UNIVERSITY OF THE ARCTIC

Module 9

Non-Living Natural Resources of the Arctic and Their Use

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Key Terms and Concepts

- natural resource
- living and non-living resources
- renewable and non-renewable resources
- sustainable use
- hydro power, or hydroelectric power
- geothermal heat
- fossil fuels
- effects of oil and gas development
- fresh water
- oil and gas regions of the Arctic
- minerals
- effects of mining

Learning Objectives

Upon completion of this module, you should be able to

1. explain, with examples, the difference between living- and non-living, renewable and non-renewable resources.

2. discuss the various uses of fresh water and its potential for the Arctic.

3. explain the similarities and differences in energy production of hydro power, geothermal heat, and fossil fuels (oil and gas).

4. explain the main environmental benefits and costs of hydro power and geothermal energy.

5. describe the main oil and gas regions in the Arctic.

6. describe the potential effects of oil and gas development.

7. list the main minerals that are mined in the Arctic and some major mining regions.

8. discuss the effects of mining activities.

Reading Assignment

There is no reading assignment for this module, though you might be interested in exploring the items in the References section for supplementary reading.

Overview

The Arctic is rich in natural resources: living and non-living, renewable and non-renewable. Human life and prosperity in the Arctic is dependent on the use of these resources, be it for sustenance consumption, export, or trade for other goods. Use of natural resources will always have some effects on the environment. Use of a non-renewable resource is fundamentally unsustainable because the resource will eventually be depleted. In order to be sustainable, the use of a renewable resource must harvest less than what is added through growth or recycling. The natural resources of the Arctic and their use will be discussed in this module as well as in Modules 10 and 11. In this module, we will explore non-living resources—water, oil and gas, and minerals—and their use.

Lecture

Broadly speaking, natural resources are any elements of nature that can be used by humans, including drinking water, oil and gas, minerals, seafood, game animals, fodder, fuel wood, timber, and pharmaceutical products. Usually, however, the term *natural resource* is used in an economic sense to mean any resource occurring in nature that can create wealth and is controlled by a particular state or authority. Distinctions are made between living and non-living resources, as well as renewable- and non-renewable resources.

A *non-renewable resource* is a resource that is not replaced or is replaced only slowly by natural processes. Primary examples of non-renewable resources are minerals and the *fossil fuels*, that is, oil, natural gas, and coal. Although fossil fuels are continually produced by the decay of plant and animal matter, the rate of their production is measured in geological time—much slower than the rate at which we use them. Therefore, once a non-renewable resource is "used up," it is gone—and no longer available for human use.

A *renewable resource*, in contrast, is a resource that is replaced rapidly by natural processes. Examples of renewable resources are sunlight, water (on a global scale), wood, and wildlife products. When sunlight is used to warm one's back, more is made almost immediately available. If you chop down a forest, it takes a while for it to grow back, but it will usually happen within your lifetime.

Natural ecosystems perform fundamental life-support services without which human civilization would cease to thrive. These include the purification of air and water; mitigation of floods and droughts; pollination of crops and natural vegetation; control of natural pests; detoxification and decomposition of wastes; regulation of climate; protection from ultraviolet radiation (UV-B); regeneration of soil fertility; and production and maintenance of biodiversity, from which key ingredients of agricultural, pharmaceutical, and industrial enterprises are derived. This array of services is generated by a complex interplay of natural cycles powered by solar energy and operating across a wide range of space and time scales. The process of waste disposal, for example, involves the life cycles of bacteria as well as the planet-wide cycles of major chemical elements, such as carbon and nitrogen.

Non-Living Resources

Fresh Water

Arctic landscapes are dominated by fresh water in various forms—frozen, still, and running. During the ice age, huge glaciers moved across much of North America and northwest Europe. As they receded, they left a vast system of lakes and wetlands in depressions in the landscape. These lake and wetland systems cover, for example, 8.5% of Sweden and 10% of Finland. In addition, there are several huge and permanent ice fields that store fresh water. The Greenland ice cap at 1.7 million km^2 is the world's second in size after the Antarctic ice cap. Permanent ice sheets also cover parts of Iceland, the Svalbard archipelago, Franz Josef Land, Novaya Zemlya, and Severnaya Zemlya. Fresh water is essential for all life, and the global demand for it is increasing. Running fresh water is also an important source of energy in many Arctic countries; geothermal hot water and steam is used as an energy source in Iceland.

Student Activity

How does your community obtain and distribute fresh water?

Water for Human Consumption

The Arctic's lakes, rivers, and ice reservoirs are becoming increasingly important as a freshwater supply for water-deficient regions of the world. Arctic fresh water for consumption, therefore, may soon become an important economic commodity, and there have already been proposals to tap such resources, for example, in Canada. Russian newspapers have also recently referred to plans, which have been on the shelf since the early 1970s, to divert the river Ob and other northbound rivers towards water-starving regions in the south. Such plans may never be implemented, but if they are, then the environmental consequences could be significant. A diminishing flow of fresh water into the Arctic Ocean will most certainly affect ice formation off the Siberian coast. The consequences for marine production, and possibly also for ocean currents and climate are unknown, but could be dramatic.

Hydro Power

Arctic rivers are important sources of hydroelectric power or hydro power generation. The Nordic countries, especially Norway, Iceland, and northern Sweden, as well as parts of the Canadian North, enjoy optimum natural conditions in this respect, that is, high precipitation and steep gradients. Hydro power is made by causing water to flow through and rotate turbines, which, in turn, create electricity.

While a society's electricity demand is greatest in winter, northern rivers tend to be much smaller in winter than in summer. Currently, there is no technology available to store large quantities of electricity. Therefore, to ensure that electricity supply meets demand throughout the year, the flow of water must be regulated. This is done through a system of dams, storage reservoirs, and flow tunnels in the upper reaches of the exploited river systems. The reservoirs fill up as the snow melts in spring and summer and gradually empty again during late fall and winter. In this way, the flow of the harnessed river remains high during times of high electricity demand.

Norwegians were the first to make use of hydro power. As early as 1890, hydroelectric lighting was installed in the city of Hamerfest in northern Norway. By about 1920, two-thirds of Norwegians had access to electricity, compared to about one-sixth of Swedes. At the same time, in the 1920s, Iceland built its first hydroelectric power station.

Norway obtains virtually all its electricity from hydro power and has the highest per-capita household electricity consumption in the world. Most Norwegians heat their homes with electricity, and a number of electricity-powered industrial plants, including energy-demanding aluminum smelters and fertilizer factories, have been built. Still, Norway exports electricity to neighbouring countries. Recently, Norway halted all large-scale hydro power developments, mainly because of environmental concerns. Sweden, too, has abundant hydro power resources, especially in the north, but still needs to supplement its hydroelectricity with nuclear power. The same is true for Finland, which, because of its gentle topography, does not obtain much energy from its rivers.

Iceland produces more hydroelectricity per capita than any other country; however, since most Icelanders use geothermal energy (see below) to heat their houses, their household electricity use is less than it is in Norway. The glacial rivers draining Iceland's vast glaciers have great potential for hydro power, but harnessing these rivers for household consumption is not considered economically viable. Instead, Iceland uses the promise of low-cost power to attract heavy industries that need much energy, such as aluminum smelters and ferro-alloy plants. If current plans are realized, 70–80% of all hydroelectricity produced in Iceland will be powering aluminum smelters by 2010. Only about one-quarter of Iceland's hydroelectric potential has been harnessed so far, and it is uncertain how much will eventually be exploited, because conservation concerns are increasingly being evaluated against economic returns.

Hydro power is a non-polluting and constantly renewable energy source and is, therefore, regarded by many as the ultimate "green" energy source. However, as we will explore below, hydro power, as currently exploited, does have many adverse environmental effects.

Impacts of Hydro Power Development

Even though hydro power can be considered a friendly source of energy in terms of being carbon-free and not adding to the global greenhouse effect and climate change, it has several drawbacks in terms of its impacts on biodiversity, both at the landscape and species levels. The impacts stem from the need to regulate water flow through the construction of dams and reservoirs. A river that is fully exploited to generate electricity is transformed from a freely flowing watercourse into sets of reservoirs, dams, and power stations, which change the river habitat entirely. Below the dams, the river water is often directed along tunnels, leaving the riverbed half-dry or completely dry. Migrating salmonid fish (salmon, trout, char) are among the freshwater species that have suffered most from hydro power development. Naturally, the fish migrate upstream to spawn in cold, well-oxygenated and relatively fast-running water. Dams or dry riverbeds block these migrations and have eliminated many valuable salmon and trout populations. According to the North Atlantic Salmon Conservation Organization (NASCO), about 25% of the almost 1,900 North Atlantic rivers have been damaged or lost because of human influence.

The reservoirs, held in place by the dams, also compromise biodiversity. First, they drown the vegetation and entire ecosystems that they inundate—this has been a particularly significant impact of reservoirs in the highlands of Iceland, which had already lost much of its highland vegetation to erosion. Second, as the water level in a reservoir drops because of water regulation in winter and early spring, a shoreline of mud and fine sediments forms that is prone to erosion.

Geothermal Energy

Geothermal energy in the form of natural hot water springs and steam holes is another non-polluting energy source that Iceland, for one among the Arctic countries, enjoys in generous supplies. In fact, there are few countries on Earth that have greater geothermal energy reserves and none that have exploited it to the same level. Iceland began using geothermal energy for providing hot running household water and for heating homes and official buildings early in the twentieth century. Currently, a maze of pumping stations and pipelines supplies hot water to more than 90% of Icelandic homes and official buildings.

Early on, hot water was simply tapped directly from natural hot springs. Nowadays, however, it is pumped to the surface through boreholes from a depth of several hundred to a few thousand metres and then distributed to towns and rural areas via well-isolated pipelines. Hot ground water is also used to heat greenhouses that in turn produce vegetables, such as tomatoes, cucumbers, and bell peppers for domestic consumption, as well as cut flowers and ornamental potting plants.

Most geothermal energy is currently extracted from so-called *low-temperature fields*, where water temperature at 1,000 m depth is about 100°C. Along the volcanically active rift zone that stretches through Iceland from the southwest to northeast, there are in addition a number of *high-temperature fields*, where bedrock temperature exceeds 200°C at 1,000 m. When boreholes are drilled into these areas, hot water comes out in great force in the form of steam, which in turn can be used to rotate turbines and create electricity. Currently, there are only three such geothermal electricity plants in Iceland, generating approximately 10% of all electricity produced. Geothermal electricity can hardly compete with hydro power in pure economic terms. However, geothermal electricity is considered environmentally less damaging overall than is hydro power, as it does not require large dams and reservoirs.

Student Activity

1. What is the main energy source in your community or region? How and where is it obtained and brought to your community? If there are more than one main energy source in your community or region, answer the questions for each energy source.
2. Much-used terms in the global press these days are “non-carbon energy sources,” “non-carbon economies,” etc. To what do these terms refer? Name some non-carbon energy sources and explain why they are becoming so popular. Is the Arctic well placed in terms of non-carbon energy sources?

Unlike hydro power, geothermal energy cannot be regarded as a fully renewable resource. The geothermal heat in areas where hot water is currently being extracted originates primarily from magma (melting rock), which arose from the Earth’s mantle a long time ago. These areas can, therefore, be considered “heat mines” whose energy will sooner or later be exhausted. However, ongoing volcanic activity ensures partial renewal. So far, however, only a fraction—less than 5%—of Iceland’s geothermal heat resource has been tapped.

Oil and Gas

The Arctic holds a significant share of the world’s oil and gas reserves. Depending on oil prices and the supply of oil from existing producing regions, such as the North Sea and the Middle East, there will likely be an increasing pressure to develop the Arctic reserves. The Arctic may thus become one of the main sources of oil and gas in the twenty-first century. Within the Arctic, oil is found in three main regions: the Beaufort Sea coast (North Slope of Alaska and the Mackenzie Delta of Canada), the Canadian northeastern Arctic (Nunavut), and northwest Russia. (See fig. 9.1 and table 9.1.)

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Source: AMAP (1998)

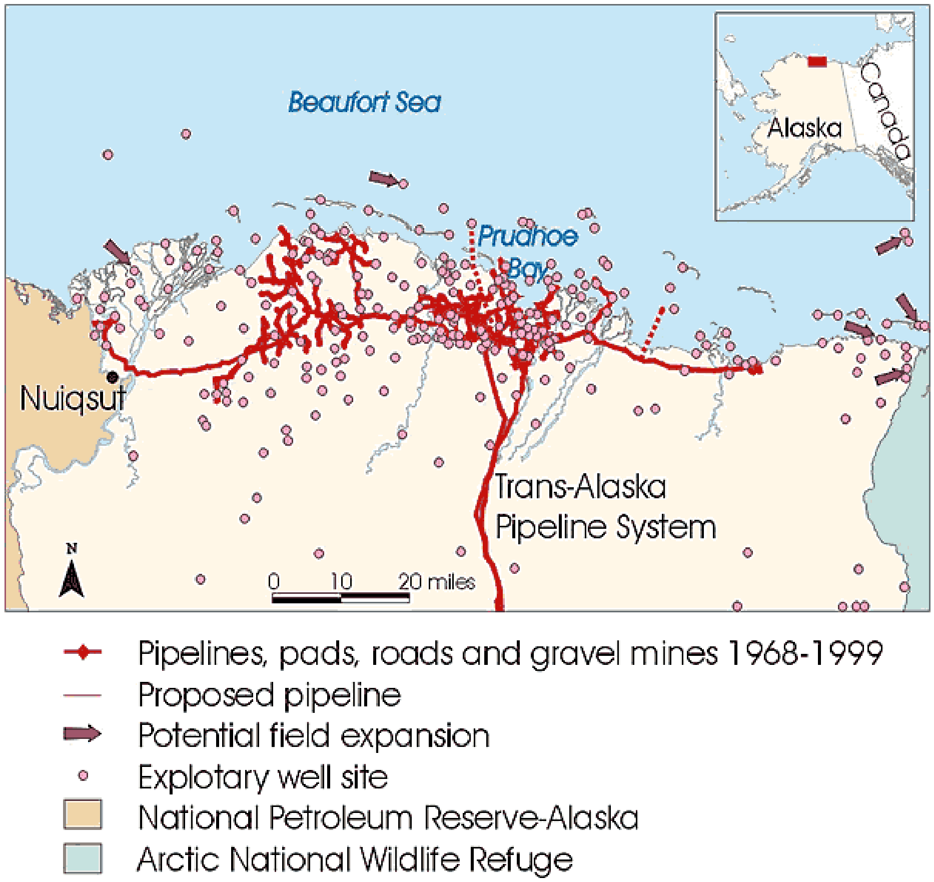
Fig. 9.1 Major areas of oil and gas in the Arctic

Table 9.1 Oil and gas reserves in the Arctic (adapted from AMAP 1997)

Country and Area	Status of Explorations	Approximate Size of the Resource (rough estimates)
United States/Alaska		
Prudhoe Bay, Beaufort Sea coast	Production: Trans-Alaska Pipeline System connects fields to Port Valdez in south-central Alaska	Original size: 3.1 billion m^3 oil; still commercially recoverable: 1.2 billion m^3 oil
Canada		
Mackenzie Delta and near shore Beaufort Sea	Reserves	Estimated size: 300 million m^3 oil 300,000 trillion m^3 gas
Nunavut (Sverdrup Basin, Melville Island, Sabine Peninsula)	Reserves	
Norman Wells, Mackenzie River	Production and pipeline to Zama, Alberta	Annual production: 1.3 million m^3 oil
Russia		
Nenets Autonomous Okrug, Komi Republic, Yamal-Nenets Autonomous Okrug	Production and network of pipelines linking production sites with national system	Estimated annual production volume from the 18 largest companies: 93 million tonnes of oil; 750 trillion m^3 of natural gas (total Arctic production may be several times greater)
Shelf areas of Barents, Kara, and Pechora seas	Exploration for oil and gas	Estimated up to 200 billion tonnes of oil equivalents
Norway		
Barents Sea	Exploration for oil and gas	Estimated reserves: 300–2,000 million m^3 oil equivalents, of which two-thirds is gas
Greenland		
Nuussuaq, Davis Strait	Exploration	

The North Slope of Alaska

Major oil and gas fields were discovered in Prudhoe Bay on the North Slope of Alaska in the late 1960s. In 1999, some 17 operational fields were producing 51 million tonnes of oil and 5 million m^3 of natural gas liquids. Thus, the North Slope provided a major portion of Alaska's total oil production (54 million tonnes in 1999), which amounts to 20% of all oil produced in the United States. Alaska ranks second only to Texas in daily oil production. The oil from the North Slope travels 800 miles from Prudhoe Bay to Valdez via the Trans-Alaska Pipeline System (see fig. 9.2).



Source: CAFF (2001, 96)

Fig. 9.2 Oil drilling activities and related infrastructure on the North Slope of Alaska

Oil revenues are the major source of income for the State of Alaska. Since oil production began on the North Slope in 1977, the state has received more than $46 billion in taxes and royalties. The oil and gas industry employs nearly 8,000 Alaskans; and University of Alaska economists have determined that, although the oil and gas industry is not labour intensive, oil revenue contributes substantially to the personal income of every Alaskan.

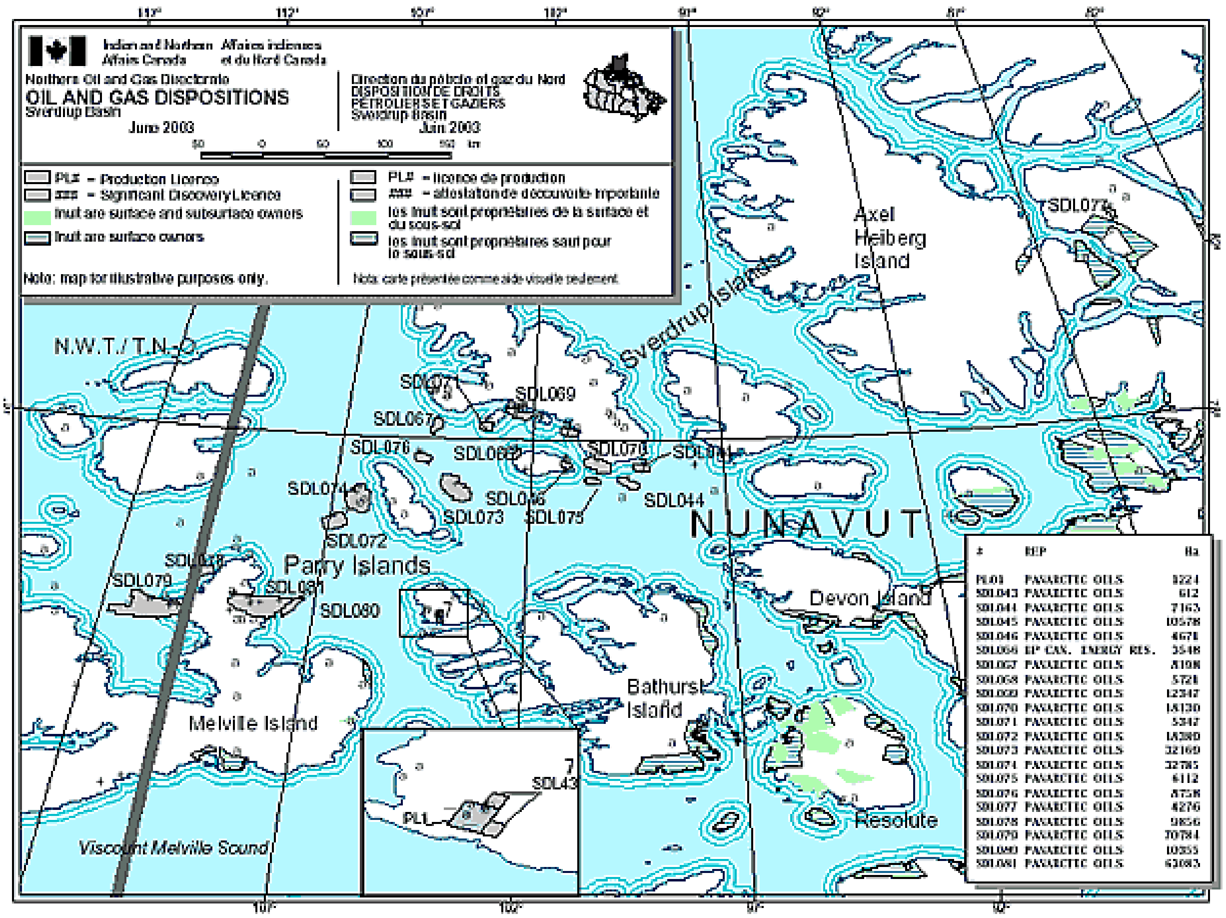
Northwest Territories

On the Canadian side, Norman Wells in the Mackenzie Delta annually produces 1.3 million m^3 of oil.

Nunavut

Nunavut encompasses one-fifth of Canada. Known petroleum resources in the territory account for 5% of Canada's known oil reserves The Sverdrup Basin is the largest and most significant petroleum basin in Nunavut (see fig. 9.3).

Nunavut's known reserves are based on data from 160 wells with significant potential in undiscovered reserves.

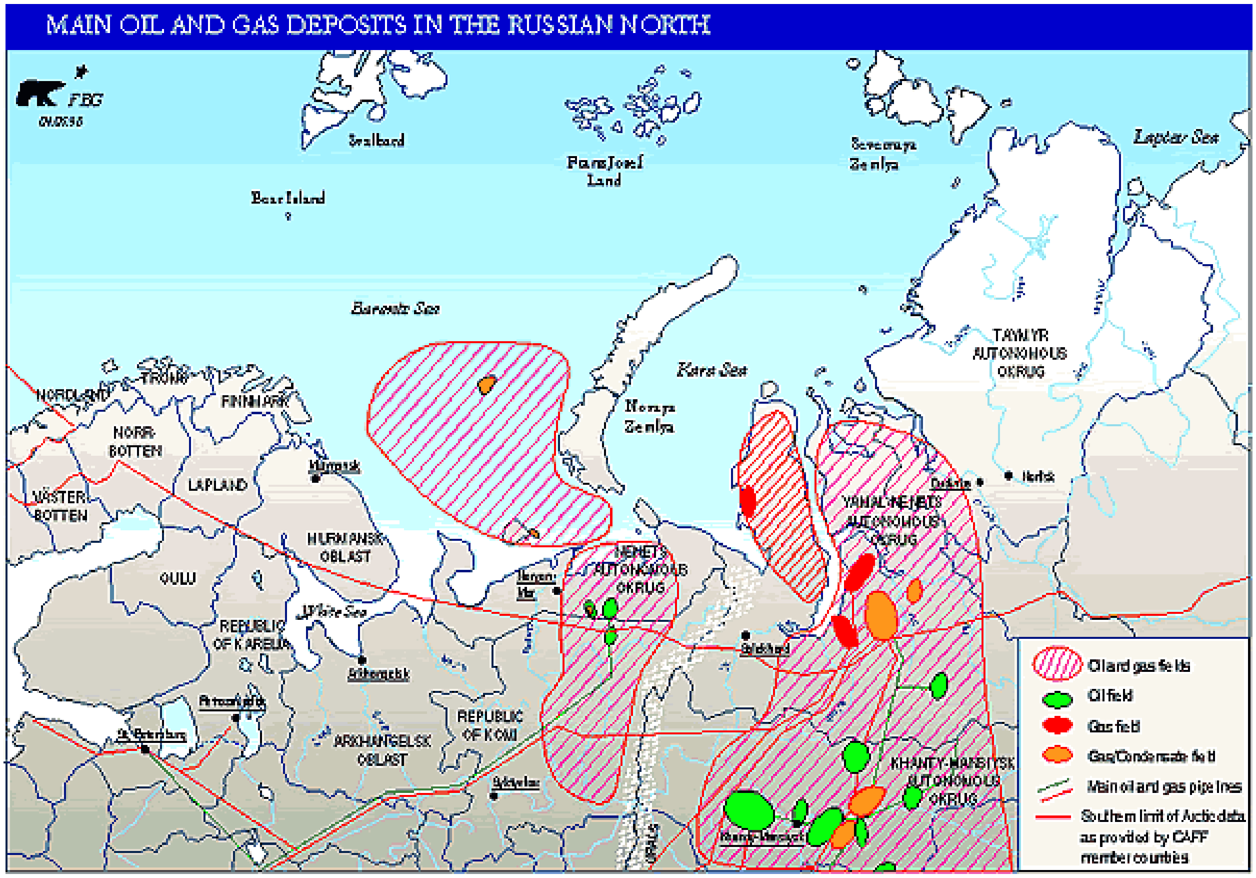


Source: Indian and Northern Affairs Canada

Fig. 9.3 Oil and gas dispositions in the Sverdrup Basin

Northwest Russia and the Barents Region

The Barents region of Russia contains large oil and gas reserves, which are found mainly in the Barents and Kara seas, the Nenets Autonomous Okrug, the Yamal-Nenets Autonomous Okrug, and the Khanty-Mansiysk Autonomous Okrug (see fig. 9.4).



Source: Arctic Centre, University of Lapland

Fig. 9.4 Main oil and gas deposits in northwest Russia

It is estimated that the Russian Arctic, especially the Russian Arctic shelf, contains 100–200 billion tonnes of oil equivalents (one oil equivalent corresponds to the energy content of 1 kg crude oil). These numbers become significant in light of total world oil and gas reserves, which in 1997 amounted to 155 billion tonnes of oil and 145 trillion m^3 of gas. Thus, the Russian Arctic may well become the dominant oil and gas producer of the twenty-first century.

Vast pipeline networks are being designed to secure the flow of Russia's crude oil to places of consumption. There are plans for an oil terminal, with a capacity of 50–60 million tonnes per year, in Murmansk for export to the United States. A western Siberia–Murmansk oil pipeline will feed this terminal. There are two options for pipeline routes. The first is 2,500 km long and lies partly across the White Sea; the other, which is 3,600 km long, is on land only. New gas pipeline projects are being planned for exporting to China, Japan, Korea, and other Pacific countries. New pipelines to the Baltic region may also be required for export of oil to Europe.

Impacts of Petroleum Exploration and Development

All phases of oil and gas exploration and development carry the risk of environmental disturbances. These disturbances can affect landscapes, soils, wildlife biodiversity, vegetation, water resources, and human quality of life (see table 9.2).

Table 9.2 Potential environmental impacts from oil and gas development activities (from AMAP 1998)

Activity	Kind of Impact	Sites Affected	Potential Impact Targets
Exploration Phase			
Rigging	Physical disturbance and presence, noise	Locally on site and along transport routes	Soils, permafrost stability, bottom sediments, vegetation, fauna, animal behaviour patterns
Seismics	Physical disturbance, noise	Locally on site	Aquatic organisms (e.g., fish larvae)
Exploratory drilling	Discharges of drill cuttings and chemicals	Locally to regionally	Soil and sediment contamination levels, vegetation, bottom and near-bottom fauna, amenities, and other environmental usage
Accidental spills (blowouts)	Oil discharge	Local (on land) to long-range (rivers, lakes, and sea)	Contamination levels (soils, snow, surface waters, ice, sediments), vegetation and fauna, amenity values, and tourism
Construction phase			
Removal of vegetation	Physical disturbance, noise	Locally on site	Habitat diversity, quality, and availability, erosion, permafrost stability (peat removal), animal behaviour
Technical installations	Physical disturbance and presence	Locally on site	Habitat quality and access, permafrost stability
Excavation and infill of soils and sediments	Physical disturbance	On-site soils and downstream ground and surface water	Water courses and drainage patterns, ground and surface water, soil, and sediment organisms
Road/trail construction	Physical disturbance and presence, noise	Locally	Access, migration routes, erosion, vegetation, animal behaviour
Use of helicopters and supply vessels	Noise, exhaust discharge	Along routes	Contamination levels of water, soils, and organisms, biotope quality, animal behaviour patterns
Dredging and construction of pipelines	Physical disturbance, noise, physical presence	Pipeline trajectory and adjacent areas	Soils, bottom sediments, vegetation, fauna, animal behaviour patterns (migration)
Production Phase			

Well drilling	Discharges of drill cuttings and chemicals	Locally to regionally	Soil and sediment contamination levels, land access, vegetation, bottom and near-bottom fauna
Well production	Discharge of production water and chemicals	Local soils, ground and surface water, surface and shallow sea water, possibly sea floor	Contamination level of soil and waters, vegetation, land fauna, and marine pelagic organisms
Other operational aqueous waste effluents	Wash and drainage water, ballast water, sanitary outlets, operation spills and leakages	Soils, local watersheds, shallow sea water	Contaminant levels, water vegetation and fauna, waterfowl, and seabirds
Flaring, venting, and purging	Air emissions	Wide range owing to atmospheric transport	Greenhouse gas and ozone levels, soil, water, sediment, and organism contaminant levels, human health, vegetation, and fauna
Use of helicopters and supply vessels	Noise, exhaust discharge	Along routes	Contamination levels of water, soils, and organisms, biotope quality, animal behaviour patterns
Accidental spills (wells, pipelines, and transport vehicles and vessels)	Oil discharge	Local (on land) to long-range (rivers, lakes, and sea) distribution	Contamination level (soils, snow, surface waters, ice, sediments), vegetation and fauna, amenity values, and tourism
Decommissioning Phase			
Technical demobilization	Physical disturbance, noise	Locally on site	Soils, permafrost stability, bottom sediments, vegetation, fauna, animal behaviour patterns

Animals in contact with oil suffer from cancer, slow development, and abnormalities of embryos and larvae. Animals with feathers or fur, such as seabirds and some marine mammals, are considered particularly vulnerable to oil pollution. Even small amounts of oil can be enough to reduce the isolative capacity of feathers or fur, resulting in death of the animal from direct cold or indirectly through inability to obtain enough food energy to keep warm. (See fig. 9.5.)

Photo: Courtesy of *Exxon Valdez* Oil Spill Trustee Council

Fig. 9.5 Oiled cormorant on a rocky oil-covered shore in Alaska after Exxon Valdez oil spill

Benthic environments usually recover from oil accidents within 1–10 years. Different species, however, have different sensitivities and recovery times. While brown algae (seaweed) are hardly affected, infauna can suffer greatly from toxic effects of the oil that penetrates the mud surface or through the death of burrowing organisms that normally maintain the air pathways in sediments and mud flats. Reduced airflow results in sediments becoming anoxic (devoid of oxygen), thus slowing down rates of oil degradation.

Two major oil accidents have occurred in the Arctic, so far. In 1989, the oil carrier Exxon Valdez ran ashore in Prince William Sound, Alaska, spilling 41,000 tonnes of crude oil. Roughly 100,000 seabirds, 1,000 sea otters, and several other species were killed in large numbers (*Exxon Valdez* Oil Spill Trustee Council). The largest crude-oil spill on land occurred in 1994 as a result of a pipeline failure in the Usinsk region of the Komi Republic in Russia. Of the 300,000 m^3 of oil spilled, as much as 120,000 m^3 is still trapped in bogs and creek beds in the area. The effects on biota from the Komi spill are poorly known.

Blowouts, spills, and leakage during production and transport of petroleum pose the largest oil pollution threats to the Arctic environment. A blowout from a sea-based oil well during spring ice break would be potentially disastrous. Under ice break conditions, containment of the oil would be extremely difficult and oil burning, as a cleaning method, would be near impossible.

Student Activity

The current US administration is interested in opening up the National Arctic Wildlife Reserve in Alaska for oil and gas development. This issue has long been hotly debated in the United States and elsewhere. What is your view? (See, for example, the Arctic National Wildlife Refuge website, www.anwr.org, and the Defenders of Wildlife website, www.savearcticrefuge.org/, for opposing views).

Minerals

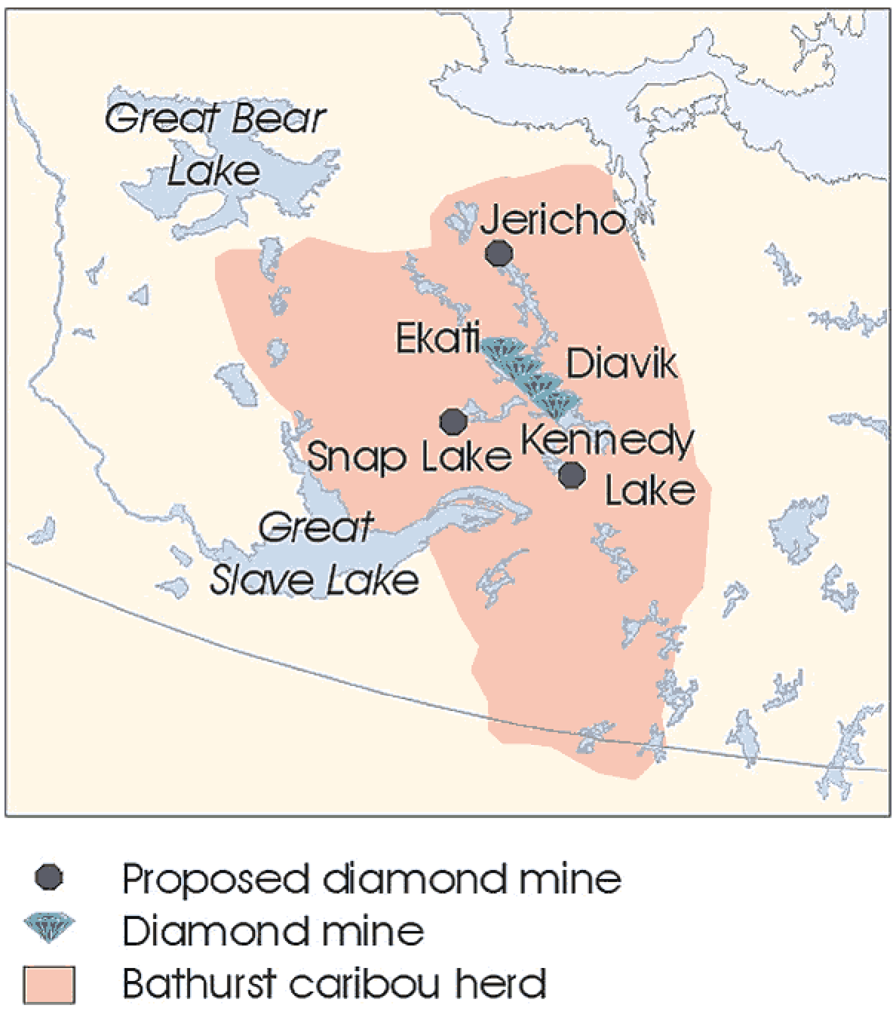
In addition to oil and gas, the Arctic region contains abundant mineral resources. Coal, iron, lead, copper, nickel, zinc, and sulphides are the most abundant and common, but rare minerals, such as gold and diamonds, are also found within the region.

Alaska's mining industry, which achieved record production in 2000, was valued at over US$1 billion/year between 1995 and 2000. Gold, lead, zinc, and diamond production continue to be important to the Canadian Arctic (see Box 9.1). Lead and zinc mining has ceased in Greenland, but a new gold mine has started test production. Russia's non-ferrous mining complexes in Norilsk, Taimyr, and Nikel in the Kola Peninsula are the world's largest nickel producers (see fig. 9.6). There is also exploration for gold and diamonds in the Russian Arctic, for example, in Yakutia. Norwegian and Russian coal mining by has always been important in Svalbard, where mining activities and associated road systems and shipping repeatedly cause concerns among conservationists (see fig. 9.4 and fig. 9.5).

Metals occur naturally in the environment and are present in rocks, soil, plants, and animals. Metals occur in different forms: as ions dissolved in water; as vapors; or as salts or minerals in rock, sand, and soil. They can also be bound in organic or inorganic molecules, or attached to particles in the air. Plants and animals depend on some of these as micronutrients.

Box 9.1. Diamond Mines in the Canadian Arctic (from CAFF 2001, 66)

Diamonds in the Arctic, outside of Yakutia, Russia, are newly discovered phenomena. In 1991, diamond-bearing volcanic shafts known as kimberlite were discovered in a previously untouched region about 300 kilometres north of Yellowknife, in Canada's Northwest Territories. This led to a hectic exploration and claiming period and, by 1998, at least 200 new kimberlite shafts had been discovered. Currently, two mines are operational, the Ekati mine, which opened in 2000, and the Diavik mine, which began producing in January 2003. Diamond mining in the Arctic requires access roads and huge machinery. Some 250 tonnes of earth must be mined and processed in order to produce a single one-carat polished, gem-quality diamond. (See fig. 9.6.)



Source: CAFF (2001, 66)

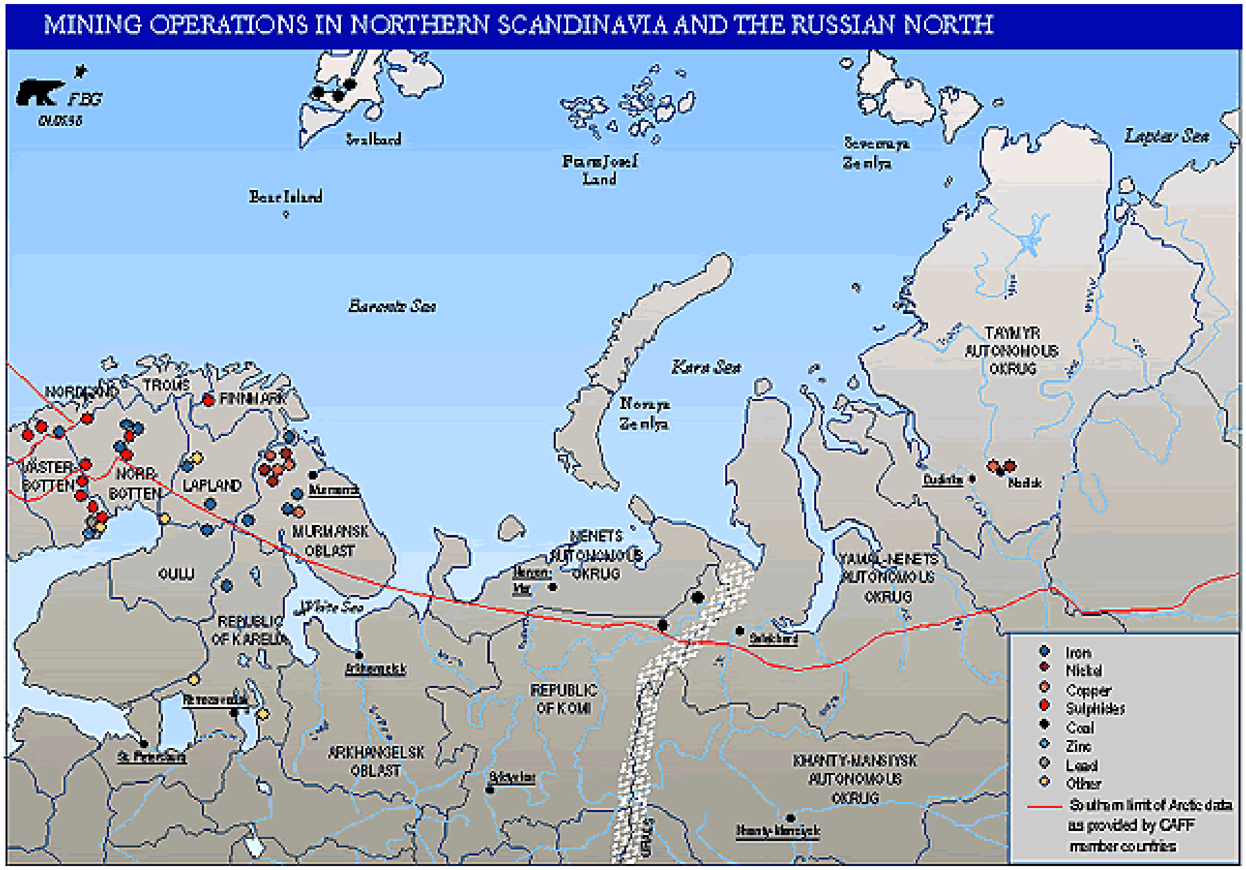
Fig. 9.6 Diamond mines on the range of the Bathurst caribou herd in the Northwest Territories, Canada

Mining Impacts

Many metals, such as iron, copper, and zinc are normally associated with living organisms and are essential for development. These so-called trace metals can, however, become harmful if concentrations grow too high. Other metals, such as lead, cadmium, and mercury, do not play any beneficial role in living organisms and are harmful, even in small quantities. Metals are, in general, more harmful to animals than plants because of their position at the upper end of the food web. Heavy metals accumulate in the bodily fats and can also be transported to unborn fetuses. Animals in danger are especially large carnivores at the top of the food chain. Of plants, lichens and submerged plants are the most susceptible to metal poisoning.

Mining causes serious threats to Arctic species. Water is a vital raw material for, and a major waste from, several mining processes. Poor design of treatment lagoons of waste water may cause contaminated waste water to seep into the ground or run into streams and lakes, where minerals and trace and heavy metals can cause serious problems. If the pH level of the waste water is low, negative effects on biota are more severe. This is especially a problem in the Nordic countries, where waters are naturally weakly buffered and acidic. In Canada and the United States, aquatic ecosystems are more alkaline and better buffered against acidic wastes.

Some of the Arctic's biggest sources of pollution occur on the Kola Peninsula, Russia (see fig. 9.7). The metals that are extracted there, primarily nickel and copper, occur in sulphur compounds. When these compounds are smelted, enormous quantities of sulphur dioxide are released into the environment and damage or destroy nearby vegetation. The area exhibiting vegetation damage has grown steadily in size since the 1970s and is now 4,000–5,000 km^2. In these areas, there is massive forest dieback and the lichen flora is greatly depleted.



Source: Arctic Centre, University of Lapland: Arctic Research Databases

Fig. 9.7 Mining operations in northern Scandinavia and the Russian North

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Student Activity

Are there any minerals found and mined in your community or region? Which ones? Does your community depend on any minerals obtained in the Arctic?

Summary

The Arctic has abundant non-living natural resources, such as water, hydrocarbons (coal, oil, and gas) and a multitude of minerals. Some of these, such as water, are mostly renewable; others non-renewable. No region on Earth, except Antarctica, contains as much water as the Arctic region. Drinking water is essential for all life; running water and steam also provide an important energy source. This energy source is carbon-free and, as such, it does not contribute to global warming. However, harnessing this energy source on a large scale can have significant effects on local biodiversity. There are further large hydrocarbon reserves (especially oil and gas), as well as important mineral regions, in the Arctic. The biggest oil and gas reserves are found in northwestern Russia, which may become the main global supplier of hydrocarbons in the twenty-first century. The exploring, mining, and distribution of oil, gas, and minerals has serious consequences for the environment, which must be taken into account when these natural resources are exploited.

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