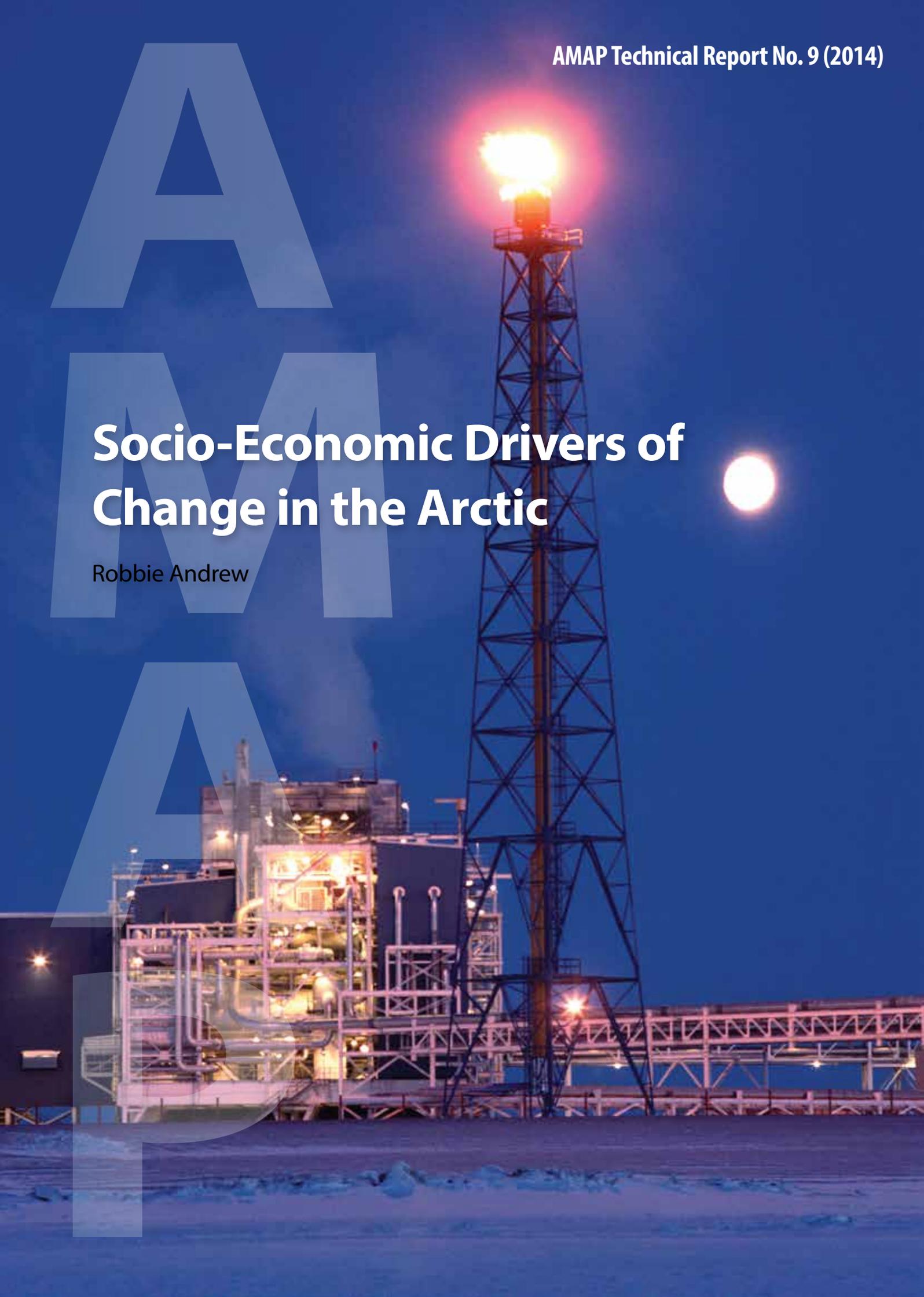


Socio-Economic Drivers of Change in the Arctic

Robbie Andrew



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AMAP's objective is to provide 'reliable and sufficient information on the status of, and threats to, the Arctic environment, and to provide scientific advice on actions to be taken in order to support Arctic governments in their efforts to take remedial and preventive actions to reduce adverse effects of contaminants and climate change'.

AMAP produces, at regular intervals, assessment reports that address a range of Arctic pollution and climate change issues, including effects on health of Arctic human populations. These are presented to Arctic Council Ministers in 'State of the Arctic Environment' reports that form a basis for necessary steps to be taken to protect the Arctic and its inhabitants.

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Executive Summary

The Arctic is undergoing rapid and fundamental change. Recent decades have seen rising temperatures and reduced sea ice, and these present substantial uncertainties to local communities. Overlaid on these climatic shifts are changes in other factors such as resource demand, globalization, transportation, economic development, and demographics, factors which are to varying degrees themselves affected by the changing climate.

In recognition of the changes occurring in the Arctic, and the need for Arctic communities and governments to respond to them, the Arctic Council launched the *Adaptation Actions for a Changing Arctic* (AACA) project, divided into three parts. The goal of Part C, of which this report is one component, is to “produce information to assist local decision-makers and stakeholders ... in developing adaptation tools and strategies to better deal with climate change and other pertinent environmental stressors.”

This report presents an overview of the potential directions of non-climate drivers affecting the Arctic, and explicitly excludes discussion of potential impacts and responses. In this report, the non-climate drivers have been split into two perspectives: global and Arctic. Global drivers set the wider context within which the Arctic is changing. How is the global economy expected to develop? What might the world's population be in 2050? How will global demand for mineral resources change over time? What are the expectations for future energy demand? These global factors – represented by large numbers and considerable momentum – come with large uncertainty, especially several decades out, yet they set the scene for change in the Arctic.

The second perspective is of factors that are explicitly Arctic in nature: the changing population of the Arctic regions, shipping through Arctic waters, the activities of oil and gas companies, mining, Arctic tourism, and food security. In each of these areas, a summary is made of the most salient issues including any expectations for how they might develop. What is driving each of these factors? What constraints are there impeding those drivers?

Real-life linkages within integrated systems are extremely complex, and one cannot hope to elucidate them all. This brief report attempts to point towards these linkages, summarizing major trends, and highlighting the factors that are likely to lead to changes in the Arctic, changes to which local communities and stakeholders must respond. As such, this report is but one input into the work still to come in the AACA project, work which will bring local knowledge and expertise to bear on the adaptation issues facing the selected trial regions, and will draw from a broad and diverse range of sources and types of knowledge.

While the AACA project is focused on adaptation, in no way do communities in the Arctic need to see this as disempowering. In fact, AACA intends to draw upon local knowledge and to move forward with mutual understanding, supporting local decision-making. Adaptation, in a deeper sense, can also suggest transformation and rebirth. Further, one important option for adaptation to changed drivers is to intervene: strategically using the community's voice to prevent or redirect change. Clearly change brings both challenges and opportunities to the communities of the Arctic.

1. Introduction

The Arctic is already changing owing to warming at a speed not seen for millennia, and is expected to change substantially over the coming decades. Some of these changes will be direct results of climate change, while others will be indirect, and still others will be unrelated to the changing climate. This report focuses specifically on the major non-climate drivers of change at both the global and Arctic level. While the report does not address climate change directly, as this will be addressed in a separate report, many of the drivers herein are influenced significantly by the changing climate. The report is to be used within part C of the Adaptation Actions for a Changing Arctic (AACA-C) project as background to develop projections, scenarios, and forecast models specific to the three Arctic regions of Barents, Bering/Beaufort/Chukchi, and Baffin Bay/Davis Strait. The focus of this report is on drivers of change, while later work

will connect these drivers with the current state, impacts and potential adaptation responses within the Arctic.

This report is divided into two main parts according to its two main themes. The first part discusses key drivers of global change and presents sources of information for these drivers, along with discussion of the robustness and uncertainties associated with this information. This first part is further divided into a discussion of scenarios in general, followed by subsections on three main driver groups: society, economy, and technology. While there are many scenarios and projections of key drivers of change, this report presents mainly those that are widely used and/or reasonably robust, with reference to additional scenarios on occasion. The second part is divided into key Arctic drivers: population, oil and gas, mining, marine transportation, tourism, and food security. The report concludes with an appendix providing a table of key global projections, and a complete bibliography.

2. The Global Context

The Arctic, its communities, and its activities are heavily influenced by what happens in the wider world, from global poverty to globalization, from resource demands to experience demands. Changes in the Arctic, therefore, both sit within the context of global changes and exhibit their own independent identity. This section discusses the global dynamic environment in which the Arctic exists, focusing on quantitative projections of change in key socio-economic drivers that are likely to influence what happens within the Arctic even if they do not necessarily occur within the Arctic.

2.1 Definitions

Before describing the scenarios and projections available, it is important to understand exactly what scenarios and projections are, and how they relate to forecasts.

The Intergovernmental Panel on Climate Change (IPCC) Data Distribution Centre has developed clear definitions of projections, forecasts, and scenarios, albeit limited to the context of climate change (IPCC, 2013). Those definitions have been used as a basis for arriving at the definitions below.

Projection	A projection is a parametric description of a future time and possibly also the pathway to that time. For example, 'the world's population in 2100 is projected to be 29 billion if fertility remains high.'
Forecast	A forecast is a projection that is considered most likely among other projections. While a projection can be simply a trajectory of a particular parameter (e.g., global population), the process of forecasting additionally assigns some likelihood to various projections and highlights the most likely among them. For example, 'the world's population in 2100 is likely to be 29 billion because fertility is expected to remain high.'
Scenario	A scenario is a coherent narrative describing a future and often the pathway to that future and the drivers of changes along the way. Scenarios are often accompanied by projections, but not always. For example, 'developed nations step up their ambition to eradicate common diseases in developing nations.'
Sensitivity Analysis	Some projections are presented as sensitivity analyses, where the uncertainty of the forecast is investigated by varying the assumed values of key parameters. Effectively this results in a number of additional projections, with no change in the forecast (the most likely projection). This is particularly common practice in economic projections.
Models	Models formalize relationships between drivers and outcomes as a way to represent reality. Usually greatly simplified compared to the real world, models can be quantitative or qualitative, deterministic or stochastic (random), process-based or empirical, spatial and/or temporal. A model can be used to assess the outcomes of a scenario.

2.2 Uncertainties in Projections

Projections require assumptions about the future course of drivers, and are therefore subject to both uncertainties in those assumptions but also in the relationships between the drivers and the parameter of interest. These uncertainties can be considerable, and all projections must therefore be viewed with a level of skepticism. However, with the understanding that they are subject to change, projections greatly facilitate policy decisions.

Very long-run forecasting is a hazardous activity because the uncertainties and imponderables of life have plenty of time to intrude, and bend and buck the charted path. At the same time, to craft policy that is rooted in reason and reality, we need to peer into the future with the best information, statistics, and models that we have.

Kaushik Basu, Senior Vice President and Chief Economist, the World Bank

In addition to uncertainty, if projections are generated by an interest group such as an industry body, they may have the purpose not only of forecasting but also of stimulating the market, and care should be taken with such projections. In the body of this report we only include projections made by industry bodies as supporting information, and only when more independent information is unavailable, and we clearly indicate this in the text to avoid misunderstanding.

The difference between forecasts and projections is often misunderstood, and often a medium scenario is assumed by readers to be most likely, whether or not that was the authors' intention. To avoid this, some projection work presents an even number of scenarios so that there is no middle choice, preventing false conclusions about likelihood. An example of this is the presentation of the four Representative Concentration Pathways used in the Fifth Assessment Report of the IPCC, which is discussed in further detail in Section 2.3.1.

While the general course of events may have some high level of certainty, individual events along the way can show significant deviations from a smooth trajectory. Such events are generally unpredictable at an individual level, but sometimes it is assumed that they will occur sometime to some degree over the projection period. For example, in a hydrological projection, based on previous empirical results and expectations for the future, the flow of a river might be projected into the future. It might be expected that a major flood event will occur once during the projection period, but there might be no way of knowing when. The cumulative flow over this period may or may not include the significant deviation caused by the flood event. Whether or not the deviation is implicit in the projection, the projection trajectory itself will be a smooth curve, with no apparent deviations, simply because the timing of such deviations is unknown. When a projection is presented as a smooth curve, there is generally no intention to imply a lack of variability. Figure 1 presents a hypothetical example of this.

Significant deviations from expected pathways can and do occur. The nuclear incident at Fukushima in Japan is a clear example of the sudden change in public opinion and policy direction that can occur as a result of an unexpected event, with knock-on effects around the world. Other examples include the collapse of the Soviet Union, and wars around the world.

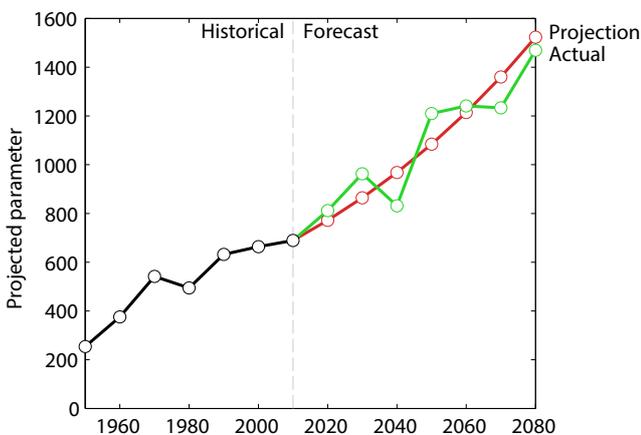


Figure 1. Hypothetical projection, demonstrating the difference between the smooth trajectory projected and a potential actual future trajectory with deviations resulting from unpredictable events.

2.3 Integrated Assessment Scenarios

The most well-known integrated assessment scenarios are probably those created by and for the IPCC. These scenarios have come through several generations, starting with the SA90 series, then the IS92, and the SRES. The most recent set of these are the Representative Concentration Pathways (RCPs).

2.3.1 IPCC Representative Concentration Pathways

The Fifth Assessment Report has seen a change in direction in the generation and use of scenarios, with the modelling community choosing four Representative Concentration Pathways (RCPs), which, strictly speaking, are not scenarios because they have been stripped of storylines (Moss et al., 2010). They are therefore naked trajectories, with the intention that the modelling community should generate a broad range of storylines that approximately realize these pathways, thereby creating scenarios. In addition, because the pathways were generated early in the reporting process, they could be accessed much earlier by the climate modelling community, preventing delays that have hampered earlier assessment report efforts. Finally, the scenarios generated by the integrated assessment modelling community will be linked with the climate projections generated by the climate modelling community, with the pathways being the link.

Moss et al. (2010) describe the criteria used to select the projections from those published: (i) representative of the range found in the literature, (ii) a ‘manageable’ and even number, (iii) relatively equally spaced so they are readily distinguishable, and (iv) availability of associated parameters for analytical purposes. Of the 324 scenarios considered, 32 met the criteria, and these were reduced to four, following a wider review process. As noted by van Vuuren et al. (2010), the scenarios are designed to be technically feasible, with no assessment of political feasibility.

While the RCPs themselves are projections rather than scenarios, it is useful to consider the scenarios that were used to generate them, because these demonstrate what have been considered storylines that feasibly result in the final trajectories. The parameters projected by the RCPs are both emissions and concentrations of greenhouse gases as well as total radiative forcing of those gases, i.e., their net effect on the energy balance of the Earth System. The descriptions below are taken directly from Bjørnæs (2013):

RCP 8.5 – High emissions

This RCP is consistent with a future with no policy changes to reduce emissions. It was developed by the International Institute for Applied System Analysis in Austria and is characterized by increasing greenhouse gas emissions that lead to high greenhouse gas concentrations over time.

This future is consistent with:

- Three times today's CO₂ emissions by 2100
- Rapid increase in methane emissions
- Increased use of croplands and grassland which is driven by an increase in population
- A world population of 12 billion by 2100
- Lower rate of technology development
- Heavy reliance on fossil fuels
- High energy intensity
- No implementation of climate policies

RCP 6 – Intermediate emissions

This RCP is developed by the National Institute for Environmental Studies in Japan. Radiative forcing is stabilized shortly after year 2100, which is consistent with the application of a range of technologies and strategies for reducing greenhouse gas emissions.

This future is consistent with:

- Heavy reliance on fossil fuels
- Intermediate energy intensity
- Increasing use of croplands and declining use of grasslands
- Stable methane emissions

CO₂ emissions peak in 2060 at 75% above today's levels, then decline to 25% above today

RCP 4.5 – Intermediate emissions

This RCP is developed by the Pacific Northwest National Laboratory in the USA. Here radiative forcing is stabilized shortly after year 2100, consistent with a future with relatively ambitious emissions reductions.

This future is consistent with:

- Lower energy intensity
- Strong reforestation programs
- Decreasing use of croplands and grasslands due to yield increases and dietary changes
- Stringent climate policies
- Stable methane emissions

CO₂ emissions increase only slightly before decline commences around 2040

RCP 2.6 – Low emissions

This RCP is developed by PBL Netherlands Environmental Assessment Agency. Here radiative forcing reaches 3.1 W/m² before it returns to 2.6 W/m² by 2100. In order to reach such forcing levels, ambitious greenhouse gas emissions reductions would be required over time.

This future would require:

- Declining use of oil
- Low energy intensity
- A world population of 9 billion by year 2100

Use of croplands increase due to bio-energy production

In summary, while the scenarios used in the Fifth Assessment Report of the IPCC are described as 'integrated', they should only be seen as a source of projections for emissions, concentrations, and radiative forcing of the main greenhouse gases.

2.3.2 Global Energy Assessment scenarios

The Global Energy Assessment (GEA) scenarios were specifically designed to explore the costs and feasibility of energy transformations based on normative objectives for access to

energy, climate change, air pollution, and energy security (GEA, 2012). For this reason, all scenarios result in improvements in those measures, except for the counterfactual, which is effectively a business-as-usual scenario.

The assumptions underlying the GEA scenarios are all generated in-house, with global population projected to peak in 2080 at 9.7 billion, and economic growth of 2% p.a. Figure 2 shows the range of assumptions and outputs for four parameters across the scenarios.

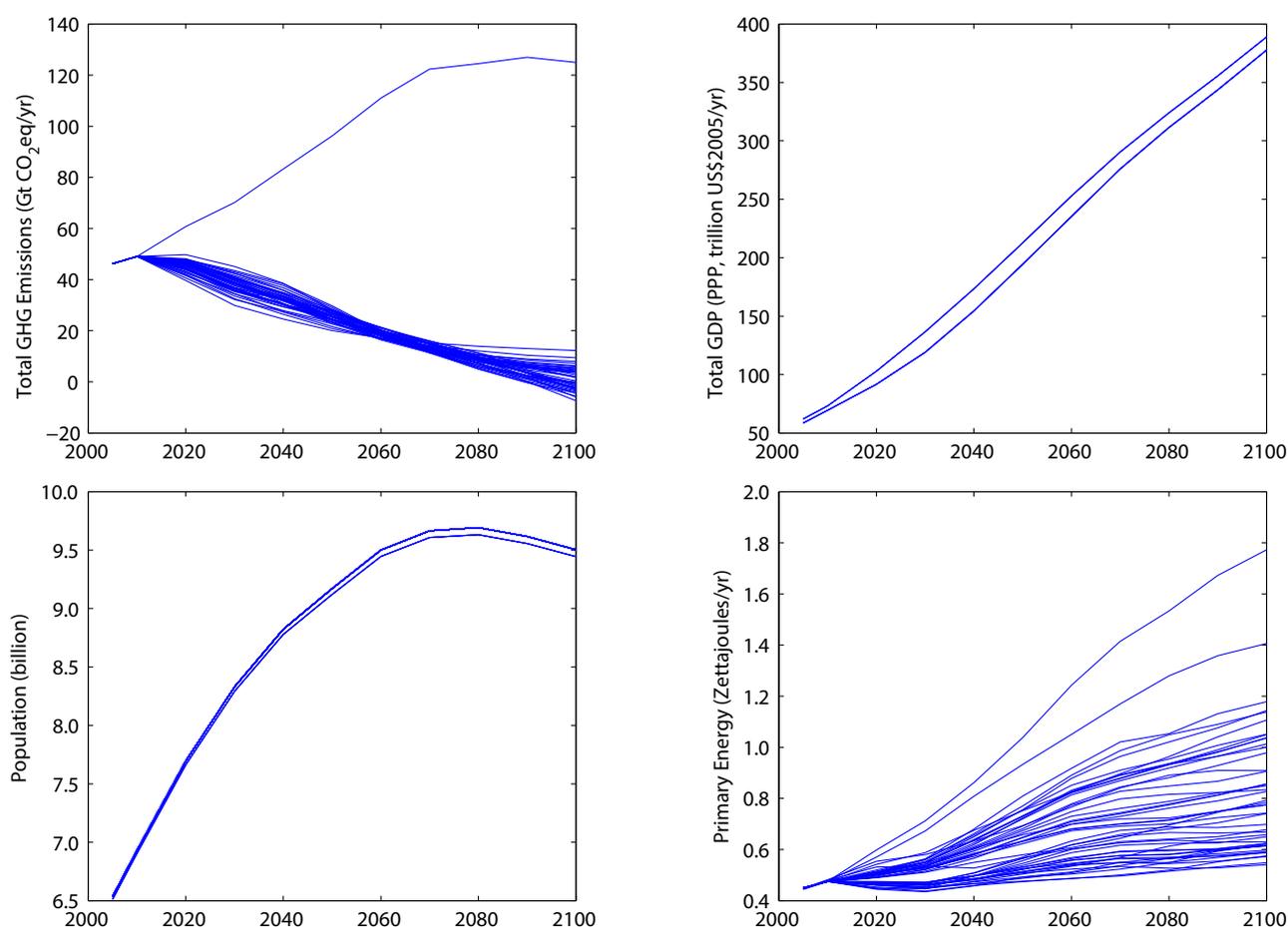


Figure 2. Global Energy Assessment scenarios. All scenarios show reduced greenhouse gas (GHG) emissions except for the counterfactual (top-left panel). In addition, there are two projections for GDP and population, one each used for the counterfactual and all scenarios (Source: GEA, 2012).

2.4 Society

Population is a core driver of future change and in many ways is more predictable than other drivers. It links directly to economic growth and resource consumption. In this section we discuss both population growth and tourism, with a short discussion on socio-political change.

2.4.1 Population

At their core, projections of population are based on projections of fertility and mortality, and these are further dependent on data on marriages, contraceptive use, migration, health, previous trends, and cohorts (population data by age group), as well as information on population policies around the world. In addition, the movement of global population via migration is important as a driver of various socio-economic pathways as migrants generally behave differently than non-migrants in both their host countries and those in their home countries. Importantly, it is implicitly assumed that larger populations are not constrained by availability of resources.

The Population Division of the United Nations Department of Economic and Social Affairs (UNPD) publishes projections every two years, with the most recent release being the '2012 Revision', published on 13 June 2013 (UNDESA, 2013b). The projections are global, but also available for over 250 countries and regions, out to 2100.

The largest source of uncertainty in population projections is in projections of fertility (number of children per woman), and the most recent population projections include significant upwards revisions of fertility in some countries. The UNPD states clearly that "small differences in the trajectory of fertility during the next decades will have major consequences for population size, structure, and distribution in the long run" (UNDESA, 2013a, p.xvi). Because of this uncertainty, the UN Population Division recommends that their projection variants be taken as a group, rather than just the medium projection. Furthermore, their three main variants (high, medium, and low fertility) each rely on reductions in fertility in developing countries, which will depend on policy intervention, and in the event such policy interventions do not take place the 'constant fertility' variant demonstrates global population reaching almost 29 billion in 2100.

The UNPD concludes that the global population in 2050 is projected to be 9.6 billion “give or take a billion” (UN, 2013), although this messaging implies that the medium fertility variant is considered most likely. The projections to 2030 and 2080 under each of the three main variants are presented in Table 1 and Figure 3.

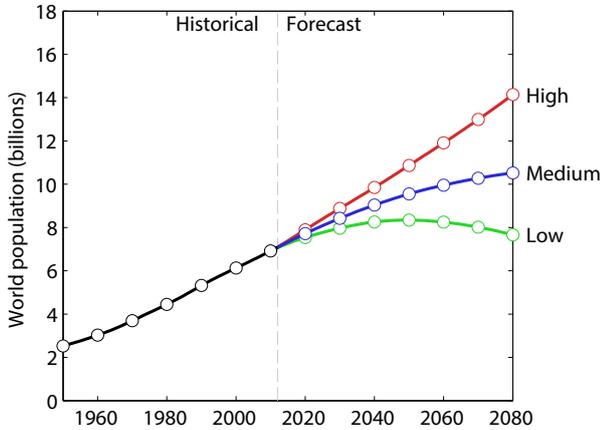


Figure 3. UN Population Division projections of global population, showing the three main ‘variants’: high, medium, and low fertility (Source: UNDESA, 2013b).

For each of the variants, the UN population projections are available disaggregated by age group, gender, country with age-specific fertility rates, mortality rates, life expectancy, and dependency ratios.

Regional differences in population growth and demographic change are important when considering how population drives global change. Only under the high-fertility variant is Europe’s population projected to increase; under the medium-fertility variant, Europe’s population is projected to decline by 11% by 2080. In all three variants, it is Africa’s population that accounts for the most growth, even almost trebling by 2080 in the low-fertility variant, and still increasing three decades after global population has peaked.

In addition to the demographic projections provided by the UN’s World Population Prospects, urbanization is an important demographic driver, relevant as both a driver and consequence of development. The UN also publishes the World Urbanization Prospects, the most recent of which is the 2011 Revision released in October 2012 (UNDESA, 2012). Figure 4 shows the world average urbanization rate from 1960.

Table 1. Projected world population for 2030 and 2080, under the three main variants (UNDESA, 2013b).

Year	Low	Medium	High
2030	8.0b	8.4b	8.9b
2080	7.7b	10.5b	14.1b

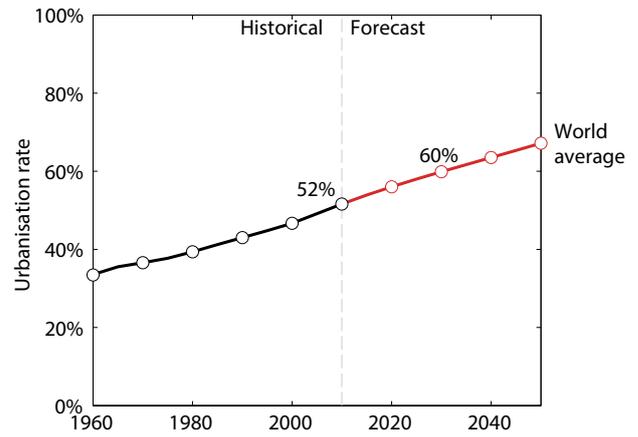


Figure 4. World urbanization rate projected to 2050 (Source: UNDESA, 2012).

While the UN population projections include projections of net migration, they do not indicate bilateral movement of migrants, and there appears to be no direct analysis of the possibility of climate change driving migration.

2.4.2 Tourism

The UN World Tourism Organization (UNWTO) published a 2030 forecast of international tourism in 2011 (UNWTO, 2011), their previous forecast having been published in 2001. The forecast is generated from derived relationships with gross domestic product (GDP, as a proxy for traveler affluence) and cost of transport. GDP projections are taken from the International Monetary Fund up to 2016 and from Oxford Economics thereafter, while transport costs are assumed to grow at 1.1% p.a. for air travel and faster for surface travel.

The relative growth rate in international tourism is expected to decline, to an average of 3.3% p.a. during 2010–2030 because of three factors: (i) lower GDP growth as economies mature, (ii) lower elasticity of travel to GDP, and (iii) an increase in transport costs. The forecast for international arrivals in 2030 is 1.8 billion (Figure 5).

Inbound tourism to emerging economies is expected to draw level with that to advanced economies in about 2015, and to be about 30% higher by 2030. The majority of new tourist arrivals and departures are expected to be to/from the Asia-Pacific region.

The UNWTO examines three scenarios in a sensitivity analysis. Under the first of these scenarios, economic growth is assumed to be significantly slower and tourism in 2030 is projected to be 1.4 billion arrivals. The second scenario envisages a faster rise in the cost of transport, but with the same economic growth as the central scenario, leading to a projection of 1.66 billion arrivals in 2030. The third scenario assumes declining transport costs, and projects 2.0 billion arrivals in 2030.

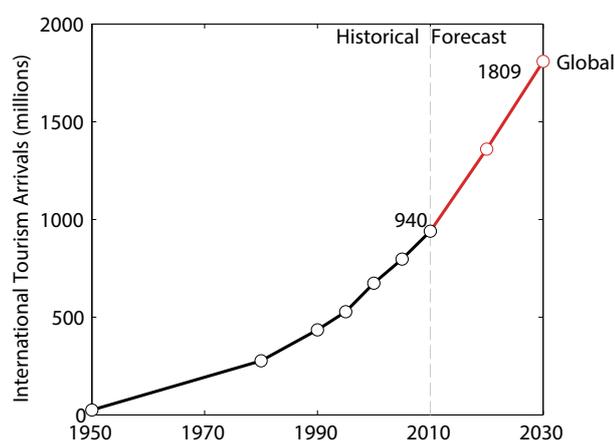


Figure 5. Global tourism projected to 2030 (Source: UNWTO, 2013).

2.4.3 Socio-political

Future socio-political change is the least predictable of all future change because of the complex integrated relationships between a very large number of drivers and parameters, most of which cannot be measured. Socio-political changes are therefore normally in the realm of scenarios rather than of projections. Future events such as social unrest, civil or international wars, regime changes, or fundamental social transformations offer little scope for quantitative projection. While some efforts have been presented in the literature to establish quantitative relationships between some measurable aspects of societies and unrest, there is as yet no consensus on the utility of such research.

2.5 Economics

Economic projections are in many ways core to projections of all other parameters. In this section we describe macroeconomic growth, as measured by global GDP; international trade; transportation; and resource demand, subdivided into minerals, food, and energy.

2.5.1 Macroeconomic growth (GDP)

Projections of macroeconomic growth underlie many other projections, with GDP being a key predictor of health, food demand, commodity prices, trade, and travel, among others. But there are conflicting theories about the drivers of macroeconomic growth, and therefore contrasting projections appear in the literature. The most widely used projections follow the neoclassical growth model, which links population (indicating labor supply and economic demand), capital (base, investment, and depreciation), and productivity (including assumptions about technological progress). Johansson et al. (2012) report that differences in productivity between countries explain the majority of differences in their growth in GDP per capita. Economic projections require a significant number of assumptions, and some of these become more 'heroic' the further away is the time horizon. In general, macroeconomic projections assume that developing countries, which have a large

labor supply and a shortage of capital, have significant capacity to grow, and grow rapidly, compared with developed countries. The consequence of this is that most projections assume that the substantially faster growth in the developing world seen in recent years will continue for several decades, and, in the long run, all countries will grow at the same rate. This is sometimes called the 'conditional convergence' of per capita incomes, and can also be considered a 'maturing' of economies.

The Organization for Economic Co-operation and Development (OECD) projects global GDP to 2060 (Johansson et al., 2012). They provide considerable detail on their assumptions and methodology. The OECD projects major changes in the composition of global GDP, including that the combined economies of China and India will increase in size from the current one-third of OECD countries to be larger in 2060. Overall, the OECD projects global GDP to grow by an average 2.6% p.a. to 2060, starting at about 4% p.a. in 2020 and declining to 1.7% p.a. by 2060. Over the period, growth is projected at 1.7% p.a. in OECD countries and 3.7% p.a. in non-OECD countries. In the baseline scenario, Global GDP is projected to be 88% larger in 2030 and 263% larger in 2060 (Figure 6). Two further scenarios discussed by the OECD result in higher growth over the period (Johansson et al., 2013). The first of these additional scenarios assumes more ambitious fiscal consolidation, while the second additionally assumes structural reforms.

Other Projections

The World Trade Organization (WTO), in its World Trade Report 2013, discusses a number of macroeconomic growth and international trade modelling exercises in the literature. In presenting their own analysis, they clearly state that the modelling exercise they undertake is not necessarily any better than others found in the literature.

The International Energy Agency (IEA) makes its own projections of economic growth, based on projections made by 'various economic forecasting bodies' (which are unspecified) and their own assessment. They project an average 3.5% p.a. growth in global GDP to 2035.

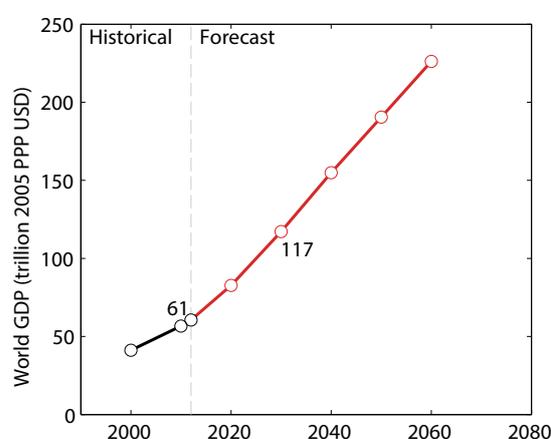


Figure 6. Projection of world economic production to 2060 (Source: Johansson et al., 2012).

Projections of global growth have also been made by large banking and financial services firms such as PwC (2013), Knight Frank (2013), and StandardChartered (2010).

2.5.2 International Trade

The projection of international trade differs from the projection of international freight transport due to the change of focus to the composition of traded goods (and services) and their value, rather than the physical volume and routing.

There is a very large body of literature on projecting international trade. The UN's World Trade Organization (WTO) uses two scenarios (high growth, low growth) to illustrate potential futures, stating clearly "The principal purpose of these simulations is not necessarily to provide better projections than elsewhere in the literature" (WTO, 2013:89). These two scenarios are vastly different, "with the aim of broadening the cone of possible trajectories" (Fontagné and Fouré, 2013:21). The WTO calls the scenarios 'boundary scenarios'.

The projections presented by the WTO are based on a model reported by Fontagné and Fouré (2013). This model is actually composed of two, sequential sub-models: the first is a macroeconomic growth model (MaGE), projecting the overall shape and size of the world economy to 2035, and the second is a dynamic computable general equilibrium (CGE) model (MIRAGE-e), which, using the macroeconomic projection as an exogenous baseline, projects economic distribution between countries and sectors.

Some key results can be drawn from the analysis. Trade in services is expected to increase as a share of overall trade in both the high- and low-growth scenarios. The country shares of global trade are vastly different under the two scenarios: in the low-growth scenario, China's share of global trade actually decreases, from the present 15% to 11% in 2035, while in the high-growth scenario it increases substantially, to 24%, of a much larger absolute volume. Trade between the economic North and South is projected to be about the same share of global trade under each scenario, but while the low-growth scenario sees the majority of remaining trade as North–North, the high-growth scenarios sees this majority swing to South–South trade.

The World Trade Report (WTO, 2013) contains a considerable amount of information and analysis of the determinants of trade, from water availability to oil prices, research and development to migration trends. The WTO concludes that the main determinants of global trade are demographics, investment, technological progress, energy and natural resources, transport, and institutions.

While the World Trade Report is published annually, the focus of the report changes with each edition, and the 2013 edition was focused on the long-term outlook. Previous editions have focused on non-tariff barriers to trade (2012), preferential trade agreements (2011), trade in natural resources (2010), and trade policy commitments (2009). The long-term outlook, therefore, is not expected to be frequently or regularly updated.

2.5.3 Resource demand

Resource demand is a function of population, affluence and technology. In this section we discuss mining and metals, food and land use, and energy.

2.5.3.1 Mining and Metals

There have been few published attempts to quantitatively project long-term demand for metals and other minerals. It must be presumed that large resource firms perform internal forecasts, but these are either not publically available or are only short term. The most common projection is qualitative and simplistic: that metal and mineral demand is expected to grow (e.g., Kesler, 2000).

However, the POLINARES project, which aimed to inform EU policy on natural resources, released a quantitative analysis of future demand for mineral resources (Keramidas et al., 2012). Four scenarios ('future world images') are presented with distinctions on two axes: economic (prevalence of market vs. state forces) and political (integration and globalization vs. competition and regionalization). The scenarios are:

- S1: Market economy and multilateral institutional structure
- S2: Strategic economy and multilateral institutional structure
- S3: Strategic economy and national institutional structure
- S4: Market economy and national institutional structure

For each scenario, quantitative assumptions were made for six major groups of parameters: macroeconomic drivers (GDP and population), geological supply of energy resources, political availability of fossil fuels, investment climate, technological development, and climate-related issues.

Several different approaches were used and combined to obtain projections. A bottom-up approach projects sectoral demand based on a sectorally disaggregated economic growth model; a top-down approach assumes a common growth and decline curve shape for all countries, with different timing, peak heights, and plateau heights; and an indirect approach, which uses

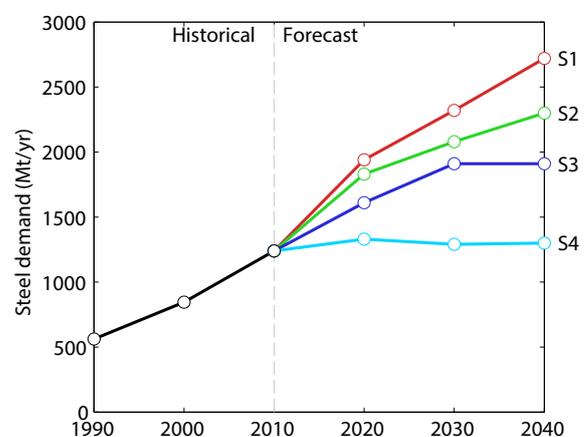


Figure 7. Steel demand projected to 2040 under four scenarios (Source: Keramidas et al., 2012).

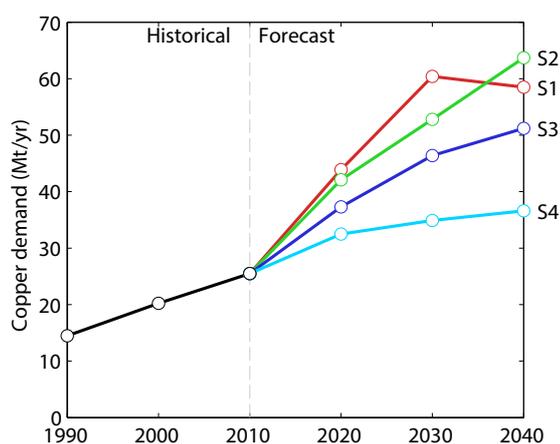


Figure 8. Copper demand projected to 2040 under four scenarios (Source: Keramidis et al., 2012).

the energy-based technology results of their energy model to project demand for other metals. In each approach, the world was divided into ten regions. Results are presented for steel and copper (shown here in Figure 7 and Figure 8, respectively) with a brief discussion of other metals.

The apparent peak in copper demand under scenario S1 (Figure 8) is described in the report as temporary, as Asian demand declines but before African demand reaches its maximum growth rate.

For some other minerals, such as neodymium, cobalt, zirconium, indium, and gallium, POLINARES sees the potentially explosive growth of renewable energy technologies (wind, nuclear, solar) as being the key drivers of demand growth.

Other projections

The World Economic Forum presents key drivers of change in mining and metals, and develops three scenarios based on these drivers, but does not extend this to generating projections (World Economic Forum, 2010). The three scenarios are called 'Green Trade Alliance', 'Rebased Globalism', and 'Resource Security'. The list of drivers given is long but not exhaustive. They are divided into five groups: social (e.g., expectations on corporate social responsibility), technological (e.g., substitutions for minerals), economic (e.g., access to capital), environmental (e.g., price of CO₂), and (geo)political (e.g., resource nationalism).

Based on a projected significant increase in the global average level of urbanization, McKinsey & Company project an 80% increase in steel demand between 2010 and 2030 (McKinsey & Company, 2011).

2.5.3.2 Food and Land Use

The future of food production is driven primarily by population growth, increased per capita food consumption resulting from increased incomes, and changes in diets particularly to more livestock products.

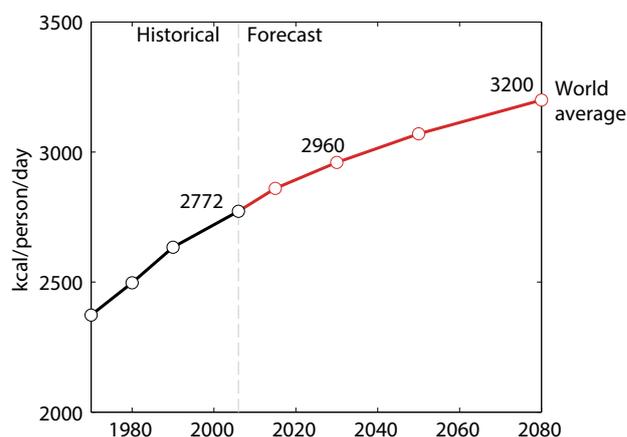


Figure 9. Projected growth in food intake in world average kilocalories per person per day (Source: Tables 1.1 and 2.1 of Alexandratos and Bruinsma, 2012).

The Food and Agriculture Organization of the UN (FAO) recently released new projections of future global food consumption (Alexandratos and Bruinsma, 2012). The projections are generated at a very detailed level of 350 food commodities by country, and distinguished further between irrigated and rain-fed land. The starting points of these projections are assumptions of growth of population (the 2008 revision from the UN) and GDP (provided by the World Bank), and expected changes in country- and commodity-specific demand with income ('Engel demand functions'). These demand projections are then combined with assumptions about self-sufficiency and trade to derive production projections. The projections at this stage are then discussed in an iterative process with a large number of experts to reach the final projections. Projections of land use are then derived by a further process requiring the projection of yield changes for 34 major crops.

Global average food consumption is expected to increase from 2772 kcal/person/day in 2006 to 2960 kcal/person/day in 2030 and 3200 kcal/person/day in 2080 (Figure 9).

Note that the chart shows food production after food wasted, fed to livestock, and used by industry. Total production is necessarily significantly higher, with considerable use of grain for livestock feed, vegetable oil for paints and biodiesel, and sugar for ethanol. In addition, growing attention is being paid to the issue of food waste (e.g., the SAVE FOOD program of the FAO), and the large proportion of waste seen today may decline in future. The chart also shows the world average, but there is significant distribution around this average.

Meat production is expected to increase by 1.5% per annum between 2006 and 2030, and by 1.3% p.a. between 2030 and 2050, and this increased production will require increased production of feed.

Increased crop production is expected to be met mostly from higher yields rather than increased arable area, such that global use of arable land may peak mid-century (Figure 10). However, there are regional differences: arable land use in developed

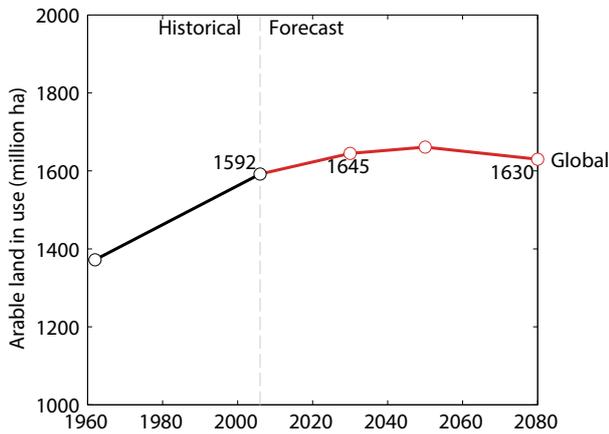


Figure 10. Projected use of arable land in millions of hectares (Source: Table 4.8 of Alexandratos and Bruinsma, 2012).

countries is projected to decline by about 6% to 2050, while that in Sub-Saharan Africa and Latin America are projected to increase by about 21% and 24%, respectively. Areas in East Asia, South Asia, and Near East/North Africa are expected to remain about the same as now.

Fertilizer consumption has been projected based on requirements to achieve the projected yields for 34 crops and 105 countries/regions. Global consumption of nitrogen, phosphorus, and potassium fertilizer is expected to increase from 166 million tonnes (of nutrient) in 2006 to 231 Mt in 2030 (Figure 11).

2.5.3.3 Fisheries

Projections of fish demand and pricing are provided by OECD and FAO (2013), but only out to 2022. World fish production, including aquaculture, is forecast to increase by 18% between the base period 2010–2012 and 2022, to reach 181 Mt/yr. Most of this increase is expected to come from aquaculture, which itself is expected to increase by 35% over the period. Asian countries are projected to continue to

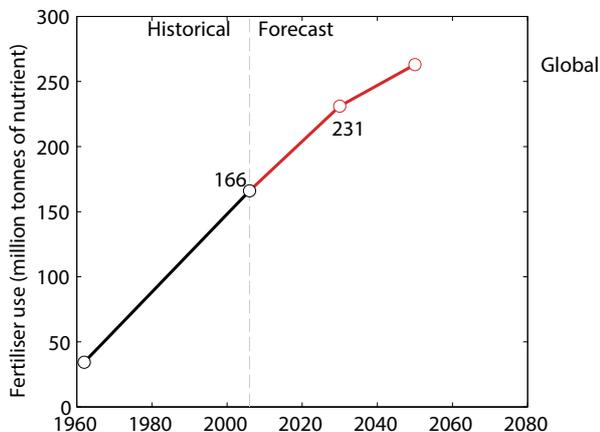


Figure 11. Projected fertilizer use, in million tonnes of the nutrients nitrogen, phosphorus, and potassium (Source: Table 4.15 of Alexandratos and Bruinsma, 2012).

dominate aquaculture production, with China, India, Vietnam and Indonesia projected to produce 89% of global aquaculture output. Higher fish prices and a slowing of population growth are expected to slightly reduce the rate of growth of global fish consumption. These projections appear to include both finfish and shellfish.

2.5.3.4 Energy

There are two prominent energy projections and these will be discussed separately.

IEA World Energy Outlook

The OECD's International Energy Agency (IEA) publishes its World Energy Outlook (WEO) annually in November. The most recent edition, published in 2012, projects energy supply and demand to 2035 using three main scenarios (IEA, 2013b). The WEO costs a minimum of €120 (for the electronic version). The IEA has only recently switched to the use of scenarios in its Outlooks, having previously used an alternative approach.

The three scenarios of the WEO distinguish policies rather than assumptions about other factors, and are described as follows:

- **Current Policies:** Government policies that had been enacted or adopted by mid-2012 continue unchanged.
- **New Policies:** Existing policies are maintained and recently announced commitments and plans, including those yet to be formally adopted, are implemented in a cautious manner.
- **450 Scenario:** Policies are adopted that put the world on a pathway that is consistent with having around a 50% chance of limiting the global increase in average temperature to 2 °C in the long term, compared with pre-industrial levels.

The New Policies scenario is labelled the 'central scenario', but, while the IEA is clear that this is not a forecast, this scenario is frequently the only one mentioned in the summary pages of the WEO.

The scenarios are built on assumptions of population growth (from the UN), GDP growth (various sources), energy prices, CO₂ prices, and technology. The first two of these are independent of the scenarios, while the last three vary with scenarios. In particular, the price of oil is assumed to be between about \$US100 and \$US140 per barrel in 2030 (in 2011 dollars), with the lower level under the 450 scenario and the higher level under the Current Policies scenario (Figure 12).

The model used by the IEA to project future energy is called the World Energy Model (WEM). It is a very detailed partial equilibrium model with a number of interconnected modules, each with a number of available technologies available via cost curves, and all over 25 regions (IEA, 2013a). The three main modules and their sub-modules are:

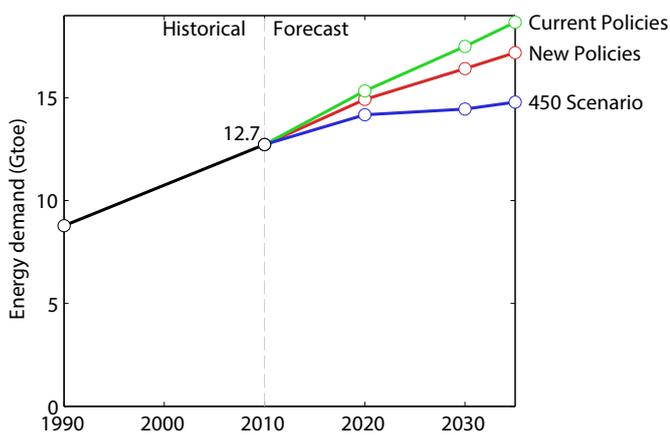


Figure 12. International Energy Agency projections of global energy demand under three scenarios, in gigatonnes of oil-equivalent (Source: IEA, 2013b).

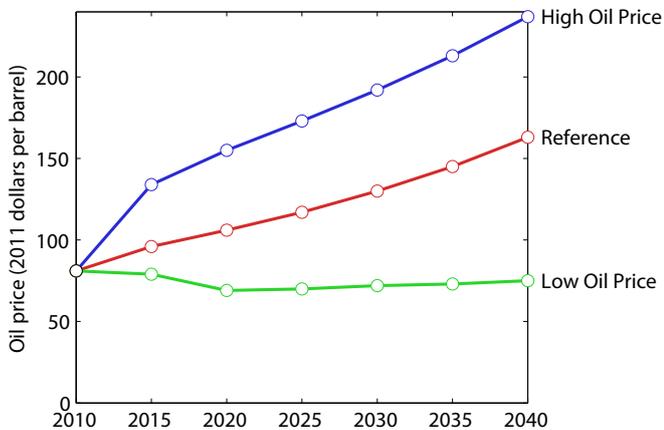


Figure 13. Exogenous oil price assumptions under three of the EIA's scenarios to 2040 (Source: EIA, 2013).

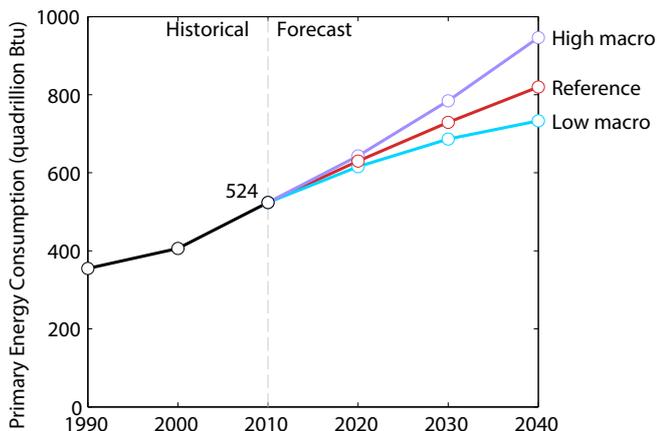


Figure 14. Three of the five scenarios from the Energy Information Administration's projections of global primary energy consumption to 2040. 'Macro' refers to macroeconomic growth, i.e., GDP growth (Source: EIA, 2013).

- Final Energy Consumption: Industry, Transport, Residential, Services, Agriculture, Non-Energy Use
- Energy Transformation: Power Generation, Heat Production, Refinery/Petrochemicals, Other Transformation
- Supply and Trade: Coal, Oil, Gas and Biomass

The use of a partial equilibrium framework permits significantly more detail than would be possible in a general equilibrium framework.

EIA International Energy Outlook

The U.S. Department of Energy's Energy Information Administration (EIA) releases its International Energy Outlook annually in July. The most recent edition projects energy supply and demand out to 2040 (EIA, 2013).

The EIA uses five scenarios in all, with the Reference Case and four additional scenarios to assess sensitivity to underlying assumptions. In contrast to the IEA scenarios, the EIA uses scenarios with no reference to policy positions. One pair of scenarios adjusts the assumptions of economic growth, with higher economic growth ('High Macro') or lower economic growth ('Low Macro'). The other pair of scenarios adjusts the price of oil, with higher and lower scenarios (Figures 13 and 14).

Global energy demand is projected to increase 39% between 2010 and 2030 under the Reference Case scenario. More than 85% of this growth is projected to occur in the non-OECD countries. Liquid fuels grow most slowly under the Reference Case, at 0.9% p.a. over the period, but remain the largest form of energy. Natural gas consumption is projected to grow at 1.7% p.a. and coal 1.3% p.a. Electricity generation from renewable sources is projected to grow at 2.8% p.a., reaching 25% of total generation in 2040. Much of the growth in renewable generation comes from hydropower and wind.

2.5.4 Transport

2.5.4.1 Passenger air travel

The International Civil Aviation Organization (ICAO) of the UN publishes its Global Air Transport Outlook every two or three years. The most recent version, published in 2013, is priced at USD950 (ICAO, 2013a). While the publication was not available for the writing of this report, selected summary information is available on the internet, and we have drawn from that information in this section.

The methodology used by ICAO is described as 'econometric bottom-up' based on assumed future economic growth and ticket prices by 53 route groups (Teyssier, 2010). ICAO uses three scenarios, of which the central one is called 'Most Likely'. The scenarios appear to be distinguished solely by assumed economic growth, with the high scenario having 0.3 percentage points higher GDP growth in developed economies and 0.6 percentage points higher in developing economies, while the low scenario has 0.5 percentage points lower GDP growth in developed economies and 0.1 points lower growth

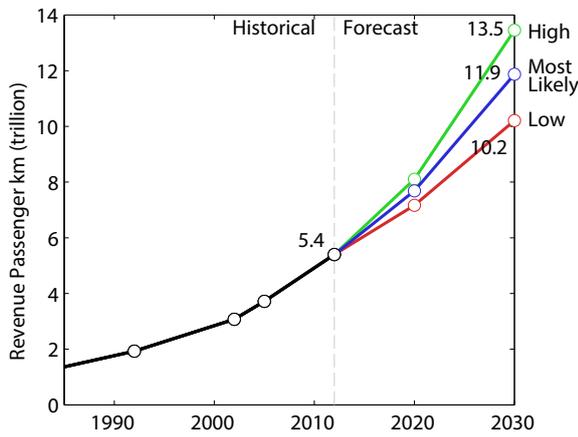


Figure 15. Projections of passenger travel to 2030 by the International Civil Aviation Organization under three scenarios (Source: ICAO, 2013b; Teysier, 2012).

in developing economies (Teyssier, 2012). The Most Likely scenario results in 4.5% p.a. growth in passenger travel, the Low scenario 3.6% p.a., and the High scenario 5.2% p.a. Growth between 1990 and 2010 was 4.4% p.a. Under the Most Likely scenario, ICAO expects traffic to reach 11.9 trillion revenue passenger kilometres (RPKs) in 2030 (Figures 15 and 16).

Without access to the full report and the details of the methodology used, it is difficult to gauge the robustness of the projections made by ICAO. It may be instructive, therefore, to consider cautiously forecasts made by major companies in the air travel industry.

Boeing forecasts 5% p.a. growth in air traffic between 2012 and 2032, based on an assumed 3.2% p.a. growth of world GDP, reaching a little over 13 trillion RPKs in 2030 (Boeing, 2013). The drivers used by Boeing include economic predictions, growth momentum, historical trends, travel attractiveness, and projections of the relative openness of air services and domestic airline regulation. Airbus forecasts overall air traffic growth of 4.7% p.a. between 2012 and 2032 (5.1% from 2012

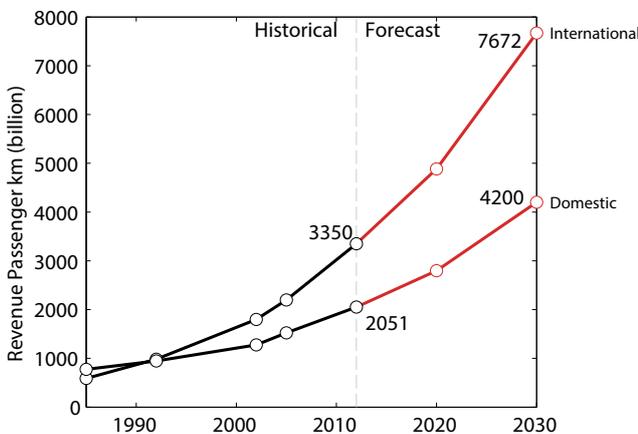


Figure 16. Air travel projected to 2030, both international and domestic flights, under the 'most likely' scenario (Source: ICAO, 2013b).

to 2022, and 4.4% from 2022 to 2032), reaching a little under 13 trillion RPKs in 2030 (Airbus, 2013). It appears that ICAO's projections are slightly conservative by industry standards, but not much more can be learned from the sparse methodological descriptions provided by Boeing and Airbus. One key aspect of the methodology of both companies appears to be an observation that airline traffic growth has historically outpaced economic growth, and that traffic numbers are relatively resilient to global economic shocks.

2.5.4.2 Freight Transport

Buhaug et al. (2009) analyze greenhouse gas emissions from ships, and include projections of shipping traffic to 2050. These projections are developed for a selection of SRES scenarios, which were developed for the Fourth Assessment Report of the IPCC. In projecting greenhouse gas emissions, they also project changes in fleet size, average speed, technology, and fuel parameters.

Figure 17 shows projected shipping traffic for four scenarios (the three variants of A1 presented by Buhaug et al. (2009) are almost identical for this parameter). The projections are made for 2050 and the report states that it is assumed that growth would be exponential between 2007 and 2050. Projections for 2030 range between 62% (B2) and 110% (A1) higher than 2007, while for 2050 this range is from 147% (B2) to 300% (A1). Under all scenarios, growth is projected to be dominated by container shipping, growing by between 425% (B2) and 800% (A1).

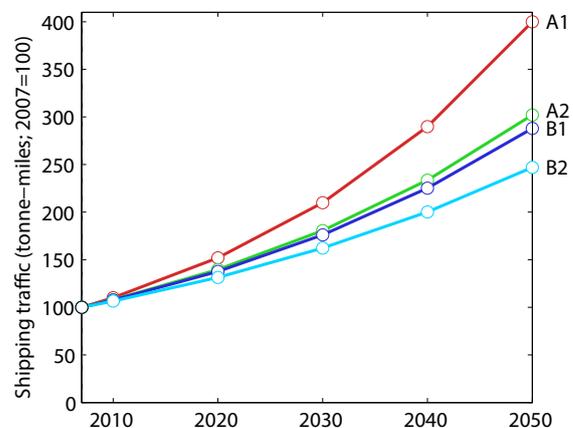


Figure 17. Projected shipping traffic to 2050 under four scenarios (Source: Buhaug et al., 2009).

Turning to air freight, there is significantly less information available. ICAO, along with its forecasts of passenger air travel also forecasts air freight. Their forecast is 5.3%/yr to 2030 (ICAO, 2013b). Boeing forecasts 5%/yr growth (Boeing, 2013).

Routing

The Ocean Policy Research Foundation (OPRF, 2008) present a number of plausible future events that could have a significant effect on the routing of global shipping traffic, although the report's focus is on Japan. Among the suggested changes are:

- Completion of modernization of the trans-Siberian railway (2030s)
- Arctic sea route to be voyageable throughout the year, taking as much as half of container-transported goods between Asia and Europe (2040s)
- Significant pipeline constructions reducing shipments of oil and gas (2010s–2030s)

The president of Russia, Vladimir Putin, recently announced funds for the development of the trans-Siberian railway (ITAR-TASS, 2013), suggesting that extra capacity might be available on that line before the 2030s.

2.6 Technology

There are very few if any scenarios/projections available for how technology will develop in the future. The nature of technological and scientific breakthroughs is that they are sporadic and surprising. However, key drivers of breakthroughs are financial support (whether governmental or private) and the socio-political environment in which research occurs.

Many economic models simply assume a constant rate of technological innovation represented as increasingly efficient use of resources to produce the same goods and services. There are some research groups studying technology diffusion, for example, the International Institute for Applied Systems Analysis (IIASA, 2013).

2.7 Summary

The first part of this report has collated and described forecasts, projections, and scenarios of key global drivers of change from the available literature. This information is to be used as background for a Drivers, Pressures, States, Impacts, Responses (DPSIR) analysis of three Arctic regions to be undertaken as part of the Adaptation Actions for a Changing Arctic part C (AACAC) project.

There is considerable variation in the availability of robust, detailed projections of the key drivers considered by this report. While some drivers have a substantial literature and relative agreement on projection methodologies, others are less amenable to quantitative analysis and appear only as scenarios.

In addition, while the AACAC project intends to look forward to both 2030 and 2080, there are few projections across the drivers that extend as far as 2080, and, for those that do, uncertainty is extremely high. However, for the purposes of AACAC it may be sufficient to extrapolate the available projections and treat the analyses as exploratory. An exploratory, scenario-based approach to future analysis allows a range of possible futures to be described, without being constrained by a lack of certainty.

The Appendix to this report provides a table of key details of recommended projections of drivers for which they are available.

3. The Arctic

We turn now to expectations of change specific to the Arctic. While many of these changes are directly influenced by increasing temperatures – most clearly seen by the reduction in sea ice – the extent of that influence varies considerably between different drivers.

Global interest in the Arctic has increased significantly in recent years, as evidenced by such things as the U.S. Geological Survey's Arctic petroleum assessment, numerous news stories about the opening up of the fabled Northwest Passage, widespread concern for iconic Arctic species such as polar bears, and territorial claims made on the basis of continental shelves. The risk of operating in the Arctic remains high, and many players are taking a cautious approach to any transition from interest to implementation, but with high risks can also come high rewards, and it has been estimated that as much as \$100 billion of new money could be invested in the Arctic over the next decade, primarily in the realms of oil and gas, minerals, and infrastructure (Emmerson and Lahn, 2012).

As in the previous section on global context, this section does not directly discuss climate change in the Arctic, which is the subject of a separate report, but rather discusses key socio-economic changes. In addition, Arctic fisheries, changes in which are expected to be substantial, are the subject of another report and will therefore not be discussed here. Within this discussion it is important to bear in mind that the definition of 'Arctic' is not entirely clear or consistent: different boundaries are used by different studies, partly because of data availability, but also because of fundamental differences in definition (isotherms, latitudes, geopolitical boundaries, etc.).

3.1 Population

As with other indicators, the resident population count of the Arctic depends strongly on the boundary used to define the Arctic. In *The Economy of the North 2008*, the total population of the 'Arctic regions' in 2006 was 10 million (Duhaime and Caron, 2009), while the *Arctic Human Development Report* provides a figure of 4 million (Bogoyavlenskiy and Siggner, 2004). In this section we rely on projections of population provided by official statistics bureaus, and are therefore constrained by the level of geographic resolution in those projections. As a consequence, the boundaries used here are similar to those of Duhaime and Caron (2009).

The Megatrends report (Nordregio, 2011) highlights urbanization as a current trend in Arctic demography. While the distinction made between urban and rural varies considerably between countries, making it difficult to perceive a clear picture in any data, Nordregio (2011) concluded that urbanization is a process occurring across the Arctic. In particular, they point to a 'step-by-step' process whereby individuals tend to move to the next urban level (from village to town and from town to city). The urbanization process was confirmed by speakers at the First International Conference on Urbanisation in the Arctic

(Hansen et al., 2012). Urbanization often occurs because people are attracted by (real or perceived) employment opportunities, educational institutions, social options, and lower costs of living (Gilbert, 2012; Nordregio, 2011).

In recent years migration has been the main driver of population change in the Arctic, both as out-migration to more southern regions and as immigration from abroad of people seeking opportunities with the resource extraction industries (Heleniak and Bogoyavlenskiy, 2013). Nordregio (2011) highlighted a specific aspect of this trend, namely out-migration of youth. Their analysis shows that the proportion of individuals aged under 20 declined in each region in the Arctic between 1991 and 2006. While this trend is present in most developed countries, its existence also in the Arctic nevertheless presents a challenge to development in these regions.

Some communities in the Arctic have experienced migration flows at times substantially larger than the natural rate of increase (births/deaths) (Hamilton and Mitiguy, 2009). Alaska and Yukon have seen their populations spike and dip with resource booms and subsequent retreats; Greenland has an age-specific migration spike, with youth travelling after finishing school and not all returning; Iceland's recent banking boom and bust saw a spike in immigration during the boom and a spike in emigration following the crisis; and Russia's Arctic regions experienced substantial immigration with massive government support, turning to substantial out-migration following the dissolution of the Soviet Union.

Data on the indigenous populations of the Arctic are not readily available, but estimates made by Bogoyavlenskiy and Siggner (2004) suggested a total in the early 2000s of between 350 000 and 400 000. In addition, Nordregio (2011) stated that the indigenous populations in the Arctic have been growing by about 1.5% annually. The populations of most Arctic regions are dominated by non-indigenous people, with the exceptions being Greenland and Arctic Canada (Bogoyavlenskiy and Siggner, 2004). Of the Arctic countries, it appears that only Statistics Canada projects aboriginal populations (Caron Malenfant and Morency, 2012).

3.1.1 Projections of Population in the Arctic

Projections of population change in the regions of the Arctic vary widely (Figure 18). Generally, population projections produced by official statistical offices do not explain the socio-economic reasons behind projected demographic changes, but rather extend recent historical trends into the future. Therefore, to understand projections we must look to the recent past. Furthermore, projections generally do not factor in the potential consequences of changing demographics: for example, if a significant increase in the age dependency ratio leads to more difficult economic conditions, then this could in turn lead to increased emigration.

When comparing projected population growth between the Arctic and non-Arctic regions of each country, we see some clear contrasts (Figure 19). In the USA, Alaska is projected to

grow significantly faster than the rest of the country, while in Canada, Norway, and Finland, the reverse is true. In Russia, the Arctic population is projected to decline even more rapidly than in the rest of the country. Figure 20 shows the projected population growth between 2012 and 2030 for each Arctic region. Overall, the population of the Arctic is projected to decline by about 2.5% between 2012 and 2030, with the effect dominated by changes in the Russian Arctic.

In the following discussions, the subnational areas mentioned are those for which projections were available. Particularly in Russia, some administrative regions previously included

within the Arctic have been merged so that data are no longer available. For example, the Russian autonomous okrugs Taimyr and Evenk – both included as Arctic regions in the Economy of the North 2008 report (Glomsrød and Aslaksen, 2009), and both with relatively low populations, have since been merged into the much more populous Krasnoyarsk Krai to form a very large region spanning from the Arctic Ocean almost as far south as Mongolia.

The raw data used in this section are available from the author on request.

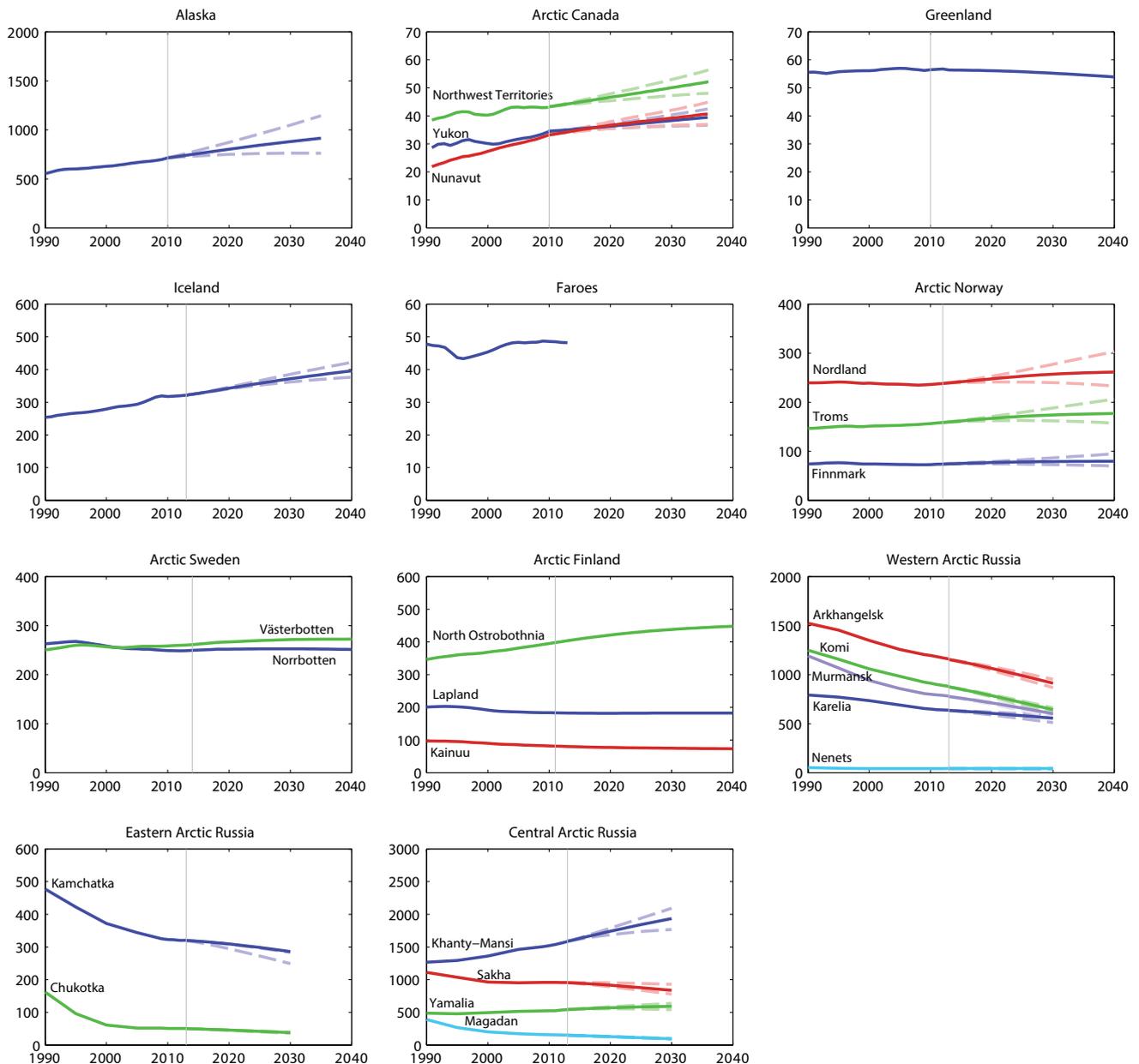


Figure 18. Recent historical and projected populations (thousands) for regions of the Arctic (sources are provided in the text). Vertical lines indicate the first year of projections. Some historical data series do not exactly match projected series because of revisions since projections were made. Medium variant projections are shown as solid lines, other variants as broken lines.

3.1.1.1 Canada

Canada’s Arctic population (in Yukon, Northwest Territories (NWT), and Nunavut) is projected to grow by 12% between 2012 and 2030 (medium variant M1; Statistics Canada, 2010). Yukon’s growth, at 6%, is projected lower than both NWT (15%) and Nunavut (14%). All three of these regions have higher fertility rates than the Canadian average (1.6), and Nunavut has by far the highest rate in Canada, with 3.0 children per woman. Overall, Canada’s population is projected to grow by 20% over the period. Separate projections were not available for sub-provincial areas Nunavik and Nunatsiavut.

3.1.1.2 Alaska

Alaska’s population is projected to grow by 20% between 2012 and 2030 (baseline variant; State of Alaska, 2012). The high and low variants show a substantial range: 47% growth under high assumptions and 7% under low assumptions. These compare with a national medium population projection of 14% growth over the same period (U.S. Census Bureau, 2012). Drilling down into sub-state population projections, the populations of Nome and NW Arctic are projected to grow by 13% and 14%, respectively, between 2012 and 2030, while that of North Slope is projected to decline by 4%. However, the population of North Slope has actually already increased by 5% since the projection was made.

3.1.1.3 Russia

Russia’s population as a whole is projected to decline by a total of 1% between 2012 and 2030, with Arctic areas declining more sharply than the national total (medium variant; Rosstat, 2013). The total population of Barents Russia (Karelia, Komi, Arkhangelsk Reg., Nenets, Murmansk) is projected to decline from about 3.5m today to about 2.8m in 2030 (medium variant), with even the high variant showing declines in all regions except for Nenets. Far-eastern Arctic Russia’s (Kamchatka, Chukotka) population is projected to decline by 12% by 2030. The populations of the two most important petroleum-producing regions, Khanty-Mansi and Yamalia, are projected to continue to increase, with Khanty-Mansi growing the fastest of all Arctic regions, 22% over the period, just ahead of Alaska.

Many of Russia’s northern cities were created during the Soviet era specifically to exploit the resources of the north and for strategic reasons (Heleniak, 2013). As part of the market reforms following the collapse of the Soviet Union, prices shifted from being set by the state to being set by the market, resulting in a significant rise in the cost of living in the Russian North, and prompting substantial out-migration to the south (Heleniak, 1999).

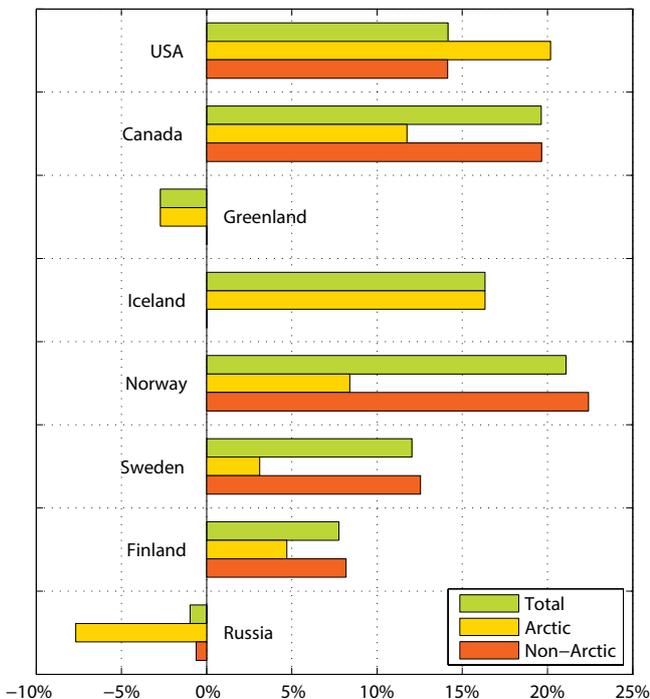


Figure 19. Projected population growth in Arctic and non-Arctic regions by country, medium projection variants, 2012–2030.

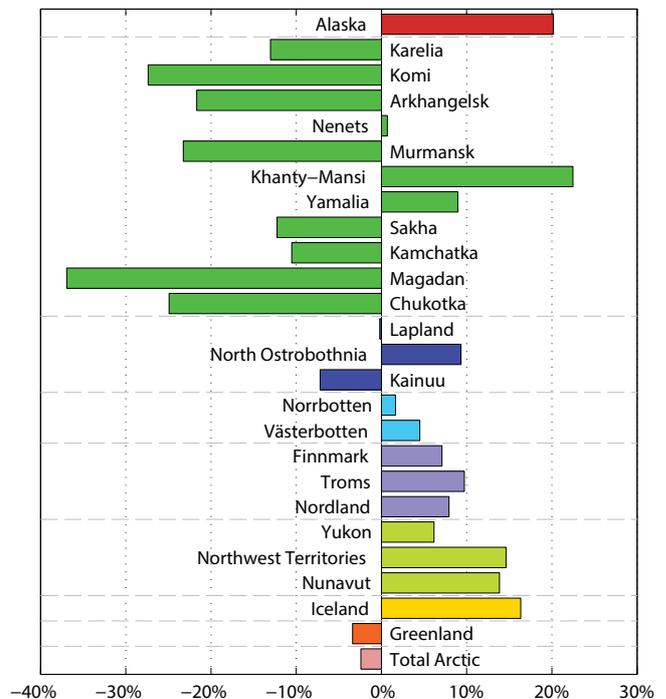


Figure 20. Projected population growth in the Arctic regions, medium projection variants, 2012–2030.

3.1.1.4 Finland

Finland's total population is projected to grow by 8% between 2012 and 2030 (Statistics Finland, 2012). The Arctic regions of Finland are also projected to grow, at 5%, but this growth is entirely in North Ostrobothnia (9%), with Kainuu expected to decline in population by 7% and Lapland remaining stable. All three regions experienced net out-migration to other regions in Finland between 2010 and 2013. North Ostrobothnia's total fertility rate was the highest in Finland in 2012, and its death rate was also lower than that of Kainuu and Lapland (both higher than the national average), resulting in a substantially higher natural rate of increase in North Ostrobothnia than in the other two Arctic regions.

3.1.1.5 Sweden

The population of Sweden is projected to grow by 12% between 2012 and 2030 (Statistics Sweden, 2013). The Arctic regions are projected to grow much more slowly, with Norrbotten at 1.7% and Västerbotten at 4.5%. Projected growth in Norrbotten is dependent entirely on net in-migration, with deaths expected to exceed births throughout the projection period, and population starting to decline from 2028 as net in-migration is insufficient to counter natural population decline. In contrast, Västerbotten is projected to have excess births over deaths until 2032, and still have net growth following that due to net in-migration.

3.1.1.6 Norway

The population of Norway is projected to grow by 21% between 2012 and 2030 under the medium variant (Statistics Norway, 2012). The Arctic regions of Norway (Nordland, Troms, Finnmark) are projected to grow more slowly, at 8% over the same period, with Troms slightly faster (10%) than Nordland (8%) and Finnmark (7%). While the population of Troms has steadily increased over the past 40 years, those of Nordland and Finnmark have declined, and their trends have only turned positive in the past five years because of recent net immigration.

3.1.1.7 Faroe Islands

Statistics Faroe Islands have produced a 'stochastic population forecast' for 2012–2051, but the data are only available for a fee (Statistics Faroe Islands, pers. comm., 12 February 2014). However, they present a chart of their projection on their website (Statistics Faroe Islands, 2013). The population of the Faroes on 1 January 2013 was 48 197 and had been relatively steady for the previous 10 years (Statistics Faroe Islands, 2014). The projected population is to remain steady until about 2025, and then to decline slowly to about 47 500 in 2030 (about a 2% drop from 2010 to 2030) and to just under 46 000 in 2050.

3.1.1.8 Iceland

The population of Iceland is projected to increase by 16% between 2012 and 2030 under the medium variant (Statistics Iceland, 2013). Iceland's short-term migration projections (to 2017) are estimated based on projected total economic production, unemployment, and number of graduates. Iceland's fertility rate (2.0) remains high by OECD standards (average

1.7), and immigration has in recent decades been generally net-positive for foreign citizens and net-negative for Icelandic citizens.

3.1.1.9 Greenland

Greenland's population is projected to decline by 3% between 2012 and 2030 with net emigration expected to continue to more than offset net births (Statistics Greenland, 2014). The projections are provided in only one variant (one set of assumptions), but user-defined variants are available for a fee (Statistics Greenland, 2014).

3.2 Petroleum Exploration and Extraction

There is already significant petroleum production in the Arctic, with 10% of global oil production and 25% of global natural gas production sited there. Of this, 97% is from onshore fields in Russia and Alaska (Le Mière and Mazo, 2013). However, there are some key drivers for current increased interest in exploration and production in the Arctic (Emmerson and Lahn, 2012; Keil, 2011). Some of these drivers act in concert, such that exploration is more likely as a result of a combination of different factors.

The widely cited USGS assessment (Bird et al., 2008; Gautier et al., 2009) concluded that the Arctic holds 30% of undiscovered gas and 13% of undiscovered oil, although there remains large uncertainty around these figures. While this sounds considerable, these estimates equate to only about 4% of remaining global conventional resources (Le Mière and Mazo, 2013). Importantly, these undiscovered resources lie mostly offshore, and 90% to 95% within existing territories (Figure 21), reducing the potential for international disputes (Wong, 2013).

3.2.1 Drivers of Change

Accessibility has improved dramatically in recent years with the reduction in sea-ice extent, and the expectation that this trend will continue encourages exploration. Sea ice is a not only a barrier to transport but also a danger to vessels, with large icebergs able to cause significant damage. Because they are mobile, icebergs remain a danger even in ice-free Arctic waters. Increased access has made exploration possible where it once was not considered. In addition, reduced sea ice potentially provides better access to markets. Beyond sea-ice reduction, access is also improved with increased infrastructure, particularly ports.

High petroleum prices are driving significant expenditure in exploration, with the combined capital investments of Chevron, Exxon-Mobil, and Shell coming to \$120 billion in 2013 alone (Gilbert and Scheck, 2014). High prices, in turn, are driven by increasing demand and declining production from conventional fields. While the costs of developing oil or gas fields in the Arctic can be between two and ten times as high as in other environments (Le Mière and Mazo, 2013), projected sustained high petroleum prices have been expected by some to cushion high costs (Emmerson and Lahn, 2012).

Improved technology for offshore oil exploration and extraction brings within reach the goal of producing from previously impossible geological provinces, including those in the Arctic.

For some countries, **sovereignty** is a major driver of exploration. Greenland, which has gradually gained increasing independence from Denmark, is economically secure because of a block grant from Denmark, but, seeking economic independence towards a goal of full sovereignty, is pushing for mineral exploration, including oil and gas (Erdal, 2013; Keil, 2011; Rosing et al., 2014). The Self-Government Act of 2009 passed responsibility for mineral resource activities in Greenland from Denmark to the Greenland Self-Government authorities (Office of the Prime Minister of Denmark, 2010). As a consequence, not only can Greenland now make its own decisions regarding exploitation of its mineral resource, but it also accrues any revenue from such activities.

Reduced **dependence on imports** of energy for both economic and strategic reasons continues to be a major driver for

exploration in many countries, and in the Arctic this applies particularly to Alaska in its role providing petroleum products to the rest of the USA.

Diplomatic resolution of **maritime boundaries** substantially reduces the uncertainty in these border areas, uncertainty that otherwise prevents exploration. For example, Norway and Russia signed an agreement in 2010 establishing the coordinates of their Barents maritime boundary, including specifications for both fishing and petroleum extraction (IBRU, 2010). More than half of the exploration areas proposed by the Norwegian government in its next licensing round are located within the previously disputed area (Holter and Magnusson, 2014). A remaining boundary dispute between USA and Canada in the Beaufort Sea hinders exploration in that area.

The Arctic Futures fact sheet on oil and gas provides a number of further drivers of exploration and extraction in the Arctic (Arctic Info, 2013).

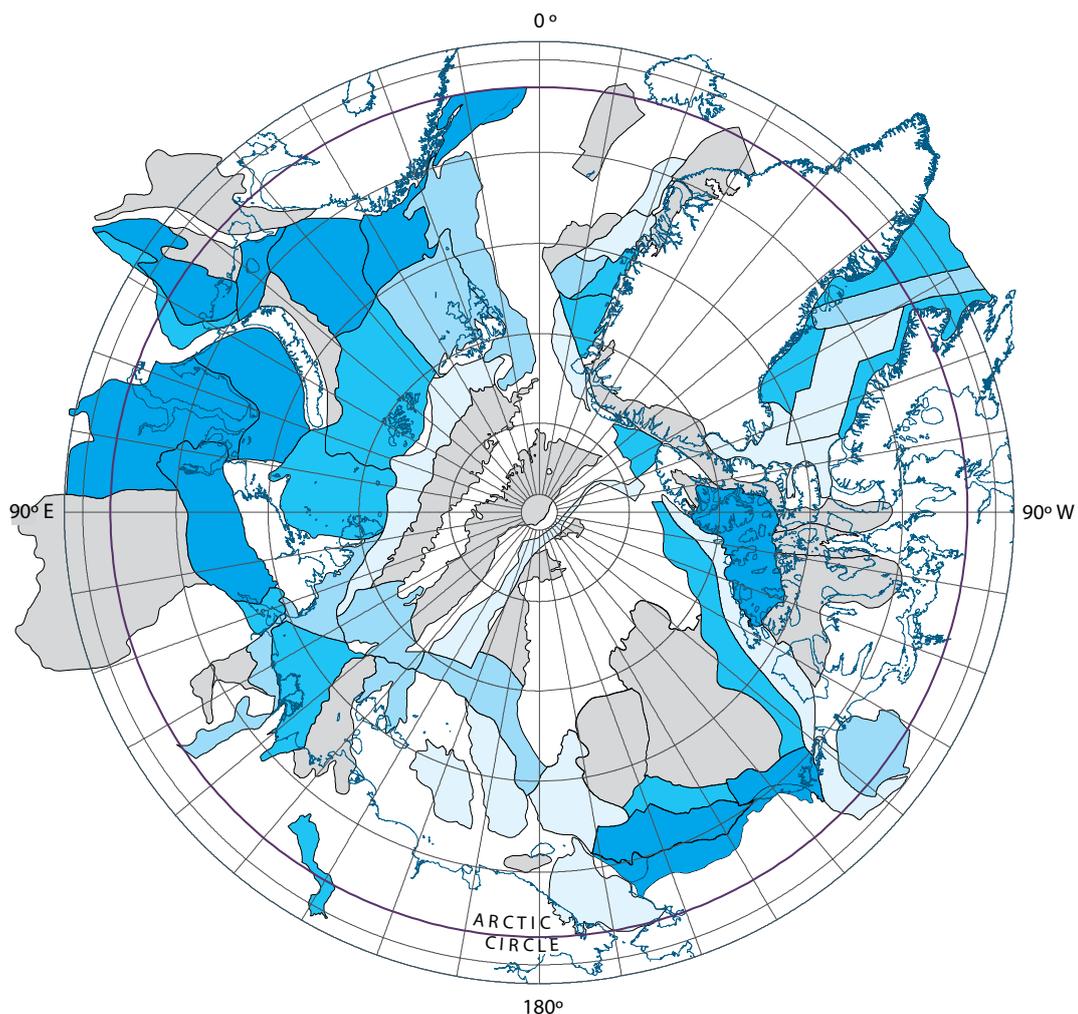


Figure 21. Assessment units used by USGS in the Arctic (in blue) with darker shades indicating higher probability of significant petroleum presence (source: Bird et al., 2008).

3.2.2 Outlook

There is considerable uncertainty about the future pathway of exploration and production of petroleum resources in the Arctic. Remoteness, lack of infrastructure, climate and sea ice all contribute to high costs for the oil business in the Arctic. Because costs there are always likely to be higher than costs elsewhere, oil and gas prices must remain high for Arctic exploration to be profitable. Murray (2006) played down opportunities in the Arctic, highlighting in particular the high proportion of gas in expected resources, and the extreme difficulty not only of extracting gas but also of bringing it to market from such remote locations.

Experience so far with Arctic exploration also suggests reason for doubting an imminent, rapid increase. Shell's experiences in the Arctic have made headlines, with up to \$6 billion invested, technical failures, the grounding and subsequent scrapping of a drilling rig, legal issues, and repeated postponements (Weaver and McGwin, 2014a). Similarly, the giant Shokman gas field in offshore Arctic Russia, originally expected to supply the North American market, has been delayed several times, most recently with the advent of cheap shale gas in the USA (Marson, 2012). After \$2 billion of exploration expenditure, Cairn Energy has so far not found commercial quantities of oil off Greenland's coast, and is postponing exploration there in preference for more certain basins elsewhere (McGwin, 2014). Furthermore, the Deepwater Horizon disaster of 2010 is fresh in the minds of many, fuelling environmental non-governmental organizations and local communities fearful of environmental damage in the Arctic.

At the time of writing, the futures market for oil expected a drop in prices of about 10% by 2016, dampening enthusiasm for Arctic exploration (Holter and Magnusson, 2014). However,

state-controlled oil and gas companies, which are driven more by state strategic interests, may be more likely to explore the Arctic than privately-held companies, which respond largely to market forces (Holter and Magnusson, 2014). In addition, the milder climate and lack of sea ice in Norway's Barents Sea make it a lower-cost exception among Arctic exploration areas, and increased production is expected earlier in that area (Holter and Magnusson, 2014).

While some are saying it may be two decades before we see production in new areas of the Arctic because of both prices and immaturity of technology (Holter and Magnusson, 2014), eventually many of the constraints to development are likely to be overcome: better technology, even less sea ice, better infrastructure, and tighter environmental regulations. So it is the dancing market forces of supply and demand that may ultimately determine how much of the Arctic's petroleum resource is developed. Using a petroleum-market model, Lindholt and Glomsrød (2011; 2012) project oil and gas production out to 2050 and conclude that, while production in the Arctic will increase, the Arctic's share of global oil production will not increase but be sustained, while its share of gas production will decline under their reference-price scenario. Figure 22 shows the projected production of oil by Arctic region. They cite significantly cheaper reserves of gas elsewhere in the world, such as Qatar and Iran, as effectively braking significant gains in market share for Arctic gas resources.

Rosing et al. (2014) present scenarios of future resource extraction activity in the context of overall economic performance of Greenland and its goal of independence from Denmark. Background papers used in the preparation of the report go into further detail.

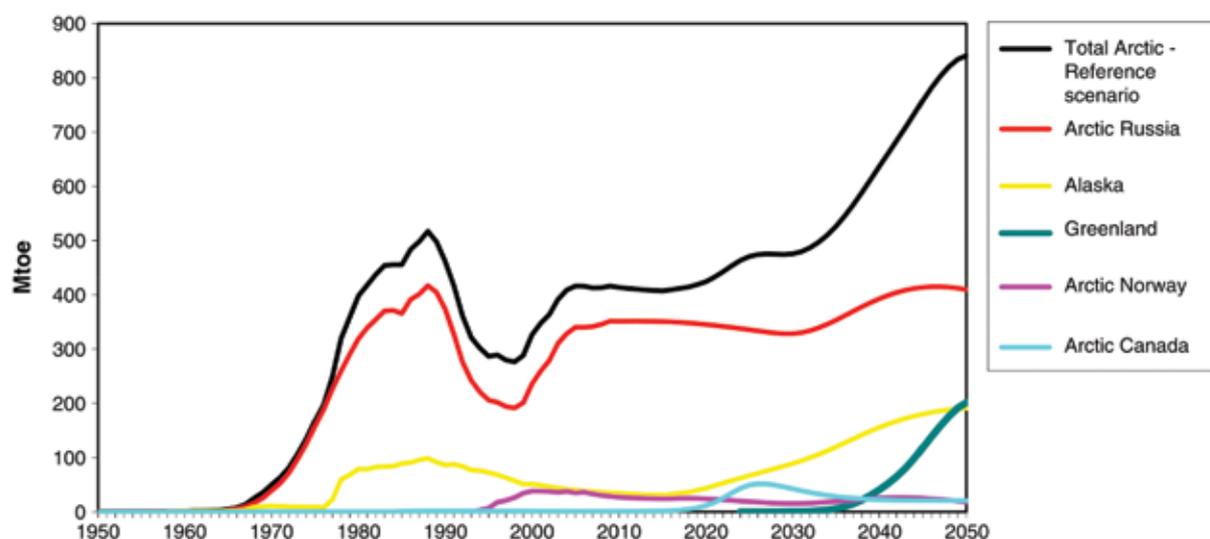


Figure 22. Projected oil production in Arctic regions under a medium oil-price scenario (Lindholt and Glomsrød, 2012).

Yamal LNG project

Russia is pursuing significant development of natural gas on the Arctic coast of Yamalia. Up to 16 ice-breaking LNG carriers are to be built by Daewoo, meeting ARC7 ice class, capable of operating in -50 °C and of breaking through 2.1-m sea ice (Interfax, 2013). A new port is under construction at Sabetta specifically for the project, requiring significant dredging of the approach channel. Gas production is planned to begin in 2017, reaching maximum capacity in 2019. Gas will be compressed at the site and shipped all year round to the west and over summer months to the east via the Northern Sea Route (Hand, 2013), with a 15-year agreement already signed with Rosatomflot for ice-breaking assistance. Novatek, majority shareholder in the project, cites “convenient location” as a key advantage of the development, along with reserves “located at the coastline” and “access to both European and Asian markets” (Gyetvay, 2013).

3.3 Mining

There is a long history of mining in the Arctic – including iron from Arctic Sweden from the 18th century – but in a global context the number of mining operations is small: there are perhaps 25 000 industrial mines worldwide (Mining Journal, no date), but probably fewer than 50 north of the Arctic Circle, half of which are in Russia (Emmerson and Lahn, 2012).

However, the scale of production is much more significant than the number of mines would suggest, with some very large operations such as Norilsk (on the largest nickel-copper-palladium deposit in the world) in Russia and Kiruna (the largest underground iron ore mine in the world) in Sweden. Additionally, some very large mines lie just outside the Arctic Circle (e.g., the Ekati and Diavik diamond mines in Canada). It is because of high production costs at Arctic sites that small operations are generally unlikely to be profitable (Reuters, 2011), leading to a bias towards large operations. In fact, mineral extraction forms a large proportion of economic output in the Arctic (Duhaime, 2004), and mining occurs in all Arctic countries except for Iceland and the Faroe Islands (Haley et al., 2011).

For some minerals, the Arctic is a significant producer on a global scale: for example, about 40% of the world’s palladium, 25% of the world’s diamonds, 15% of platinum, over 10% of apatite and tungsten, and high quantities of zinc, lead, and chromite (Lindholt, 2006).

3.3.1 Drivers of Change

There are strong overlaps between the drivers of change in mining and in petroleum exploration.

Because of the relative inaccessibility of the Arctic, it has not thus far been explored and exploited as strongly as other parts

of the world, but with resource deposits becoming depleted elsewhere, and with global demand continuing to increase, the Arctic becomes the obvious **next place to exploit** (Emmerson and Lahn, 2012). This is encouraged by governments, with the hope of jobs and investment, by conducting geological surveys and providing these data and also mining rights at low prices.

For Greenland, a **change in sovereignty** has put more focus onto exploitation of the mineral resource. With its increased devolution of authority from Denmark, Greenland has more control over its mineral resource estate (Rosing et al., 2014; Erdal, 2013). Greenland has ended its ban on mining radioactive materials, originally put in place by Denmark (Reuters, 2013). Nunavut, which was formed in 1999, is also seeking to greatly expand resource exploitation in its territory as a central part of its plans towards economic development, with business-friendly regulations including low tax rates and streamlined processes (DEDI, 2007).

Securing supply chains is an important issue for countries with strong manufacturing sectors. With the supply of some minerals potentially subject to political intervention, there is additional value in the same commodities being supplied from alternative sources. For example, with rare earth metals a by-product of other mineral extraction, and therefore marginal production costs being low, it is expected that their supply will remain higher than demand through till 2025 (Le Mièrre and Mazo, 2013), but with China supplying more than 95% of these important minerals, other countries are looking to increase the security of their supply chains, and Greenland has substantial unexploited deposits.

With the **reduction in Arctic sea ice**, access to marine export terminals becomes significantly more practical, substantially reducing the costs of transporting minerals to markets.

Most of the countries of the Arctic have **strong institutions**, and the U.S., Canada, Denmark, Norway, Sweden, Iceland, and Finland all rank among the top 20 in the World Bank’s Ease of Doing Business Index (The World Bank, 2013). The stability and certainty of strong institutions provide an attractive environment for business.

Just as high energy prices are driving oil and gas exploration in the Arctic, so too are **high commodity prices** driving Arctic mineral exploitation.

3.3.2 Constraints

While marine access to Arctic areas is certainly improving with retreating sea ice, land access is actually becoming worse in many areas: thawing permafrost and shorter ice-road seasons are making already difficult land-based transport even more difficult. Furthermore, the improvement in marine access in summer coincides with the worsening land access in the same season (Stephenson et al., 2013). While Arctic waterways are opening up, not all of them are navigable by large cargo vessels, with parts of the Northwest Passage apparently too shallow for iron ore bulk carriers (Waldie, 2013).

Prices of mineral commodities have been increasingly volatile in recent years, and the significant up-front costs required of

Arctic exploitation projects are difficult to justify in the face of such uncertainty. The original intention of the Mary River iron ore development on Baffin Island was to send the ore to a port in Steensby Inlet via a purpose-built rail line, with a construction cost of \$2 billion, but a steep reduction in the price of iron has forced the developer to postpone those plans and begin instead with what it calls an 'early-revenue phase' with the use of trucks driven 100km to a port at Milne Inlet (Nunatsiaq News, 2013). This revised solution provides for lower capital costs while incurring higher production costs, substantially reducing the investment risk.

Establishment and operating costs for Arctic mining projects will remain high, with remoteness, lack of infrastructure, and difficult physical conditions all significant drivers of these costs. Remote locations mean that workers must be transported in, often by air, roads and ports must be constructed, and emergency services are distant. Difficult conditions lead directly to higher production costs, can require higher wages, and potentially limit the production season, depending on the severity of the climate.

Environmental concerns remain a potential barrier to the exploitation of mineral resources, depending on the local conditions, the influence and priorities of governments, involvement of environmental NGOs, and how indigenous and other local people see the issue.

3.3.3 Outlook

With the attraction of economic development, Arctic governments are enticing mining companies with business-friendly regulatory and fiscal environments, and new regulations on environmental and social responsibility can help companies streamline the process of allaying local protest. With large territories and few residents, the per capita cost-benefit ratios to local communities can appear very substantial.

Le Mière and Mazo (2013:1123) point to difficulties in projecting the longer-term future of Arctic mining: "every resource and deposit needs to be treated on an individual basis, in the context of other Arctic deposits; other reserves and resources worldwide; viability for extraction; access; [and] demand projections." Given that, and with the small number of mining ventures in the Arctic, we consider instead some significant, isolated cases.

The combination of increased accessibility, government encouragement, and presumed mineral riches has thrust Greenland into the limelight as a golden opportunity for prospectors. However, Rosing et al. (2014) caution that it is extremely unlikely that Greenland can displace its dependence on the financial support of Denmark through mineral resource exploitation alone. They present five scenarios to 2040 with varying levels of exploitation and use of a sovereign wealth fund, but conclude that none of the scenarios would result in a significant reduction in the annual financial transfer from Denmark.

While there has been considerable concern in Greenland over the prospect of mining companies bringing in labor from other countries (in particular, London Mining looking to subcontract to a Chinese firm with the potential for 3000 Chinese workers to live on the island during the construction phase), the government of Greenland has passed an act of parliament specifically to allow such immigration. This act, the Large-Scale Projects Act, attempts to prevent the payment of low wages to foreign workers, and must first be ratified by the Danish government before it becomes law (Reissmann and Christensen, 2013).

Construction of the Mary River iron ore mine on Baffin Island – 'the largest mining development to date in the Arctic' – is already under way and production is expected to commence in 2015 (ArcelorMittal, 2013). One of the largest and highest-concentration undeveloped deposits of iron ore in the world, the mine is expected to generate 55 ship transits per year from Milne Inlet. The original development plans would have had a lifetime of 21 years, but with the change in plan and lower initial extraction rates, it could be several additional years before the deposit is depleted. The developer expects to employ 2000 staff on site in 2015. The mine development has been subject to environmental review, and some of the contents of that review may be relevant to other potential developments in the Arctic (Fisheries and Oceans Canada, 2012).

An unofficial forecast of economic activity for the northern regions of Canada points to their having higher economic growth in the next few years than in southern regions because of the establishment of new mines (Jeffrey, 2013).

Some mention has been made of the potential for seabed extraction technology, but Le Mière and Mazo (2013) suggest that, even if such technology matures, it would be unlikely to be used in the Arctic for a considerable period because such technology would be used in other locations where operating costs would be lower.

3.4 Marine Transportation

Headlines such as "Arctic shipping is set for a record year" (Milne, 2013) appear to herald the dawn of a new era of shipping through the Arctic Ocean. The 2013 transit of the large Danish freighter *Nordic Orion*, laden with coal from Vancouver via the Northwest Passage and destined for Finland, was widely reported. Also in 2013, the transit of Chinese 'container' ship¹ *Yong Sheng* from northeastern China across the north of Russia and destined for Rotterdam was similarly widely reported. These two transits were certainly unusual, and the firsts of their kinds through waters historically choked with sea ice, but what, if anything, do they herald? In this section we discuss the apparent drivers of renewed interest in Arctic shipping, and the evidence for and against a significant increase in such shipping.

¹In fact a general cargo ship that can carry some containers.

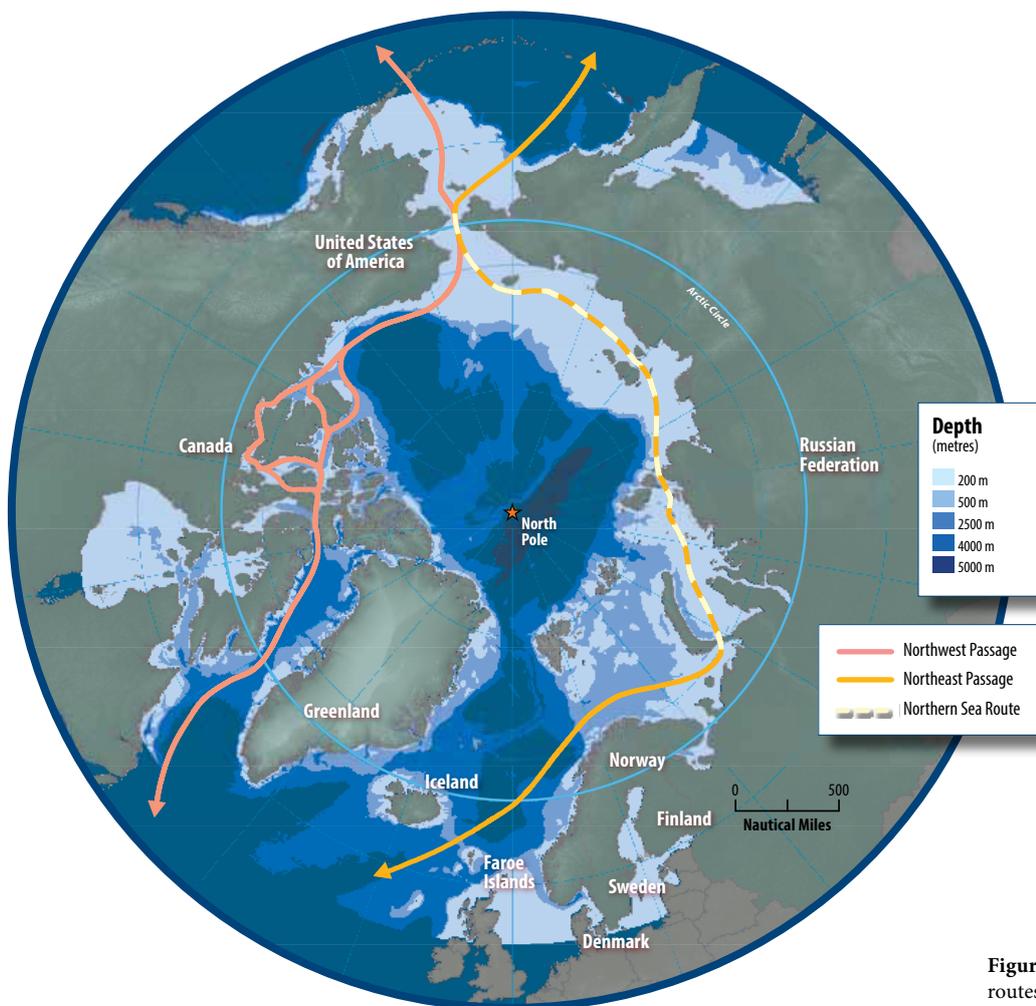


Figure 23. Potential Arctic shipping routes (Source: Arctic Council, 2009).

3.4 1 Recent Trends

There are two major transit routes of interest through the Arctic in the near term (Figure 23). The Northeast Passage runs from the Atlantic Ocean across the top of Russia to the Pacific Ocean via Bering Strait, with the part of this passage north of Russia known as the Northern Sea Route (NSR). The Northwest Passage denotes any of several possible corridors between the Atlantic and Pacific Oceans via the northern coast of North America. In addition, further into the future, the prospect of sailing directly over the North Pole may present itself as sea ice declines even more.

However, in addition to full Arctic transit, entailing shipping between the Atlantic and Pacific Oceans, there is also what is generally called destination shipping, where ships make only parts of these journeys, to service ports in the Arctic. The distinction is important because, while Arctic transit shipping is an alternative to existing shipping routes to the south, Arctic destination shipping depends on activities and communities in the Arctic, and can either be entirely new transportation or displace other transportation modes, such as by land and air. Nearly all current shipping in Arctic waters is destination (Arctic Council, 2009).

It has been reported that traffic on the Northern Sea Route has been increasing substantially in recent years (e.g., Milne, 2013).

Certainly a small number of shipping companies are beginning to use the route in cases where there are obvious savings, such as the shipment of minerals from northern Scandinavia to eastern Asia (e.g., Petterson, 2012). However, analyzing detailed per-ship statistics, Keil (2014) concludes that most of the increase in use of the NSR has been by Russian ships and international interest in using the NSR has been ‘rather humble’, with only 25 foreign-flagged ships making the transit in 2013. Total transit cargo shipped in 2013 amounted to about 1.4 Mt.

As context, most shipping between the Atlantic and Pacific Oceans currently takes either the Suez or the Panama Canal. In 2013, 14 000 ships passed through the Panama Canal with 210 Mt of cargo (Panama Canal Authority, 2014), while 17 000 passed through the Suez Canal with 770 Mt of cargo (Suez Canal Authority, 2014). However, while commonly made, the comparison of transits through the canals with transits along the NSR is imperfect: just as shipping through the Northeast Passage is composed of transit and destination journeys, so is shipping through the canals composed of journeys of various durations and distances.

Although NSR shipping is currently relatively minor, the American Bureau of Shipping has produced a guidance document to the use of the NSR, including information on

regulations, ports, and extreme-cold navigation, suggesting an expectation of increased activity (ABS, 2014). The International Maritime Organization (IMO) has been developing a Polar Code, which will specify mandatory requirements for vessel construction, operation, safety, search and rescue, training, and environmental protection in polar waters (IMO, 2014).

The Northwest Passage has seen significantly slower transport development. While Russia has made use of its Arctic coast to host protected ports (such as Murmansk) for decades, and has therefore built significant infrastructure in selected locations, Canada has not faced the same coastal constraints and has therefore had no clear reason historically to develop infrastructure on its northern coastlines. In addition, the sea ice is clearing much less rapidly in the Northwest Passage than in the NSR, partly because the Beaufort Gyre keeps ice against the Canadian coastline (Snider, 2013).

Related to changing marine transportation in the Arctic is the development of internet infrastructure. Two subsea internet cables will be laid in the Arctic in the very near future, both with completion dates in 2016 (PliMetrica, 2014). One will run between Tokyo and London via the Northwest Passage, while the other will connect Tokyo to the UK via the Northeast Passage. These signify substantial investments, but their primary goal is increased global internet redundancy and speed rather than connecting communities in the Arctic. With few landing points along their routes, local governments would need to provide significant additional funding to connect to remote Arctic areas.

3.4.2 Drivers of Change

Of the main drivers of increased interest in Arctic shipping, the one that stands in front is the rapid **decline in summer sea ice** in recent years, and the expectation that sea ice will continue to retreat further in the near future. Sea-ice decline has been substantially faster than models have predicted, and further decline would “effectively unlock the Arctic Ocean area, leaving it increasingly open to human activity” (Buhaug et al., 2009:121). As a consequence of reduced sea ice, other latent drivers have arisen.

There is an expectation of **reduced costs** by making use of Arctic shipping routes as opposed to existing shipping routes, such as via the Suez and Panama canals. Because the Arctic routes are substantially shorter than existing routes (e.g., up to 40% shorter transit distances between eastern Asia and northern Europe), it is generally assumed that both fuel costs and overall costs will be lower.

As a corollary to reduced fuel consumption, there is an expectation of **reduced climate impacts** when Arctic shipping displaces transit shipping elsewhere. Climate policy might then lead to an incentive to shift shipping to the Arctic to achieve policy goals.

The push for Arctic **resource exploitation**, discussed in Section 3.2, is expected to lead to increased use of marine transportation to supply and service installations, and to transport extracted resources to refineries and markets.

One driver for increased encouragement of Arctic shipping and development of the infrastructure required is **legitimization of sovereignty**. For example, Canada claims much of the Northwest Passage as its internal waters, but both the U.S. and the EU claim that the Passage represents international straits, the distinction critical to whether Canada has the right to refuse entry into those waters (Carnaghan and Goody, 2006). One reason for increased activity in the Northwest Passage by Canada (such as infrastructure development, oceanography, etc.) is to bolster claims to sovereignty (Wohlberg, 2014). According to the Canadian Prime Minister, Stephen Harper, “the first principle of Arctic sovereignty is use it or lose it” (BBC, 2007).

The potential for **safer passage** is also seen as a driver, although a less important one than those discussed above. Piracy and other turbulence in both Southeast Asia and the Middle East present significant costs to shipping companies and governments, costs which, for Somali piracy alone, have been estimated to total about \$6 billion in 2012 (Bellish et al., 2013). The contrasting relative stability of countries along the Arctic routes is an incentive.

3.4.3 Constraints

Pushing back against the drivers listed above are a number of constraints, potentially limiting the force of these drivers. With respect to reduced sea-ice extent, the definition of ‘ice-free’ conditions is usually taken to mean less than 15% sea-ice cover, with still the chance for significant icebergs. Moreover, an earlier melt season may lead to more ice floes breaking off from northern sea ice (Humpert and Raspotnik, 2013). In addition, even without sea ice, the conditions are extreme, with sea spray freezing on ships’ fittings, powerful wind chill, and long periods of winter darkness. It will probably be a long time before sailing the Arctic Ocean is physically equivalent to sailing the Indian Ocean.

Secondly, distance savings do not necessarily translate directly into overall cost savings. There are additional costs as a result of Arctic shipping, for example, pilotage by icebreakers, insurance, transit charges (to cover search and rescue, and other services) (Snider, 2013). Furthermore, the fees charged by Russian authorities have thus far been opaque and negotiable, but if they were set to cover actual costs, they would likely offset any fuel savings, at least until icebreakers are no longer needed (Le Mièrè and Mazo, 2013). Further costs are faced in the construction and maintenance of ships suitable for transit in extreme-cold conditions (Humpert and Raspotnik, 2013).

Thirdly, it is unclear whether displacing shipping from the traditional canal routes to the Arctic would result in a net benefit for global warming. In general, combustion of fuels used by ships (particularly heavy fuel oil) leads to emissions of a mix of pollutants, some with short-term cooling effects (e.g., SO₂) and others with short-term (e.g., black carbon) and long-term (e.g., CO₂) warming effects. On balance, annual emissions from global shipping lead to a short-term cooling effect, followed by a long-term warming effect (Fuglestedt et al., 2009). Furthermore, emissions of these pollutants are

expected to have different effects at high latitudes (Ødemark et al., 2012; Shindell and Faluvegi, 2009). The displacement of marine traffic to the Arctic may therefore counterintuitively be of net detriment to the climate, with less cooling effect and more warming effect, and further research in this area is required before climate benefits are held up as a reason to champion Arctic transits.

Fourthly, sea ice is expected to remain a significant and unpredictable obstacle to marine access through the Northwest Passage, and this unpredictability is likely to make the route unattractive to commercial shipping companies (Eide et al., 2010).

Furthermore, infrastructure in the two Arctic passages is extremely limited, with very few repair facilities and search-and-rescue bases, poor-quality oceanic maps, few market ports, and limited navigational satellite coverage. In the Northwest Passage, the shallow depth of some channels may limit their commercial usage: the CEO of Baffinland, a mining company operating on Baffin Island, is quoted as having said that the Northwest Passage is too shallow for his company to consider using (Waldie, 2013).

3.4.4 Outlook

A number of moves by governments point to the constraints mentioned above being addressed. For example, the Canadian Coast Guard is to identify potential heavy commercial corridors and prioritize their oceanographic mapping (Berthiaume, 2014); the U.S. is looking to develop a deep-water port in Arctic Alaska, although it may not be complete before 2030 (Weaver and McGwin, 2014b); and Russia has opened the first of ten new search-and-rescue bases along the Northern Sea Route (Vokuev, 2013), and has also eased the requirement for icebreaker assistance along the Route (Koranyi, 2013). At a pan-Arctic level, in 2011 the member states of the Arctic Council reached consensus on the Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic, and this treaty went into force in early 2013.

While most commentators are clear that the Northeast Passage (NEP) will not take significant traffic from the Suez Canal, there is an expectation that use of the NEP will increase substantially over current levels.

The IMO's Polar Code already bans the use and carriage of heavy fuel oil in Antarctic waters as an addition to the MARPOL Convention in 2010, and a similar ban is under consideration for Arctic waters. Such a ban was agreed in principle by the IMO in 2013, but a decision has been postponed until the 2014 meeting of the Design and Equipment Sub-committee (Lloyd's Register, 2013). Given the significantly greater number of ships operating in Arctic waters than in Antarctic waters, the negotiation process would be expected to be substantially more difficult.

3.4.4.1 Projections

There have been a small number of quantitative projections and forecasts for future marine transportation in the Arctic.

There are some rather simplistic analyses, such as that by Francois et al. (2013), who assume only reduced fuel costs as a function of reduced distance and, using an economic model, conclude that there will be a consequent 20% increase in trade between Asia and Europe solely on the back of reduced sea ice in the Arctic.

The Arctic Marine Shipping Assessment (Arctic Council, 2009) used a scenario approach based on the work of GBN (2008). To develop four scenarios, each with a detailed narrative, GBN used two main axes: governance (varying from unstable and ad-hoc to stable and rules-based) and resources and trade (varying from more to less demand). The scenarios are entirely exploratory, without any implicit likelihood associated with them. In addition, a number of 'wildcards' are presented: events that could significantly change the future course of events, such as scientific breakthroughs, wars, and abrupt climate change.

Corbett et al. (2010) created Arctic shipping scenarios derived from global shipping scenarios by the IMO (Buhaug et al., 2009). Within-Arctic shipping growth rates were assumed to be the same as global growth rates, with additional diversion from other global shipping routes: 1% diversion to the Arctic by 2020, 2% by 2030 and 5% by 2050. These scenarios have since been used by others to estimate the environmental consequences of future Arctic shipping (e.g., Dalsøren et al., 2013).

Eide et al. (2010) used two scenarios of future container shipping along the Northern Sea Route and compared the total costs to the status quo of using the Suez Canal. One scenario sees all-year use of the Arctic route with high ice-class vessels, while the other sees summer use of the route with lower ice-class vessels.

Stephenson et al. (2013) modelled future marine accessibility of the Arctic Ocean for three different classes of vessel, concluding that the Northern Sea Route will experience the greatest relative increase in navigable season.

3.4.4.2 Survey of Intentions

Lasserre and Pelletier (2011) conducted a survey of shipping companies' intentions in the Arctic, finding a strong contrast between transit carriers and destination carriers: the former were highly skeptical of any potential future in the Arctic, while the latter were optimistic. A number of concerns were raised in the survey by both groups of firms. One of these was an expectation of increased risks and uncertainties from drifting ice, extreme cold, interannual variability of ice extent, poor infrastructure and navigational aids, poor nautical charts, isolation, and insurance concerns. In addition, firms expected increased costs of ship construction, with significant strengthening required for icy conditions, the consequent reduced space for cargo in the hold, and lower fuel efficiency because of the ice strengthening.

Transit carriers pointed to the fact that the Arctic is seen as experimental, and experiments are expensive in a highly competitive industry with low margins. Changing schedules twice each year – because of winter ice, severe cold, and

darkness – was seen both as costly and likely to increase occurrence of mistakes. These companies also argued that competition in their industry is not just about cost, but also significantly on reliability of delivery schedules; it is a just-in-time operation, where certainty is very important, and the Arctic does not present such certainty to container shipping operators.

In contrast, surveyed destination carriers were more positive about their future prospects in the Arctic. They saw potential for cost-competitive delivery of goods to local communities in the Arctic compared with existing delivery modes (road or plane), and resource extraction was seen as another key driver, although requiring relatively few ships. This confirms the conclusion of the Arctic Marine Shipping Assessment: “Arctic voyages through 2020 will be overwhelmingly destination, not trans-Arctic” (Arctic Council, 2009:5).

3.5 Tourism

In particular areas of the Arctic, tourism has had a long history, with interest as far back as the early 19th century (Arctic Council, 2009). More recently, North Pole tours have become available either by chartered icebreaker over summer – with the first such voyage in 1991 (Arctic Council, 2009) – or since 2008 by April flights to the Russian research and tourism tent camp ‘Barneo’ at 89° N and thereafter helicopter or sled to the Pole.

The features of the Arctic that appeal to tourists include wildlife, scenery, beauty and power of ice, purity, change, vulnerability, the northern lights, the midnight sun, exclusivity, remoteness, heroic history and indigenous culture. These fall under the more general trinity of common tourist desires: newness, otherness, and exoticism (Johnston et al., 2012). The vulnerability of the Arctic has been studied in terms of ‘last-chance tourism’ where not only is this a form of adventure that has rarely been experienced before (‘last frontier’), but the opportunity to experience it may soon vanish (Johnston et al., 2012). While Arctic tourism is very small in a global context, the small number of tourists is seen as a draw card for those who do visit, with ‘a feeling of exclusivity’ expressed as one of the attractions of Svalbard to passengers of cruise ships, along with ‘beautiful nature, wilderness, unique bird and animal life, combined with facilities on board’ (Vold et al., 2013:32).

Svalbard is accessible by both regular flights and by cruise ships, with the number of tourists increasing in recent years (on fewer but larger ships). To protect Svalbard’s environment, there is a ban on the use of heavy fuel oil and of ships with more than 200 passengers in nature reserves on the east side of Svalbard (Vold et al., 2013).

In 2009 Russia created the ‘Arctic Russia’ national park by setting aside the northern parts of the Novaya Zemlya archipelago, as well as Franz Josef Land and adjacent waters, with the Russian president expressing the hope that it be a major attraction for tourism (WWF, 2009). Clean-up of substantial Soviet-era waste is under way and is necessary before any tourist ambitions can be realized.

Guidelines have been produced by a number of organizations to promote sustainable tourism in the Arctic. The Association of Arctic Expedition Cruise Operators (AECO), headquartered on Svalbard has produced specific guidelines for 20 sites in Svalbard, along with guidelines for encounters with wildlife (currently limited to walrus) (AECO, 2014). The WWF, in consultation with tour operators, governments, researchers, conservation groups and communities across the Arctic, produced a code of conduct for tour operators in the Arctic (WWF, 2004).

3.5.1 Outlook

Snyder (2008) suggests that Arctic tourism will continue to grow owing to reduced ‘barriers to entry’. These barriers include physical inaccessibility, lack of infrastructure, poor regulations, high costs, and large travel distances. In combination with the general trend worldwide of increasing tourism because of greater disposable income, increased leisure time and improved transportation (Mason et al., 2000), increasing demand for nature-based tourism (Nordregio, 2011) and also feelings of exclusivity (Vold et al., 2013), reduced barriers to such tourism in the Arctic seem likely to lead to an increase.

For established Arctic tourist destinations, such as the north of Norway, projected future increases in precipitation run counter to tourist weather preferences and are likely to negatively impact future tourist numbers (Førland et al., 2013). On the other hand, warmer days may lengthen tourist seasons, providing a boost. However, such effects in these locations are not isolated from how the climate changes in other tourist destinations, along with other factors driving tourist decisions.

Just as for marine transportation, improved oceanographic maps will improve access for cruise ships in the Arctic. The grounding of the *Clipper Adventurer* in the Northwest Passage in 2010 partly because of its use of outdated maps (Stewart and Dawson, 2011) may have raised awareness of this issue throughout the Arctic cruise ship industry.

There are very few quantitative projections of future Arctic tourism. While one such study projects a significant increase (Tol et al., 2004), the study differentiates the Arctic solely on a functional relationship of tourism with precipitation and temperature. They use their Hamburg Tourism Model for international tourism at national level, and then downscale to Arctic regions based on a posited relationship between tourist numbers and these two climate variables.

With much of Arctic tourism likely to be aboard cruise ships, which can be largely self-sufficient, there is significant potential for very little economic benefit for Arctic communities (Enzenbacher, 2011; Loper, 2005). According to Nordregio (2011:71), “The cruise vessel is itself a destination and can be in direct competition with the land-based destination, however exotic these destinations may be.” Le Mière and Mazo (2013) suggest that the economic benefits from increased tourism in the Arctic are likely to be insignificant against those from increased resource extraction, but the likely negative impacts, such as environmental damage and burden on search and rescue services, could be substantial.

3.6 Food Security

Food security in the Arctic is a complex nexus of poverty, social cohesion, transport linkages, employment, climate change, government assistance, cultural change, traditional hunting, self-sufficiency, and other factors. Definitions of food security vary, but there are two distinct perspectives: national security and individual poverty. These two perspectives form ends of a continuum, with the national security perspective simply representing a scaling up to (national or state) population level of the concern that individuals have access to food. There are further important nuances to the notion of 'access to food', including that such food be safe, nutritionally adequate, and culturally appropriate (FAO, 2013; Papatsie et al., 2013).

The dominant perspective taken on food security varies by Arctic country, with wealthier areas, such as the Nordic countries, generally considering the state security view, and poorer areas, such as parts of Arctic Russia, Northern Alaska, and Northern Canada, considering the community- and individual-level view, although both views exist and are important in all Arctic countries. This distinction reflects the prevalence of individual-level food security concerns in each region; for example, some communities in Northern Canada have shown very high levels of food insecurity in surveys. But it also reflects the natural agricultural resource endowment of each country and the production efficiency that this brings; some Arctic countries, such as Iceland, Greenland, and Norway, are not as well-suited to agricultural production as other parts of the world, and therefore either import extensively or impose high import tariffs on food to protect expensive production at home, or both. One argument for such protection is the maintenance of national security via greater self-reliance, as a sort of insurance policy against a crisis in world food markets.

From a state security perspective, most likely climate changes are expected to have overall positive effects on existing agriculture in Arctic regions via longer growing seasons, although there may be some regional exceptions to this rule (Hovelsrud et al., 2011). However, Smith (2011) argues that agriculture is unlikely to expand greatly in geographical extent because of poor soils, inappropriate terrain, and permafrost.

The impact of climate change on the food security of the Arctic's indigenous people is expected to vary widely. Arctic hunting is very sensitive to snow and ice conditions, and inhabitants of the Arctic coastal areas are adapted to local conditions and normal seasonal changes in those conditions. Climate change is expected to bring new snow and ice regimes to these areas, forcing adaptation onto these communities. Goldhar et al. (2010) discuss the consequences of recent changes in sea-ice coverage on hunting in a Greenlandic village. Hunters traditionally use a mix of winter/on-ice and summer/on-sea methods depending on seasonal sea-ice conditions, but with rising temperatures these conditions have become less predictable, requiring greater capital investment to be prepared for uncertain conditions.

Reindeer husbandry is important for food security among the Sami of Fennoscandia as well as a number of indigenous peoples across Arctic Russia (Hovelsrud et al., 2011). Changes

in snow and ice conditions are expected to have a wide range of impacts on reindeer, both positive and negative.

Other potential effects of climate change on food security include consequences for traditional methods of conserving food by using the outdoors as a natural freezer (Nordregio, 2011), altered migration routes (Papatsie et al., 2013), reduced access to sea ice as a source of drinking water, increased contaminants in the food chain as pollutants are released from long-term storage in ice and snow (Hovelsrud et al., 2011), and increased competition for marine mammals from predators such as orca extending their range (Higdon and Ferguson, 2009).

However, these effects of climate change must be considered within the broader set of determinants of food insecurity among indigenous communities, on which the published literature is largely limited to a Canadian context (Goldhar et al., 2010). Beaumier and Ford (2010) report that food insecurity among Canadian Inuit women is determined by increased costs of hunting (more capital intensive, reliance on gasoline), weakening of food-sharing networks, the decline of traditional practices, gambling and substance addictions, unemployment and poverty, lack of knowledge about store (modern) food, and poor budgeting skills. In addition, the availability, quality, and affordability of store food can put significant pressure on Inuit: all modern food is transported great distances and anything fresh must be flown, with flights frequently delayed because of poor weather. Despite government subsidies, food remains very expensive in the Canadian North.

There exist still other drivers of change for the future of food security in the Arctic. The remoteness of Arctic communities may decline as transport infrastructure improves, bringing benefits of increased availability and quality of food and reduced prices; government subsidy schemes may change, for better or worse; the influence of conservation groups aimed at reducing traditional harvests may change; the trend of moving away from traditional food sources may continue; alternative, local food-production systems may be established; alternative employment opportunities may be found, providing some relief from poverty; and migration to southern towns may accelerate.

The level of adaptation of indigenous peoples across the Arctic to western influence varies considerably, and this has significant ramifications for their food security. So too does the connectedness of communities: those in Arctic North America (particularly Canada) and northeastern Russia are much more remote than those in Fennoscandia, for example. In Greenland, no two towns are connected by road (Erdal, 2013). Clearly the issue of food security is highly diverse across Arctic regions.

3.7 Summary

This section has discussed some of the key drivers of change in the Arctic. In general, it is easy to conclude that the situation is highly complex and that there is considerable uncertainty.

Population projections for the Arctic regions show a decline in the total number of people living in the Arctic. However, the story is highly diverse, with considerable declines in some

(particularly Russian) regions, but also growth in others. Further nuances within these projections relate to urbanization and demographic changes.

There seems little doubt that the activity in the Arctic of both oil and gas exploration and mining will increase, but the scale of that increase is highly uncertain. While there are clear drivers for these activities to grow – including increased accessibility, high commodity prices, and sovereignty issues – there are also a number of clear, strong constraints such as high production costs and the volatility of commodity prices. Similarly, the prospect of large-scale Arctic shipping has been a headline for the media, perhaps partly because of the astonishment with which the idea is held and how suddenly the notion seems to have become practical, but while it is likely that Arctic shipping will increase over present levels, it appears unlikely that this growth will be substantial in absolute terms.

Arctic tourism has been increasing markedly, driven again by accessibility but also by the tourist's notions of novelty and exclusivity. Tourism is likely to increase further as infrastructure is improved, oceanographic maps are updated, sea ice continues to retreat, and Arctic communities take up the challenge of obtaining and holding the attention of visitors. Questions

remain over how much return these communities will see from tourism, especially with the growth of cruise-ship tourism, which can be largely self-sufficient. Moreover, the negative environmental and cultural consequences of increased tourism could be substantial.

Food security in the Arctic is a complex and diverse issue. While residents of Arctic Canada have reported very high levels of food insecurity, and there are probably similar problems in Arctic Alaska and parts of Arctic Russia, residents of the Nordic Arctic appear to have much better levels of food security. One reason for this substantial divergence is the connectedness and transport linkages of these communities, while another is how completely the indigenous populations have learned to manage foods from both traditional and modern sources. This diversity requires highly specific study in different parts of the Arctic.

The Arctic is certainly facing continued change from a number of angles and its resilience will be tested. The next stages of the AACA project will set these drivers of change into a wider narrative of states, impacts, and responses, to provide local decision-makers and stakeholders with the information they need to develop strategies to adapt.

4. Appendix: Global projection sources and data

Driver	Source	Projection extent	Main reference [charge]	Website	Data URL	Update frequency
Population	UN Department of Economic and Social Affairs, Population Division (UNPD)	2100	UNDESA (2013b) [free]	http://esa.un.org/	http://esa.un.org/	Every two years
Tourism	UN World Tourism Organization (UNWTO)	2030	UNWTO (2013) [€75]	http://mkt.unwto.org/		Irregular and infrequent
Macroeconomic growth	OECD Economics Department	2060	Johansson et al. (2012) [free]	http://www.oecd.org/	http://stats.oecd.org/	Irregular and infrequent
Food and Land Use	UN Food and Agriculture Organization (FAO)	2080	Alexandratos and Bruinsma (2012) [free]	http://www.fao.org/		Every few years
Fisheries	OECD and FAO	2022	OECD and FAO (2013) [€70]	http://www.oecd.org/	http://www.oecd-ilibrary.org/	Annual
Energy	OECD International Energy Agency (IEA)	2035	IEA (2013b) [€120]	http://www.worldenergyoutlook.org/		Annual
Energy	U.S. Energy Information Administration (EIA)	2040	EIA (2013) [free]	http://www.eia.gov/	http://www.eia.gov/	Annual
Passenger Air Travel	UN International Civil Aviation Organization (ICAO)	2030	ICAO (2013a) [\$US950]	http://www.icao.int/		Every few years
Freight Transport	UN International Maritime Organization (IMO)	2050	Buhaug et al. (2009) [free]	http://www.imo.org/		Irregular and infrequent
International Trade	UN World Trade Organization	2035	WTO (2013) [free]	http://www.wto.org/		Irregular and infrequent

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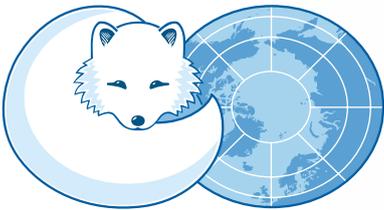
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