Technical Sciences
Academy of Romania
www.jesi.astr.ro

Journal of Engineering Sciences and Innovation
Volume 5, Issue 3 / 2020, pp. 273-286

F. Petroleum and Mining Engineering

*Received **20 Apryl 2019*** *Accepted 15 September 2020*
*Received in revised from **28 July 2019***

Challenges of oil and gas exploration in the Arctic

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Abstract *The Arctic is a cold, remote, dark, dangerous and expensive place to explore for oil and natural gas. Recent appraisals suggest that a considerable fraction of the worlds undiscovered petroleum reserves lie within the Arctic. The oil and gas resources in the Arctic, but also their price, are what will draw the attention to the Arctic area in the future. Offshore exploration in the Arctic currently targets oil instead of natural gas. The relative ease of transport is what causes companies to favor oil. 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, polar bears, seals, whales, and other Arctic sea life. 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.*

Keywords: *oil, natural gas, Artic Ocean, jurisdiction, international, map, offshore, resources.*

1. Introduction

The Arctic Ocean has a surface area of about 14.056 million square kilometers (5.427 million square miles), making it the smallest of Earth's five oceans. Baffin Bay, Barents Sea, Beaufort Sea, Chukchi Sea, East Siberian Sea, Greenland Sea, Hudson Bay, Hudson Straight, Kara Sea, and Laptev Sea are generally considered to be part of the Arctic Ocean. It is connected to the Pacific Ocean through the Bering Strait and connected to the Atlantic Ocean through the Labrador Sea and the Greenland Sea [1].

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The dominant topographic feature of the Arctic Ocean seafloor is the Lomonosov Ridge. This feature is thought to be part of the Eurasian continental crust that rifted from the Barents-Kara Sea margin and subsided in early Tertiary time (about 64 to 56 million years ago). The side of the Ridge facing Eurasia is bounded by half-graben faults, and the side facing North America is gently sloping.

The Lomonosov Ridge traverses the Arctic Ocean from the Lincoln Shelf (off Ellesmere Island and Greenland) to the New Siberian Islands off the coast of northern Russia. It divides the Arctic Ocean into two major basins: the Eurasian Basin on the Eurasian side of the ridge and the Amerasian Basin on the North American side. It rises over 3000 meters above the floors of these basins and at its highest point is about 954 meters below sea level. It was discovered by Russian scientists in 1948.

In 1982 a United Nations treaty known as the "Law of the Sea" was presented. It addressed navigational rights, territorial waters limits, exclusive economic zones, fishing, pollution, drilling, mining, conservation, and many other aspects of maritime activity. It was the first attempt by the international community to establish a formal agreement on a logical allocation of ocean resources. Under the Law of the Sea, each country receives exclusive economic rights to any natural resource that is present on or beneath the sea floor out to a distance of 200 nautical miles beyond their natural shorelines. In addition to the 200 nautical mile economic zone, each country can extend its claim up to 350 nautical miles for those areas that can be proven to be an extension of that countrys continental shelf.

Nations could use the "Law of the Sea" treaty to determine who owns the Arctic Ocean seafloor. Russia has presented a claim to the United Nations that the Lomonosov Ridge is an extension of Eurasia and that entitles Russia to an extended exclusive economic zone. Canada and Denmark make similar claims to extend their control from the opposite side of the Arctic Ocean [1].

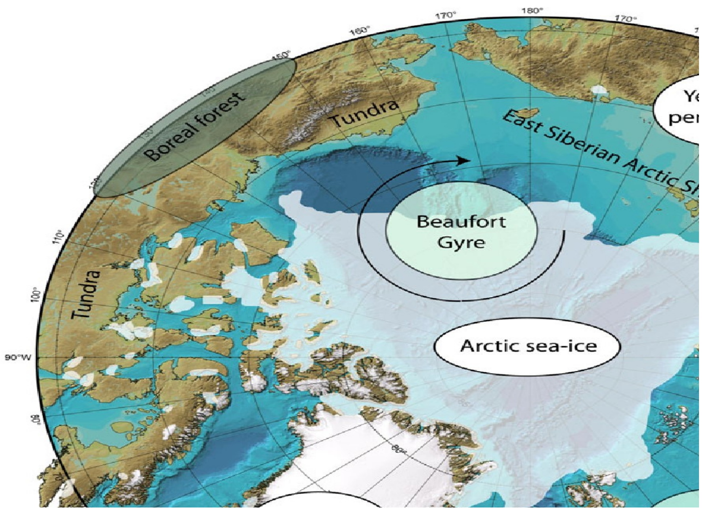


Fig. 1. Arctic Ocean Seafloor Features Map: International Bathymetric Chart of the Arctic Ocean (IBCAO) annotated with the names of seafloor features [1].

In Fig. 1 is shown Map of Arctic climate tipping elements, based on the International Bathymetric Chart of the Arctic Ocean (IBCAO) with land topography, and the September 2008 minimum sea-ice extent overlain [1].

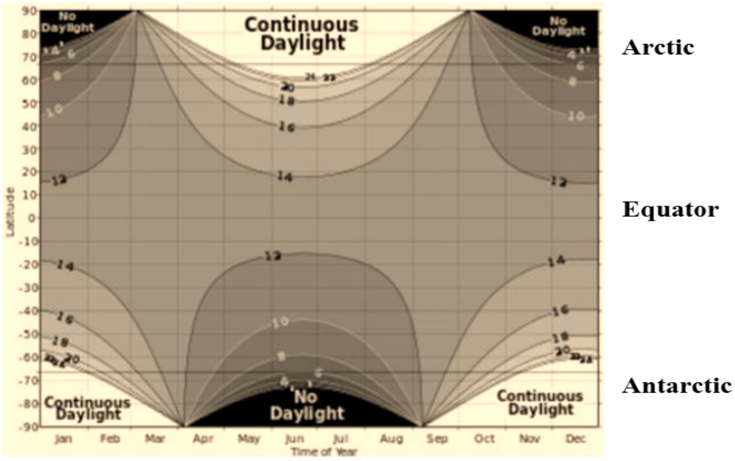
2. Oil and natural gas resources of the Arctic

The area above the Arctic Circle is underlain by sedimentary basins and continental shelves that hold enormous oil and natural gas resources. Most of this area is poorly explored for oil and natural gas; however, the United States Geological Survey estimates that the Arctic contains approximately 13 percent of the worlds undiscovered conventional oil resources and about 30 percent of its undiscovered conventional natural gas resources (Fig. 2).
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 [2].

Source: U.S. Geological Survey
Fig. 2. Resource Basins in the Arctic Circle Region.

The Arctic weather and climate are influenced by several factors, the most important of which is the solar radiation. The amount of solar radiation reaching the Earth varies with the latitude and the cloud cover. Since the incident solar radiation decreases from the Equator to the poles, temperature decreases with increasing latitude. An interesting plot showing the variation of the duration of the daylight with latitude over the year is provided in Fig. 3. The smaller angle with which the sun intersects the horizon in the Polar regions, compared to the Tropics, leads to longer periods of twilight in the Polar regions, and accounts for the asymmetry of the plot.

Comparing the two poles of the Earth, the Arctic and the Antarctic, in Fig. 3, it can be said that the former is mostly an ocean surrounded by land whereas the latter is mostly land surrounded by water. The Arctic's thin ice cover has water, not land, under it. Subsequently, there is always a small scale heat transfer from the warmer water mass under the ice to the Arctic air. From the other hand, Antarctica has mountains with an average elevation of about 7,500 feet (2.3 km) and stronger winds than the Arctic. As a consequence, Arctic clime is less cold than that of the Antarctic [3].



Source: wikipedia

Fig. 3. Variations in the duration of daylight with latitude and time of year [3].

This figure also shows the latitude of 66°33’ of the Arctic Circle. Following this line, the number of daylight hours can be read for each month of the year.

The Arctic experiences the extremes of solar radiation. During the Northern Hemisphere’s winter months, the Arctic is one of the coldest and darkest places on Earth. Following sunset on the September equinox, the Earth’s tilted axis and its revolution around the sun reduce the light and heat reaching the Arctic until no sunlight penetrates the darkness at all. The sun rises again during the March equinox, and increases the light and heat reaching the Arctic. By the June solstice, the Arctic experiences 24-hour sunshine.

Therefore, the climate of the Arctic is characterized by long, cold winters and short, cool summers. Some parts of the Arctic are always covered by ice whereas others experience long periods with some forms of ice on the surface. In winter, temperatures can drop below −50°C whereas in summer temperatures range from about −10 to +10°C, with some land areas occasionally exceeding 30°C.

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.

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 [4]. 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.

This makes the Arctic an incredibly rich area. It is about the same geographic size as the African continent - about 6% of Earth's surface area - yet it holds an estimated 22 percent of Earth's oil and natural gas resource [5].

Most of the exploration in the Arctic to-date has taken place on land. This work has resulted in the Prudhoe Bay Oil Field in Alaska, the Tazovskoye Field in Russia and hundreds of smaller fields, many of which are on Alaska's North Slope. Land accounts for about 1/3 of the Arctic's area and is thought to hold about 16% of the Arctic's remaining undiscovered oil and gas resource [6].

3. **Discovered Arctic oil and natural gas resources**

The Arctic, a region that proved elusive to explorers for centuries, is now more important than ever. As ice thaws and the Arctic warms at a rate twice that of the global average [7] international interest and attention in the region has piqued. The combination of natural resources, potential new trade routes, and strategic interests holds the possibility of shifting international dynamics, for better or worse.

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 [8]. One of the world's last remaining great frontiers, the Arctic is expected to play a major role in supplying the world's future energy, for example in the Fig. 4. is illustrated a foto the on Arctic drilling to discovereds resources of oil and gas Arctic.

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 [9] made the construction of the Alyeska Oil Pipeline [10] 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 [11] (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.

Large Arctic oil and natural gas discoveries began in Russia with the discovery of the Tazovskoye [12]. 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 [13]. 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.

Source: www.telegraph.co.uk/

Fig. 4. Arctic drilling is inevitable -
International oil companies are in a race to exploit Arctic resources.

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 [14]. 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.

Thus, it seems very likely that, if the Arctic region is to become a major oil and gas province within the next two to three decades, it will be in Norway and Russia that the major activity takes place.

Russia has by far the largest resource base but lacks the experience and technology to develop it alone. Norway has significant offshore experience and has at least started the long process of developing infrastructure in the Barents Sea. Moreover, both countries are highly motivated to find new oil and gas resources to bolster their economies in the long term. Beyond the geopolitical difficulties that Russia is currently facing, all these factors may provide the catalyst for the development of the Arctic as an oil-producing region, although the realistic timetable for significant output must surely be after 2030, not before [15].

The irony is that the drilling is only possible because manmade climate change is already causing this region to grow warmer twice as fast as the rest of the planet. The melting ice makes these huge reserves of oil and gas more accessible.

In conclusion, the combination of regional exploration and climate change has culminated in the high stakes environment we see today - one where the prospect of abundant natural resources, more efficient trading routes, and the ability to advance strategic goals has piqued the interests of many. In continuing to develop the Arctic, measures should be taken to guarantee that the environment and international relations are supported. In order to ensure future international cooperation and inclusion of all concerned, the Arctic must be developed in strategic and tempered ways.

4. Jurisdiction of the Arctic

Significant volumes of oil and natural gas resources are assumed in the Arctic Ocean. While their exploitation has not been feasible due to unfavorable climate and geographic conditions until today, global warming might improve accessibility in times to come. In the future timing of specific exploration and development activities remains highly uncertain. Portions of eight countries are situated above the Arctic Circle: Canada, Denmark (via Greenland), Finland, Iceland, Norway, Russia, Sweden, and the United States. Six of them border the Arctic Ocean and thus have a jurisdictional claim to portions of the Arctic seafloor: Canada, Denmark (via Greenland), Iceland, Norway, Russia, and the United States.

Their claims to oil and gas beneath the Arctic Ocean seafloor have historically been determined by unilateral decrees; however, the Law of the Sea Convention provides each country an exclusive economic zone extending 200 miles out from its shoreline. Under certain conditions the exclusive economic zone can be extended out to 350 miles, if a nation can demonstrate that its continental margin extends more than 200 miles beyond its shore. Russia, Canada, and the United States are currently working to define the extent of their continental margin.

This provision has led to some overlapping territorial disputes and disagreements over how the edge of the continental margin is defined and mapped. For example, Russia claims that their continental margin follows the Lomonosov Ridge all the way to the North Pole. In another, both the United States and Canada claim a portion of the Beaufort Sea in an area that is thought to contain significant oil and natural gas resources.

The United States Geological Survey has estimated the undiscovered technically recoverable conventional oil, natural gas, and natural gas liquids resources north of the Arctic Circle to be approximately 412 billion barrels of oil equivalent.

Their estimates place over 87% of the resource (360 billion barrels oil equivalent) into seven Arctic basin provinces: Amerasian Basin, Arctic Alaska Basin, East Barents Basin, East Greenland Rift Basin, West Greenland-East Canada Basin, West Siberian Basin, and the Yenisey-Khatanga Basin, and their resource distributions are presented in Table 1 and Fig. 5. [5,9,11].

Table 1. Arctic area mean estimated undiscovered technically recoverable, conventional oil and natural gas resources for the seven largest Arctic basin provinces.

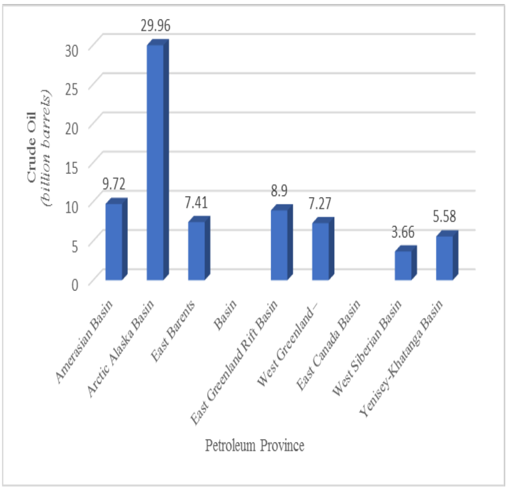
Petroleum Province	Crude Oil *(billion barrels)*	Natural Gas *(trillion cubic feet)*	Natural Gas Liquids *(billion barrels)*	Total *(billion barrels of oil equivalent)*
Amerasian Basin	*9.72*	*56.89*	*0.54*	19.75
Arctic Alaska Basin	*29.96*	*221.40*	*5.90*	72.77
East Barents Basin	*7.41*	*317.56*	*1.42*	61.76
East Greenland Rift Basin	*8.90*	*86.18*	*8.12*	31.39
West Greenland – East Canada Basin	*7.27*	*51.82*	*1.15*	17.06
West Siberian Basin	*3.66*	*651.50*	*20.33*	132.57
Yenisey-Khatanga Basin	*5.58*	*99.96*	*2.68*	24.92
Total 7 Basin	*72.5*	*1,485.31*	*40.14*	360.22
TOTAL Arctic	**90**	**1,669**	**44**	**412**
These seven provinces account for about 360 billion barrels oil equivalent or over 87% of the total undiscovered Arctic area resource.				

It is clear from this data that most of the Arctic area resource is natural gas and that the Asian side of the Arctic area has the highest proportion of natural gas and natural gas liquids.

Fig. 5. Arctic Oil and Natural Gas Provinces Map

Arctic oil and natural gas resources are not evenly distributed among the Eurasian and North American continents. In general, the North American regions of the Arctic tend to possess more oil resources, while the Eurasian regions tend to be more gas-rich.

A distribution of the potential Arctic oil and gas resources among the Arctic countries, in conformite of Table 1, is illustrated in Fig. 6.



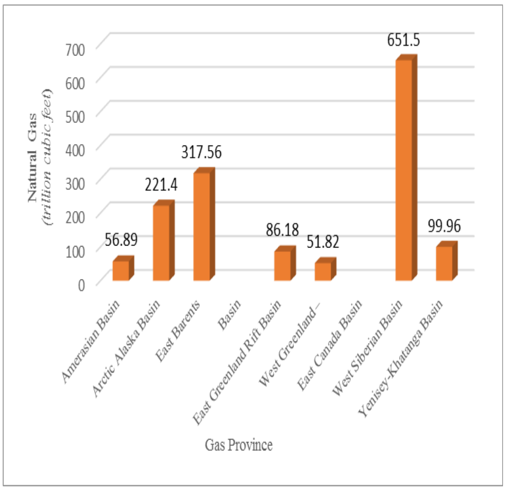


Fig. 6. Distribution of potential Arctic Oil & Gas Resources.

It could be deducted that Russia is estimated to hold more than half of the total Arctic hydrocarbon resources (for gas). However, U.S.A. appears to be the country with the largest undiscovered Arctic oil reserves which gather the most of the probabilities for a possible development.

In conclusion, the future of oil and gas drilling in the Arctic is a problem with many uncertainties. Even though with a high degree of certainty it contains a large amount of natural resources, their actual recovery depends on many hard-to-predict factors from the climate change and the development of the world's economy to the political situation in the individual countries with the access to the resources.

5. Arctic oil and natural gas potential

Despite the massive size of the Arctic's resources, looking to the region as a potential source of commercially viable crude oil production is a relatively recent development. While costs remain high due to harsh environmental conditions, high crude oil prices have made this region more economically attractive. Finding large Arctic oil and natural gas deposits is difficult and costly; developing them into commercially profitable ventures is even more challenging due to the following factors:

- Severe winter weather requires that 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;
- Gas hydrates can also pose problems for drilling wells in both on- and offshore Arctic areas;
- Long supply lines and limited transportation access from the world's manufacturing centers require equipment redundancy and a larger inventory of spare parts to insure reliability, while increasing transportation costs;
- Spills among ice floes can be much more difficult to contain and clean up than spills in open waters;
- Higher wages and salaries are required to induce personnel to work in the isolated and inhospitable Arctic.

Natural gas development could be especially challenging. Although the Arctic is rich in natural gas, the development of Arctic natural gas resources could be impeded by the low market value of natural gas relative to that of oil. Furthermore, natural gas consumers live far from the region, and transportation costs of natural gas are higher than those for oil and natural gas liquids. [16]

5.1. Arctic standards

Arctic standards, would must provide consistent requirements how to design, build, install, and operate equipment to safely explore and develop oil and gas resources and respond to accidents in the region using best Arctic science, technology, and practices.

Arctic standards must account for the area's remote location, lack of infrastructure, and unique operating conditions due to the severe and changing climate to ensure that oil spills are prevented and the capability exists to respond to a worst-case oil spill.

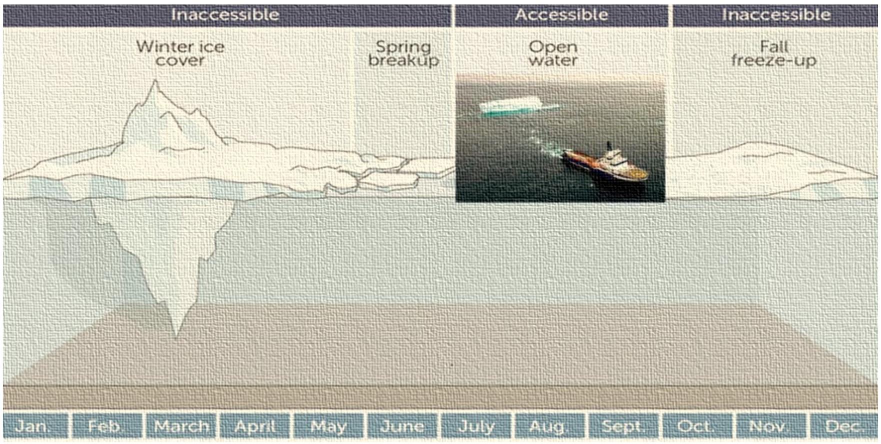
Arctic Standards recommend [17]:

- Vessels, drilling rigs, and facilities should be built to withstand maximum ice forces and sea states that may be encountered;
- Equipment needed to control a spill, such as relief rigs and well-control containment systems, should be designed for and located in Alaska's Arctic so they can be readily deployed;

- Spill response equipment should be located in Alaska's Arctic and be sufficiently robust to remove oil caught in ice-infested waters and trapped under ice;
- Redundant systems-including blowout preventers, double-walled pipelines, double-bottom tanks, and remotely operated controls-should be installed because equipment and logistical access is unavailable for large parts of the year due to harsh weather or ice cover;
- Arctic offshore drilling operations into hydrocarbon-bearing zones should be limited to periods when the drilling rig and its associated spill response system are capable of working and cleaning up a spill in Arctic conditions, for example in Fig. 7.

5.2. Arctic drilling limits

Arctic Drilling Limits, believ that decisions about whether, where, and how oil and gas exploration and production activities are conducted in the Arctic Ocean should be based on sound scientific information, thorough planning, the best available technology, and full involvement of the communities most affected.
A balanced and careful approach to development must account for environmental protection and the social, cultural, and subsistence needs of Arctic area communities. [17]



Source: google search.
Fig. 7. Arctic offshore drilling operations, in zones limiteds to periods accessible.

The effect that Arctic development will have on the future of international relations is anything but clear. The multiple motivations for getting involved in the region contribute to a plentitude of potential outcomes.
The best-case scenario is that future relations in the Arctic remain emblematic of peaceful international cooperation, largely as they are now. The possibility of nations working together to further develop efficient Arctic trade routes could help

facilitate unprecedented international partnership. This could help improve diplomatic relations and further the advancement of the global economy.

6. Conclusions

The Arctic is a dynamic region of critical importance. It has the potential to affect both the present and future of the globe, in positive and negative ways.

According to an assessment conducted by the U.S. Geological Survey (USGS), the Arctic holds an estimated 13 percent (90 billion barrels) of the world's undiscovered conventional oil resources and 30 percent of its undiscovered conventional natural gas resources. While risks associated with economics, the region's harsh environment, and ongoing territorial disputes are considerable, potential rewards are immense.

U.S. studies on the economics of oil and natural gas projects in onshore Arctic Alaska estimate costs to develop reserves in the region can be 50 to 100 percent more than similar projects undertaken in Texas. Challenges facing natural gas development can be especially daunting. Despite the fact that the Arctic is particularly rich in natural gas, exploitation of those resources could be impeded by the low market value of natural gas relative to that of oil and because the world's natural gas consumers live far from the region and the long-distance transportation of natural gas is considerably more expensive than that for oil and natural gas liquids.

Weather conditions can be particularly challenging in that both colder-than-normal and warmer-than-normal conditions can cause problems in the Arctic. Onshore, the marshy Arctic tundra can preclude exploration activities during the warm months of the year, thereby confining exploratory drilling to a few winter months. If summer comes earlier than expected (for example, as was the case in Alaska in April 2009), it can leave equipment stranded and hinder some exploratory well drilling. Similarly, a late onset of winter weather delays construction of the ice roads required to transport heavy equipment across the tundra. Offshore, cold conditions can lead to greater than anticipated ice pack, which can damage offshore facilities, while also hindering the shipment of personnel, materials, equipment, and oil for long time periods. Further challenges are associated with severe weather search and rescue operations.

Political issues stemming from the overlapping and disputed claims of economic sovereignty between neighboring jurisdictions also pose a challenge to resource development in the Arctic. The area north of the Arctic Circle is apportioned among eight countries - Canada, Denmark (Greenland), Finland, Iceland, Norway, Russia, Sweden, and the United States. Under current international practice, countries have exclusive rights to seabed resources up to 200 miles beyond their coast, an area called an Exclusive Economic Zone (EEZ). Beyond the EEZ, countries must demonstrate that the seabed is a "natural prolongation" of the continental shelf in order to claim seabed rights. These practices have led to several overlapping claims between countries.

Beyond the economic and political challenges, environmental issues and regulatory permitting also figure prominently in Arctic exploration and production. Environmental issues pertain to the preservation of animal and plant species unique to the Arctic, particularly tundra vegetation, polar bears, seals, whales, and other sea life. Of particular concern is the capability of existing technology to handle offshore oil spills in an arctic environment; spills among ice flows and can be much more difficult to contain and clean up than spills in open waters.
In the future timing of specific exploration and development activities remains highly uncertain. With major territorial disputes not likely to have an impact on resource development in the near term, producers still need to find ways to extract oil and natural gas in an economic and environmentally acceptable manner, something that has and will continue to differ across countries and development tracts.
These are but one set of aspects that will influence how, where and when the Arctic will become an arena of much more intensive exploration and extraction activities of oil and gas than today. Technology, climate change and environmental regulations will also weigh heavily, not to mention a variety of political, economic, and social factors.
In this article, we have shown that for parts of the Arctic Ocean, an exploitation of oil and gas might be technologically possible in the future. However, under current prices today and with competing fossil and renewable energy sources, an exploitation does not seem to be rational from an economic point of view.

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[7] Tim Koivurova, *The Dialectic of Understanding Progress in Arctic Governance*, 22 Mich. St. Int'l L. Rev. 1, 2013, p. 1-21.
[8] 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.

[9] Figure does not 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.
[10] Also known as the Trans Alaska Pipeline System (TAPS).
[11] Op. cit. Alaska Department of Natural Resources, Table III.1, page 3-2.
[12] There are often multiple variations for the English spelling of foreign oil and natural gas fields.
[13] 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°33' latitude to qualify as Arctic fields.
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