Arctic Oil and Natural Gas Potential

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Introduction

The Arctic is defined as the Northern hemisphere region located north of the Arctic Circle, the circle of latitude where sunlight is uniquely present or absent for 24 continuous hours on the summer and winter solstices, respectively. The Arctic Circle spans the globe at 66.56° (66°34′) north latitude (Figure 1).[1]

The Arctic could hold about 22 percent of the world's undiscovered conventional oil and natural gas resources. The prospects for Arctic oil and natural gas production are discussed taking into consideration the nature of the resources, the cost of developing them, and the political and environmental issues associated with their development.

Background

The area above the Arctic Circle encompasses about 6 percent of the Earth's surface area. While the Arctic is about the size of the African continent, most of the Arctic is oceanic.[2] About one-third of the Arctic is occupied by land. Another one-third of the Arctic consists of offshore continental shelves located in less than 500 meters (1,640 feet) of Arctic Ocean water. The remaining one-third of the Arctic is in Arctic Ocean waters deeper than 500 meters.

Jurisdictionally, the Arctic contains portions of eight countries - Canada, Denmark (Greenland), Finland, Iceland, Norway, Russia, Sweden, and the United States. Finland and Sweden do not border the Arctic Ocean and are the only Arctic countries without jurisdictional claims in the Arctic Ocean and adjacent seas.[3]

The sun does not rise above the Arctic horizon for days or weeks during the winter, depending on how far north of the Arctic Circle you are. Sunlight hits Arctic surfaces at an angle of much less than 90 degrees over much of the year, further diminishing the amount of incident solar radiation. As a consequence, the Arctic experiences freezing temperatures for most of the year with brief interludes above freezing. For example, at

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[1] U.S. Geological Survey, "Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle," USGS Fact Sheet 2008-3049, Washington, DC (2008), page 1. USGS website URL is: http://pubs.usgs.gov/fs/2008/3049/

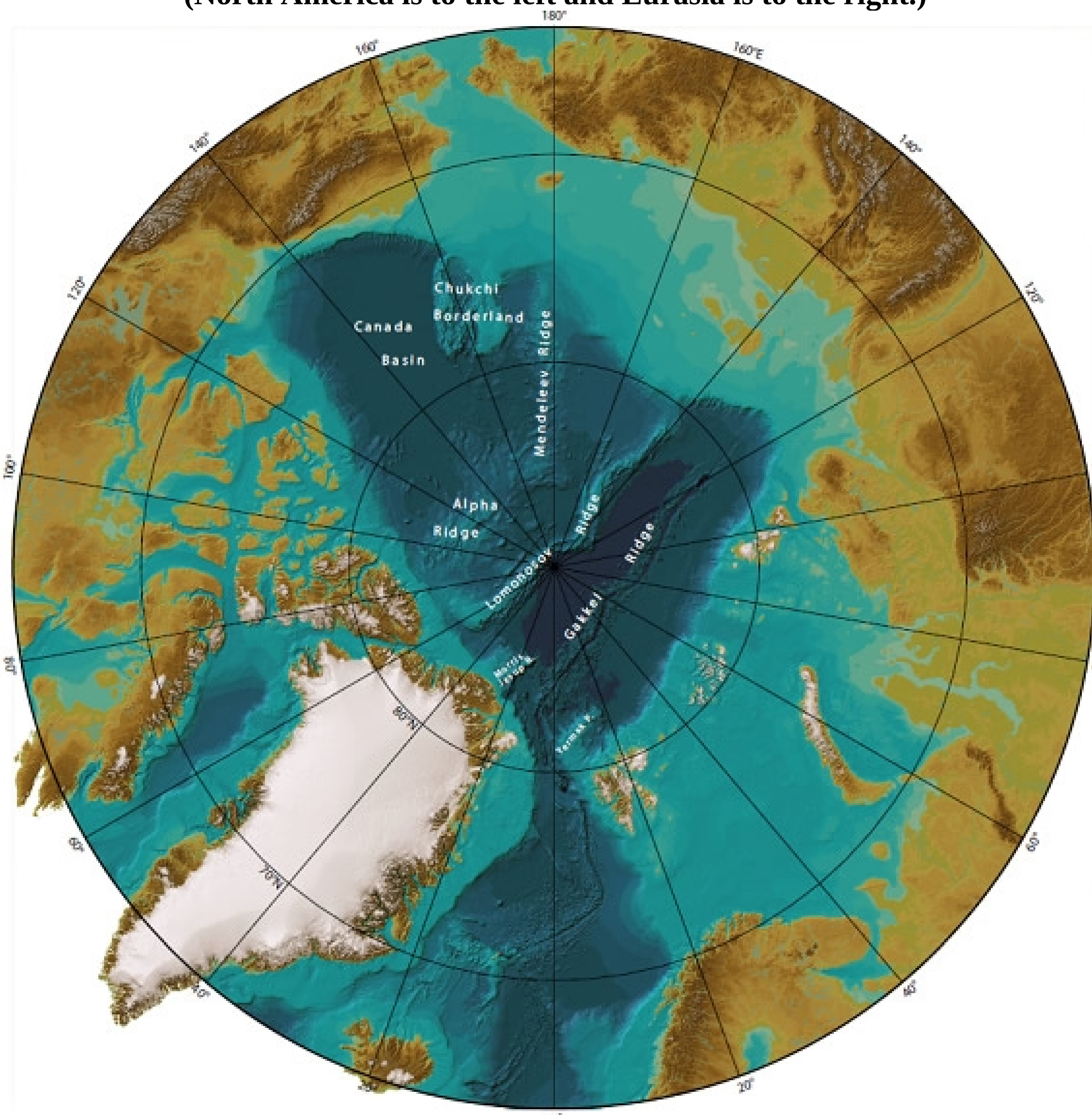
[2] Donald L. Gautier, et. al., "Assessment of Undiscovered Oil and Gas in the Arctic," *Science*, May 29, 2009, Volume 324, page 1175 - 1179.

[3] Sweden and Finland have onshore territory in the Arctic but none with any known or projected oil and natural gas resources.

Prudhoe Bay, Alaska,[4] winter temperatures can fall below −50 °F (−45 °C), while July temperatures range between 37 and 54 °F (3 to 12 °C) (Appendix A). The central Arctic Ocean is ice-covered year-round, and snow and ice are present on land for most of the year.[5]

The cold Arctic air inhibits evaporation so little precipitation occurs, with much of the Arctic having an average annual precipitation rate of 100 mm (4 inches) or less,[6] mostly in the form of snow.

FIGURE 1
Region within the Arctic Circle
(North America is to the left and Eurasia is to the right.)



Source: National Geophysical Data Center, Marine Geology and Geophysics Division, website: http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html

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[4] Latitude: 70.2552778 (70-15'19" N) and Longitude: -148.3372222 (148-20'14" W); source: http://www.lat-long.com/Latitude-Longitude-1408327-Alaska-Prudhoe_Bay.html

[5] National Snow and Ice Data Center website at: http://nsidc.org/arcticmet/basics/arctic_definition.html

[6] Arctic Council, "Arctic Climate Impact Assessment," Cambridge University Press, 2005, page 10.

Because limited sunlight, limited heat, and snow and ice are all unsupportive of plant and animal metabolism, biological activity is limited. Harsh weather and low biological fecundity has limited human activity in the Arctic. In 2000, about 3.5 million humans lived in the Arctic,[7] mostly on lands bordering the Arctic Ocean.

> "In the 20th century, immigration to the Arctic has increased dramatically, to the point where non-indigenous persons outnumber indigenous ones in many regions. The new immigrants have been drawn by the prospect of developing natural resources, from fishing to gold to oil, as well as by the search for new opportunities and escape from the perceived and real constraints of their home areas."[8]

Discovered Arctic Oil and Natural Gas Resources

The best place to find oil and natural gas is where oil and natural gas have already been found. So the large, existing Arctic oil and natural gas fields are reviewed prior to the discussion of the undiscovered Arctic oil and natural gas resource base. In this review, "large" oil and natural gas fields are those that exceed 500 million barrels of oil equivalent of recoverable oil and natural gas.[9]

Large Arctic oil and natural gas fields are particularly crucial with respect to future oil and natural gas development because the cost of developing oil and natural gas fields in the Arctic is so high that large fields are initially necessary to pay for the infrastructure required to later develop the smaller oil and natural gas deposits. For example, the Prudhoe Bay Field with 13.6 billion barrels of recoverable oil[10] made the construction of the Alyeska Oil Pipeline[11] commercially viable. Without the Prudhoe Bay Field, it is unlikely that the smaller Alaska North Slope oil fields would have been developed.

Arctic infrastructure development is sufficiently expensive that many large Arctic fields remain undeveloped. For example, 35.4 trillion cubic feet[12] (6.3 billion barrels of oil equivalent) of the discovered Alaska North Slope natural gas resources remain unexploited due to the absence of transportation infrastructure. About two-thirds of this natural gas is in the Prudhoe Bay Field.

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[7] Ibid. Table 1.1, page 14.

[8] Ibid. page 13.

[9] The exact recovery of oil and natural gas from a field is not known with certainty until that field has been permanently abandoned. Actual recovery is often greater than the original estimate, as the producer learns how to apply technology to enhance recovery rates. Ultimate field recovery rates are also affected by oil and natural gas prices, with higher prices resulting in higher recovery rates. Consequently, the exact number of large discovered fields above the Arctic Circle can only be approximate. Large field data source: Petroleum Source to Reservoir, Giant Oil and Gas Fields database, Version 14, 2009, website address: http://www.sourcetoreservoir.com/index.html

[10] Figure does <u>not</u> include natural gas. Source: Alaska Department of Natural Resource, Division of Oil & Gas, *Alaska Oil and Gas Report*, July 2007, Anchorage, Alaska, Table III.1(Oil and Gas Reserves), page 3-2 and Table III.3 (Oil Production – Historic), page 3-5.

[11] Also known as the TransAlaska Pipeline System (TAPS).

[12] Op. cit. Alaska Department of Natural Resources, Table III.1, page 3-2.

Large Arctic oil and natural gas discoveries began in Russia with the discovery of the Tazovskoye[13] Field in 1962 and in the United States with the Alaskan Prudhoe Bay Field in 1967. Approximately 61 large oil and natural gas fields have been discovered within the Arctic Circle in Russia, Alaska, Canada's Northwest Territories, and Norway.[14] Fifteen of these 61 large Arctic fields have not yet gone into production; 11 are in Canada's Northwest Territories, 2 in Russia, and 2 in Arctic Alaska.

Forty-three of the 61 large Arctic fields are located in Russia. Thirty-five of these large Russian fields (33 natural gas and 2 oil) are located in the West Siberian Basin.[15] Of the eight remaining large Russian fields, five are in the Timan-Pechora Basin, two are in the South Barents Basin, and one is in the Ludlov Saddle.

Of the 18 large Arctic fields outside Russia, 6 are in Alaska, 11 are in Canada's Northwest Territories, and 1 is in Norway.

Arctic Undiscovered Technically Recoverable, Conventional Oil and Natural Gas Resources

In 2008, the United States Geological Survey (USGS) released an assessment of Arctic undiscovered technically recoverable,[16] conventional oil and natural gas resources.[17] The assessment excluded from consideration any sedimentary provinces that were less than 3 kilometers deep. Of the 33 Arctic provinces that surpassed this depth and that were evaluated by the USGS, 8 were not "quantitatively assessed" because they had less than a 10-percent probability of having an oil and/or natural gas deposit larger than 50 million barrels of oil equivalent in any of their assessment units.[18] The USGS therefore provided quantitative estimates of undiscovered oil and natural gas resources for 25 Arctic sedimentary provinces.

Because some of the sedimentary provinces evaluated by the USGS lay both above and below the Arctic Circle, the USGS apportioned the total resource base within those provinces into estimated resources above and below the Arctic Circle. Only the Arctic portion of each province's resource estimate is shown in Table 1.

[13] There are often multiple variations for the English spelling of foreign oil and natural gas fields.
[14] This number is approximate because it depends on the latitude coordinates provided in the Giant Oil and Gas Fields database. The oil and natural gas fields' latitude in the database had to be greater than the 66.56° latitude to qualify as Arctic fields.
[15] All sedimentary province names are those used by the United States Geological Survey.
[16] Technically recoverable resources are resources that can be produced using current technology.
[17] U.S. Geological Survey, "Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle," USGS Fact Sheet 2008-3049, Washington, DC (2008). The USGS is currently preparing a more extensive report regarding their Arctic assessment.
[18] Source: Personal communication with Ronald R. Charpentier of the USGS on May 12, 2009. Seven of the eight provinces that were not quantitatively assessed have only one assessment unit. The Franklinian Shelf province has three separate assessment units

TABLE 1
Arctic Mean Estimated Undiscovered
Technically Recoverable, Conventional Oil and Natural Gas Resources
By Arctic Province, Ranked by Total Oil Equivalent Resources

USGS Petroleum Province Name	Crude Oil (billion barrels)	Natural Gas (trillion cubic feet)	Natural Gas Liquids 1/ (billion barrels)	Total Resources, Oil Equivalent 2/ (billion barrels)
West Siberian Basin	3.66	651.50	20.33	132.57
Arctic Alaska	29.96	221.40	5.90	72.77
East Barents Basin	7.41	317.56	1.42	61.76
East Greenland Rift Basins	8.90	86.18	8.12	31.39
Yenisey-Khatanga Basin	5.58	99.96	2.68	24.92
Amerasia Basin	9.72	56.89	0.54	19.75
West Greenland-East Canada	7.27	51.82	1.15	17.06
Laptev Sea Shelf	3.12	32.56	0.87	9.41
Norwegian Margin	1.44	32.28	0.50	7.32
Barents Platform	2.06	26.22	0.28	6.70
Eurasia Basin	1.34	19.48	0.52	5.11
North Kara Basins and Platforms	1.81	14.97	0.39	4.69
Timan-Pechora Basin	1.67	9.06	0.20	3.38
North Greenland Sheared Margin	1.35	10.21	0.27	3.32
Lomonosov-Makarov	1.11	7.16	0.19	2.49
Sverdrup Basin	0.85	8.60	0.19	2.48
Lena-Anabar Basin	1.91	2.11	0.06	2.32
North Chukchi-Wrangel Foreland Basin	0.09	6.07	0.11	1.20
Vilkitskii Basin	0.10	5.74	0.10	1.16
Northwest Laptev Sea Shelf	0.17	4.49	0.12	1.04
Lena-Vilyui Basin	0.38	1.34	0.04	0.64
Zyryanka Basin	0.05	1.51	0.04	0.34
East Siberian Sea Basin	0.02	0.62	0.01	0.13
Hope Basin	0.002	0.65	0.01	0.12
Northwest Canadian Interior Basins	0.02	0.31	0.02	0.09
Total	**89.98**	**1,668.66**	**44.06**	**412.16**

Source: U.S. Geological Survey, “Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle,” USGS Fact Sheet 2008-3049 Washington, DC (2008), Table 1, page 4.
Note: The column totals do not equal the sum of the rows due to rounding. USGS website URL is: http://pubs.usgs.gov/fs/2008/3049/. The relative location of these provinces is identified in Appendix B.
1/ Natural gas liquids are composed of ethane, propane, and butane.
2/ The USGS uses a natural gas to oil conversion factor in which 6 thousand cubic feet of natural gas equals 1 barrel of crude oil.

The USGS Arctic assessment estimated a total oil and natural gas resource of 412 billion barrels of oil equivalent, with 78 percent of those resources expected to be natural gas and natural gas liquids (NGL). The composition of undiscovered Arctic hydrocarbons is largely determined by the West Siberian Basin and East Barents Basin, which hold 47 percent of the undiscovered Arctic resources, with 94 percent of those resources being natural gas and NGL.

According to the USGS mean estimate, the Arctic holds about 22 percent of the world's undiscovered conventional oil and natural gas resource base, about 30 percent of the world's undiscovered natural gas resources, about 13 percent of the world's undiscovered oil resources, and about 20 percent of the world NGL resources.[19]

The fact that the Arctic is particularly rich in natural gas and NGL may impede the exploitation of its resources, because the world's natural gas consumers live far from the Arctic and the long-distance transportation of natural gas and NGL is considerably more expensive than oil transportation due to the significantly lower energy density of these fuels relative to crude oil. Although the low energy density of natural gas and NGL can be offset by liquefaction or pressurization, transportation as liquefied natural gas (LNG) is particularly expensive due to the large capital costs required to build the liquefaction facilities and the LNG tankers.

While the Arctic is rich in undiscovered oil and natural gas resources, the resources are concentrated in just a few sedimentary provinces. Table 2 illustrates the Arctic's cumulative oil and natural gas resource concentration for those provinces with the largest share of the Arctic resource base. For example, the 3 largest Arctic provinces account for 65 percent of the total Arctic oil and natural gas resources, and the largest 10 oil and natural gas provinces account for 93 percent of the total. The remaining 15 provinces (out of 25 qualitatively evaluated provinces) are estimated to hold only 7 percent of the Arctic resource base.

TABLE 2
Arctic Crude Oil, Natural Gas, and Natural Gas Liquids Resource Concentration for Provinces with the Greatest Share of Total Resources, Based on the USGS Mean Estimates

Largest Arctic Resource Provinces	Cumulative Percent of Total Arctic Oil, Natural Gas, & NGL Resources (Percent)
Largest Resource Province	32
Largest 2 Resource Provinces	50
Largest 3 Resource Provinces	65
Largest 5 Resource Provinces	78
Largest 10 Resource Provinces	93

Source: Table 1.

[19] USGS Newsroom release dated July 23, 2008. USGS website URL: http://www.usgs.gov/newsroom/article.asp?ID=1980&from=rss_home. Figures do not include or consider world unconventional oil and natural gas resources, such as Rocky Mountain oil shale, Canadian oil sands, Venezuelan Orinoco heavy oil, etc. Inclusion of these unconventional resources would reduce the Arctic proportion of total world oil and natural gas resources.

Arctic oil and natural gas resources are not evenly distributed among the Eurasian and North American continents (Table 3). Eurasia is estimated to hold about 63 percent of the total Arctic resource base, while North America holds about 36 percent. The Eurasian resource base is predominantly natural gas and NGL, which account for about 88 percent of the total Eurasian resource base. The Eurasian West Siberia Basin and East Barents Basin account for 194.3 billion barrels of oil equivalent of undiscovered resources, which is 74 percent of the total Eurasian resource base.

TABLE 3
Regional Concentration of Arctic Oil and Natural Gas Resources
By Continental Land Mass,
Based on the USGS Mean Estimates

Region	Crude Oil (billion barrels)	Natural Gas (trillion cubic feet)	Natural Gas Liquids (billion barrels)	Total Resources, Oil Equivalent (billion bbl)
Eurasia	30.70	1,219.39	27.55	261.49
North America	58.09	435.40	16.20	146.85
Indeterminate	1.20	13.87	0.31	3.82
Total	**89.98**	**1,668.66**	**44.06**	**412.16**
Eurasia	34.1 %	73.1 %	62.5 %	63.4 %
North America	64.6 %	26.1 %	36.8 %	35.6 %
Indeterminate	1.3 %	0.8 %	0.7 %	0.9 %
Total	**100.0 %**	**100.0 %**	**100.0 %**	**100.0 %**

Source: Table 1. The column totals might not equal the sum of the rows due to rounding. Indeterminate regions are those that could not conclusively be assigned to either continent; includes: Lomonosov-Makarov, Hope Basin, and North Chukchi-Wrangel Foreland Basin.

While the Eurasian side of the Arctic is more natural-gas-prone, the North American side is more oil-prone. The North American side of the Arctic is estimated to have about 65 percent of the undiscovered Arctic oil, but only 26 percent of the undiscovered Arctic natural gas.

The Arctic Alaska region is estimated to hold the largest undiscovered Arctic oil deposits, about 30 billion barrels. The second largest oil province in the Arctic is the Amerasia Basin, located just north of Canada, and estimated to have about 9.7 billion barrels of undiscovered oil. The third largest Arctic oil province is the East Greenland Rift, which is estimated to hold about 8.9 billion barrels of undiscovered oil. Collectively, these 3 North American provinces are expected to hold about 48.6 billion barrels of undiscovered oil, which is about 54 percent of the total undiscovered Arctic oil. Approximately 2.5 billion barrels of oil have already been discovered in large fields in both the Amerasia Basin and the Northwest Canadian Interior Basins that are not yet being produced.[20]

There is considerable uncertainty regarding undiscovered Arctic oil and natural gas resources. Table 4 illustrates the wide variation in oil and natural gas resource estimates for the 2 assessment units within the most prolific Arctic province, the West Siberian

[20] Op. cit. Source to Reservoir.

Basin.[21] In both assessment units, the 95-percent probability estimates are about one-fourth the mean estimate, while the 5-percent probability estimates are over twice the mean estimate and about 10 times greater than the 95-percent probability estimate.[22]

TABLE 4
USGS Assessment of the Oil and Natural Gas Resource Probability Distribution For the Arctic Portion of the West Siberian Basin[23]

Resource Category	Mean Estimate	95-Percent Probability Estimate	5-Percent Probability Estimate
	Assessment Unit 1		
Crude Oil (billion barrels)	1.15	0.22	2.93
Natural Gas (trillion cubic feet)	29.28	7.48	68.39
Natural Gas Liquids (billion barrels)	0.85	0.22	1.98
	Assessment Unit 2		
Crude Oil (billion barrels)	2.51	0.57	6.02
Natural Gas (trillion cubic feet)	622.22	157.86	1,409.29
Natural Gas Liquids (billion barrels)	19.48	4.86	44.85

Note: The 95-percent and 5-percent probability figures cannot be arithmetically added, whereas the mean estimates can be added together. With respect to the 95-percent and 5-percent probabilities, the proper interpretation of these probability estimates is that they represent an "X" probability of finding "Y" **or greater** volume of undiscovered resources. For example, there is a 95 percent probability that the West Siberian Assessment Unit 1 will contain 0.22 billion barrels **or greater** of undiscovered oil resources.

Though there is considerable resource uncertainty, the allure of the Arctic is great because of the significant oil and natural gas deposits that have already been found and the large areas that have not yet been explored. For example, Cairn Energy PLC[24] notes that the sedimentary provinces offshore of West Greenland are three times larger in extent than the North Sea basin and yet only six oil and natural gas exploration wells have been drilled off of West Greenland.[25] Offshore West Greenland is particularly intriguing to Cairn Energy due to extensive offshore oil seeps, thick organic shale beds, and oil shows in prior drilling. The company currently plans to commence a West Greenland exploratory drilling program in 2011. Only as more wildcat exploration wells are drilled in the Arctic will the actual Arctic oil and natural gas resource base become apparent.

[21] Ibid.

[22] From the perspective of mathematical probability and statistics, the resource probability distribution is skewed, such that the median value is less than the mean value.

[23] Donald L. Gautier, et. al., "Assessment of Undiscovered Oil and Gas in the Arctic," *Science*, May 29, 2009, Volume 324, page 1175 - 1179. Specific numbers came from the Excel spreadsheet file associated with the *Science* article, labeled as: "1169467TableS1s.xls".

[24] Cairn Energy PLC is headquartered in Edinburgh, Scotland.

[25] Cairn Energy PLC presentation, "Oil, Deserts, and Ice: A Focus on Challenges and Rewards in India and Greenland," presented by Dr. Michael Watts at the Scottish Oil Club on May 26, 2009, Slide 38. Available at: http://www.cairn-energy.plc.uk/downloads/ScottishOilClubwebopt.pdf

Arctic Development Costs and Risks

Even if the Arctic oil and natural gas resources eventually prove to be considerably greater than the USGS estimates, they will be expensive to develop. As noted earlier, 15 large Arctic oil and natural gas fields are awaiting development. Most were discovered in the 1970s and 1980s. Thirteen of the undeveloped fields are located in North America, where oil and natural gas field development is governed by market-based economics, with fields only being developed if and when they are expected to generate sufficient profits. Of the 17 large Arctic fields located in North America, only 3 have been so-developed, all located in Alaska, around the Prudhoe Bay Field complex.

In contrast, Russia's Arctic resources were predominantly developed under a Soviet command-and-control economy. Many of Russia's large producing Arctic fields might not have been commercially viable under market-based economics, when they were originally developed.[26]

Finding large Arctic oil and natural gas deposits is difficult and expensive; developing them as commercially profitable ventures is even more challenging. Arctic oil and natural gas resource exploration and development are expensive because:

- Harsh winter weather requires that the equipment be specially designed to withstand the frigid temperatures
- On Arctic lands, poor soil conditions can require additional site preparation to prevent equipment and structures from sinking
- The marshy Arctic tundra can also preclude exploration activities during the warm months of the year
- In Arctic seas, the icepack can damage offshore facilities, while also hindering the shipment of personnel, materials, equipment, and oil for long time periods
- Long supply lines from the world's manufacturing centers require equipment redundancy and a larger inventory of spare parts to insure reliability
- Limited transportation access and long supply lines reduce the transportation options and increase transportation costs
- Higher wages and salaries are required to induce personnel to work in the isolated and inhospitable Arctic.

Economic studies involving onshore Alaska North Slope project development costs invoke a capital cost factor ranging from 1.5 to 2.0 relative to similar oil and natural gas projects undertaken in Texas.[27] The development of new Alaska North Slope fields near existing fields is economically benefited by the ability to use whatever infrastructure already exists, for example, roads, railroads, harbor facilities, air fields, electric power generation, and living quarters. Even so, Arctic oil and natural gas project costs and schedules can prove to be significantly greater than originally planned due to supply

[26] The future development of Russia's Arctic resources in a market-based economy is greatly facilitated by the extensive Arctic oil and natural gas infrastructure that was built under the Soviet regime.
[27] E.P. Robertson, Idaho National Engineering and Environmental Laboratory (Bechtel BWXT Idaho, LLC), "Options for Gas-To-Liquids Technology in Alaska," INEEL/EXT-99-01023, December 1999, page vii.; and Charles B. Thomas, et. al., Idaho National Engineering and Environmental Laboratory (Lockheed Martin), "Economics of Alaska North Slope Utilization Options," INEL-96/0322, August 1996, page B-19.

chain delays, abnormal weather conditions, and court challenges emanating from environmental concerns.

As an example of supply chain difficulties, the multinational Italian-based petroleum company, Eni S.p.A. originally announced that the Nikaitchuq oil field on the Alaska North Slope would start production by year-end 2009.[28] More recently, Eni announced that the field would not begin production until year-end 2010 partly because the company had missed the summer season opportunity to ocean barge the field's processing and operations modules to the North Slope from a Louisiana fabrication yard. Such supply chain delays increase project costs and reduces the rates of return as expensive equipment remains idle.

Abnormal weather can increase costs by hindering transportation and drilling activity. The early onset of warm weather on the Alaska North Slope during April of 2009 stranded equipment and precluded some exploration well drilling.[29] Similarly, a late onset of winter weather delays construction of the ice roads required to transport heavy equipment across the tundra.[30]

Court challenges stemming from environmental concerns can also increase Arctic project costs. Shell Oil has paid over $2.2 billion since 2005 to secure Federal oil and natural gas development leases offshore of Alaska (Appendix C) and was planning to drill three wells in its Beaufort Sea leases during the summer of 2007. On July 19, 2007, those plans were suspended by the Ninth Circuit Court of Appeals in response to law suits, filed by the North Slope Borough and the Alaska Eskimo Whaling Commission, regarding the potential impact of Shell's offshore drilling on subsistence hunting and on the environment.[31]

As part of its 2007 Beaufort Sea exploration drilling program, Shell had reactivated and towed the Kulluk arctic drilling ship to the Beaufort Sea,[32] constructed the Nanuq, a 300-foot, ice-strengthened oil-spill response vessel, and chartered the Arctic Endeavor, a 200-foot, 500,000-barrel, double-hulled tanker to hold any oil recovered from a spill.[33] In total, Shell Oil employed 24 vessels and hundreds of people just for the purpose of responding to an accidental offshore oil spill. Although public figures are not available, it would be reasonable to assume that Shell had also already spent hundreds of millions of dollars on its Beaufort Sea exploration program, in addition to the lease bonus payments. Shell currently hopes to begin its Beaufort Sea and Chukchi Sea drilling

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[28] Eric Lidji, "Nikaitchuq oil in 2010," *Petroleum News*, Volume 14, Number 21, May 24, 2009, pages 1, 13.

[29] Yereth Rosen, "Sudden Spring jolts Alaska's oil exploration," Thomson Reuters, June 3, 2009.

[30] The movement of heavy equipment in the Arctic to drilling locations is usually confined to the winter months when the tundra is frozen. During the rest of the year, the tundra is too marshy and boggy to permit the off-road transportation of heavy equipment.

[31] Alan Bailey, "9th Circuit suspends Shell's Beaufort Sea drilling program," *Petroleum News*, Volume 12, Number 30, July 29, 2007, pages 1, 15.

[32] Alan Bailey, "Shell wells still possible," *Petroleum News*, Volume 12, Number 37, September 16, 2007, pages 1, 22.

[33] Alan Bailey, "Shell: Prepared for the worst," *Petroleum News*, Volume 12, Number 35, September 2, 2007, pages 9 - 11.

program in 2010.[34] If these drilling plans come to fruition, the drilling program will have been delayed 3 years at a substantial cost.

The long lead-times required for Arctic projects also add considerable risk because the business environment can change dramatically between a project's initiation and completion dates. For example, oil and natural gas prices could be considerably lower when an Arctic project begins producing than was anticipated at the planning stage. Also, at a given level of capital investment, longer lead-times reduce the return on that investment, all else being equal. Arctic oil and natural gas projects can exacerbate this problem by requiring considerably larger investments than comparably productive projects pursued elsewhere in the world.

As the Shell and Eni experiences demonstrate, already long lead-times can become even longer. A Deutsche Bank (DB) analysis notes that development of the Russian Shtokman natural gas project in the Barents Sea could take 5 to 8 years from the initiation of substantial capital investment to full production.[35] The DB analysis notes that "With the technical and environmental complexities involved in the development, we see a high risk of delays and cost over-runs."[36]

The Arctic physical environment presents special challenges not experienced elsewhere in the world. Several oil and natural gas fields have been discovered on Russia's Yamal Peninsula but have not been developed because of the daunting physical challenges. As noted in a Cambridge Energy Research Associates report[37] on this matter:

> "Intermittent permafrost becomes continuous, winds rise to a steady 40 m per second, wind-driven water up to 10 m deep covers the low-lying land several months of the year, and solid ground gives way to friable sand that offers little support to drill pads or to pipelines and other infrastructure. In winter, instead of soil there is a frozen mixture of one part sand to four parts of ice, shot through with salt. At greater depths one encounters cryopegs—liquid saltwater lenses that slide under pressure, further weakening the load-bearing capacity of the soil….The most difficult part is getting gas and liquids to market as well as getting equipment and materiel in."

Currently, Gazprom is considering the construction of a new railroad line and a new harbor to move men and material into the Yamal Peninsula. The requirement to undertake such expensive efforts as a precursor to actual development underscores the high cost of developing the Yamal Peninsula oil and natural gas fields.

Arctic operating costs are also increased by the ice-pack conditions that extend over much of the Arctic Ocean. The requirement for ice-resistant tankers and ice-breaker

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[34] Kay Cashman, "Shell pushes drilling out to 2010, '11," *Petroleum News*, Volume 13, Number 52, December 28, 2008, page 3.

[35] Dave Thomas, et.al., "Shtokman – The big cod," Deutsche Bank Company Research, March 22, 2006, pages 14 – 16, 19.

[36] Ibid, page 19.

[37] Cambridge Energy Research Associates, "Conquering Yamal," October, 2007, Cambridge, Massachusetts, page 14.

escorts adds to the cost of transporting oil and natural gas through Arctic waters. To deal with the ice-pack, Russian companies use ice-resistant tankers in conjunction with ice-breaker escorts to transport oil in Arctic waters throughout the year.[38] For example, Rosneft purchased 30,000 deadweight double-hulled, ice-reinforced shuttle tankers to transport oil to the Russian port of Arkhangelsk.[39] As of 2008, the Russian Arctic ice-breaker fleet consisted of 28 ice-breakers.[40]

Additional costs might be imposed on future oil and natural gas development if a warming of the Arctic region melts the permafrost and turns currently firm soils into marshes and bogs. On the other hand, warmer Arctic temperatures would shrink the ocean icepack,[41] thereby facilitating and reducing the cost of water transportation and offshore drilling.

The high cost of doing business in the Arctic suggests that only the world's largest oil companies, most likely as partners in joint venture projects, have the financial, technical, and managerial strength to accomplish the costly, long-lead-time projects dictated by Arctic conditions.

Arctic Oil and Natural Gas Development Issues

Arctic oil and natural gas development also faces political and environmental issues. Political issues stem from the overlapping and disputed claims of economic sovereignty. The environmental issues pertain to the preservation of animal and plant species unique to the Arctic, particularly tundra vegetation, caribou, polar bears, seals, whales, and other Arctic sea life.

Arctic Economic Sovereignty Claims

Denmark, Canada, Norway, Russia, and the United States have overlapping economic sovereignty claims in Arctic waters. The existence of these offshore boundary disputes could forestall Arctic oil and natural gas resource development in areas where the sovereignty claims overlap.

Some of the competing claims stem from the fact that the 1982 United Nations Convention on the Law of the Sea (UNCLOS) permits countries to claim economic sovereignty as much as 350 nautical miles (403 U.S. statutory miles) beyond the point where the sea depth exceeds 2,500 meters (8,200 feet) of water.[42] The existence of extensive Arctic continental margins[43] and numerous subsea ridges possibly related to those continental margins, permit the littoral nations to make competing claims for most Arctic waters (Figure 1).

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[38] Sarah Hurst, "Varandey Arctic oil terminal starts up," *Petroleum News*, Volume 13, Number 25, June 22, 2008, page 10.

[39] Norwegian Barents Secretariat, "Oil transport from the Russian part of the Barents Region, Status per January 2009," Kirkenes, Norway, 2009, page 50.

[40] Ibid., Norwegian Barents Secretariat, page 31.

[41] National Snow and Ice Data Center, "Arctic Sea Ice Down to Second-Lowest Extent; Likely Record-Low Volume," Boulder, Colorado, October 2, 2008.

[42] Part VI, Article 76, at http://www.un.org/Depts/los/convention_agreements/texts/unclos/unclos_e.pdf

[43] Defined in the UNCLOS, ANNEX II as being any water depth less than 200 meters (~656 feet).

Denmark, Norway, and Russia have made claims of economic sovereignty in Arctic waters under the auspices of the UNCLOS. Norway's recent territorial claims are separately located in the Barents Sea, the Norwegian Sea, and Arctic Ocean.[44] Russia's UNCLOS claims of economic sovereignty extend through much of the Arctic Ocean, based on the existence of the Lomonosov Ridge that extends from Russia's coast across the Arctic Ocean to Greenland.[45] Viewed in reverse, this situation makes Denmark a potential claimant to the same Arctic regions claimed by Russia.

Although the existence of the UNCLOS has increased the number of overlapping claims of economic sovereignty in Arctic waters, two pre-existing claims also remain unresolved.[46] One disputed offshore boundary exists in the Barents Sea between Norway and Russia. The other disputed offshore boundary exists between Canada and the United States in the Beaufort Sea.

Arctic Environmental Policies and Regulations

The extent to which environmental laws and regulations impact Arctic oil and natural gas development will depend on the specific laws and regulations of each nation having economic sovereignty over Arctic areas. However, the experience in the United States indicates that such policies can preclude the development of significant Arctic oil and natural gas resources.

In the Alaska Arctic, oil and natural gas development is banned within the Arctic National Wildlife Refuge (ANWR). ANWR is located on the northern coast of Alaska due east of Prudhoe Bay. ANWR was created by the Alaska National Interest Lands Conservation Act (ANILCA) in 1980. Section 1002 of ANILCA deferred a decision on the management of oil and natural gas exploration and development of 1.5 million acres of potentially productive lands in the coastal plain of ANWR. The coastal plain area represents about 8 percent of the total area of ANWR.

In 1998, the USGS estimated that between 5.7 and 16.0 billion barrels of technically recoverable oil are in the coastal plain area of ANWR, with a mean estimate of 10.4 billion barrels. These USGS resource estimates include State and Native lands in and adjacent to the Federal lands in ANWR.

Several legislative attempts have been made to open ANWR to oil and natural gas development, but none have been successful. The lack of support to open ANWR to oil and natural gas development comes from the concern that caribou migration and breeding could be detrimentally affected by ANWR oil and natural gas development and the concern that the ANWR is a unique, yet fragile wilderness that would be damaged by oil and natural gas development and production.

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[44] Norwegian Petroleum Directorate, "Continental Shelf Submission of Norway," 2006, http://www.regjeringen.no/upload/kilde/ud/prm/2006/0374/ddd/pdfv/299461-sokkel.pdf

[45] Associated Press, "Russian Navy Staking Arctic Ocean Sea Bed," *Petroleum News*, Volume 12, Number 30, July 29, 2007, page 17.

[46] International Boundaries Research Unit, "Maritime jurisdiction and boundaries in the Arctic region," Durham University, United Kingdom, August 15, 2008. http://www.dur.ac.uk/resources/ibru/arctic.pdf

Similarly, the environmental challenge to Shell's offshore drilling program was motivated by concern that noise and potential oil spills could be harmful to migratory whales and the Beaufort Sea ecosystem.

Conclusions

The Arctic presents a "good news, bad news" situation for oil and natural gas development. The good news is that the Arctic holds about 22 percent of the world's undiscovered conventional oil and natural gas resources, based on the USGS mean estimate. The bad news is that: (1) the Arctic resource base is largely composed of natural gas and natural gas liquids, which are significantly more expensive to transport over long distances than oil; (2) the Arctic oil and natural gas resources will be considerably more expensive, risky, and take longer to develop than comparable deposits found elsewhere in the world; (3) unresolved Arctic sovereignty claims could preclude or substantially delay development of those oil and natural gas resources where economic sovereignty claims overlap; and (4) protecting the Arctic environment will be costly. The high cost and long lead-times of Arctic oil and natural gas development undercut the immediate importance of these sovereignty claims, while at the same time diminishing the economic incentive to develop these resources.

Given that the Arctic resource base is predominantly composed of natural gas and natural gas liquids, the importance of Arctic oil and natural gas resources is likely to be affected by the growing realization that shale beds in existing petroleum provinces around the world might be capable of producing 5,000 to 16,000 trillion cubic feet of natural gas.[47] This potentially large shale gas resource could significantly defer the future development of Arctic natural gas resources. Of course, there could be exceptions. Hypothetically, growing European demand for natural gas, the depletion of existing North Sea and Russian natural gas fields, and disappointing European shale gas exploration and development results could act as a strong incentive to develop Russia's Arctic natural gas resources in the West Siberian Basin and East Barents Basin.

Other aspects of the estimated Arctic oil and natural gas resource base are more neutral in character. For example, the fact that the expected undiscovered Arctic resource base is largely confined to a few sedimentary provinces might be more reflective of the fact that little, if any, oil and natural gas exploration drilling has been conducted in those provinces with low resource estimates. On the other hand, if the estimates for these unexplored and underexplored provinces prove correct, and they have little or no oil and natural gas, then the drive by nations to claim economic sovereignty over these offshore provinces would diminish.

The bottom line for Arctic oil and natural gas potential is that high costs, high risks, and lengthy lead-times can all serve to deter their development in preference to the development of less challenging oil and natural gas resources elsewhere in the world. Also, the less abundant Arctic oil resources will be more readily developed than the Arctic's natural gas resources. Thus, while the Arctic has the potential to be a more

[47] Barbara Shook and Leslie Palti, "Shale Gas Developed in U.S., Canada; Yet to be Exploited Worldwide," *Oil Daily*, April 7, 2009, page 4.

important source of global oil and natural gas production sometime in the future; the timing of a significant expansion in Arctic production is difficult to predict.

Appendix A
Weather Conditions at Prudhoe Bay, Alaska

	Average High Temperature	Average Low Temperature	Mean Temperature	Average Precipitation	Record High Temperature (Year)	Record Low Temperature (Year)
January	- 11°F	- 23°F	- 17°F	0.15 in.	35°F (1991)	- 62°F (1989)
February	- 13°F	- 26°F	- 20°F	0.13 in.	39°F (1989)	- 57°F (1987)
March	- 7°F	- 22°F	- 15°F	0.14 in.	34°F (1998)	- 54°F (1995)
April	7°F	- 8°F	- 1°F	0.10 in.	43°F (1988)	- 47°F (1986)
May	27°F	16°F	22°F	0.08 in.	55°F (1996)	- 19°F (1992)
June	44°F	31°F	37°F	0.37 in.	83°F (1991)	18°F (1997)
July	54°F	37°F	46°F	0.72 in.	82°F (1994)	28°F (1996)
August	51°F	36°F	44°F	0.95 in.	80°F (1994)	23°F (1996)
September	38°F	28°F	33°F	0.65 in.	67°F (1986)	1°F (1996)
October	21°F	10°F	15°F	0.40 in.	45°F (1991)	- 30°F (1996)
November	2°F	- 10°F	- 4°F	0.14 in.	39°F (1997)	- 45°F (1986)
December	- 7°F	- 19°F	- 13°F	0.19 in.	34°F (1998)	- 47°F (1990)
Total				4.02 in.		

Source: http://www.weather.com/weather/wxclimatology/monthly/USAK0197

Appendix B
Location of U.S. Geological Survey Arctic Provinces
Based on the Maps Shown in the USGS Arctic Assessment

USGS Petroleum Province Name	Countries Located Nearest To USGS Petroleum Province	Onshore/Offshore
West Siberian Basin	Russia	Onshore and Offshore
Arctic Alaska	United States	Onshore and Offshore
East Barents Basin	Norway, Russia	Offshore
East Greenland Rift Basins	Greenland (Denmark)	Mostly Offshore
Yenisey-Khatanga Basin	Russia	Onshore
Amerasia Basin	Canada, United States	Offshore
West Greenland-East Canada	Canada, Greenland (Denmark)	Offshore
Laptev Sea Shelf	Russia	Mostly Offshore
Norwegian Margin	Norway	Offshore
Barents Platform	Norway	Offshore
Eurasia Basin	Norway, Russia	Offshore
North Kara Basins and Platforms	Russia	Offshore
Timan-Pechora Basin	Russia	Mostly Onshore
North Greenland Sheared Margin	Greenland (Denmark)	Offshore
Lomonosov-Makarov	Canada, Greenland (Denmark), Russia	Offshore
Sverdrup Basin	Canada	Onshore and Offshore
Lena-Anabar Basin	Russia	Onshore
North Chukchi-Wrangel Foreland Basin	Russia, United States	Offshore
Vilkitskii Basin	Russia	Offshore
Northwest Laptev Sea Shelf	Russia	Offshore
Lena-Vilyui Basin	Russia	Onshore
Zyryanka Basin	Russia	Onshore
East Siberian Sea Basin	Russia	Offshore
Hope Basin	Russia, United States	Offshore
Northwest Canadian Interior Basins	Canada	Onshore

Note: The designation of the closest country or countries does not imply territorial or economic sovereignty by these countries over the petroleum province associated with them. Source: Op.cit. USGS, "Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle"

Appendix C
Shell Oil Offshore North Alaska Lease Purchases

MMS Lease Sale Number	Date of MMS Lease Sale	Offshore Region	Value of Winning Bids (million dollars)
195	March 30, 2005	Beaufort Sea	$44.4
202	April 18, 2007	Beaufort Sea	$39.3
193	February 7, 2008	Chukchi Sea	$2,117.8
Total Bonus Bids			**$2,201.5**

Source: U.S. Minerals Management Alaska leasing website at http://www.mms.gov/ld/AKsales.htm