future Russia anticipates being able to meet as much as 70% of total European natural gas consumption by 2020 and Gazprom hopes to have captured 33% of the entire natural gas market in the EU by 2015.³²

This energy trade between the EU and Russia has created a mutual dependency that neither country, particularly the EU, is comfortable with. The leverage that Russia gained from acting as the dominant supplier of natural gas was made obvious in 2009 when Russia's dispute with Ukraine caused a cessation of natural gas shipments to the EU for a total of two weeks. As 70% of Russian gas to the EU is shipped through Ukraine, this disruption was both significant and jarring for the EU.³³ Other incidents have been Russia's frequent disagreements on royalties with President Alexander Lukashenko of Belarus and Russia's use of preferential gas tariffs to make political statements, particularly in regard to Poland.³⁴ On the Russian side, post financial crisis the stability of EU demand has been less than reliable. In 2009 Gazprom announced that it would be decreasing its output by 10% to adjust for falling demand.³⁵ This decrease led to a significant drop in Gazprom profitability estimated to be between 63-91 billion USD.³⁶ With Russia

³⁰ Godzmirski 3

³¹ Ibid 7

³² Ibid 3

³³ Bomberg Elizabeth et. al., *The European Union: How Does It Work?* (Oxford University Press 2008)

³⁴ Ibid 78

³⁵ Godzmirski 4

³⁶ Ibid

increasingly looking to bolster its economy on international energy exports, this fluctuation in demand is a cause for real concern.

In order to mitigate this risk the EU has plans to integrate its natural gas infrastructure to make it more difficult for Russia to choose which countries receive its natural gas.³⁷ The European Union has also begun to negotiate as a bloc with Gazprom, to further reduce the chance of price differentials between member nations.³⁸

As the EU takes steps to lessen the leverage Russia holds as an energy supplier, Russia could gain additional power by opening up a robust trade with the Northeast Asian sphere. This would have the benefit of giving Russia options as to where it chooses to export its energy supplies, negating some of the gains the EU would accumulate with collective bargaining arrangements.

C. Democratic People's Republic of Korea

Immediately following the end of the Korean War in 1953, The Democratic People's Republic of Korea's (DPRK) economy was relatively prosperous, bolstered by heavy subsidies from both the Soviet Union and China.³⁹ However, entering into the 1990's the collapse of the USSR had disastrous effects on North Korea's economy. Starting in 1989 the USSR and China began demanding hard currency for all oil products shipped into North Korea.⁴⁰ This was the first of many events that lead to the rapid decline of the DPRK's economic activity. From 1990-1995

³⁷ Bomberg 81

³⁸ Ibid

³⁹ Bertil Lintner, Great Leader, Dear Leader: Demystifying North Korea Under the Kim Regime, *Silkworm Books*, 2005

⁴⁰ Ibid 32

exports to North Korea fell by more than 50%, freezing up industrial activity due to a lack of energy inputs.⁴¹

Today, North Korea's economy is in dismal condition. Its capital stock is almost beyond help, suffering from disrepair due to lack of parts, technical expertise, and poor maintenance.⁴² Its 2010 estimated GDP was 40 billion, with a real growth rate of -.9%.⁴³ North Korea only real exports are military technologies to a select few pariah nations and hard drugs such as opium and methamphetamines to the Chinese market.⁴⁴ Further, with an estimated 46.7% of GDP dependent on energy intensive industries such as fertilizer production, petrochemicals, and steel factories North Korea's chronic energy shortages have had severe effects on its ability to sustain any kind of legitimate economic activity.⁴⁵

Like South Korea, the DPRK's has few natural resources to tap within its own borders. A notable exception to this is coal; the DPRK has an estimated 600 megatons of estimated coal reserves.⁴⁶ Because of decreasing imports of oil, North Korea has become increasingly reliant on its coal reserves to meet both its industrial and consumer energy needs. However, the coal is of uneven quality and frequently results in complications when burned for fuel in the many coal fired power plants around the country.⁴⁷ By some estimates North Korea loses as much as 50% of the effective energy of its coal due to inefficiencies in its power structure.⁴⁸

⁴¹ Oberdorfer Don, *The Two Koreas*, New York Basic Books 2009

⁴² "Korea, North" *CIA World Factbook*, <https://www.cia.gov/library/publications/the-world-factbook/geos/kn.html>

⁴³ Ibid

⁴⁴ Haggard Stephan and Marcus Noland, *Famine in North Korea: Markets, Aid, and Reform*, Columbia University Press 2009

⁴⁵ Paik Keun-Wook, "Low on Power," *World Today*, vol. 57 iss. 2 (February 2001)

⁴⁶ Calder 4

⁴⁷ Paik

⁴⁸ Ibid

Although North Korea is notorious for its adversity to the international community its dependence on international aid has ironically increased the more it attempts to follow its isolationist policies. In 2006, an estimated 86% of all North Korea energy supplies were a result of Chinese aid donations.⁴⁹ While North Korea will remain adverse to outside intervention for the foreseeable future, it is also becoming apparent how dire the economic situation is for both the regime and the country as a whole. As North Korea's increasingly aggressive actions result in decreasing amounts of international attention and aid, it is conceivable that the DPRK will soon have no choice but to be more open to legitimate methods of economic stimulation. This is particularly salient after the release of classified State Department documents hinting that China may not be as supportive of North Korea as it once was.⁵⁰ Should North Korea lose its largest benefactor it will soon have no choice but to pursue alternative methods of raising capital.

IV. Corporate Background

A. Gazprom

Gazprom was formed in 1989 when the former USSR Ministry of Gas and Industry transformed itself into a publicly held private company, retaining control over all of its previous assets.⁵¹

Upon its initial conception, the Russian Federation held a 100% stake in Gazprom. While it has since been opened up to private investment, the Russian government still controls a 50.002% controlling stake in the company.⁵²

⁴⁹ Haggard and Noland 102

⁵⁰ Tisdall Simon, "Wikileaks Cable Reveals China 'ready to abandon North Korea'," *The Guardian*, (November 29, 2010) <http://www.guardian.co.uk/world/2010/nov/29/wikileaks-cables-china-reunified-korea>

⁵¹ "About Gazprom," *Gazprom*, <http://www.gazprom.com/about/>

⁵² Thorton 13

Like its counterpart in South Korea, Gazprom is not only the best choice for the Russian side of this project, it is the only choice. Because of the 2006 Law on Gas Exports, Gazprom is currently the only company legally entitled to export natural gas originating from fields located within the Russian Federation to foreign governments and consumers.⁵³ Furthermore, even if other providers were allowed to export to foreign nations, all are dependent on Gazprom in some manner, usually through the need to utilize Gazprom's vast network of pipelines to transport their gas.⁵⁴ Currently, Gazprom produces 580 bcm/yr of natural gas while all other companies combined extract only 115bcm/yr. In other words, Gazprom accounts for 85% of total natural gas production in Russia.⁵⁵

Supplementing Gazprom's vast network of resources is the stake the Russian government holds in this company. While state involvement may prove to be a hindrance in certain projects, it would be a significant benefit for this project. Unlike other ventures, where private innovation and market competition are preferred, state involvement would bolster the element most needed for a Trans-Korean pipeline, security. Unlike a private enterprise, the Russian Federation holds the coercive resources that may be necessary to encourage a reluctant DPRK to cooperate should complications arise during the life of the project. Further, competition in the energy industry is already quite limited in Russia and South Korea, and nonexistent in North Korea thus the monopolistic tendencies that state participation tends to encourage in industry would not significantly alter the existing business environment.

⁵³ Godzmirski 4

⁵⁴ Ibid 7

⁵⁵ Ibid 7

Most significant, is Gazprom's expertise in the natural gas industry. Gazprom is the world's largest extractor of natural gas and currently operates the largest pipeline network, the Unified System of Gas Supplies (USGS), spanning 158,200 kilometers and over twenty countries.⁵⁶ Gazprom also controls 268 gas compressor stations, 24 underground storage facilities, and 6 gas condensate plants.⁵⁷ This allows Gazprom not only to satisfy large quantities of demand but also to effectively control the actions of all other gas producers within the Russian State. Therefore, to work with any other producer would make little sense as Gazprom would eventually have to be dealt with. Further, in 2009 Gazprom's total natural gas production was 549.7 billion cubic meters (BCMs) or 17% of total world production.⁵⁸

While Gazprom's traditional operations center on the western provinces of Siberia and the supply of European demand there are signs that the company is laying the groundwork for supplying the growing market of Northeast Asia. In 2006 Gazprom sign an agreement with Royal Dutch Shell, Mitsui, and Mitsubishi, purchasing an interest in the Sakhalin Development Fund for the Sakhalin-2 pipeline exploration project.⁵⁹ This project's primary goal is to explore ways in which Russia's largely untapped natural gas fields of the Far East can be utilized to provide energy to the Northeast Asian countries, particularly China, Japan, South Korea, and Taiwan.⁶⁰ In 2005 Gazprom also acquired 72.7% of Sibneft, a company licensed to work on Sakhalin and Krasnoyarsk Krai.⁶¹ Finally, in spring 2008 Gazprom was granted access to the Chayandinsk Fields in Yakutiya, the Kirinsk field in Sakhalin, and eight fields on the Yamal

⁵⁶ Godzmirski 3

⁵⁷ Ibid 2

⁵⁸ "Natural Gas Consumption", *CIA World Factbook*, <https://www.cia.gov/library/publications/the-world-factbook/rankorder/2181rank.html?countryName=Korea,%20South&countryCode=ks®ionCode=eas&rank=25#ks>

⁵⁹ Thorton 14

⁶⁰ Ibid

⁶¹ Godzmirski 6

peninsula. Currently, Gazprom has not only been exempt from taxes on these fields but is the only company with the rights to initial exploration.⁶²

B. Korea Gas Corporation (KOGAS)

Established by the South Korean government in 1983 the Korea Gas Corporation (KOGAS) is the world's single largest importer of natural gas.⁶³ As South Korea's sole provider of natural gas KOGAS operates three regasification terminals and 2,721 kilometers of pipeline within South Korea.⁶⁴ Its primary function is to convert the imported Liquefied Natural Gas (LNG) from liquid to gas and then to distribute that product to gas utility companies, city gas stations, and power generation plants in South Korea. Similar to Gazprom, KOGAS is a publicly held company, with 51% of its stock owned by the Korean National Government.⁶⁵ Also similar to Gazprom, KOGAS is the only truly viable alternative for a large scale transnational pipeline project. However, unlike Gazprom KOGAS is not the most likely company due to regulations; it is simply the only company in South Korea that is both involved in the natural gas sector and large enough to support such a significant undertaking.⁶⁶

In addition to having industry expertise KOGAS is already in control of an effective and elaborate distribution network within Korea. This consideration is key as the existence of such a network significantly cuts down on the cost of bringing natural gas to consumers. A counter example is Japan which currently does not have an advanced natural gas infrastructure. The

⁶² Ibid 6

⁶³ "Our Profile," *Korea Gas Corporation*, http://www.kogas.or.kr/kogas_eng/html/who/who_01.jsp

⁶⁴ Ibid

⁶⁵ Ibid

⁶⁶ Baker and McKenzie Consulting, "Clean and Renewable Energy Market Opportunities in Korea and Australia" *Australian Trade Commission*, pp 1-48 http://www.bakermckenzie.com/files/News/4769bb3d-b368-4afd-80099c540d2628a4/Presentation/NewsAttachment/1e97d42d-04aa-45c1-89a5-5f8ee54d6253/bk_cleanrenewableenergymarketopportunitiespart1_may10.pdf

government of Japan estimates that to create one would cost anywhere from 12 – 40 billion dollars.⁶⁷ Considering that estimates for building the main pipeline run anywhere from 20 -24 billion, the cost of having to create an internal structure would more than double the necessary initial capital outlay.

V. Proposal Analysis

A. Finance

As both Gazprom and Korea Gas Corporation are state owned companies, primary financial support would be expected to originate from the national governments of Russia and South Korea. The historical tendency of both countries to support their energy industries would suggest that, even if these were private companies, heavy state involvement would be inevitable.⁶⁸

In South Korea, corporations such as KOGAS have traditionally been referred to as Chaebols, or large conglomerates that are given preferential treatment by the national government. KOGAS compliment, the Korean Electric Power Company (KEPCO), is also a state owned apparatus and is responsible for providing electricity to the entire South Korean nation.⁶⁹ While both KOGAS and KEPCO are scheduled to be broken up into smaller firms to foster competition, neither entity has gone through any serious steps toward this goal. Since KEPCO has supposedly been going

⁶⁷ Choi Hyun Jin, "Fueling Crisis or Cooperation? The Geopolitics of Energy Security in Northeast Asia," *Asian Affairs and American Review*, vol. 36 iss. 1 (Spring 2009) PAIS International Database

<http://search.proquest.com.proxyau.wrlc.org/pais/docview/197418836/fulltextPDF?accountid=8285>

⁶⁸ Lee Kwang-Suk, " A Final Flowering of the Developmental State: the IT Policy Experiment of the Korean Information Infrastructure, 1995-2005" *Government Information Quarterly* vol. 26 issue 4 567-576 (October 2009)

⁶⁹ Ibid 569

through “privatization” since 1998 it is a reasonable assumption that neither will be going through any significant change in the immediate future.⁷⁰

Compounding the South Korean government’s likelihood to finance this activity is the flagship program of the Lee Myung Bak administration. In 2008 President Lee Myung Bak announced his “Low Carbon Green Growth” initiative, with the intent to invest an estimated 200 billion dollars from 2010 – 2015 on green energy initiatives.⁷¹ As natural gas is one of the most efficient and clean energy sources available for mainstream energy usage, investing in this pipeline would be well aligned with the current trajectory of this administration.⁷²

Russia’s interest in Gazprom’s success is in large part, an interest in the success of Russia as a whole. In 2008 Gazprom revenues accounted for an estimated 10% of Russia’s entire GDP.⁷³ Further, Gazprom accounted for 83% of Russia’s total energy output in 2008. It is the vehicle through which Russia exerts the majority of its foreign policy leverage, in the form of threats to cut off European energy supplies, such as it did when it temporarily closed off gas pipelines to Ukraine in 2009.⁷⁴ Russia has also designated Gazprom a “national champion” corporation, meaning that Gazprom makes decisions not only for the sake of its shareholders but with the

⁷⁰ OECD Review of Innovation Policy: Korea 2009” *Source OECD* vol. 2009 no. 14 1-268

<http://titania.sourceoecd.org.proxyau.wrlc.org/vl=2427292/cl=13/nw=1/rpsv/~6681/v2009n14/s1/p11>

⁷¹ Lee Kon Seong, Gento Mogi and Jong Wook Kim, “Energy Technology Roadmap for the Next 10 Years: The Case of Korea,” *Energy Policy* Vol 37. Issue 2 588-596 (February 2009)

⁷² Ibid 590

⁷³ Gazprom

⁷⁴ Bomberg 78

greater interests of Russia as a whole in mind.⁷⁵ In exchange for this Gazprom enjoys implicit government backing and explicit benefits such as tax breaks and fee waivers.⁷⁶

B. Marketing

Advertising this pipeline poses significant challenges for all three national governments involved. It will require both careful coordination and delicate handling of several politically sensitive subjects in order to both effectively convey the benefits of this collaboration while addressing the justifiable concerns of all national citizenries involved.

i. South Korea

The most significant obstacle that will need to be overcome in South Korea will be convincing the Grand National Party (GNP), which holds a majority in the 18th Assembly, or Korea's version of Congress. Traditionally conservative and hawkish toward North Korea the GNP was responsible for curtailing all aid to North Korea soon after gain a majority in the Assembly in 2008.⁷⁷ After the sinking of the Korean submarine, The Cheonan, in March and the shelling of the border island Yeongpyeong in November, convincing the GNP to fund a Trans-Korean gas pipeline will require a significant investment of political capital.

Lee Myung Bak's administration will need to stress two major points for this project. The first is that it is primarily an initiative to bolster South Korea's long term energy sustainability, not an aid program for North Korea. The second element President Lee Myung Bak must focus on are

⁷⁵ Thorton 2

⁷⁶ Ibid

⁷⁷ "South Korean Political Parties Unite Against Yeonpyeong Bombardment," *Arirang*, Nov. 23rd 2010, http://www.arirang.co.kr/News/News_View.asp?nseq=109410&code=Ne2&category=2

the natural incentives built into the program to prevent North Korea from seizing control of the pipeline or disrupting the flow of gas to South Korea. With two acts of North Korean aggression so recent in history, the second point, the assurance of security, must take precedence when presenting this idea to the Assembly.

ii. Russia

Russia will also need to convince its constituents that North Korea does not pose a significant enough security threat to overshadow the attractiveness of this project. However, unlike South Korea, Russia's Duma does not need to approve the appropriation of funds, making it much easier for Russia to approve financing of this project.⁷⁸

The main question Russian proponents of this project will need to address is the need to diversify its markets into Northeast Asia. Currently, Russia enjoys growing demand from Europe for its energy resources. In fact, the majority of Russian energy is focused on improving supply lines to the European Union, with two major pipelines planned, Nord Stream and South Stream.⁷⁹

Russians in favor of an Asian Pacific pipeline will need to convince their constituents that the growing economies of Asia offer substantial long term opportunities for Russian energy concerns.

iii. North Korea

Being one of the most autocratic governments in existence, North Korea does not have any national constituency it needs to convince in order to agree to this pipeline project. Furthermore,

⁷⁸ CIA

⁷⁹ Bomberg 81

with a state budget estimated at 3.3 billion for 2009 it is unlikely that North Korea can even be expected to contribute to the financing of the eight 250 megawatt gas fired plants that will bring benefit only to North Korean homeowners.⁸⁰

Despite this North Korea remains the most challenging country to cooperate with. Because of the clandestine nature of its political system there is no real method of identifying who holds the power within North Korea to approve a project such as this. For North Korean's who would support such a plan they would need to first assure fellow power brokers that this pipeline would neither jeopardize North Korea's sovereignty or serve as a conduit for western interference in its internal affairs.⁸¹ North Koreans would also need to be assured that the aid for the construction of the eight power plants would be continued until the projects were completed. The last aid based energy projects, two 1000 megawatt Light Water Reactors, were abandoned half finished by the Japanese and Korean authorities after North Korea revealed its continuing nuclear program in 2002.⁸²

If North Korea could be assured of its sovereignty and guaranteed the benefits of allowing a Trans-Korean pipeline, securing their cooperation would be much more likely.

C. Construction and Operation

Construction of the main pipeline will only be part of the process of successfully moving Sakhalin gas deposits into South Korean homes. First, a system of pipes within Siberia must be

⁸⁰ Paik

⁸¹ Sung Chull Kim and David Kang, Engagement with North Korea: A Viable Alternative, *State University of New York Press*, 2009

⁸² Funabashi Yoichi, The Peninsula Question: A Chronicle of the Second Korean Nuclear Crisis, *The Brookings Institute* 2007

developed to move gas from several disparate fields toward one central station where it can be funneled into the main line.⁸³ Second, South Korea will need to have a sophisticated distribution system set up in order to move gas from the main line into the city and corporate utility stations that will then distribute it to local consumers.⁸⁴

To complete the network of Siberian pipeline Russia has already committed to spending an estimated 25-30 billion USD to construct an integrated system that in their words, “will be friendly to robust energy exports.”⁸⁵ South Korea already has made significant investments into a natural gas infrastructure and has consolidated all assets under the control of KOGAS.⁸⁶

The construction of the actual pipeline should be overseen by Gazprom in Russia, KOGAS in South Korea, and be a joint effort within North Korea. Should Gazprom head up the construction within Russia any foreign companies participating will enjoy “joint partner” status that will both simplify Russian regulations and bring down the cost of administrative fees. Because very little of the main line will actually be constructed in South Korea (Seoul is only 40 kilometers away from the De-Militarized Zone separating North and South Korea) KOGAS can logically handle a construction project of that scale on its own.

Construction of the pipeline in North Korea can be modeled after the arrangements that have been utilized in the Kaesong Industrial Complex, the only site where South and North Korean

⁸³ Thorton 9

⁸⁴ KOGAS

⁸⁵ “North Korea to host Russian Gas Pipeline?,” *United Press International*, (July 31st, 2009)
http://www.upi.com/Science_News/Resource-Wars/2009/07/31/North-Korea-to-host-Russian-gas-pipeline/UPI-50101249054314/

⁸⁶ KOGAS

business ventures have jointly operated since the end of the Korean War.⁸⁷ Kaesong, begun as part of previous South Korean President Kim Dae Jung's Sunshine Policy, operates with South Korean firms supplying capital and management while North Korea provides largely unskilled labor.⁸⁸ While this project has been more a symbol than a serious economic asset, its model could prove useful when planning the construction of a Trans-Korean pipeline.

VI. Cost Benefit Analysis

A. Costs

Costs for constructing pipelines from Russia to Northeast Asia have traditionally fallen within the range of 18 billion -24 billion USD. However, these plans almost all call for some portion of the pipeline to be run under large bodies of water, raising both the expense and technical complexity of the projects. They are also inevitably longer, due to the necessity of circumventing either geographical obstacles or politically risky areas.⁸⁹

Therefore, the cost of pipeline construction if run directly from Southeast Russia through North Korea would be significantly smaller. Based on a study done of 893 U.S. pipeline projects over a 13 year time span average costs of typical pipeline construction include:⁹⁰

1. material costs- 26%
2. labor costs- 45%

⁸⁷ Oberdorfer 229

⁸⁸ Ibid 229

⁸⁹ Thorton 16

⁹⁰ Parker Nathan, "Using Natural Gas Pipeline Cost to Estimate Hydrogen Gas Pipeline Cost," *Institute of Transportation Studies UC Davis*, (December 2004) http://pubs.its.ucdavis.edu/publication_detail.php?id=197

3. right of way- 22%

4. miscellaneous*- 7*

* includes including surveying, engineering, supervision, contingency allowances, overhead, and filing fees

The same study offers general equations to estimate the cost of a typical pipeline project. The equations are all functions of two variables:⁹¹

1. Project Length- for this project the length has been estimated to be 3200 kilometers
2. Pipe Diameter- For this project a diameter of 36 inches will be assumed as it is the most common for natural gas systems.

Specific Calculations-

* All equations assume cost is in dollars, diameter is measured in inches, and length in kilometers

i. Material Cost

$$\text{Material Cost (diameter, length)} = 330.5(\text{dia})^2 + 687(\text{dia}) + 26,920(\text{length}) + 35,000^{92}$$

$$\text{Total Material Cost} = \$2,566,320,060.00 \text{ USD}$$

⁹¹ Parker 9

⁹² Ibid 11

ii. Labor Cost

$$\text{Labor Cost (diameter, length)} = 343(\text{dia})^2 + 2074(\text{dia}) + 170,013(\text{length}) + 185,000^{93}$$

$$\underline{\text{Total Labor Cost} = \$5,144,745,792.00}$$

iii. Right of Way

$$\text{Right of Way Cost (diameter, length)} = (577(\text{dia})^2 + (29,78)\text{length} + 40,000)^{94}$$

$$\underline{\text{Total Right of Way Cost} = \$2,096,109,392.00}$$

iv. Miscellaneous Costs

$$\text{Misc. Costs (diameter length)} = (8,417(\text{dia}) + (7324)\text{length} + 95,000)^{95}$$

$$\underline{\text{Total Miscellaneous Cost} = \$823,834,812.00}$$

TOTAL ESTIMATED PROJECT COST = \$10,631,010,000.00 USD

B. Revenue

To simplify this equation, it is assumed that pipeline will operate at optimal capacity year round and that all natural gas forwarded to South Korea will be consumed. It is also assumed, for simplification and to avoid analyst bias, that the spot price of natural gas will remain the price of gas for the duration of this project.

$$1. \text{ Anticipated total output} = \underline{750,000,000 \text{ tons/yr}}^{96}$$

⁹³ Ibid 13

⁹⁴ Ibid 14

⁹⁵ Ibid 17

For recent pipeline proposals this number has oscillated between 750,000,000 tons/yr - 1,000,000,000 tons/yr. For this initial revenue estimation we will use the conservative estimate of 750,000,000 tons/yr.

2. Current International Spot Price of Natural Gas = \$4.37. USD/MMbtu⁹⁷

3. According to a unit conversion table (see appendix) one ton is equivalent to 48.7 MMBtu thus:

$$\text{Price/Ton of Natural Gas} = \underline{\$213.01 \text{ USD}}$$

4. Total Revenue (per annum)

$$= \text{Price/Ton of Natural Gas} * \text{Total Expected Output}$$

TOTAL EXPECTED REVENUE (Per Annum) = \$1,597,603,500.00 USD

C. Project Evaluation

To evaluate the attractiveness of this project the Net Present Value (NPV) is calculated. For this initial calculation, cash flows are assumed to be constant throughout the life of this project.

⁹⁶ Economic Times

⁹⁷ "International Natural Gas Price," *U.S. Energy Information Agency*,
<http://www.eia.doe.gov/emeu/international/gasprice.html>

Furthermore, as similar pipelines in discussion have an expected life of thirty years it is assumed the project will see thirty years of steady cash flows.

To estimate the cost of capital it is assumed that this project will be jointly funded by the Russian Federation and the South Korean National Government. Thus to compute the cost of capital the interest rate was found for ten year Russian (.06%) and ten year South Korean (.0452%) bonds. Assuming that the costs are shared evenly, the estimated cost of capital for this project was found to be 5.26%.

TOTAL ESTIMATED NPV = \$13,216,653,480.23

VII. Concluding Remarks

A Trans-Korean Pipeline has benefits that cannot be quantified. By bringing North Korea into the broader global community it will increase security across the Northeast Asian sphere. Within North Korea a pipeline could act as both the beginning of a legitimate economy and a way for the more than 23 million impoverished North Korean's to access heat and electricity for vital needs such as warmth and the running of medical equipment. In time, this could lead to a more robust North Korean economy that would not only make its nuclear program redundant, but lessen the possibility of nuclear proliferation by transforming North Korea from a pariah state into an actor with a stake in global security.

In the context of Russia, an Asian Pacific option would allow it to leverage a diversified demand portfolio into higher gas prices. Further, it would allow Russia to begin utilizing the energy

resources of the Far East which up to now have been too geographically distant to serve as viable options for foreign markets. For South Korea, it would mean a stable energy supply that does not have to be shipped halfway around the globe. These benefits are not captured in the NPV analysis conducted above. All three nations have much to gain from this proposal. While the investment may seem significant, it is nothing compared to the possible benefit it could bring to both these nations and their people.

Appendix

Figure 1. Map of Northeast Asia



Figure 2. Pipeline Proposal



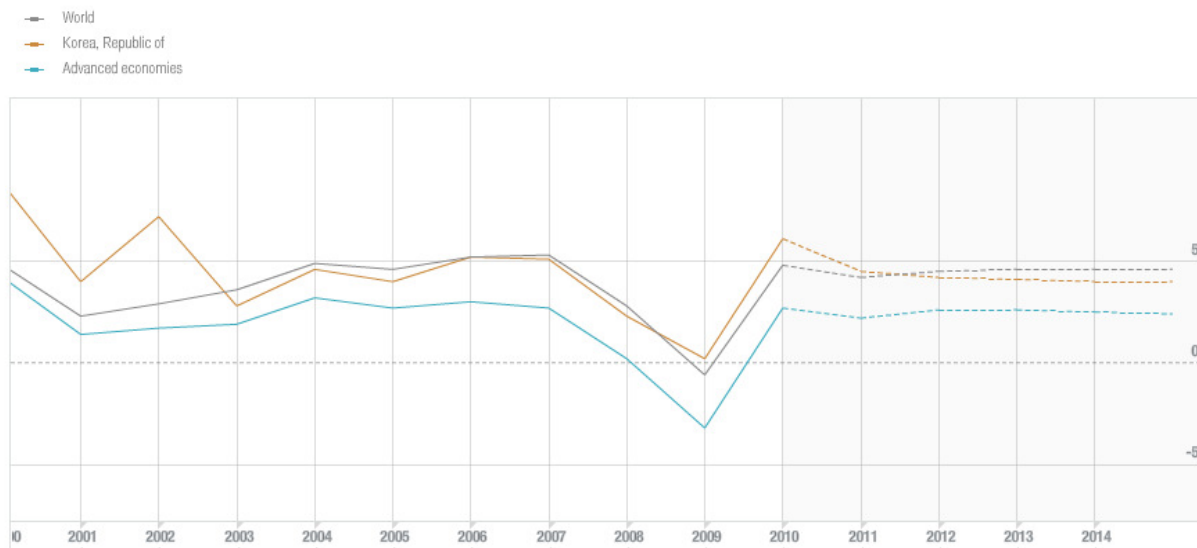
Figure 3. Northeast Asian Natural Resource Endowment

	Coal	Oil	Natural Gas	Hydropower
	Proven Reserves (Mton)	Proven Reserves (Mton)	Proven Reserves (Bil.m³)	Technically Exploitable Capability (TWh/yr)
S. Korea	82	-	6	55
N. Korea	600	-	-	N/A
Japan	785	7	32	134
China	95,900	5,272	1,171	1,923
Mongolia	10,000	-	-	6
Russia	200,580*	6,654	47,700	1,670
(RFE & E. Siberia) ¹⁾	(169,300)*	(1,570)*	(3,204)*	(1,008)**
NE Asia Total (a)	253,927	11,933	48,909	3,788
(share a/b)	(39.1%)	(8.2%)	(33.2%)	(26.5%)
World Total (b)	788,511	146,102	147,265	14,284

Figure 4. South Korean Economic Growth

IMF Data Mapper ®

Real GDP growth (Annual percent change)



©IMF, 2010, Source: World Economic Outlook (October 2010)

Figure 5. Russian Federation Economic Growth

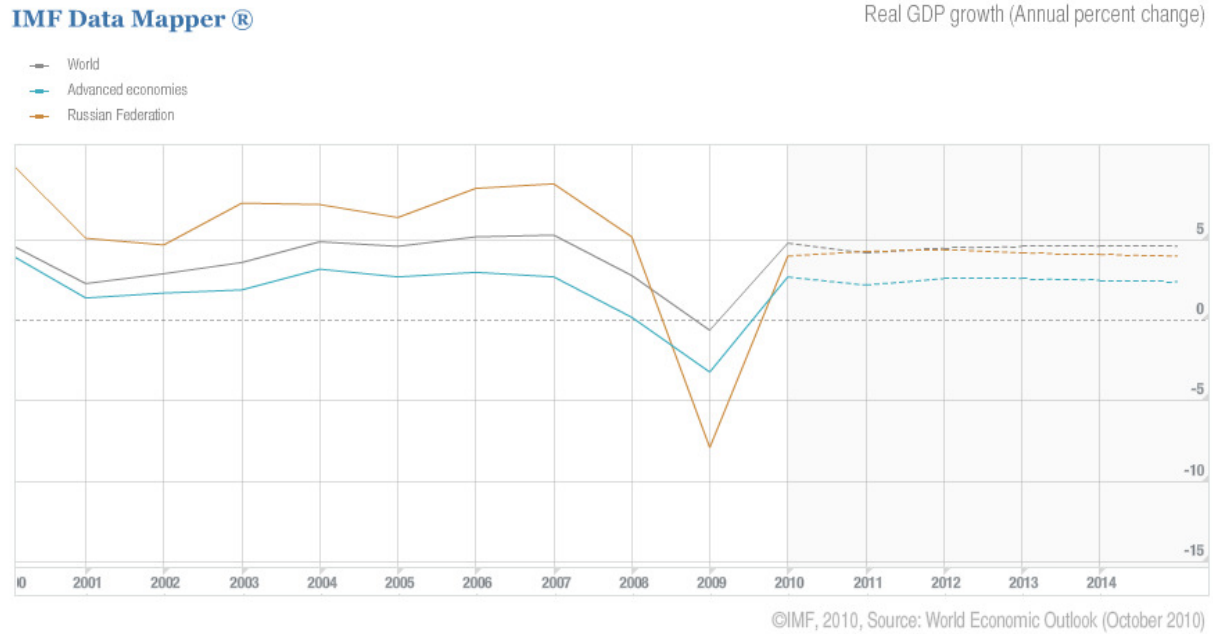
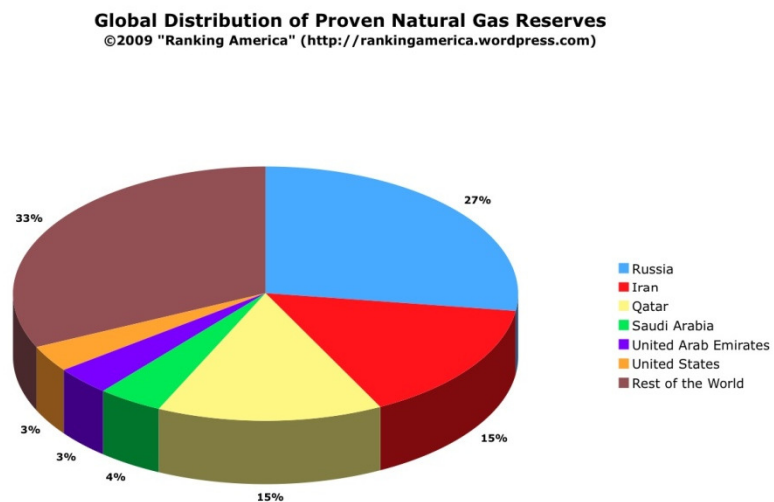


Figure 6. Natural Gas Resource Distribution



Data from CIA World Factbook 2008
<https://www.cia.gov/library/publications/the-world-factbook/rankorder/2179rank.html>

Figure 7. Northeast Asia Natural Gas Consumption Projection

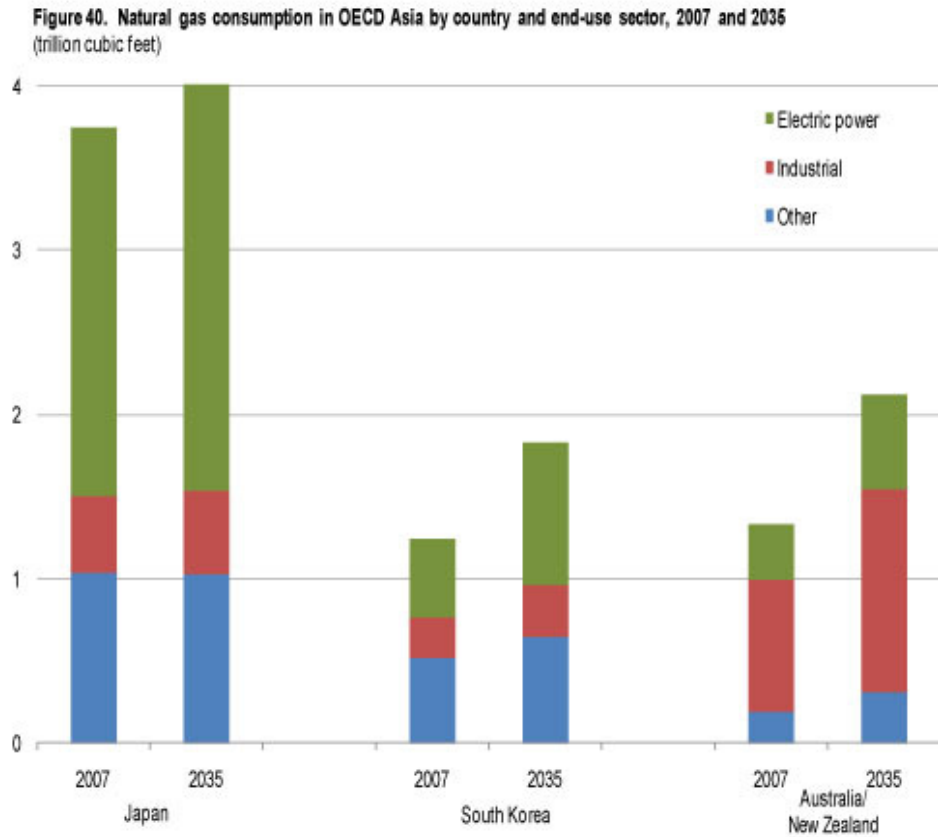


Figure 8. Russian Natural Gas Consumption Projection

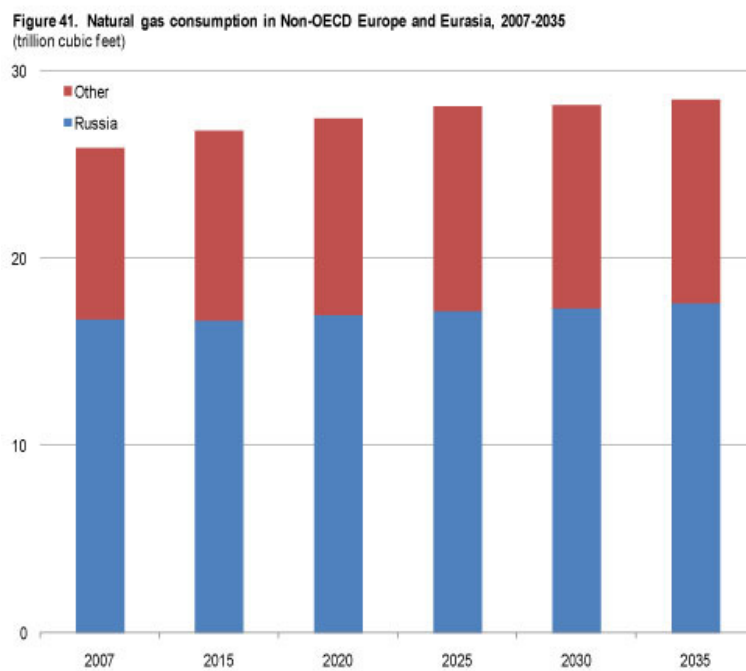


Figure 9. Non-OECD Natural Gas Production Projection

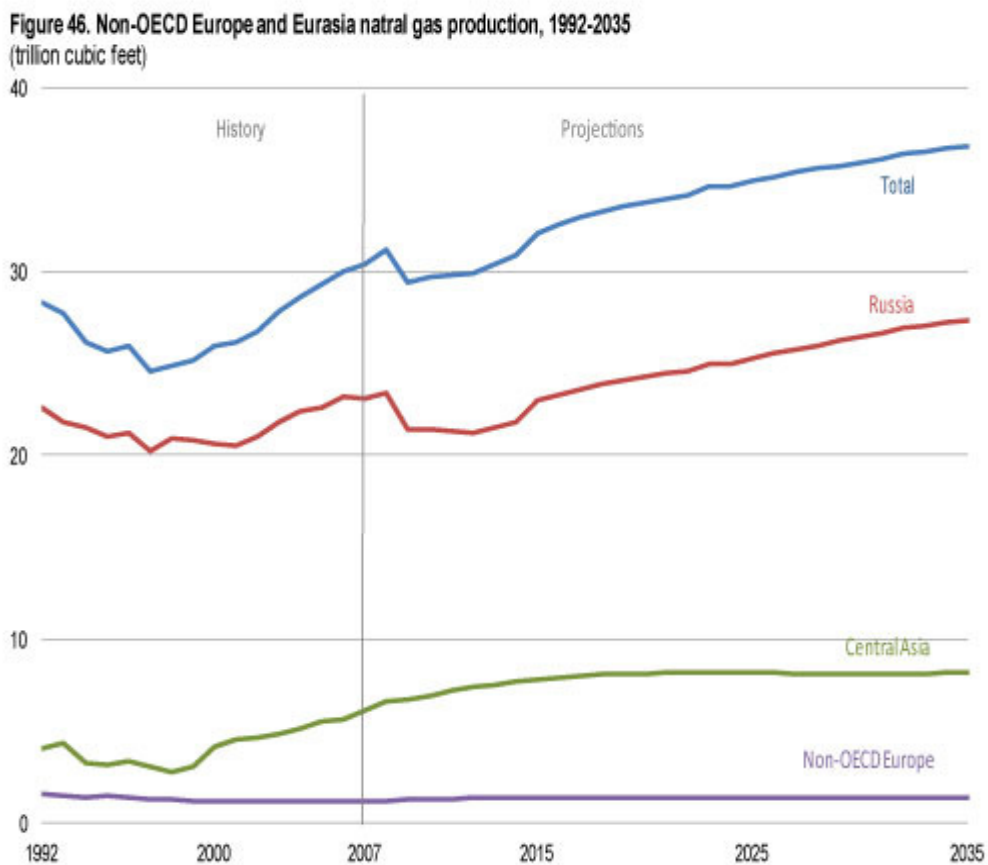


Figure 10. Gazprom Balance Sheet

Notes		30 September 2010	31 December 2009
	Assets		
	Current assets		
6	Cash and cash equivalents	315,832	249,759
6	Restricted cash	3,658	4,872
7	Short-term financial assets	19,901	52,137
8,24	Accounts receivable and prepayments	668,266	846,725
9	Inventories	333,859	286,719
	VAT recoverable	122,586	144,691
	Other current assets	<u>160,619</u>	<u>107,044</u>
		1,624,721	1,691,947
	Non-current assets		
10,25	Property, plant and equipment	5,245,555	4,899,223
11	Investments in associated undertakings and jointly controlled entities	827,073	794,705
12	Long-term accounts receivable and prepayments	423,387	413,309
13	Available-for-sale long-term financial assets	85,197	106,658
14	Other non-current assets	<u>482,353</u>	<u>462,686</u>
		<u>7,063,565</u>	<u>6,676,581</u>
	Total assets	8,688,286	8,368,528
	Liabilities and equity		
	Current liabilities		
	Accounts payable and accrued charges	547,358	502,075
	Profit tax payable	7,687	37,267
24	Other taxes payable	64,013	71,934
	Short-term borrowings and current portion of long-term borrowings	220,673	424,855
	Short-term promissory notes payable	<u>5,399</u>	<u>11,761</u>
		845,130	1,047,892
	Non-current liabilities		
15	Long-term borrowings	1,065,196	1,184,457
	Long-term promissory notes payable	1	4,592
22	Provisions for liabilities and charges	148,626	143,591
16,25	Deferred tax liabilities	357,945	321,524
	Other non-current liabilities	<u>23,028</u>	<u>17,151</u>
		<u>1,594,796</u>	<u>1,671,315</u>
	Total liabilities	2,439,926	2,719,207
	Equity		
17	Share capital	325,194	325,194
17	Treasury shares	(104,204)	(104,204)
	Retained earnings and other reserves	<u>5,710,679</u>	<u>5,105,525</u>
		5,931,669	5,326,515
	Non-controlling interest	<u>316,691</u>	<u>322,806</u>
	Total equity	6,248,360	5,649,321
	Total liabilities and equity	8,688,286	8,368,528

Figure 11. Korea Gas Corporation Balance Sheet

Consolidated Statements of Financial Position

As of December 31, 2009 and 2008

(In millions of Korean Won and thousands of U.S. dollars, except share data)

			Won		U.S. dollars (Note 3)	
	Note		2009	2008	2009	2008
Assets						
Cash and cash equivalents	4,17	₩	219,774	552,469	\$ 188,227	473,166
Government grants			(3,888)	(5,264)	(3,330)	(4,508)
Short-term financial instruments	4,13		38,400	3,428	32,888	2,936
Trade accounts receivable, less allowance for doubtful accounts of ₩24,040 (US\$20,589) in 2009 and ₩20,844 (US\$17,852) in 2008	19,35		4,533,199	4,047,387	3,882,493	3,466,416
Other accounts receivable	9,17		1,852,433	1,810,750	1,586,530	1,550,831
Prepaid expenses			26,254	30,597	22,485	26,205
Special consumption tax refundable			105,087	151,450	90,003	129,711
Inventories	5,10		1,641,318	3,261,739	1,405,719	2,793,541
Current portion of derivative financial instruments	21		283,941	38,384	243,183	32,874
Other current assets	7,17		56,352	393,653	48,263	337,146
Total current assets			8,752,870	10,284,593	7,496,461	8,808,318
Long-term trade accounts receivable, less present value discount of ₩720 (US\$617) in 2009 and ₩923 (US\$790) in 2008	19		4,145	5,958	3,550	5,103
Long-term loans, less allowance for doubtful accounts of ₩28,476 (US\$24,388) in 2009 and ₩28,187 (US\$24,141) in 2008 and present value discount of ₩20 (US\$17) in 2009 and ₩33 (US\$28) in 2008	17,19,35		258,565	194,963	221,450	166,978
Long-term investment securities	6		251,370	248,665	215,288	212,971
Equity method accounted investments	8,35 10,11,13,16,		106,432	54,168	91,155	46,393
Property, plant and equipment, net	32		10,159,885	8,219,140	8,701,512	7,039,346
Intangible assets	12		99,879	88,986	85,542	76,213
Derivative financial instruments, net of current portion	21		50,950	459,287	43,637	393,360
Long-term advance payments	20		141,887	193,381	121,520	165,623
Other non-current assets	9		3,188,914	2,281,762	2,731,170	1,954,231
Total non-current assets			14,262,027	11,746,310	12,214,824	10,060,218
Total assets		₩	23,014,897	22,030,903	\$ 19,711,285	18,868,536

			Won		U.S. dollars (Note 3)	
	Note		2009	2008	2009	2008
Liabilities						
Trade accounts payable	17	₩	1,360,142	1,844,304	\$ 1,164,904	1,579,568
Short-term borrowings	13,17,20		2,555,986	3,700,599	2,189,094	3,169,406
Current portion of long-term debt	15,17,20		2,277,369	1,110,018	1,950,470	950,683
Current portion of finance lease liabilities	16,17,35		27,305	15,191	23,386	13,010
Income taxes payable			2,551	1,388	2,185	1,189
Other accounts payable	9,17,35		182,575	374,109	156,368	320,409
Accrued expenses			110,192	75,725	94,375	64,855
Current deferred tax liabilities	28		2,964	61	2,539	52
Current portion of derivative financial instruments	21		12,084	72,673	10,349	62,241
Other current liabilities	14		90,465	60,610	77,479	51,911
Total current liabilities			6,621,633	7,254,678	5,671,149	6,213,324
Debt, net	15,17		8,936,833	7,972,577	7,654,019	6,828,175
Long-term borrowings	13,15,17,20		811,376	1,294,097	694,909	1,108,339
Other non-current accounts payable	9		-	175,525	-	150,330
Finance lease liabilities	16,17,35		940,855	1,043,562	805,803	893,767
Retirement and severance benefits	18		33,242	36,858	28,470	31,567
Derivative financial instruments, net of current portion	21		30,088	21,843	25,769	18,708
Non-current deferred tax liabilities	28		458,423	123,281	392,620	105,585
Other non-current liabilities	17		2,912	2,937	2,494	2,515
Total non-current liabilities			11,213,729	10,670,680	9,604,084	9,138,986
Total liabilities			17,835,362	17,925,358	15,275,233	15,352,310
Stockholders' equity						
Common stock of ₩5,000 par value						
Authorized - 200,000,000 shares						
Issued - 77,284,510 shares	22		386,423	386,423	330,955	330,955
Capital surplus			1,384,870	1,384,870	1,186,083	1,186,083
Capital adjustments	23		(102,474)	(102,461)	(87,765)	(87,754)
Accumulated other comprehensive income	24		939,255	6,646	804,432	5,692
Retained earnings	25		2,554,798	2,401,713	2,188,076	2,056,966
Minority interest in consolidated subsidiaries			16,663	28,354	14,271	24,284
Total stockholders' equity			5,179,535	4,105,545	4,436,052	3,516,226
Total liabilities and stockholders' equity		₩	23,014,897	22,030,903	\$ 19,711,285	18,868,536

Figure 12. Perspective and Actual Pipeline Routes



Figure 2. Pipeline natural gas and LNG flows across Northeast Asia

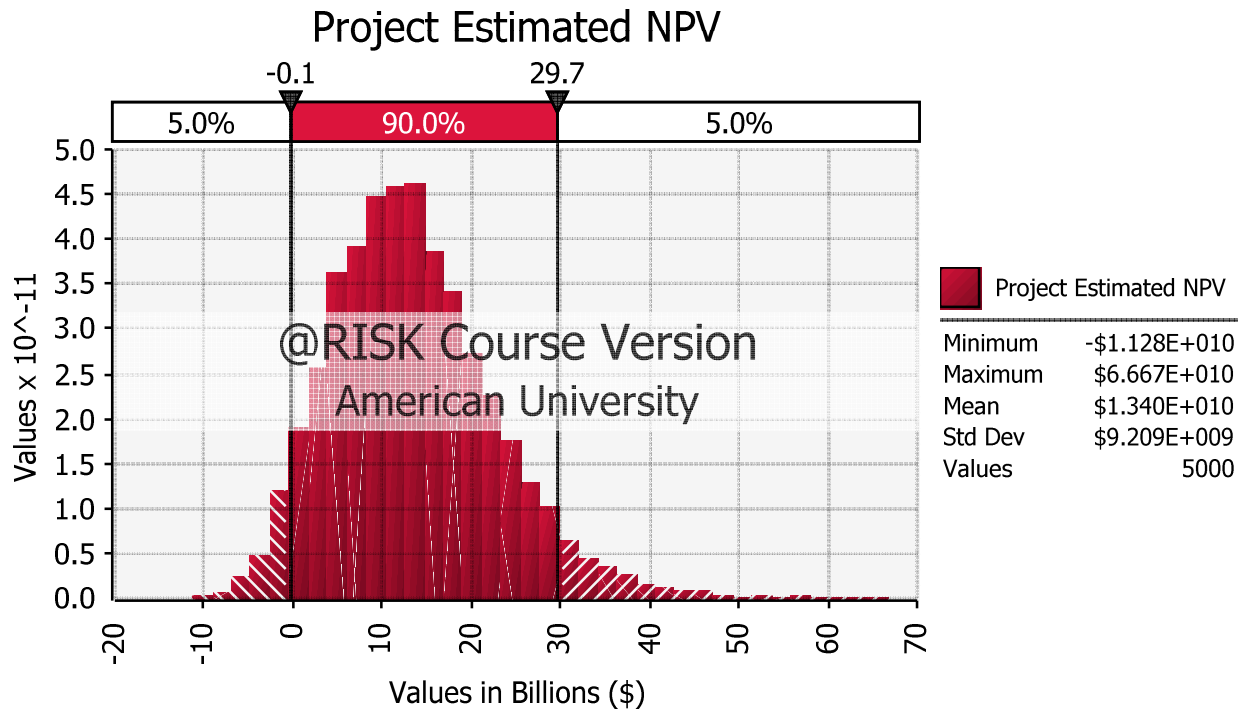
Figure 13. Example Russia-Northeast Asia Pipeline Proposal



Figure 14. Conversion Tables

1 cf (1 ft ³) is equal to	1 cm (1 m ³) is equal to
0.0283 m ³	35.31 ft ³
1,000 Btu	35,314.67 Btu
1 MBtu	35.31 MBtu
0.000172 boe	0.00609 boe
1,055 kJ	37,257 kJ
1 Mcf (1,000 ft ³ ; 1x10 ³ ft ³) is equal to	1 Mcm (1,000m ³ ; 1x10 ³ m ³) is equal to
28.32 m ³	35,314.67 ft ³
1,000,000 Btu	35,314,666 Btu
1,000 MBtu	35,314.67 MBtu
1 MMBtu	35.31 MMBtu
10 Therm	353.15 Therm
0.17241 boe	6.09 boe
1,055 MM J	37,256.97 MM J
0.0205 ton LNG	0.7251 ton LNG
1 MMcf (1 million ft ³ ; 1x10 ⁶ ft ³) is equal to	1 MMcm (1 million m ³ ; 1x10 ⁶ m ³) is equal to
28,320.6 m ³	35,314.67 Mcf
1,000,000 MBtu	35,314.67 MMBtu
1 billion Btu (1x10 ⁹)	35.31 billion Btu (1x10 ⁹)
10,000 therm	353 M therm
172.41 boe	6,088.74 boe
1.06 TJ (1x10 ¹²)	37.26 TJ (1x10 ¹²)
20.53 ton LNG	725.15 ton LNG
1 Bcf (1 billion ft ³ ; 1x10 ⁹ ft ³) is equal to	1 bcm (1 billion m ³ ; 1x10 ⁹ m ³) is equal to
28,320.6 M m ³	35,314.67 MM ft ³
28.321 MM m ³	35.31 bcf
0.0283 bcm	0.0353 tcf
1 trillion Btu (1x10 ¹²)	35.315 trillion Btu (1x10 ¹²)
10,000 M therm	353,147 M therm
10 MM therm	353.15 MM therm
172.41 Mboe	6,088.74 Mboe
1.06 PJ (1 x 10 ¹⁵)	37.26 PJ (1 x 10 ¹⁵)
0.021 MM ton (MT; million) LNG	0.725 MM ton (MT; million) LNG

Figure 15. Risk Analysis Results



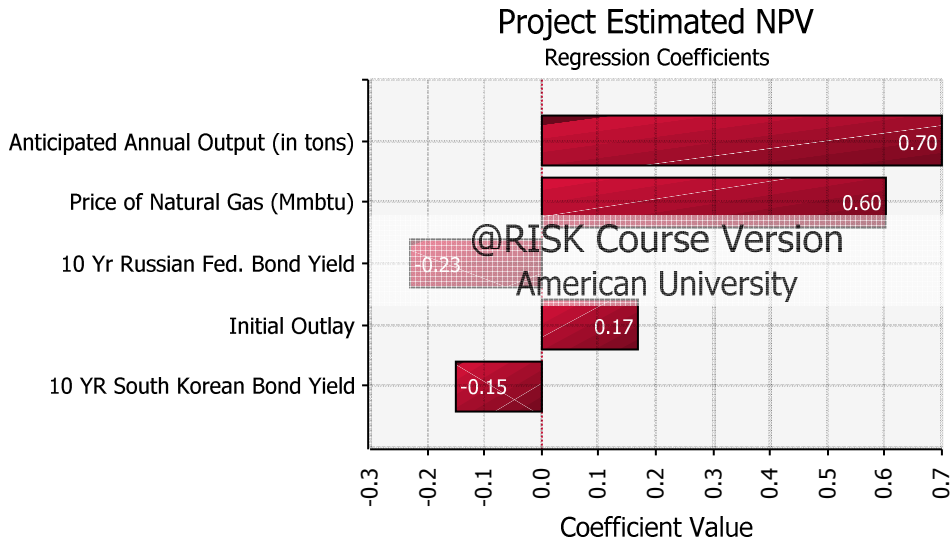
The initial estimation of NPV had several assumptions built into it for the sake of simplicity. In order to calculate more realistic return on investment it was necessary to run a probabilistic risk simulation that varied several of the input factors used to calculate NPV. Essentially, this accounts for the inherent risks that will come about during the life of the project. For example, it is unlikely that South Korea's 10 year bond, or borrowing cost, will remain at exactly 4.52%. Thus this simulation models how the NPV would change if South Korea's borrowing cost varied within a given range. The inputs that are subject to variation are:

- a. Initial Outlay or Cost of Construction
 - This variable was given a normal distribution with a mean value of \$10,631,010,000.00 USD with a standard deviation of \$1,500,000,000.00.
- b. Cost of Capital
 - As this variable was determined by the interest rate on 10 year South Korean and Russian Federation bonds it was altered by placing probability distributions on the interest rates of those securities. Specifically, a normal distribution was used where the spot rate was used as the mean and the standard deviation was defined as 1% for South Korea and 1.5% for Russia, based on the larger historical volatility of Russian bonds over the last 15 years.

c. Payment

-As this variable is determined by the anticipated output of the pipeline and the expected price of natural gas it was altered by placing probability distributions on those two variables. For anticipated output a normal distribution was used with the mean value being 7.5 billion with a standard deviation of 2 billion. For the price a normal distribution was also used with the current spot rate of \$4.37 USD being used as the mean with a \$1.00 standard deviation.

Once all inputs likely to fluctuate during the life of the project were given a probability function the simulation ran 5000 iterations to compile the probability curve seen above. From this curve it can be seen that, even with all of the inputs fluctuating within a reasonable range, there is only a 5% chance of this project returning an NPV below zero.



The graph above simply shows the regression coefficients for the input variables likely to change. In other terms, this graph shows which input variables, when fluctuating, have the most effect on the final NPV of the project. From this graph we can see that the most important factor for a predicting the NPV of this project is the anticipated output of the pipeline once installed. This is both positive and negative in nature. It is positive, because even if the South Korean or Russian government's borrowing costs increase significantly it will have little effect on the profitability of the project. However, this also means that if North Korea does disrupt the flow of natural gas during the life of the project, its profitability will be severely affected.

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