6. Climate change in the Arctic: A discussion of the impact on economic activity

Gunnar S. Eskeland and Line Sunniva Flottorp

The Arctic has vast reservoirs of natural resources serving the world market, and extraction of these on a massive scale largely underpins all other economic activity. Also, and only in part related to this, government's civilian and military presence is important, both in terms of service provision and income generation in the Arctic. Finally, subsistence activity continues to be important to a large number of households and small



communities. In this chapter we discuss the impact of climate change in the Arctic region, and in particular how it relates to the economy.

Our discussion is predominantly in qualitative terms. This relates to the nature of present knowledge of climate change and its impact on the Arctic, but also to our present understanding of the structure of regional and local economies. The knowledge of climate change in the Arctic in both qualitative and quantitative terms is thoroughly described in the 2005 report from the Arctic Climate Impact Assessment (ACIA), which is an important source for this chapter, together with the 2001 report from the Intergovernmental Panel on Climate Change (IPCC).

Expected climate trends in the Arctic

The ACIA report concludes that increased atmospheric concentrations of greenhouse gases (GHGs) are likely to have larger and more rapid effects on the climate in the Arctic than in any other region, and the report found that average temperatures in the Arctic have risen at almost twice the rate of the rest of the world. In addition, ACIA warns that the consequences associated with these changes will be serious and felt far beyond the Arctic region.

To a great extent, the expected climate-induced changes in the Arctic are associated with warmer temperatures, degrading permafrost as well as changes in precipitation and extension of snow and ice. One such expected change is more winter rains, leading to faster melting of snow and ice, and possibly flooding in some areas. Table 6.1 briefly lists the expected changes, uncertainty and regional variation, as well as impacts on natural systems.1

Another expected outcome of climate change is increased exposure to extreme weather events. When one part of the Arctic gets warmer, the temperature increase can change the strength and direction of wind and water currents, which can result in a decrease in temperature in other parts of the Arctic. The observation that climate impacts may be neither linear nor smooth seems to be particularly appropriate for the Arctic.

In the Arctic, the sea ice cover is an important climatic factor. It affects surface reflection of solar radiation, cloud cover, humidity, exchanges of heat and moisture at the ocean surface, and ocean currents. Over the last 30 years Arctic sea ice has become thinner and its extent has been reduced by approximately 8 per cent ². The expected impacts resulting from reduced sea ice include increased air temperatures and decreased salinity of the ocean's upper layers, as well as coastal erosion.

Climate change in the Arctic will happen over time. Most changes are expected to be gradual, and as the climate changes, the people and economies will adapt. To give a general idea of time perspectives, ACIA has studied possible scenarios to 2070–2090. Thus, it is expected that the impacts of climate change as described in ACIA and in this chapter will

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Table 6.1.	Expected	climate	change a	ina imp	Jacts In	the	Arctic

Climate change indicator	Expected change	Average over period	Uncertainty and regional variation	Physically projected changes	Impacts in natural systems
Changes in temperature (2071–2090)	1	3.7°C in the Arctic 1.9°C globally	3°C Scandinavia and East Greenland 2°C Iceland 5°C Canadian Archipelago and Russian Arctic	-melting glaciers -reduction in extent and thickness of sea ice -thawing permafrost -rising sea levels	-the Arctic climate is warming with temperatures during the winter increasing more rapidly than in the summer
Changes in precipitation (2071–2090)	1	12.3% in the Arctic 2.5% globally	5-10% in the Atlantic sector 35% locally in the high Arctic Autumn and winter greatest increase	 -increase in water availability for soil infiltration and runoff -increase in fresh water supplied to the Arctic Ocean, which will increase the stratification of the Arctic Ocean, facilitate formation of sea ice, and enhance freshwater export from the Arctic ocean to the North Atlantic -likely degradation of coastal permafrost in some areas 	-increase in plant growth in regions that are presently moisture-limited -Increase in river discharge is likely to increase nutrient and sediment fluxes to the Arctic Ocean with corresponding effects on marine ecosystems -Higher flood rates in rivers cause accelera- ted flood events -wetland ecosystems are likely to expand
Changes in sea ice (2000–2100)	ļ	-17.2% Northern Hemisphere	Regional differences are small Both winter and summer sea-ice retreat projected to be greatest in European Arctic, Chukotka, Alaska and Western Canada	 -increase in atmospheric humidity, cloudiness and precipitation -higher ocean temperatures and salinity -biogenic aerosol fluxes likely to increase -possibly stronger low-pressure systems which increase sea levels and storm-surge height, as well as wave generation 	-expected phytoplankton blooms and marine food web changes -distributions of fish stocks will be affected -marine mammals that depend on sea ice must find new habitats -whale migration routes are likely to change
Changes in snow cover (2071-2090)	ļ	9 to18% retreat in snow cover	Seasonal retreat in snow extent -3.8% Winter -4.9% Spring -1.1% Summer -3.3% Autumn	-surface energy budget (soil temp and perma- frost) and the surface moisture budget (runoff, evaporation) will be affected -earlier pulse of river discharge to the Arctic Ocean and coastal seas -less snow, and shorter snow season, will influence the distribution of vegetation	-accumulation component of ice sheets and glaciers decreases -the ground thermal regime will be influenced, thus warming the soil and thawing permafrost -the growth of seasonal high-latitude vegetation will be affected, as snow insulates underlying vegetation and other biota

happen before 2090. To what extent and when the climate effects will become visible depend on how the Arctic adapts to climate change.

Climate change in the Arctic might make some economic activities in the region more profitable and others less profitable or non-viable. As an example of the former, higher ocean temperatures may increase fish growth (at least up to a certain point), and thus increases the amount that can be sustainably harvested. In the case where higher temperature increases fish growth, harvesting costs for fish in the Arctic are reduced, and both profits and the supply of fish is increased. Generally, such cost reductions will lead to overall improvements in welfare in the Arctic and in the non-Arctic, but distributional impacts may be such as to be negative for some. As we will show in the following, nature based activities in the arctic are sensitive to climate change, but there is great uncertainty as to which will be impacted negatively and which positively. What is clear is that change will be challenging, as both real assets, people and institutions are based on conditions that will be changing.

A sectoral perspective on climate sensitivity

Climate-induced changes in the Arctic will affect nature and society. Our focus here is on selected naturebased activities, reflecting a combination of their importance in the Arctic region and their sensitivity to changes in climatic conditions. The main naturebased activities in the Arctic are fisheries, agriculture, livestock, forestry, hydroelectric power and other renewable energy sources, fossil fuels, mineral extraction, tourism and transportation infrastructure. These activities are dependent on the environment and can have a relatively large impact on it. Table A-1 in the appendix gives a detailed overview of the main activities in these sectors across the Arctic regions.

The tertiary sector (service sector) is by far the dominant sector in the Arctic: see Chapter 1. It accounts for more than 50 per cent of all economic activity. Public administration, in general, accounts for approximately 20 to 30 per cent of all economic activity. In addition, the development of other service industries, such as trade, transportation and real estate, accounts for a large share of the Arctic tertiary sector. We include a tentative discussion of whether and how the government sector itself is likely to change as a result of climate change in the region. However, our main focus is on the direct potential impacts of climate change on nature-based activities. Their importance may go beyond their quantitative share of the formal economy, since they provide the basis for life in many Arctic communities. As an example, fishing may be more important to a fishing village than its share of employment would indicate, since subsistence fishing provides food and sustains a way of living.

Figure 6.1. Possible changes in selected Arctic fish species' location in the Norwegian and Barents Seas resulting from an increase in ocean temperature of 1 to 2°C



Source: ACIA (2004)

Marine fisheries

Arctic marine fishing is an important food source for the Arctic nations, and in scale and income terms the catch is also an important export commodity and constitutes a large share of the economy of the Arctic region. The total fish catch in the Arctic constitutes approximately 10.1 per cent of the world catch of fish. Climate changes are expected to impact on marine fishing in several ways across the Arctic. Warmer sea temperature is expected to increase stock productivity for many species. It is also likely that shifts in the ecosystems will lead to changes in fish migration routes. As an example, cold-water species are expected to migrate further north, or their stocks will decline. Examples of changes that cause reductions in fish stocks are changes that either improve conditions for com-



Figure 6.2. Norwegian herring spawning stock and ocean temperature

peting species or changes in ocean currents that degrade favourable nutrient conditions.

Moderate warming is likely to improve the conditions for cod and herring, as higher temperatures and reduced ice cover could possibly increase the productivity of their prey and provide a more extensive habitat. Nevertheless, many species are expected to migrate further north or decline in stock, as described in Figure 6.1. One consequence of this can be increasing harvesting costs, perhaps making some fishing activities (and communities) non-viable.

An additional effect of climate change is the introduction of new species in Arctic waters. Changes in ocean currents, nutrient availability, salinity, and the temperature of ocean waters can be expected to influence the distribution of larval and juvenile organisms, the growth rates of individuals, and the population structure of different fish species³. An example provided by IPCC is that during a warm phase between the 1920s and the 1960s, Norwegian herring fed in Icelandic waters, but disappeared when the water temperature cooled by 1°C (see Figure 6.2). Overfishing was the primary cause of the collapse of the population, although climatic cooling was probably a contributing factor.

Considering the economic impacts of these changes, the fishing industry in the Arctic will probably experience changes in stocks that can be positive or negative. The general picture can be visualized as in figure 6.3 which displays growth rates for freshwater species in the arctic. It can be seen that fish species all have their ideal temperature, above and below which they display lower growth. Northern species in blue (A: Arctic char, B: Lake cisco, C: Lake trout, and D: Brook trout) have their peak conditions at lower temperature ranges and also display more peaked curves, so their ability to adapt to climate change might be very limited.⁴ The unlabelled growth curves are for various lower latitude species.





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The Economy of the North

For marine species, additional questions relate to migration, so that harvesting sites may change considerably. For each, it is uncertain whether higher or lower yields will result, and a similar uncertainty exists about harvesting costs.

Cod and herring are very important commercial marine species in the atlantic arctic region, and both of these are generally assumed to benefit from increased plankton growth associated with higher temperature and less sea ice5. For cod, the longer time series display migration further north and east as well as higher weight in warmer periods during the last century. But the uncertainty about fisheries related to climate change is high, not only because more than temperature changes is involved. An important illustration of this is that a healthy fish stock depends on closing its life cycle geographically, a question that depends on a coincidence between where ocean currents carry larvae, nutrient availability, and other factors. There is thus little reason to rely on the basic logic that higher temperatures improve living conditions: as important is the fact that change challenges an observed state, and thus introduces unpredictability.

The great complexity of changes in ocean currents, temperature and nutrient availability makes predictions about how fisheries will be affected by climate changes in the Arctic uncertain. An expected increase in ocean temperature alone could improve growth conditions in northern waters; nevertheless there is a great possibility that an increase in ocean temperature will be accompanied by changes in other factors, such as available nutrients. Similarly, since migratory patterns as well as competition between species might change, it is likely that positive effects on fishing in some areas will occur together with negative ones in the same or other areas. It is possible that the overall effect6 on fishing will be negative, even if there is assumed tendency towards improved growth conditions in Arctic waters.

Fish farming

Considering fish farming, expected impact of climate change is that warmer water will increase fish growth rates and expand areas suitable for cultivation. However, if the sea temperature changes too much and the temperature exceeds the temperature tolerance of the farmed species, increased incidences of fish diseases and algal blooms are expected.

Agriculture, livestock and forestry

The boreal forest⁷ covers about 17 per cent of the global land area.⁸ However, a large part of the boreal forests is not commercially harvested to any significant extent. This is because of harsh climatic conditions increasing the costs, and the scale of transportation costs to markets. Hence, only 2.2 per cent of the world's wood removal in million cubic meters takes place in the Arctic. Climate change is expected to cause vegetation shifts, which are likely to create taller, denser vegetation and new wetland development as permafrost areas are thawing. Forests are likely to expand, and the total number of species present is projected to increase. Further, forest fires are a major climate-related disturbance in the boreal forest⁹. Forest fire is strongly controlled by both temporal and spatial patterns of weather and climate, and effects are therefore not easily predictable.

The boreal forest is affected by, and also contributes to climate change, through its influence on the carbon cycle. Figure 6.4 illustrates changes in the Arctic carbon cycle as the climate warms. Beginning at the left of the figure, the boreal forest absorbs CO_2 from the atmosphere via photosynthesis and vegetation growth. This absorption is expected to increase, although forest fires and insect damage will increase in some areas, releasing more carbon to the atmosphere. Increasing amounts of carbon will also move from the tundra to ponds, lakes, rivers, and the continental shelves in the form of carbon dissolved in water (dissolved organic carbon, dissolved inorganic carbon, and particulate organic carbon).

In addition, climatic warming is likely to alter animal husbandry. Concerns include the presence of deep snow with an ice surface that stops animals from obtaining forage, regional overgrazing, and establishment of southern weedy species under a warmer climate¹⁰. In northern areas of Norway, Sweden, Finland and the Kola region of Russia, indigenous people pursue reindeer husbandry on the basis of ancient rights. However, since these rights are exercised across four nations and legal systems, jurisdictional complexity counteracts adaptation of the herding system in response to climate change.

Agriculture in polar lands is limited by the harsh climate, contributing only 1-2 per cent of regional GDP. Agriculture in the Arctic regions mostly produces forage crops and climate-adapted vegetables and grains in addition to livestock and reindeer herding. Temperature increases are likely to move the grain production boundary northward. Climate changes that increase growing-season length and daily maximum temperatures, while maintaining or slightly decreasing the persistence of growing-season clouds and rainfall, are likely to be favourable to agricultural production in the Arctic region. In brief, agricultural opportunities are likely to remain of minor importance to the Arctic economy.

Hydroelectric power and electricity production

Many of the countries in the European Arctic rely on hydropower for electricity generation: see Table A.1 in the appendix. Climate change could affect the re-

Figure 6.4. Changes in the cycling of carbon in the Arctic as the climate warms



newable electricity sector in several ways. Precipitation changes will influence inflow, storage and production, with the possibility that existing dimensions of dams and the distribution network are poorly suited for new precipitation patterns. The thawing permafrost may affect hydropower production facilities negatively, but increased precipitation is likely to increase hydropower yields, in particular as adaptation and new construction takes the changed conditions into account.

Wind power and tidal power development are potentially important energy sources for some of the Arctic regions. Both onshore and offshore wind energy may become more important. More wind can result in higher effectiveness and economic potential of wind power, but this again depends on weather patterns. Ice combined with wind could represent a risk for the electricity cables.

For other parts of the Arctic regions, the dominant sources of electricity production are the conventional combustion of fossil fuels and nuclear power. In the discussion in this chapter, it is assumed that these production facilities will not be influenced by climate change. However, any production facilities as well as their logistics could be potentially impacted by changes such as thawing permafrost.

Fresh water

The Arctic landscape is dominated by ice and freshwater systems. As fresh water supplies decrease in the rest of the world, Arctic lakes, rivers and ice reservoirs may become increasingly important as possible fresh water supplies. As an example, there have already been proposals to tap some of these resources. The European Environmental Agency notes in a 2005 report that Russian newspapers have recently referred to plans, originally dating from the early 1970s, to divert the river Ob and other northbound rivers towards water-starved regions in the south. If such plans were implemented, the impacts and consequences could be major. A diminishing flow of fresh water into the Arctic Ocean will affect ice formation off the Siberian coast. The consequences for marine productivity, and possibly also ocean currents and climate, are unknown but potentially dramatic¹¹. It is unclear how such interventions would relate to international conventions

Petroleum and mineral extraction

Most of the regions in the Arctic have both onshore and offshore production and exploration of a variety of non-renewables: see Table A.1 in the appendix. The Arctic holds a great share of the world's oil, coal and gas reserves. As shown in chapter 3, the arctic presently produces about 10 percent of the world's oil and a quarter of its gas, and for these critical commodities the region's role is estimated to be greater in he future.

For oil and gas, climate change will challenge the petroleum sector in many ways. Offshore oil exploration and production is likely to benefit from less extensive and thinner sea ice, although equipment will likely be costlier as it will be required to withstand increased wave forces and ice movement. Onshore, the impact of climate change is likely to lead to increased costs, but offshore the consequences are uncertain and will probably vary.

The Arctic regions are categorized by extreme weather conditions. The increase in temperature and melting sea ice will open new sea routes, but will increase the frequency of icebergs, which may damage sub-sea pipelines and offshore petroleum production facilities. Conditions in Siberia and Alaska will also be challenging, with thawing permafrost making it more difficult to transport heavy equipment over the tundra. In addition, swings in temperature will cause the frozen ground to move and thus threaten to destabilize oil and gas pipelines.

Increased activity in this sector is expected not only from climate change-related factors, such as increased access caused by receding sea ice, but also from changes such as improvements in offshore technology, oil-price development, and the political landscape in the Arctic. The International Energy Agency has estimated that the cost of petroleum extraction in the Arctic is about three times higher than in other petroleum provinces (see chapter 3). However, the Arctic regions represent stable political and institutional conditions, providing opportunity for long-term involvement for oil companies that elsewhere face diminishing access to oil provinces operated by national oil companies.

Beyond fossil fuels, the Arctic has large reserves of minerals, ranging from gemstones to fertilizers: see appendix Table A.1 as well as the treatment in chapter 3. Russia extracts the largest quantities of these minerals, including nickel, copper, platinum, apatite, tin, diamonds and gold, mostly on the Kola Peninsula but also in the northern Ural Mountains, the Taymir region of Siberia, and the Far East. In the Canadian Arctic—which includes Nunavut, Yukon and Northwest Territories— lead, zinc, copper, gold and diamonds are mined. In Alaska, lead and zinc are extracted from the Red Dog Mine, which sits atop twothirds of the US zinc resources. In addition, Alaska mines gold in several locations.

Generally, mining on land is believed to benefit from permafrost, since it is easier to build and move heavy equipment on frozen ground. Thus, the mining industry in the Arctic may experience increased costs as permafrost in the region shrinks, but such effects are likely to vary by region and type of activity. In addition, storm surges and erosion will also increase costs. As with petroleum and gas extraction, mining activities in the Arctic are important contributors of raw materials to international markets, and likely future expansion relates not only to climate change but also to changes in technology, costs, and transportation availability. Transportation itself is affected by climate change, and itself implies challenges in terms of environmental management and international institutions.

Tourism

Tourism is expected to experience a longer season; however the sector is very dependent upon weather conditions. These are likely to get more unpredictable (and rainier) because of climate changes. In addition, the tourist sector in the Arctic regions is very dependent on nature-based activities, so disruptions of both wildlife and nature may be harmful. In extremely northern locations such as Svalbard, increased marine activity is expected to increase the visits of cruise vessels. Cruise ships currently also visit communities such as Pond Inlet, Cape Dorset, Kimmirut and Pangnirtung in Nunavut, Canada. An impact of climate changes to economic activity in these ports is anticipated because of the longer period in which cruise vessels can visit. However, increasing frequency of icebergs, due to melting sea ice, may also make access to these ports more complex.

Long-term climate changes will impact particularly on the Arctic's main tourist attractions. Tourists are attracted to the region because of the unique Arctic experience, perhaps represented directly by low temperatures and the presence of ice, and certainly by Arctic wildlife, vegetation and scenery. The polar bear, a big tourism magnet, is considered very vulnerable to climate change, since it depends on hunting seals on the sea ice. In brief, these tourist attractions will change, perhaps dramatically. In addition, snow-dependent activities such as dog sledging and snow-mobile riding are expected to decline if snow-cover is reduced.

Tourism in the Arctic will be influenced by climate change in many ways, with current impact assessments indicating substantial uncertainty. One scenario, for instance, is that accessibility will increase as sea ice recedes. Also, the Arctic regions may become less attractive if snow and ice recedes, but with an effect that is compensated by even greater removals of snow and glaciers in other regions (for instance in the European Alps). However, an opposite effect can make the Arctic less special and less attractive as the climate changes, for instance if the polar bear disappears from the fauna. There will also be other important influences-such as income growth in rich countries generating increased demand for Arctic tourism services. One may guess that an overall trend towards climate change will influence the tourism industry in

Table 6.2. Maritime activity in the Arctic regions

Activity	Expected trend in the future
Transport of general cargo, bulk cargo and containers	Increase
Fisheries	Remain stable
Tourism, including whale-watching cruises and passenger vessels	Increase
Research and other vessels	Remain stable
Transport of vessels for scrapping	Increase
Icebreakers and tugs	Increase

Source: Norwegian Maritime Directorate (2000).

the Arctic in important ways, without being able to assess exactly how, or even if, the changes will be positive or negative.

Maritime activity

Maritime activity in the Arctic consists mainly of transport, fisheries, tourism, research and icebreaking. Of all these maritime activities, the transport of general cargo, bulk cargo and containers, and fisheries have the greatest share¹². Seasonal variation in shipping activities is caused primarily by prevailing ice conditions. In areas of lower or no ice coverage, transportation activity has a more regular pattern. Fishing varies with the resource distribution, including seasonal variations. Tourism, including cruises, is a summer activity.

Climate change is expected to increase marine access to the Arctic regions, especially with the possible opening of closed passages such as the North-West Passage and the northern sea route (north of the North American and the Eurasian continents, respectively). Thus, harbour facilities will probably have to be developed in many parts of the Arctic regions. Table 6.2 gives an overview of predicted impacts of climate change on maritime activity. One benefit of the opening of new passages is that energy companies may find it easier to transport oil and gas in the new, open sea routes. In addition, increased offshore and mining development will increase maritime activity in the region.

Shipping in the Arctic is mainly a result of transportation of goods either in or out of the region. Imports of goods are demanded by both industry and settlements. Exports are mainly concentrated around the petroleum industry, fisheries and mining. Canada, the USA, and Norway have major shares of the exports from the Arctic regions. Oil companies are engaged in petroleum activities offshore near the arctic parts of mainland Norway, but the commercial production of oil or gas in the Norwegian Arctic is yet to start (the Snow White Field). However, increased economic activity in Northern Norway is expected to increase shipping activity. Increasing shipping activity in the Arctic raises questions of maritime law that will need to be resolved soon. These issues include accident and collision insurance, authority for regulation, enforcement and cleanup in management of natural resources and environment. These questions are important because sovereignty over Arctic waters is still not firmly settled among polar nations, and increased ship access could raise many destabilizing international issues.

Infrastructure on land

The infrastructure in the Arctic regions may experience increased incidents of floods, avalanches and mudslides because of climate changes in the region. Increased temperature is also expected to melt parts of the permafrost in the regions. Roadway quality, in particular, is expected to decrease in permafrost regions as the temperature increases.

Irrespective of climate changes, the number of scheduled flights in Arctic regions is likely to increase.¹³ However, airport installations will require improved engineering designs to handle permafrost instability. Another effect of the increased activity in shipping transportation and air travel is the requirement for a more extensive weather service and navigational aids than now exist.

The impact of warming is likely to lead to increased building costs, at least in the short term, as new designs are developed to handle permafrost instability. Snow loads and wind strengths may increase, which also could require modifications to existing buildings.

Subsistence activities and small communities in the Arctic

The subsistence economy is important to many individuals and communities in the Arctic. Climate change has already affected and continues to affect their way of life. The indigenous people maintain a strong connection to the environment through hunting, herding, fishing and gathering of renewable resources. These practices provide the basis for food production that is often based on thousands of years of tradition. Cultural adaptations and the ability to utilize resources are often associated with, or affected by, seasonal variation and changing ecological conditions. Climatic variation and weather events have always affected the abundance and availability of resources, and thus the abilities and opportunities to harvest and process food in subsistence activities.

The indigenous communities are already subject to stress that restricts the harvesting and herding routines, some of which may be associated with climate change. For many Arctic communities, consuming food from animals is fundamentally important for survival and personal well-being. Indigenous people have reported a loss of vitality, a decline in health, and decrease in personal well-being when they are unable to



A fishing boat cruises in the Ilulissat fjord, Greenland/Scanpix,AFP



eat traditional foods.¹⁴ The potential impacts of climate change thus include a concern for access to traditional food resources, and the social and economic well-being and the health and cultural survival of the indigenous people of the Arctic. These issues are dealt with in greater detail in chapter 5.

Government institutions in the Arctic

Climate change and its impacts will include challenges of coordination between nations as well as for regional levels of government. What a government does to change resource allocation is called the allocative function of government. Allocative interventions in the Arctic include the management of natural resources such as fisheries or mineral extraction, law enforcement, and institutional mechanisms such as pollution control or biodiversity protection. Government is also essential for allocation of resources to public service and infrastructure provision. The redistributive function of government refers to action to protect the poor, provision of income support, and so-

cial insurance. Both the allocative and the distributive functions of government will probably be strongly affected by how governments choose to adapt to climate change and its impacts.

In practice, government involvement usually blends the functions of allocation and redistribution, an important example being the provision of subsidized education and health services. This provision enhances the human capital of the recipient and also conveys insurance benefits, in particular when the recipient household is poor. Thus, many government services both redistribute income and influence how it is spent. For remote and sparsely populated regions such as many areas in the Arctic, such services are often expensive to provide, and the local tax base may be limited. For these reasons, service provision also in effect conveys income transfers from a higher level of government (often national) to the population in the Arctic region.¹⁵ The recipient region then benefits both through the consumption value of the service provided and through the local economic repercussions of increased spending and increased employment. When resources are allocated to national public goods that are not principally consumed locally—such as national defence—there will still be important impacts locally, such as the positive effects on local employment.

The direct effects of climate change on government services will vary by location: less sea ice may reduce costs of sea transport; permafrost thawing may increase costs of on-land transportation, construction and infrastructure; higher temperatures will reduce costs of heating, etc. In addition to these direct effects, there will be adaptive effects related to the economic impacts of climate change. As an example, assume that there will be an economic upswing in some Artic regions because of improved fishing. An economic upswing will either improve the local tax base or reduce the need for income support from the national government. In addition, it will increase the demand for services in most areas, depending on the inflow of workers with families, and a need for supportive industries. In consequence, communitites affected positively by climate change may share the experience with communities affected negatively that change itself increases demand on government service provision.

There are no direct links between climatic conditions such as reduced sea ice and issues of national sovereignty and maritime law. There are, however, several reasons why there are issues of international relations relevant to the changing climatic conditions in the area. First and most obvious, is the fact that the conditions for harvesting natural resources will change, and this will demand changes in the institutions involved in managing these resources. The most obvious example relates to management of fish stocks. Historical examples of tragic losses due to mismanagement of marine resources are many. These range from cases in which a nation has mismanaged a resource all on its own, via mismanagement in a setting of national authority but involving harvesters from other countries that are hard to control, to examples where transnational coordination is required either because of migratory fish species or because of enforcement challenges.

Climate change influences the control regime of natural resources in many ways. Most simply, if harvesting costs are falling (because of increased stock growth, for instance), a stock that has been "naturally protected" by high harvesting costs may be threatened by overfishing (either immediately, or when increased harvesting capacity has emerged). Sadly, the opposite effect of climate change, a reduction in the fish stock, could also result in overfishing, since both the oversized harvesting capacity and the overly generous harvesting quotas might be adjusted downwards too slowly. Such non-symmetric effects highlight how—in ecosystem management—any change in underlying conditions put strain on management institutions, since these will typically be better geared to manage the existing situation than any new situation.

Another example would be when the migratory patterns or extent of a stock changes, such that a stock that has previously thrived without transnational management institutions may come to require such institutions. The same may happen if reduced sea ice facilitates the movement of vessels between the waters of different nations, thereby reducing the effectiveness of national management schemes (via enforcement costs, for instance).

Similar issues are involved in the management of mineral resources and fossil fuels. Issues not fully negotiated or settled in terms of national control may become important-and subject to dispute-as climate change gives value to areas formerly not considered of importance. An example may be the "grey zone" in the Barents Sea between Norway and Russia. The balance of power, as well as the need to agree on a scheme for authority and exploitation, will change along with climate. In addition, economic and other activities in such areas may have consequences for future control, and will then in turn be influenced by this possibility. An example of such effects is that both Russia and Norway have included strategic considerations for future control when maintaining a presence through coal mining activities in Svalbard.

One of the projected impacts of climate change in the Arctic is increased access, which at times is assessed as one of the most important changes. BBC reports that "climate change is seen by some as a boon to businesses in the Arctic regions", and that "adventur-ous capitalists are desperate to obtain access to resources that are uncovered as the ice retreats"¹⁶. Lack of access is generally an excellent protector of natural assets, and stability is typically found to be essential to institutions for resource management. Climate change will thus increase the need for protective institutions due to increased activity levels, while simultaneously making it harder to build and maintain the institutions.

However, the predicted increase of activity in the Arctic caused by climate change factors combined with the search for new energy supplies might lead to a new "gold rush" in the far north, bringing diplomatic problems in its wake as countries vie for access to the resources. The US and Canada argue over rights in the North-West Passage; Norway and Russia bicker over the Barents Sea; Canada and Denmark are competing for a small island off Greenland, Hans Island; the Russian Parliament is refusing to ratify an agreement with the US over the Bering Sea; and Denmark hopes to trump everyone by claiming the rights to the North Pole itself.

Pollution issues will be of increased importance as economic activity expands in the Arctic. Since pollution migrates across borders and affect global public goods (biodiversity, for instance), these issues will also result in increasing demands on transnational institutions for coordination. An example of this is the regulatory regime for marine transport; another will be regimes evolving for such activities as petroleum exploration and extraction.

Concluding remarks

The ACIA report stated that changes in temperature, precipitation and storm patterns can affect the type, abundance, and location of animals and plants available to humans and may lessen the productivity of certain traditional forms of hunting and gathering. A decrease in the extent and thickness of sea ice can alter the distribution, age structure and size of marine mammal populations, expose the Arctic coast to more severe weather events, exacerbate coastal erosion, and affect modes of transportation and the ability of people to reach hunting locations and other villages. Changes in surface water budgets and wetlands can change coastal microclimates, alter the size and structure of peatlands, and result in pond drainage. These changes would in turn result in effects not only in human communities in the Arctic, but in other areas of the world as well.

Climate change is likely to be greater and more dramatic in the Arctic than in most other areas. The factor that will impact on the economy in the Arctic is first and foremost changes in mean surface temperature. An increase in temperature will result in reduced sea ice, increased precipitation and decreased snow cover in the Arctic regions. The impact of these changes on nature-based activities will be significant. In addition, climate change in the Arctic will also impact on other economies.

Climate change is expected to have an impact on most of what happens in the Arctic, and the emphasis in this study has been on resources and trade flows, which will be affected due to the importance of what we call "nature-based activities", which in addition to primary sectors include tourism and transportation infrastructure. Table 6.3 below gives an overview of expected impacts of climate change on sectors on the Arctic.

Table 6.3. Expected impacts of climat	te change on sectors in the Arctic
Fishing	 changes in stock and species. alternation of migration routes. uncertain harvesting costs. increased stock productivity.
Agriculture, livestock, forestry	 vegetation shifts. expansion of forests. altered husbandry practices. probable expansion of agricultural opportunities increased growing season. wetland development. increased forest fires.
Renewables: Hydroelectric power	 change in precipitation affecting thereservoirs. increased maintenance costs caused by thawing permafrost.
Non-Renewables: Mining and Petroleum	 shorter season for mining. offshore production likely to benefit from less sea ice. increased design and operational costs.
Tourism	 reduced access costs. increased scarcity value. snow dependent activities more limited. longer season. more cruise tourism. weather events, like storms, have unknown trends.
Maritime transportation	 dependent on prevailing ice conditions. reduced access costsincreased appearance of icebergs. opening of closed passages (north-west passage and northern sea route). weather events, like storms, have unknown trends.
Infrastructure on land	 increased costs from impacts of natural disasters. increased maintenance costs. increased flight activity in the Arctic regions. increased building costs. construction season extended.
Governmental services	 increased demands on the federal budget associated with climate change. possible increased federal economic support.
Subsistence activities	- change in harvest patterns.

With regard to economic impacts of climate changes in the Arctic, the fishing industry will most likely experience changes in stocks, and harvesting locations may change considerably. It is uncertain whether higher or lower yields will result, and a similar uncertainty exists about harvesting costs. As shown in chapter 3, the arctic is very important in providing about 10 percent of the world's wild fish, so changes in this activity will be important to the world. About 65 percent of this fish is cod and herring, and since these are species for which migratory patterns are shown to be sensitive to changing sea temperatures, it is highly uncertain how these fisheries will be impacted by climate change. With regard to cultivated fish species, expected impacts of climate change include warmer water increasing the growth rates of fish. However, if the sea temperature changes too much, and the temperature exceeds the temperature tolerance of the farmed species, increased incidences of fish diseases and likely algal blooms are expected.

Agricultural opportunities are likely to expand because of a warmer climate, moving the grain production boundary northward. Climate changes that extend the growing season and raise daily maximum temperatures while maintaining or slightly decreasing persistence of growing-season clouds and rain are likely to be favourable to agricultural production in this area. Nevertheless, apart from the importance of livestock for selected households and communities, agriculture is not of great importance in the Arctic.

Climate change in the Arctic is likely to influence the production of oil and gas in the region in many ways. Offshore oil exploration and production is likely to benefit from less extensive and thinner sea ice, although equipment may also become costlier, to withstand increased wave forces and ice movement. Onshore, the impact of climate change is expected to raise costs, but offshore the consequences are uncertain and will probably vary. For oil and gas, Arctic regions are estimated to represent 12 per cent for oil and 23 per cent for gas of global proven and expected undiscovered reserves, respectively, see Chapter 3, indicating that the Arctic will be increasingly important to the world through these critical commodities. For oil and gas together, the Arctic shares are 13 per cent of proven global reserves and 24 per cent of expected

undiscovered global reserves. Thus, the possible impacts of climate change on extractive activities – likely combining positive and negative impacts - is exceedingly relevant to the non-arctic world.

Tourism is expected to experience a longer season in the Arctic; however the sector is dependent on weather conditions, which are likely to get more unpredictable (and rainier) because of climate changes. Some areas may lose their attraction.

The impact on the Arctic economies, and on the rest of the world through trade flows, is in many ways less subtle and more direct, noticeable and predictable. Nature-based activities will be affected by climate change, in some instances by a direct boost to profitability and in other cases with a direct reduction in profitability. In all cases, the longer-term effect will depend on adaptive responses in the private and the public sector.

We have emphasized the fact that any change, positive or negative, represents increased demands on government institutions. Three illustrative points makes this evident: first, a fish stock may be "protected" by high harvesting costs, so increased fish growth may place new demands on management institutions (as would reduced fish growth). Second, a booming town may demand increased government expenditures to take care of incoming households and firms, but a town facing decline may require increased transfers for adjustment and social insurance. Third, reduced sea ice improves mobility of vessels and therefore presents new transnational cooperation challenges for such purposes as fisheries and environmental management. Climate change will put pressure on the Arctic governments' abilities to adapt to climate change and build institutions, both on national and transnational levels.

Further research

Further research is necessary to quantify the impacts of climate change in the Arctic. We have shown that for commodities such as fisheries and gas and oil, for civilian and military marine activities, climatic change will be important, and in ways that are relevant not only for the arctic regions. This report and this chapter represent some initial steps, but additional research is needed on how climate change in the Arctic might affect other economies, both globally and on a more regional level. Research on how the Arctic nations might envisage future control rights as evolving is also necessary and should be part of the future research agenda.

Notes

- ¹ Sources for Table 6.1: Table 4.3 (ACIA, 2005: 122), Table 4.4 (ACIA, 2005: 127), Table 6.3 (ACIA, 2005: 195), Table 6.4 (ACIA, 2005: 199) and Table 6.5 (ACIA, 2005: 200). Authors are listed in each chapter, *«Arctic Climate Impact Assessment Scientific Report»*. Edited by Carolyn Symon (lead editor), Lelani Arris and Bill Heal. New York, USA: Cambridge University Press, 2005.
- ² ACIA (2004), Hassol, Susan Joy, 2004, «Impact of a warming Arctic - synthesis report of the Arctic Climate Impact Assessment», Cambridge University Press, pages: 1-140, online: http:// /amap.no/acia/
- ³ IPCC, Intergovernmental Panel on Climate Change (2001) Authors are listed in each chapter,»Climate Change 2001: Impacts, Adaptation and Vulnerability», Series Editor: McCarthy, James J.; Canziani, Osvaldo F.; Leary, Neil A.; Dokken, David J.; White, Kasey S., Cambridge University Press, pages: 1-1033, online: http://www.grida.no/climate/ipcc_tar/wg2/index.htm
- ⁴ Drinkwater, K.F. (2005): «The response of Atlantic cod (Gadus morhua) to future climate change». Journal of Marine Science, 62: 1327–1337.
- ⁵ Skjolddal, H., H. Loeng, K. Drinkwater (2006). 'The ice in the arctic is melting: what does it mean for our ecosystems?' Havets ressurser og miljø, chapter 4. .IMR.NO.
- ⁵ ACIA (2005), Authors are listed in each chapter, *«Arctic Climate Impact Assessment Scientific Report»*. Edited by Carolyn Symon (lead editor), Lelani Arris and Bill Heal. New York, USA: Cambridge University Press, 2005.



- ⁷ The boreal forest is defined as a belt of forest south of the tundra characterized by coniferous species, such as spruce, larch, pine and fir.
- ⁸ ACIA (2005) Authors are listed in each chapter, «Arctic Climate Impact Assessment - Scientific Report». Edited by Carolyn Symon (lead editor), Lelani Arris and Bill Heal. New York, USA: Cambridge University Press, 2005.
- ⁹ IPCC Intergovernmental Panel on Climate Change (1998), «Special Report on Regional Impacts of Climate Change», Cambridge University Press, online: http://www.grida.no/climate/ ipcc/regional/index.htm
- ¹⁰ EEA, European Environmental Agency, 2005. «The state of the Arctic Environment». European Environmental Agency, Online: http://reports.eea.eu.int/MON3/en/
- ¹¹Norwegian Maritime Directorate (2000). «Pame Snap Shot Analysis of Maritim Activities in the Arctic», revision no 01, report no. 2000-3220. Online: http://www.pame.is/sidur/ uploads/Norwegian_maritime_directorate.PDF
- ¹² Norwegian Maritime Directorate (2000). «Pame Snap Shot Analysis of Maritim Activities in the Arctic», revision no 01, report no. 2000-3220. Online: http://www.pame.is/sidur/ uploads/Norwegian_maritime_directorate.PDF

- ¹³ IPCC, Intergovernmental Panel on Climate Change (2001) Authors are listed in each chapter,»Climate Change 2001: Impacts, Adaptation and Vulnerability», Series Editor: McCarthy, James J.; Canziani, Osvaldo F.; Leary, Neil A.; Dokken, David J.; White, Kasey S., Cambridge University Press, pages: 1-1033, online: http://www.grida.no/climate/ipcc_tar/wg2/index.htm
- ¹⁴ ACIA (2005) Authors are listed in each chapter, «Arctic Climate Impact Assessment - Scientific Report». Edited by Carolyn Symon (lead editor), Lelani Arris and Bill Heal. New York, USA: Cambridge University Press, 2005.
- ¹⁵ For seven of the eight Arctic countries, the Arctic is a minor share of the country's territory and population. The exception is Iceland.
- ¹⁶ BBC /Jorn Madslien, 2005, «Global Warming: Help or Hindrance?» In *BBC News*, online: http://news.bbc.co.uk/1/hi/business/4357240.stm

Appendix

Table A1. Activities in nature-based sectors in the Arctic regions

		Fishing	Agriculture, livestock, forestry	Electric power production	Non-renewables: Mining and petroleum	Tourism	(Maritime) transportation activities	
Sub-region I the European Arctic	Arctic Norway	Arctic cod, shrimp, capelin, salmon, trout ¹⁰	Reindeer-herding, hunting, trapping ⁹	Hydropower, windpower ¹⁰	Offshore oil and gas production, offshore exploration drilling ¹¹ , coal ¹⁰	App. 1.7 mill. guestnights in 2002 ¹⁰	Many important navigation routes along the coast, from both Norway and Russia ³	
	Arctic Sweden	No significant fishing activity	Timber, barley, wheat, sugar beets, meat, milk ⁹	Hydropower ⁹	lron ore, copper, lead, zinc, gold, silver, tungsten, uranium, arsenic, feldspar ⁹	App 2.7% of GNP⁵	Ice floes in the Gulf	
	Arctic Finland	Inland fishing: Herring, sprat, vendace, salmon, trout ⁸	Barley, oats, sugar beets, potatoes, milk, poultry, pigs, cattle, reindeer and forestry (timber) ⁹	Nuclear energy, wood fuel, oil, coal, natural gas, peat and hydro- power ⁸	lron ore, copper, lead, zinc, chromite, nickel, gold, silver, limestone ⁹	4.4 mill. guestnights in 2004 ⁸	interfere with maritime traffic ⁹	
	East Green- Iand	Northern prawns, halibut, lumpfish, snow crab, cod ⁴	Forage crops, garden and greenhouse vegetables, sheep, reindeer ⁹	Hydro ⁴	Zinc, lead, iron ore, coal, molybdenum, gold, platinum, uranium, possible oil and gas ⁹	App. 64 000 guests total for Greenland in 2004 ⁴	Ships, aviation⁴	
	Iceland	Capelin, blue whiting, cod, herring ⁵	Sheep-, cattle-, hens- and mink production, small-scale agriculture ⁹	Hydro, geothermal, oil ⁵	Processing aluminium ¹³	4.4% of employees ⁵	Ships, aviation⁵	
	North- west Russia	Consentrated in Murmansk. Cod, herring, saithe, capelin, northern shrimp, halibut ³	Timber, much of the country lacks proper soils and climates (either too cold or too dry) for	Relies on fossil fuels for most of its electrici- ty generation: app. 65 % conventional thermal ¹⁷	Offshore and onshore oil and gas production and exploration, gemstones, fertilizer, nickel, copper, plati- mun, apatite, tin, diamonds, gold and coal ³	Science-based tourism and journalists. Rapidly growing industry ¹⁴	Unfavorably located in relation to major sea lanes of the world ⁹	
Sub-region II	Russia (Siberia)	No significant fishing activity ³						
Sub-region /	Russia (Chukotka)	Large-scale trawl fisheries, ground- fish (app. 90% walleye pollock) ³	agriculture					
	Alaska	Groundfish (app. 75% walleye pollock), salmon, halibut, shellfish ³	Timber, agriculture ⁹	Natural gas (51%), hydropower (21%), petroleum (15%), coal (13%) ¹	Mining for lead zinc and gold ³ , off- and onshore oil and gas production and exploration ¹¹	Season-dependent ¹³ – 90% during the summer, but expanding sector	International air freight important ¹³	
	Canada (west)	No significant fishing activity ⁷	Franktin franktine	Relies on fossil fuels for most of its electricity generation	Onshore oil production and onshore gas exploration ¹¹ , mining for diamonds, sand and gravel ¹³ , lead, zinc, copper and gold ³	App. 85 000 guests total in 2002 ¹⁴ , Aurora Tourism ¹⁵ , vital and growing industry ¹⁶		
Sub-region IV	Canada (central and east)	Capelin, cod, sand lance, herring, halibut, plaice, snow crab, northern shrimp ³	greenhouse vegetable potential ⁹				Opening of north- west passage ³	
	West Greenland	Northern prawns, halibut, lumpfish, snow crab, cod ⁴	Forage crops, garden and greenhouse vegetables, sheep, reindeer ⁹	Hydro⁴	Offshore exploration drilling ¹¹ , gold explorati- on, zinc, lead, iron ore, coal, molybdenum, gold, platinum, uranium ⁹	App. 64 000 guests total for Greenland in 2004 ⁴	Ships, aviation ⁴	

¹ U.S. Department of Energy; Energy Efficiency and Renewable Energy «EERE State Activities and Partnership: Alaska Energy Statistics... http://www.eere.energy.gov/states/state_specific_statistics.cfm/state=AK online: Feb. 1, 2006.
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 ⁴ Statistics Greenland.
 ⁵ Statistics Lealand.
 ⁶ Statistics Sweden.
 ⁷ Natural Resources, Canada: *The Atlas of Canada* Fisheries—Selected-Characteristics; Pacific Fisheries http://atlas.gc.ca/site/english/maps/archives/4thedition/economic/resourceindustries/169_170 online: Feb. 1, 2006.
 ⁸ CIA country information «Natural resources». http://www.cia.gov/cia/publications/factbook/fields/2111.html online: Jan. 31, 2006.
 ⁹ Statistics Norway.
 ¹¹ Arctic Monitoring and Assessment Programme, «AMAP-assessment report: Arctic Pollution Issues. Figure 10-01».
 ¹² Natural Resources, Canada: *The Atlas of Canada* Electrical Power Generating Stations, (1997) http://atlas.gc.ca/site/english/maps/economic/generatingstations/utilitybytech online: Feb. 1, 2006.
 ¹⁴ Pagnan and Dolphins (2003) «The impact of climate change on arctic tourism – a preliminary review» http://www.world-tourism.org/sustainable/climate/pres/jeanne-ganan.pdf.
 ¹⁵ Resources, Wildlife and Economic Development—Government of the Northwest Territories», Aurora Tourism-Economic Impacts in the Northwest Territories. «Tourism in the NWT» http://www.iti.gov.nt.ca/iea/pdf/fact_sheets/tourism2001.pdf Online. Feb 1, 2006.
 ¹⁷ Carbon Sequestration Leadership Forum (CSLF) «An Energy Summary of the Russian Federation http://www.csflorum.org/russia.httn Online: Feb 1, 2006.