3. Arctic natural resources in a global perspective

Lars Lindholt

Large and population-rich developing countries have experienced rapid economic growth in recent years, and we see the footprint of this development in rising demand for raw materials even in remote areas where reserves are available as in the Arctic. The Arctic is endowed with petroleum, minerals, fish and forests that increasingly attract the interest and mobilize the purchasing power of the emerging economies. The Arctic is also of interest to many industrialized countries trying to find secure supplies of many natural resources. In this chapter, we examine the Arctic contribution to global production of some major raw materials. Typically, we will depict production in the natural resource extraction sector in the Arctic as a share of world production. Further, we indicate the Arctic's share of world reserves for some core resources.

Petroleum extraction

Petroleum production in the Arctic is mainly taking place in Alaska and Northern Russia[1]. Around 97 per cent of total Arctic oil and gas production is located in those two Arctic regions. Alaska contributes around 20 per cent of total US production. The centres of Russian oil and gas production are West Siberia and Timan Petchora located in the republic of Komi and the Nenets region. In both these Russian petroleum rich regions, production is land-based. Oil production in Alaska has centred around the Prudhoe Bay field on Alaska's North Slope, where production peaked in the 1980s and thereafter has been in decline in spite of the surrounding new but small field discoveries.

Figure 3.1 shows that the Arctic shares of global oil and gas production are 10.5 and 25.5 per cent, respectively. For petroleum in total, the Arctic region produces 16.2 per cent, a significant share considering the modest size of the Arctic population and economies. Like the Middle East, the cold Arctic offers large areas of land unsuitable for agriculture, but rich in resources that, earlier, were not utilized by people searching for a living.

With respect to proven petroleum reserves, gas is much more important than oil. Of the total global proven reserves of oil and gas, 5.3 and 21.7 per cent, respectively, are located in the Arctic (see Figure 3.2). Almost all of the Arctic proven gas reserves are found in Russia. Also regarding the Arctic oil reserves, we find around 90 per cent in Russia. The oil price is expected to remain high over the next two decades[2], thus Arctic resources are attracting considerable attention, in spite of the relatively high extraction costs in these areas. Consequently, the Arctic is under vigorous pressure to lift production.

In Siberia and Alaska, operations have historically mainly been pursued on land in response to the focus on land-based exploration. Beyond that, the Arctic and its waters represent virgin territory. In Alaska, areas along the northern coast (east of Prudhoe Bay) are regarded as promising for oil and gas discoveries. To US authorities, this represents an opportunity to reduce dependence on oil and gas imports from politically unstable areas. However, these plans have met strong opposition from environmental groups who argue that petroleum production might damage the vulnerable Arctic ecosystem. Russia will also intensify exploration in its Arctic regions, and production is expected from offshore fields on the Russian continental shelf in the Barents Sea and the Petchora Sea[3]. The best-known discovery is Schtokmanovskoye in the Barents Sea, with estimated reserves of around 3200 billion cubic metres of gas. Production of oil and gas for the US market is seen as an important option for development of petroleum resources in North-western Russia. However, Europe will remain a core market for oil and gas exported from this area. Explorations in the Norwegian sector of the Barents Sea (outside Hammerfest in Northern Norway) have yielded several discoveries, including the Snøhvit gas field now under development.

Figure 3.1. Arctic share of global petroleum production. 2002

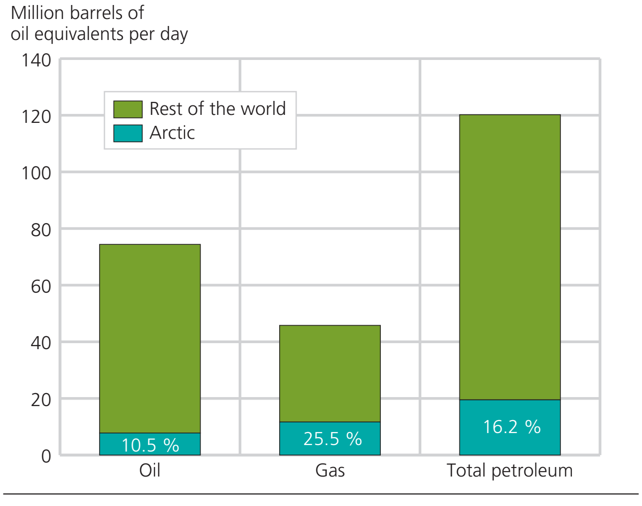
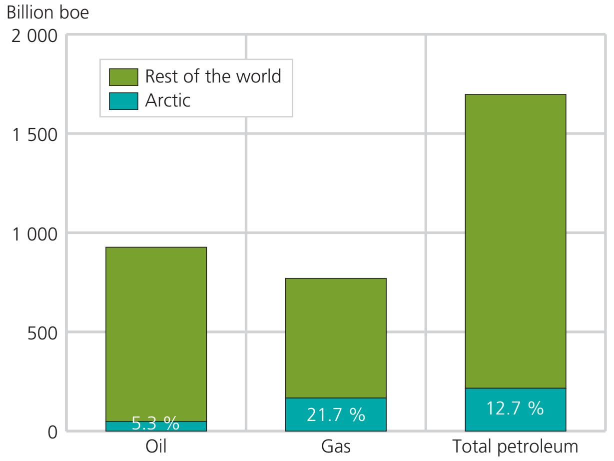
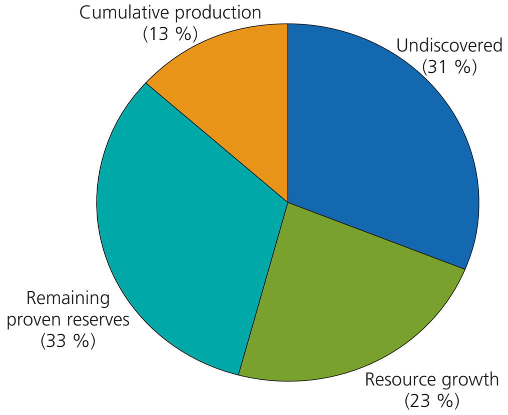


Figure 3.2. Arctic share of proven petroleum reserves.[1] 2002



[1] Quantities indicated with reasonable certainty from geological and engineering information that that can be recovered in the future from known reservoirs under existing economic operating conditions.

Figure 3.3. Global endowments of petroleum resources. 2002



The fact that discoveries are made does not in itself imply that petroleum will come on stream in the near future, particularly not in the Arctic, with such extreme climatic conditions and challenges. It has taken around 23 years to consider and develop Snøhvit, which is expected to start production in 2007. Schtokmanovskoye was proven in 1988, but it is still not under development. High oil and gas prices will tend to counteract such delays, but the environmental, biological and fishery matters represent issues that concern the respective authorities in each case. Many regard the Barents Sea as Europe's last large, clean and relatively untouched marine ecosystem.

In Figure 3.2, *proven* petroleum reserves are displayed. However, besides proven reserves, there probably exist large endowments of undiscovered petroleum resources that may add to reserves if they are discovered. Based on geological evidence and methods, such undiscovered resources can be assessed, including those shared by the Arctic.

The US Geological Survey, completed in 2000, assessed the world's conventional petroleum resources outside the United States[4]. The petroleum geology of each province was investigated and an assessment was made based on this, combining geologic analysis with a probabilistic methodology to estimate total and remaining resource potential. Probabilistic methods attach probabilities to the resource potential in the various geological sediments and regions. In Figure 3.3, we present the USGS's median estimate of resources, i.e., it is estimated that there is a 50 per cent chance of finding at least these amounts of petroleum. The USGS assessment is not exhaustive, because it does not cover all sedimentary basins of the world.

When combining this assessment with estimates for the United States, the world's endowment of recoverable petroleum (including natural gas liquids) is estimated to be at about 5.2 trillion barrels of oil equivalents[5]. Figure 3.3 shows that about 13 per cent of the world's endowment had already been produced by 2002 and an additional 33 per cent had been discovered and booked as reserves. Furthermore, the USGS attribute 23 per cent of the remaining oil and gas resources to resource growth; i.e., the observed increase in reserves for petroleum fields over their lifetime. The initial estimates of reserves in many fields are lower than the ultimate volume of petroleum produced from these fields, due to technical change and better information. Furthermore, the data suggest that undiscovered resources constitute 31 per cent of the world's petroleum resources.

About half of the estimated undiscovered petroleum potential of the world is offshore, especially outside the established provinces of the United States, former Soviet Union, Middle East and North Africa. Arctic basins, which are estimated to hold 23.9 per cent of the undiscovered petroleum resources, may make up the next great frontier (see Figure 3.4). The expected amount of undiscovered petroleum in the Arctic equals around 390 billion barrels of oil equivalents. The Arctic share amounts to 20.5 per cent and 27.6 per cent of undiscovered oil and gas, respectively.

When adding total proven reserves and undiscovered *oil* resources, we find around 13 per cent of the world reserves in the Arctic. As around ten per cent of the global oil production takes place in the Arctic today, this shows that the Arctic has the potential to continue as an important supplier of oil in the future. Various surveys indicate that global oil supplies in many areas outside OPEC will begin to decrease from around 2010–2020[6]. This may put further pressure on developing Arctic areas, especially if many oil-importing countries find this supply more stable and secure than that of many OPEC suppliers. Around 25 per cent of total proven reserves and undiscovered gas-resources are located in the Arctic, matching the Arc-

Figure 3.4. Arctic share of undiscovered petroleum resources. 2002

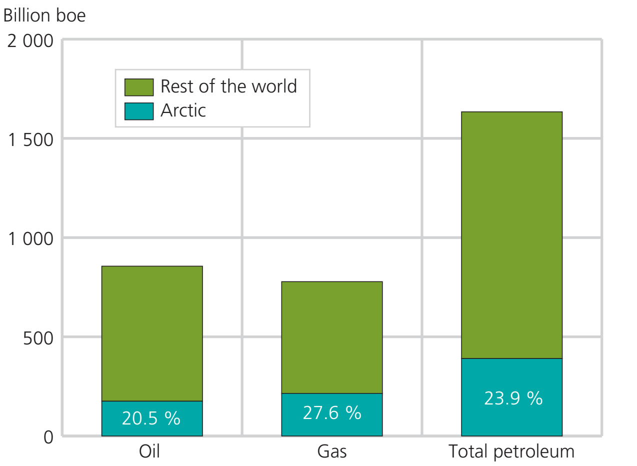
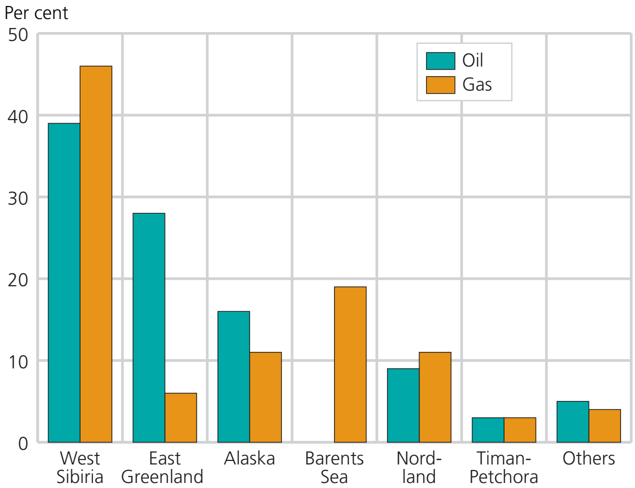


Figure 3.5. Regional distribution of undiscovered petroleum resources in the Arctic.[1] 2002



[1] Timan-Petchora is located in the Nenets region of Russia. The Barents Sea covers both Russian and Norwegian areas.

tic share of global gas production today, which is around 25 per cent. As global gas demand continues to increase in the future, the Arctic has the potential to continue to supply around one-quarter of total demand.

The Arctic Ocean surrounding the geographical North Pole is the core of the region, and its deepest part goes down to almost 5 500 metres. However, the surrounding continental shelf is wide and shallow off Europe and Asia, all the way from the Barents Sea in the west to the Bering Strait. In some areas along this coast, the continental shelf extends a long way towards the pole. The corresponding continental shelves off Alaska, Canada and Greenland are significantly narrower[7].

Norway, Russia, the US, Canada, Iceland and Denmark via Greenland all have an Arctic continental shelf. Arctic Russia embraces by far the largest area and may cover 45–55 per cent of the total volume of the undiscovered oil and gas resources in the Arctic (Figure 3.5).

Areas that contain the greatest volumes of undiscovered conventional oil include West Siberia (in the republic of Komi), Alaska and the Norwegian Sea (Norway). A significant undiscovered oil resource potential is also found in areas that do not have a significant production history, such as Northeast Greenland. Areas that contain the greatest volumes of undiscovered conventional gas include the West Siberian Basin, the shelves of the Barents and Kara Seas, offshore Norway in the Norwegian Sea and Alaska. As not all sedimentary basins in the Arctic have been surveyed, significant *additional undiscovered* gas resources might occur in a number of areas where large discoveries have been made but remain undeveloped, such as East Siberia. The Barents Sea is the least explored part of the *Norwegian* continental shelf. Since its southern area was opened for exploration by the Norwegian Storting (parliament) in 1979, only around 60–70 wells have been drilled there.

Future petroleum production in the Arctic will involve offshore investments. Developers are indeed approaching the new frontier of cold, permafrost and winter darkness, which is challenging on land but even worse at sea. The petroleum industry has not been paying attention to offshore activities in northern waters for more than a decade. To begin with, the strategy was built around massive platforms that could withstand icebergs. Now the industry sees new and better opportunities in smaller and more mobile units that can avoid collisions with heavy icebergs. The harsh environment poses very special demands on technology, and this is also reflected in the level of supply costs. Exploration wells drilled from vessels specially designed for icy waters are expensive. Total supply costs end up being somewhere between three and five times the cost of similar projects in temperate locations. Most conventional Arctic petroleum resources will eventually become profitable at long-term oil prices of between USD 20 and USD 60 per barrel[8]. Extraction of relatively low-cost resources are the type of projects already being developed, while high-cost resources have supply costs estimated at around three times higher than for conventional resources in temperate locations *outside the Middle East*. Many of the promising areas are in Russian waters north off Siberia, where the continental shelf is less than 200 metres deep, even far from the coast.

With a future oil price around USD 60 per barrel and a supply cost around USD 10 in areas outside the Arctic[9], the net value of a barrel of oil from those areas is around USD 50. If the supply costs are three times higher in the Arctic, the corresponding net value will be around USD 30. Hence, although the Arctic contains around 24 per cent of the volume of undiscovered petroleum resources, our simple example shows that the *value* of these Arctic resources is around 16 per cent of the total value of undiscovered petroleum[10]. The purpose of this simple example is not to present exact figures, but simply to stress the fact that the Arctic share of the global *monetary* value of petroleum might be less than the share of the global *physical* value. However, the future cost level is also subject to further technological development based on new experiences in Arctic offshore exploration and production. Learning by doing has not yet flowed through to lower costs in Arctic offshore activities, however. The future will eventually reveal how much of the Arctic resources are recoverable given terms by the markets, the technology and environmental regulations.

Other mining

In addition to oil and gas, the Arctic region contains other abundant mineral resources. However, many known reserves are not exploited because of their inaccessibility. Arctic Russia clearly extracts the largest amount of minerals, but the other Arctic nations also have certain important extractive industries, providing raw materials to the world economy[11, 12].

Below is a survey of important minerals that are found in the Arctic, including coal, iron and ferro-alloy minerals, several non-ferrous minerals and industrial minerals. Due to the numerous types of minerals that exist, the list will obviously not be exhaustive. We also lack data on certain minerals. Some limited information on reserves of the specific mineral will be included in the comments. For information on the application of the different minerals, we have relied on different sources[13].

Mineral fuels

Coal is the world's most abundant and widely distributed fossil fuel. Coal is still the primary energy source for several countries worldwide, and it is used primarily for electricity generation and steel production. Coal is clearly a less abundant fossil fuel in the Arctic than oil and gas. From Figure 3.6 we note that 2.1 per cent of the world's coal extraction takes place in the Arctic, mostly in Russia. There is only some minor production in Norway (Svalbard) and Alaska.

Iron and ferro-alloy minerals

Iron ore is the basic raw material used for the iron- and steel-making industry. Although iron has many specific uses, e.g., pipes, fittings and engine blocks, its main use is in the production of steel. We see from Figure 3.6 that 2.3 per cent of the global iron ore extraction takes place in the Arctic, of which three-quarters is in Kiruna in Sweden.

Nickel is used in the manufacture of stainless steel, steel alloys and super alloys, which all have a major role in the chemical and aerospace industries. Nickel

Figure 3.6. Arctic share of global coal, iron and ferro-alloy mineral extraction. 2002. Per cent

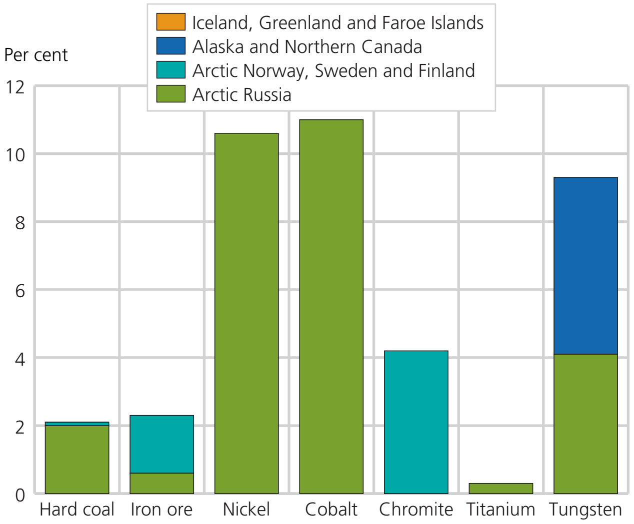
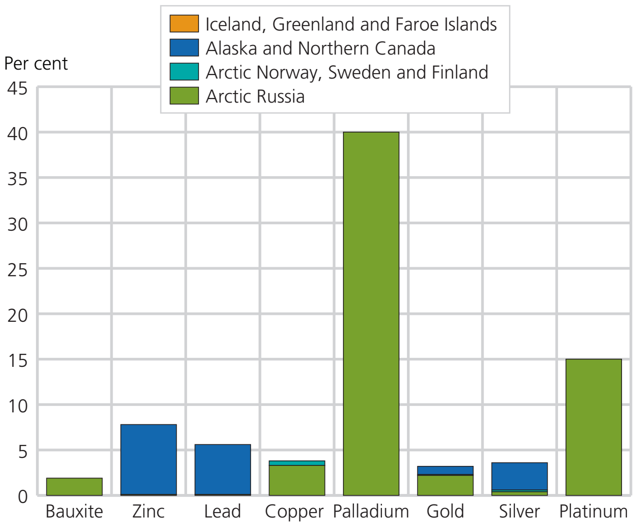


Figure 3.7. Arctic share of global non-ferrous minerals and precious metals ore extraction. 2002. Per cent



is also used in batteries and fuel cells, and as a catalyst in the production of fats and oils. Russia and Canada are two of the world's major producers of nickel, but nickel extraction only takes place in the Arctic regions of Russia. Total production amounts to 10.6 per cent of the world's production.

Cobalt is mainly used as an alloy with iron, nickel and other metals to produce corrosion- and wear-resistant products used in high-temperature applications such as jet engines and gas turbine engines. Cobalt-based alloys are also used in highly durable steels. Cobalt oxide is an important additive in paint, glass and ceramics. Arctic Russian cobalt production is around 11 per cent of global production.

Chromite is used for a host of purposes. It is considered a strategic metal, and is used in alloys for hardening and corrosion resistance. There is no economical substitute for chromite ore in the production

A general view of the diamond pipe Mir in the town of Mirny, in the Siberian province of Yakutia. Scanpix/AP Photo/Mikhail Metzel

of ferrochromium. We also find chromite in paints and glass. Northern Finland is the only Arctic producer, where we find 4.2 per cent of total global production.

Titanium is lightweight, non-corrosive, is able to withstand temperature extremes and has the strength of steel. Titanium alloys have many applications in aircraft, missiles, and space vehicles and even in surgical implants. The Arctic produces around 0.3 per cent of global titanium.

Tungsten is produced in Arctic Canada and Arctic Russia, where we find 9.2 per cent of worldwide production. Tungsten is used for hardening steel and in the manufacture of «hard metal», with a hardness close to that of diamond. Tungsten metal products are extensively used in electric and electronic equipment. It is also used in the chemical industry as a catalyst.

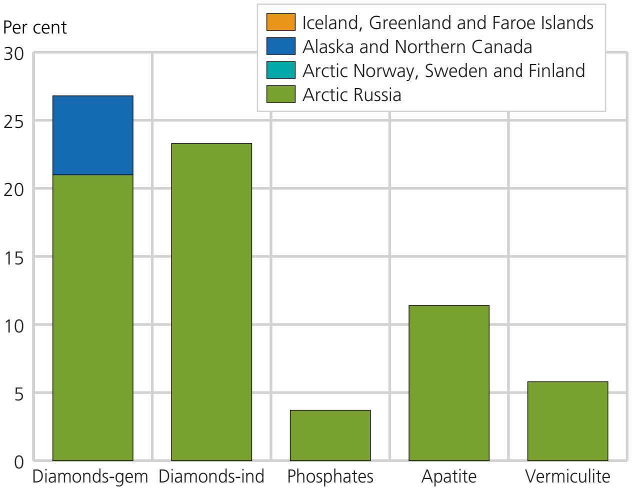
Non-ferrous minerals

Bauxite is the main raw material for the production of alumina, and ultimately aluminium. The production of alumina consumes over 90 per cent of global bauxite output. Applications of aluminium include electrical equipment, and car, ship and aircraft construction. It is also used in metallurgical processes, buildings and packaging materials. Figure 3.7 shows that Russia extracts around 1.9 per cent of global production of bauxite in its Arctic area. With respect to production of aluminium, we find the Arctic's share to be around 3.6 per cent of world production. Russia's bauxite reserves are less than one per cent of the world's total[14] and therefore nepheline and apatite are used as alternatives. These minerals have the disadvantage of needing more energy than bauxite in the production of aluminium. The Murmansk Oblast is the main region of nepheline and apatite production in Arctic Russia and these reserves are considered sufficient for 60–100 years of production.

Zinc is used in special alloys for its unique industrial properties from great strength to unusual plasticity. Zinc coating of iron and steel products makes them more corrosion resistant. Total extraction in the Arctic constitutes around 7.8 per cent of world production. Alaska extracts almost all arctic zinc, with only a small share in Russia. Production in Northern Canada was around 2 per cent of world production during 2000–2002, but the mines were closed due to depleted resources.

Lead has a variety of uses in the manufacturing, construction and chemical industries. The manufacture of lead-acid storage car batteries, chemical products and cables dominate the end uses of lead. Lead is also used in X-ray shielding equipment and at nuclear plants. Environmental regulations (particularly in the western world) now control the use of lead in end-products such as tetra ethyl, paint and as a petroleum additive. A large amount of lead is recycled (from old car batteries), resulting in quite a large «secondary»

Figure 3.8. Arctic share of industrial mineral extraction. 2002. Per cent



production amounting to about 50 per cent of current global lead production. The Arctic produces around 5.6 per cent of the world total, mostly in Alaska and to a minor degree in Russian Arctic regions. Production in Northern Canada was around one per cent of world production during 2000–2002, but, as was the case with zinc, the mines were closed due to depleted resources.

Copper has its end uses in construction and in the electrical and electronic sector. The Arctic produces around 3.8 per cent of total copper production, mostly in Russia and to a minor extent in Northern Finland.

Palladium is mainly used by the car industry for making catalytic converters. It is also used as a catalyst, in the production of nitric acid and in laboratory equipment. Palladium is also used in the electronics industry and as a dental material. Arctic Russia alone produces as much as 40 per cent of the world's palladium. Data suggest that Arctic Russia has around ten per cent of global reserves[15].

Precious metal ores

Gold has historically been used for jewellery and as a base for global monetary reserves. However, gold's role as a monetary reserve has been changing over recent decades, with several banks selling their reserves. This is seen as a move to disconnect gold from currencies. However, most countries hold gold as official reserves and large stocks of gold and jewellery are still held by banks and individual investors worldwide. Gold also has a wide range of uses from catalysts in industrial processes to dental material and for decorative purposes. Of the world's gold production, the Arctic has a 3.2 per cent share, primarily in Arctic Russia and to some extent in Alaska and Northern Canada. A small amount of production also takes place in Northern Finland and Sweden.

Silver is often classified, along with gold and platinum, as a precious metal. Silver is primarily used in photographic paper and film, and for medical and dental purposes. It is also used as jewellery and in the electronic sector. The Arctic extracts 3.6 per cent of the global amount of silver. Around 80 per cent of Arctic production takes place in Alaska, and there is also some production in Arctic Russia and Northern Sweden. In addition, there is some minor production in Arctic Canada.

Platinum is used in jewellery, laboratory equipment, cars, electrical contacts and dentistry. Around 15 per cent of the world's platinum extraction is found in Arctic Russia.

Industrial minerals

Diamonds are famous for their use in jewellery. However, not all diamonds are of gem quality and, in fact, most diamond deposits contain a varying proportion of industrial and gem-quality stones. Industrial diamonds make up about 40 per cent of global production by weight. Industrial diamonds' main use is in lens manufacture and in wires in electrical circuits. Originally, crushed diamonds were used for these purposes, however synthetic diamonds are now being produced in laboratories and pose a threat to global industrial diamond mine production. Synthetic diamonds have replaced natural diamonds in more than 90 per cent of industrial applications. Figure 3.8 shows that Arctic Russia produces 21 and 23 per cent of global gem-quality diamonds and industrial diamonds, respectively. There is an increasing diamond production of gem quality in Northern Canada. In 2002, it constituted around 5.8 per cent of world extraction, but in 2004, the production figures more than doubled[16].

Phosphate rock minerals are the only source of phosphorus globally, and phosphorus is essential for plant and animal nutrition. We see from Figure 3.8 that Arctic Russia produces 3.7 per cent of the world's phosphate minerals of which *apatite* is the most important. Most of the phosphorus is consumed in fertilizers, which are used on food crops. Arctic Russia is one of the world's major producers, extracting 11.4 per cent of global production. As mentioned earlier, apatite is an important raw materials in the production of aluminium in Russia.

Vermiculite is a kind of clay, which is very useful for many industrial purposes. It is very light, chemically non-reactive and fire-resistant. Vermiculite can be used to soak up toxic liquids such as pesticides. This ability makes vermiculite useful as bedding for pets and livestock. In addition, vermiculite can be used in concrete and ceramics as a heat-resistant additive. Of total global production, Russian Arctic regions provide 5.8 per cent.

Table 3.1. Marine fishery in the Arctic. 2002. Million tonnes

Species	North-east Atlantic	Eastern Bering Sea	Western Bering Sea	Central North Atlantic (Iceland, Greenland and Faroe Islands)	North-eastern Canada (Newfoundland and Labrador Sea)	Total
Capelin	0.64			1.12	0.02	1.78
Herring	0.83		0.05	0.27	0.01	1.16
Cod fish						3.58
North-east Atlantic cod	0.49[1]			0.25		
Saithe north of 62°N	0.15					
Haddock, saithe				0.42[2]	0.01	
Pollack		1.50	0.40			
North-east Arctic haddock	0.08					
Blue whiting				0.28		
Greenland halibut	0.01			0.04	0.04	0.09
Pacific salmon		0.04	0.02			0.06
Other groundfish		0.20				0.20
Flatfish		0.06	0.01			0.07
Others	0.01	0.04	0.04	0.23		0.32
Total wild fish	**2.21**	**1.84**	**0.52**	**2.61**	**0.08**	**7.26**
Shrimps	0.06			0.13	0.10	0.29
Snow crab		0.01[3]		0.01	0.05	0.07
Total crustaceans	**0.06**	**0.01**		**0.14**	**0.15**	**0.36**
Aquaculture (salmon, trout)	0.09			0.01		0.10

[1] Includes coastal cod.
[2] See endnote 19.
[3] Includes king crab and Tanner crab.

Fisheries

Data on fishing and aquaculture are available for four large Arctic marine ecosystems: The North-east Atlantic (the Barents and the Norwegian Seas), the Central North Atlantic (the waters around Iceland, Faroe Islands and Greenland), the waters of North-eastern Canada (Newfoundland/Labrador area) and the Bering Sea. The areas seem to cover most of the important commercial fisheries in the Arctic.
The major circumpolar species are capelin, Greenland halibut and northern shrimp. In addition, there are species of high commercial importance in specific regions, like Atlantic cod, haddock, Alaskan pollack, Pacific cod and snow crab.

In 2002, total catch of wild fish in the Arctic amounted to 7.26 million tonnes (Table 3.1)[17]. This constitutes around ten per cent of the world catch of fish. Total catch in 2002 was somewhat lower than the average over the period 1970–2000, but variations among species are large, especially related to the fisheries of cod, capelin and herring. As in the past, fisheries policies and their enforcement and effect on exploitation rates are important for the abundance of different fish populations. Fisheries policies will probably be more important for fish stock levels in the future, than the total effect of climate change[18].

In addition to the marine wild fish catch, there is an Arctic fishery of shrimps and snow crab. In 2002, 290 000 tonnes of shrimps and 65 000 tonnes of snow crabs were landed. The Arctic catch of these two species was 5.3 per cent of the global catch of crustaceans. Total Arctic fish farming of salmon and trout was around 100 000 tonnes or 7.7 per cent of the world aquaculture production of these species.

The North-east Atlantic – the Barents and Norwegian Seas

The fisheries in this area take place in areas under Norwegian and Russian jurisdictions as well as in international waters. The resources in the area are exploited mainly with vessels from Norway and Russia, but also from other countries. While the Norwegian fishing industry is located in many communities along the northern coast, the north-west Russian fishing fleet is based in large cities, primarily in Murmansk. In addition to the Murmansk Oblast, Russia’s northern fisheries comprise Archangelsk Oblast, the Republic of Karelia and Nenets Autonomous Okrug. There is no significant commercial fishing activity east of these regions until the far eastern fishery basin in the North Pacific, i.e., the Western Bering Sea.

Total harvest in the Barents and Norwegian Seas was around 2.2 million tonnes in 2002. This level is somewhat below the average catch from 1970–2000, mainly due to a decline in the catches of cod and capelin. Aquaculture in the North-east Atlantic is dominated by salmon and trout, and produced 86 000 tonnes in 2001.

The Eastern and Western Bering Sea

The continental shelves of the Eastern and Western Bering Sea offer one of the world’s largest and most productive fishing areas. In comparison with other areas of the Arctic, the commercial fisheries of the

North Pacific, including those of the Sea of Okhostk and the Bering Sea, are of relative recent origin. The vast majority of the commercial fisheries started in the 1950s. In the Bering Sea large vessels trawl for groundfish. About 30 per cent of the trawler's total catch is processed at sea and the rest is delivered to processing plants in Russia, Alaska, and other parts of the US.

Total catch in the Bering Sea was around 2.4 million tonnes in 2002, of which 65 per cent was the walleye pollack. The rest of the harvest mainly consisted of Pacific cod and flatfish. Total catch in 2002 matched the average of the last 30 years, mainly due to a relatively stable fishery of pollack.

The Central North Atlantic – the waters around Iceland, Faroe Islands and Greenland

The waters around Iceland and the Faroe Islands are warmer than those around Greenland and are generally ice free. The influence of warm Atlantic water makes the fauna of Iceland and the Faroe Islands particularly rich in species. In contrast, there are only a few commercial fish and invertebrate species in the waters of Greenland.

Total catch in the Central North Atlantic was around 2.6 million tonnes, of which 43 per cent was capelin. Other important species harvested were cod, haddock, saithe[19] and herring. Total catch was not far from the average catch since 1970. However, behind this figure lie increased catches of capelin outside Iceland, and a reduced cod fishery outside Greenland. Total fish farming in 2002 was around 10 000 tonnes of salmon and related species. Total shrimp catch was around 130 000 tonnes, mainly harvested off Greenland. The shrimp harvest has increased over the last decade.

North-eastern Canada (Newfoundland, Labrador Sea)

Fisheries in this region may be divided into those near the coast of Greenland, those near the coast of Canada and those in the deep waters of Baffin Bay and Davis Strait between Greenland and Canada.

The catch of fish in this area is low compared with the other Arctic regions and was around 80 000 tonnes in 2002. The average annual catch from 1970 to 1990 was around 350 000 tonnes. Atlantic cod and species that were not targeted by commercial fishing, declined to very low levels by the early 1990s. Similarly, off Greenland, the shrimp fisheries have increased during the last years and amounted to almost 100 000 tonnes in 2002. Total snow crab catch was around 45 000 tonnes.

Table 3.1 demonstrates that codfish makes up almost 50 per cent of the total fish catch in the Arctic. When we include herring, it amounts to 65 per cent. These species have a higher monetary value than, e.g.,

Figure 3.9. Arctic share of global wood removal. 2002. Per cent

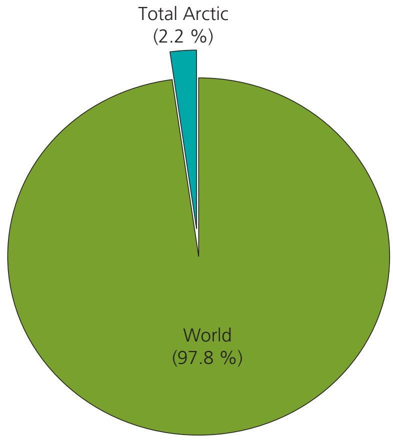
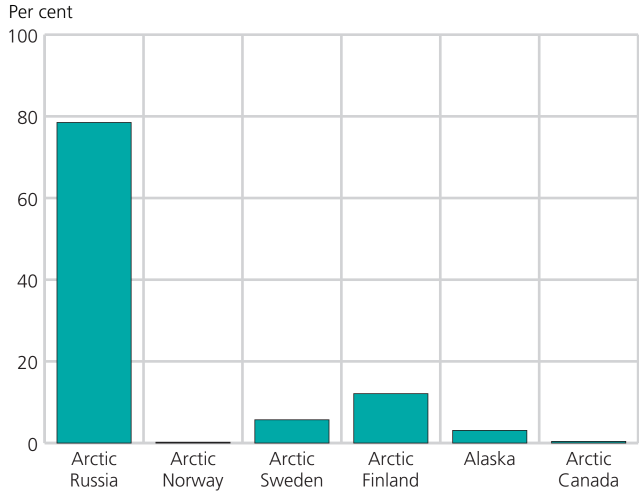


Figure 3.10. Wood removal by region, 2002. Per cent



capelin, anchovy and sardine. However, because capelin is at least as important in the Arctic fisheries (25 per cent) as anchovy and sardines seem to be in the world fisheries[20], it is difficult to draw conclusions about the value share of Arctic fisheries in world fisheries without further investigation.

Forestry

Forests cover 30 per cent of the world's land area and the boreal forests surrounding the northern tip alone cover about 17 per cent of the global land area[21]. The boreal forest is a belt with a limited variety of coniferous species (spruce, pine, larch and fir) and a few broad-leaved species, primarily birch and poplar.

The boreal forests of the Arctic represent the largest natural forests in the world, but most of the boreal forests are uncultivated due to the harsh climate, remoteness and lack of infrastructure. Consequently, only 2.2 per cent of total wood removal, in million cubic metres, takes place in the Arctic, as illustrated in Figure 3.9[22]. Today, most of the Arctic forests are beyond the economic limits for logging and transportation.

Figure 3.11. Arctic share of global wood volume of forests, 2002

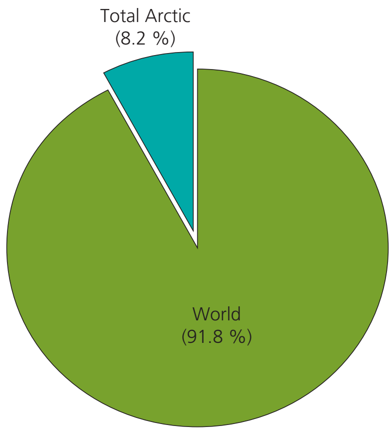
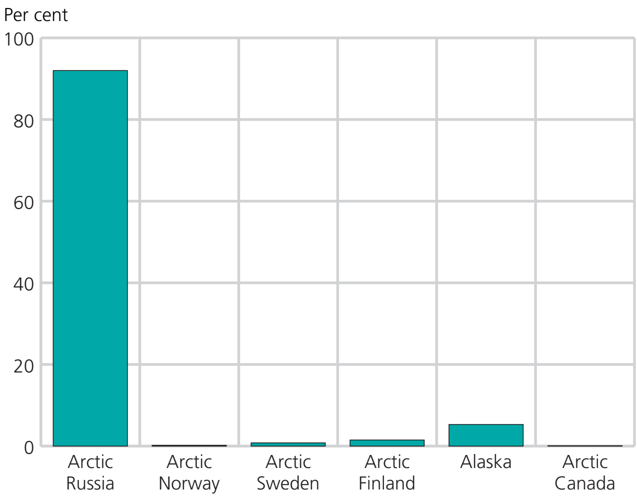


Figure 3.12. Wood volume by region, 2002. Per cent



When it comes to the different regions' contribution to total Arctic wood removal, Figure 3.10 shows that Arctic Russia is clearly the most important. Northern Finland, and to a lesser degree, Northern Sweden and Alaska also contribute to the Arctic production of wood, pulp and paper. The other Arctic areas contribute less than one per cent of the Arctic wood harvest.

Wood removal includes harvesting for several purposes, among them wood fuel, which for a major part is collected by households for their own consumption. The Arctic share of industrial round wood and sawn wood is around 3.4 per cent of the world's production. Clearly, the Arctic is relatively more important in the production of these wood products than in total wood removal. This partly reflects the fact that wood also serves as a major source of fuel in many densely populated parts of the world, e.g., Africa, and that the wood-fuel consumption of the relatively sparsely populated Arctic counts far less in proportion to the total Arctic wood harvest.

With respect to wood volume of forests, around 42 per cent of the earth's resources are found in the countries belonging to the Arctic, mostly in North America and Russia[23]. However, only 20 per cent of the northern forests are in the Arctic area itself. When estimating the Arctic share of the global wood volume of forests, we find the share to be around 8.2 per cent (Figure 3.11) [24]. Hence, the Arctic share of global wood volume is around four times higher than the share of global wood removal.

The Arctic consists not only of forested land, however. Most of the high Arctic consists of vast areas of polar desert and tundra. While the polar desert can be described as open areas of bare ground without any plants, the tundra is characterized by low shrub vegetation.

Figure 3.12 shows how wood volume is distributed among the Arctic nations. Arctic Russia contains over 90 per cent of the wood volume in the Arctic, while somewhat over five per cent is found in Alaska. The other Arctic areas, except Northern Finland, contain less than one per cent of the Arctic wood volume. Again, we see that Russia, with its vast Arctic areas, is very dominant when it comes to holding natural resources.

However, although Arctic Russia has more than 90 per cent of the standing wood volume, it has slightly less than 80 per cent of Arctic wood removal (Figure 3.10) Hence, Russia is clearly more important in terms of wood volume compared with wood removal. This is also true for Alaska, where logging was reduced by 80 per cent during 1992–2003 when two pulp mills closed, owing to a combination of high harvest and production costs and environmental concerns. We see from the figure that Arctic Sweden and Finland, especially, have less wood volume compared with production, thanks to a more benign climate and support from a more developed infrastructure.

Environmental regulations limit the degree of wood harvesting from Arctic forests. In remote Siberian forests and other areas of Russia, production of wood is partly or totally prohibited in order to protect habitats and wildlife. A large proportion of Alaska is managed as a strict nature reserve and as resource land for biodiversity and ecosystem services.

Even if vast areas of the Arctic's forest probably could be more intensively cultivated, the northern forest could also be a significant contributor to carbon sequestration. Certain forest biomass sinks can be used to meet national commitments to reduce the emission of greenhouse gases under the Kyoto protocol. «Carbon cropping» of the Arctic forests could also lead to payments from organizations wishing to sustain or increase carbon storage. If an international, effective system of placing value of transfers of carbon is established, the cultivation of the Arctic forest could lead to increased flow of wealth into the Arctic nations[25].

Russia has already made commitments to the management of carbon stocks, and has obtained substantial carbon emission credits for its participation in the Kyoto Protocol[26].

Concluding remarks

The Arctic population constitutes 0.16 per cent of the world population and the Arctic GDP is 0.44 per cent of the world GDP. Compared with these figures, we find that the Arctic is abundant in many important resources, such as petroleum, several minerals, fish and forest products. The Arctic share of global petroleum production is 16.2 per cent. When total proven reserves and undiscovered *oil* resources are added, we find around 13 per cent of the world reserves in the Arctic. As around ten per cent of the global oil production takes place in the Arctic today, it can be seen that the Arctic has the potential to continue as an important supplier of oil in the future. Around 25 per cent of total proven reserves and undiscovered gas resources are located in the Arctic, matching the Arctic share of global gas production today, which is around 25 per cent. As global gas demand continues to increase in the future, the Arctic has the potential to continue to supply around one-quarter of total demand. The vast majority of the Arctic proven petroleum reserves are found in Russia. Significant undiscovered petroleum resource potential is also estimated to be located in areas that do not have important production histories, such as North-east Greenland.

In addition to oil and gas, the Arctic region contains abundant mineral resources. The magnitude differs between the various minerals, from an Arctic share of 0.3 per cent of global production of titanium to 40 per cent of global production of palladium. Even though Arctic Russia, generally, is the most important region in terms of mineral reserves and extraction, other Arctic areas also have significant amounts of certain minerals.

Total catch of fish in the Arctic in 2002 amounted to around ten per cent of the world catch of wild marine fish. We would need stock figures to outline possible future development of these catches. In addition, the Arctic catch of shrimps and snow crab was 5.3 per cent of the global catch of crustaceans. Total Arctic fish farming of salmon and trout was around 7.7 per cent of the world aquaculture production of these species.

Only 2.2 per cent of total wood removal, in million cubic metres, takes place in the Arctic. Today, most of the Arctic forests are beyond the economic limits to logging and transportation. Even if Russia is clearly the most important in terms of wood removal, Northern Finland, and to a lesser degree, Northern Sweden and Alaska, contribute to the Arctic production of wood, pulp and paper. When estimating the Arctic share of the global volume of forests, we find the share to be around 8.2 per cent. Hence, the Arctic share of global wood volume is around four times that of its share of global wood removal. Around 92 per cent of the Arctic wood volume is found in Arctic Russia.

Table 3.2. Estimated Arctic share of global production and reserves of fossil energy resources[1]. 2002. Per cent

Mineral extraction	Arctic share of global		
	Production	Proven reserves	Undiscovered reserves[2]
Mineral fuels			
Oil	10.5	5.3	20.5
Gas	25.5	21.7	27.6
Coal	2.1		

[1] Some Arctic shares are estimated and must be considered as approximate figures. Consequently, the findings in this table should be treated with caution.
[2] Based on USGS estimates. See endnote 5.

Table 3.3. Estimated Arctic share of global production of some raw materials[1]. 2002. Per cent

Iron and ferro-alloy minerals	
Iron ore	2.3
Nickel	10.6
Cobalt	11.0
Chromite	4.2
Titanium	0.3
Tungsten	9.2
Non-ferrous minerals	
Bauxite	1.9
Zinc	7.8
Lead	5.6
Copper	3.8
Palladium	40.0
Precious metal ores	
Gold	3.2
Silver	3.6
Platinum	15.0
Industrial minerals	
Diamonds - gem	26.8
Diamonds - industrial	23.3
Phosphate	3.7
Vermiculite	5.8
Fishery	
Wild marine fish	10.1
Crustaceans	5.3
Salmon and trout fish farming	7.7
Forestry	
Wood[2]	2.2

[1] Some Arctic shares are estimated and must be considered as approximate figures. Consequently, the findings in this table should be treated with caution.
[2] The Arctic share of global wood reserves is esimated to 8.2 per cent.

In this chapter, we have indicated the Arctic resource sectors' contribution to the global economy in physical terms. Future analysis should include an evaluation of resource values. Even if the Arctic has a large share of world production and reserves of various raw materials, it is difficult to assess the future relative importance of Arctic production. In order to say more about possible future developments in Arctic natural resource extraction, we need more information about the likely extraction costs. Such information would bring us closer to measuring the resource rent, i.e., the excess value of a raw material beyond the supply costs.

Petroleum dominates the resource extraction industries of the Arctic today. Climate policy may add bio-energy to current fossil fuel-related production. The Arctic forests may serve both bio-energy and carbon sequestration purposes. Hence, the resources of the Arctic also provide services that are compatible with a global redirection towards more sustainable development.

We summarize the discussion in this chapter by referring to tables 3.2 and 3.3.

Notes

1 Data on production, proven reserves and undiscovered resources are taken from BP (2006): «Statistical review of world energy», Jumppanen, P. (2002): «Global views and challenges on the development of Arctic technology projects», Paper presented at the conference: Technological Challenges for Sustainable Development in the Arctic, Kajaani, Finland, 17–18 June, Burakova, I. (2005): «Russia should get the Arctic ready for global warming», Pravda, 21. April, Ahlbrandt, T. S. (2001): «Future oil and gas resources of the world – unresolved issues», Conference proceedings from the US DOE Natural gas/renewable energy hybrid workshop at National Renewable Energy Laboratory, Morgantown-West Virginia, US, 7-8. August and Ahlbrandt, T. S. (2002): «Future petroleum energy resources of the world», International Geology Review 44 (12), 1092–1104.

2 See e.g. Aune, F.R., Glomsrød, S., Lindholt, L. and K.E. Rosendahl (2005): Are high oil prices profitable for OPEC in the long run?, Discussion Papers 416, Statistics Norway.

3 NCS – Norwegian Continental Shelf (2004): «Cold opportunities», NCS, 1, 12–17.

4 USGS – US Geological Survey (2000): «World petroleum assessment», USGS Report.

5 See Ahlbrandt, T. S. (2001): «Future oil and gas resources of the world – unresolved issues», Conference proceedings from the US DOE Natural gas/renewable energy hybrid workshop at National Renewable Energy Laboratory, Morgantown-West Virginia, US, 7-8. August and Ahlbrandt, T. S. (2002): «Future petroleum energy resources of the world», International Geology Review 44 (12), 1092–1104.

6 See e.g. Aune, F.R., Glomsrød, S., Lindholt, L. and K.E. Rosendahl (2005): Are high oil prices profitable for OPEC in the long run?, Discussion Papers 416, Statistics Norway.

7 NCS – Norwegian Continental Shelf (2004): «Cold opportunities», NCS, 1, 12–17.

8 IEA – International Energy Agency (2005): «Resources to Reserves», OECD.

9 IEA – International Energy Agency (2005): «Resources to Reserves», OECD.

10 $(60–30)*0.24/((60–10)*0.76+(60–30)*0.24) = 15.9$.

11 For some of the surveyed minerals in Russia, it is difficult to measure the Arctic share. The most important source for separation between Arctic and non-Arctic extraction is the information given in Levine, R.M. and G.J. Wallace (2000): «The mineral industries of the Commonwealth of Independent States», Levine, R.M., Bendiner, M. and G.J. Wallace (2002): «The mineral industries of the Commonwealth of Independent States» and Levine, R.M., Steblez, W.G., Kuo, C.S., Newman, H.R., Wallace, G.J. and D.R. Wilburn (2002): «The mineral industries of Europe and Central Asia», For all three publications, see http://minerals.usgs.gov/minerals/pubs/country. They describe specific mining areas and locations of mines, but sometimes the production figures are lacking detail. The Arctic shares must therefore be regarded as approximate estimates. Consequently, the findings that follow must be treated with caution.

12 Sources: Kommersant (2006): Russia's Daily Online, see www.kommersant.com (Regions of Russia), Szumigala, D.J. and R.A. Hughes (2005): «Alaska's mineral industries 2004", Information Circular 51, Division of Geological and Geographical Surveys, Statistics Canada (2004) and 2005): «Provincial and territorial economic accounts», see also www.statcan.ca/English, Statistics Canada (2006): www.statcan.ca/english, Statistics Finland (2006): www.stat.fi, Statistics Faroe Islands (2005): «Faroe Islands in figures», Statistics Greenland (2005): «Greenland in figures», Greenland Home Rule Government, Statistics Norway (2006): www.ssb.no and Statistics Sweden (2006): ww.scb.se.

13 See Mbendi (2006): www.mbendi.co.za/indy/ming/p0005.htm and Minerals Gallery (2005): www.galleries.com/minerals. The most important source for world production broken down at a country level is Weber, L. and G. Zsak (2005): «World mining data», Bundesministerium für Wirtschaft und Arbeit, Volume 20, Vienna.

14 Leijonhielm, J. and R. Larsson (2004): «Russian strategic commodities: Energy and metals as security levers», FOI Report 1346, Swedish Defence Research Agency.

15 Leijonhielm, J. and R. Larsson (2004): «Russian strategic commodities: Energy and metals as security levers», FOI Report 1346, Swedish Defence Research Agency.

16 Diamonds in Canada (2004): see www.ainc-inac.gc.ca/ps/nap/diamin/dianarr_e.html

17 Sources: ACIA (2004): «The Arctic climate impact assessment», Cambridge University Press, FAO (2005): «Review of the state of world marine fishery resources», FAO Fisheries Technical Paper 457, ICES – International Council for the Exploration of the Sea (2005): «Report of the Arctic fisheries working group», AFWG: 20, Copenhagen, Statistics Faroe Islands (2005): «Faroe Islands in figures», Statistics Greenland (2005): «Greenland in figures», Greenland Home Rule Government and Statistics Norway (2005): «Fishery Statistics 2002–2003", Official Statistics of Norway D321.

18 ACIA (2004): «The Arctic climate impact assessment», Cambridge University Press.

19 Some of the haddock and saithe fishing in table 3.1 may contain other species, see e.g. Statistical Faroe Islands (2005): Faroe Islands in figures.

20 Statistics Norway (2004): «Natural resources and the environment. Norway», Statistical Analysis 70.

21 See FAO (2005): «Global forest resource assessment», available at www.fao.org. Sources for wood removal and wood volume of forests are ACIA (2004): «The Arctic climate impact assessment», Cambridge University Press, FAO (2005) «Global forest resource assessment», available at www.fao.org. , Goldsmith (2006): Personal information, Kommersant (2006): Russia's Daily Online, see www.kommersant.com (Regions of Russia), Statistics Canada (2006): www.statcan.ca/english, Statistics Finland (2006): www.stat.fi, Statistics Norway (2006): www.ssb.no and Statistics Sweden (2006): www.scb.se.

22 Wood removal used for wood fuel, industrial roundwood, sawnwood, wood-based panels, paper pulp, paper and paperboard.

23 Wood volume refers to total volume over bark of living trees, usually above 10 cm in diameter at breast height. For some countries, the stem volume of all living trees is included. See FAO (2004): «FAOSTAT statistical database», Rome, available at apps.fao.org/faostat/collectionc.

24 For some Arctic Russian regions, it is difficult to find up-to-date figures for both wood removal and wood volume of forests. See ACIA (2004): «The Arctic climate impact assessment», Cambridge University Press and Kommersant (2006): Russia's Daily Online, see www.kommersant.com (Regions of Russia). The Arctic shares must therefore be regarded as approximate estimates. Consequently, the findings that follow must be treated with caution.

25 ACIA (2004): «The Arctic climate impact assessment», Cambridge University Press.

26 Webster, P. (2002): «Climate change: Russia can save Kyoto, if it can do the math», Science, 296, 2129–2130.

Box 3. Notes on Gross Domestic Product and Value Added Comparisons Across Arctic Regions

Gross Domestic Product (GDP) is the total value of final goods and services[1] produced within a territory in a specified time period. It is one of the important measures of the level of economic activity in a region, along with employment and personal income.

GDP is a measure of how much output a region can produce as well as how much income it can generate from that production. In this regard GDP is equivalent to Value Added (VA), defined as the economic contribution to goods and services production at each step in the production process by the factors of production—mostly labor and capital. Since the sum of value added equals both the value of output and the income to factors of production, total income equals total output.

The international standard for measuring GDP is established in the System of National Accounts (SNA93) prepared by representatives of the International Monetary Fund, European Union, Organization for Economic Cooperation and Development, United Nations, and World Bank. The rules and measures for the measurement of national accounts are designed to be flexible, to allow for differences in local statistical needs and conditions.[2] GDP statistics are available for most countries and are commonly used to track and compare economic performance.

GDP is generally measured in the local currency, and so to compare the economic activity or performance between different countries requires that they be converted to a common base, typically using either the currency exchange rate or the purchasing power parity exchange rate. The choice depends on the objective of the comparison. The former compares the international purchasing power of different economies. The latter is a better measure of the domestic purchasing power of the average producer or consumer within the countries. Some implications of this choice with relevance for The Economy of the North are illustrated in Box 1, pages 14-15.

Analysts using GDP as a measure of economic performance for a country need to keep in mind that it has a number of well-known shortcomings including:

1. Non-market transactions (child rearing, homemaker production, etc.) are generally excluded.
2. Economic «bads» are included. More production simply means a higher GDP, regardless of what is produced.
3. The value of leisure and other aspects of the quality of life are excluded.
4. The distribution of income across the population is not measured.
5. The sustainability of production is ignored.

In many countries GDP is also calculated at a regional level, allowing comparisons between regions within a country as well as between regions in different countries. These comparisons need to recognize certain features of regional GDP calculations, particularly when the regions are small and remote.

1. Residency—GDP is a measure of the value of production within a region, regardless of the residence of the labor used in production or the ownership of the capital. A companion measure at the national level, Gross National Product (GNP), measures the value of production by the residence of the owners of the labour and capital used in production, wherever that production takes place, but there is no comparable figure at the regional level, at least in the United States.

This can be a problem when using GDP as a measure of the income of a small and remote regional economy. A significant share of the work force could consist of commuters or seasonal workers who live outside the region. A large share of the capital could be owned by non-residents and the profits from production could leave the region. If these conditions are true then the income accruing to the residents of the regional economy will be less than the value of production.

It is also possible that the opposite would be the case. The state of Alaska controls a large investment fund, the Alaska Permanent Fund, with a portfolio of investments that is entirely outside the state. Each year the Fund generates several billion dollars of income that is not included in Alaska GDP because the production associated with those investments occurs outside the state.

2. Federal Assistance—A remote rural region of a national economy may be dependent upon assistance from the central government to pay for and provide public services, over and above the level that taxes from the region to the central government can provide. In such a case the GDP, which generally includes all public sector spending in the region, will be an overestimate of the productive capacity of the region itself by the amount of the «subsidy». For example, an increase in the subsidy will increase GDP, even though it does not represent a strengthening of the regional economy.

3. Location of Production—When production involves inputs located in different regions it can be difficult to allocate the share of value added attributable to each region. For example oil production on Alaska's North Slope depends on the inputs physically located in Alaska, but also on capital and labor inputs located in the headquarters offices of the oil companies outside the state. Allocating economic rents (the value of output in excess of that required to compensate capital and labor) between regions in this case is arbitrary.

Production may occur in one region and be reported in another. A share of the seafood harvested in the ocean adjacent to Alaska is done by boats headquartered outside the state. The value of their harvest is reported as occurring in other locations rather than in Alaska.

4. Valuing Subsistence Activities—A share of the population in many remote rural regional economies engages in productive activities outside normal economic markets, such as the subsistence activities of indigenous people. The valuation of these subsistence activities can be handled in several different ways in the GDP accounts. They may be excluded altogether as is the case in the United States. If they are included, there may be differences in the types of activities included. For those included activities valuation may be done by comparison of the outputs to similar outputs that have market prices (replacement value), by valuing the outputs at the cost of the inputs, or by some other method of imputing a value to the activity.

5. Price Variation—Small remote regional economies may be dominated by a limited number of primary commodity producing industries. The value added in the production of those commodities can be quite volatile from year to year because of volatility in their market prices. The Alaska GDP is heavily influenced by the importance of oil production, and much of the change in GDP from year to year is a result of the change in the price of oil rather than any change in the physical output of the economy.

This volatility means that comparisons with other regions are sensitive to the year in which the comparison is made. A comparison when the price of oil is high will indicate a larger Alaska economy relative to other locations than would be the case of a comparison when the price of oil is low.

6. Data Collection Difficulties—The small size of regional economies results in less precision in estimates of GDP based on sampling (due to sampling error). Remoteness can also contribute to imprecision due to the challenges of data collection associated with travel, weather, and other variables.

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[1] Including exports.

[2] Countries may differ in the types of non-market activities they chose to include in GDP. They also may differ in which prices they use to present output figures. Among the alternatives are market prices (including any sales, property, and excise taxes) or factor costs (market prices net of taxes which are not a return to a factor of production).

Village of Uummannaq, Greenland/ Scanpix