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The Arctic environment

European perspectives on a changing Arctic

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European Environment Agency

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Country groupings

The report addresses European perspectives on a changing Arctic and is primarily directed at EU institutions and EEA member countries. However, some of the issues raised are also of relevance to a wider European and global audience, given that a number of these issues have wide-ranging effects or require an international response. In this context, the report makes references to geographic regions and country groupings and for these purposes the following definitions and abbreviations are used:

Arctic States (8): Canada, Denmark (including the Faroe Islands and Greenland), Finland, Iceland, Norway, Russia, Sweden and the United States of America (Alaska). These countries also make up the member countries of the Arctic Council.

Arctic Council (8 + 6): Canada, Denmark (including the Faroe Islands and Greenland), Finland, Iceland, Norway, Russia, Sweden and the United States of America (Alaska), and six Permanent Participants representing the indigenous peoples' organisations Aleut International Association (AIA), Arctic Athabaskan Council (AAC), Gwich'in Council International (GCI), Inuit Circumpolar Council (ICC), Russian Association of Indigenous Peoples of the North (RAIPON) and the Saami Council (SC).

EU (28): Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

EEA member countries (33): EU-28 and Iceland, Liechtenstein, Norway, Switzerland and Turkey.

EEA cooperating countries (39): EEA-33 and Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Montenegro, Serbia and Kosovo ([1]).

Europe (47): EEA-39 and Andorra, Belarus, Holy See, Moldova, Monaco, Russia, San Marino and Ukraine.

Arctic partners ([2]): Arctic States (8), China, India, Japan, the Republic of Korea, Singapore, intergovernmental organisations (IGOs), Regional Seas Conventions (RSCs), non-governmental organisations (NGOs), civil society organisations and indigenous peoples' organisations.

European Arctic is defined, for the purposes of this report, as the zone between Greenland in the west and the Ural Mountains in Russia to the east (see Map 2.1).

Circumpolar Arctic. The Arctic Ocean, sub-regional seas and land areas identified as Arctic by the eight Arctic States. The definitions of the Arctic Council working groups Arctic Monitoring and Assessment Programme (AMAP) and Conservation of Arctic Flora and Fauna (CAFF) are used where appropriate.

([1]) Under United Nations Security Council Resolution 1244/99.

([2]) China, India, Japan, the Republic of Korea and Singapore are named specifically as they have Arctic Council observer status, along with EEA member countries France, Germany, Italy, Netherlands, Poland, Spain, Switzerland and the United Kingdom. The EU has applied to become an observer and has been invited to follow the work of the Arctic Council while the application is pending.

Abbreviations

7th EAP	Seventh Environment Action Programme to 2020 (EU)
AC	Arctic Council
AACA	Adaptation Actions for a Changing Arctic
AMAP	Arctic Monitoring and Assessment Programme (Arctic Council working group)
AR5	Assessment Report 5 (IPCC)
CAFF	Conservation of Arctic Flora and Fauna (Arctic Council working group)
CBD	Convention on Biological Diversity (UN)
CBMP	Circumpolar Biodiversity Monitoring Programme (Arctic Council)
CFP	Common fisheries policy (EU)
CLCS	Commission on the Limits of the Continental Shelf (UN)
CO_2	Carbon dioxide
EC	European Commission
EEA	European Environment Agency
EEAS	European External Action Service
EEZ	Exclusive economic zone
Eionet	European Environment Information and Observation Network
EMODnet	European Marine Observation and Data Network
ESA	European Space Agency
EU	European Union
EU-PolarNet	European Polar Research Programme
GEO	Global Environment Outlook (UNEP)
IASC	International Arctic Science Committee
ICES	International Council for the Exploration of the Sea
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
JRC	Joint Research Council
LRTAP	Long-range Transboundary Air Pollution (convention)
MEAs	Multinational Environmental Agreements
MPAs	Marine Protected Areas
PAME	Protecting the Arctic Marine Environment (Arctic Council working group)
POPs	Persistent organic pollutants
SAON	Sustained Arctic Observing Networks
SDGs	Sustainable Development Goals (UN 2030 Agenda)
SLR	Sea level rise
SOER2015	The European environment — State and outlook 2015 (report)
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme (now UN Environment)
UNFCCC	United Nations Framework Convention on Climate Change
WWF	World Wide Fund for Nature

Foreword

This European Environment Agency (EEA) report contributes to the growing international discourse on the Arctic region. It is both timely and important, since it examines the increasingly rapid changes that are taking place in the Arctic from a European perspective. It considers the national, regional and global challenges and opportunities that are emerging as a result.

There is increasing awareness that changes in the Arctic have considerable impacts beyond its boundaries. For example, the Arctic's role in global climate regulation and sea level rise is now widely recognised. The region is seen as an important barometer of global climate change.

Similarly, many of the mega-trends that affect the Arctic environment come from outside the region, such as climate change, long-range pollution or demand for resources. Such changes are having a massive impact on the Arctic environment, human health and the degradation of natural capital. These are challenges that the Arctic States cannot solve alone.

Change also brings about opportunities. The strategic importance of the Arctic region is growing as ice and snow conditions are changing rapidly. Access to natural resources is becoming easier and new transport routes are opening up. Economic developments too are accelerating, benefiting the region's inhabitants through improved job potential, better living conditions and higher health standards. Beyond the boundaries of the Arctic, the significant potential of green and blue growth may also benefit the global economy.

Yet, if not managed with care, such developments will have repercussions on the Arctic's fragile environment and the livelihood of its peoples. We must give sufficient attention to environmental protection and sustainable development. The Arctic is unique with its rich biodiversity and ecosystems. It is, therefore, important to continuously monitor and assess the changing environment in the Arctic region.

Europe, and the European Union in particular, has a key role to play in shaping the future of the Arctic. For this reason, the EU has identified the Arctic as a priority region in the 7th Environment Action Programme. Moreover, in 2016 the European Commission and the EEAS launched an integrated EU Arctic policy. This is expressly designed to frame the main areas of EU engagement in the region and to foster cooperation with Arctic partners. The Council of the European Union responded with Arctic conclusions in 2016 and the European Parliament with an Arctic Resolution in 2017, reaffirming the EU's commitment to the region.

Despite the economic, environmental, social and scientific importance of the Arctic, it remains one of the least understood regions on Earth. That is changing, with monitoring and assessments revealing some of the Arctic's secrets. This report aims to contribute to the enhanced understanding of the region. It distils the most relevant Arctic knowledge from a European perspective and indicates where the EU can play a positive role.

The European Union recognises the urgent need for collective effort. We hope this report can play a part.

Karmenu Vella
Commissioner for Maritime Affairs and Fisheries,
European Commission

Dr Hans Bruyninckx
Executive Director
European Environment Agency

Executive summary

The Arctic is currently warming at a rate of almost twice the global average. As a result, the circumpolar Arctic region is seeing profound and rapid changes that can dramatically alter living conditions locally, regionally and, because of the Arctic's role in climate regulation and sea level rise, globally. The box below provides an overview of the challenges and impacts we face as a result of a warming Arctic.

The above climatic stressors are coupled with pressures from economic development: exploration for minerals and fossil fuels; increased transportation and shipping; comprehensive fishing efforts; local pollution from industrial activities and historical waste disposals; land fragmentation; infrastructure developments; tourism; and decline in biodiversity and threat from invasive species. These multiple stressors do not act in isolation. They often exacerbate one another, leading to cumulative impacts greater than those from individual activities or stressors. **Collectively, these changes challenge ecosystem resilience, and Arctic species and inhabitants**, particularly indigenous peoples, all of whom and which will have to adapt to pressures and rapid transformation in both the environment and living conditions.

These impacts will affect Europe and in some cases already are doing so. The two regions' shared geography, ecosystems and weather systems, and ocean connectivity, as well as longstanding historical and cultural ties, and close economic links, make this inevitable. Equally, **Europe bears some responsibility**

The European and global challenges and impacts as a result of a warming Arctic

- Melting ice on Greenland, Svalbard and on glaciers in Continental Europe, contributes to **global sea level rise**.
- Diminishing snow cover and sea ice extent accelerate **global warming** due to albedo loss ([3]).
- Changes in the strength and position of the jet stream, which governs large-scale weather patterns at middle latitudes, in turn, may lead to **increased precipitation** and thereby flooding and more frequent storms in northern Europe.
- Altered ecosystems change breeding conditions for **migrating species**, including a large number of European bird populations. In addition, invasive species, which affect Arctic biodiversity and endemic species, are appearing in the Arctic.
- Rising atmospheric greenhouse gas concentrations have led oceans to absorb more carbon dioxide (CO_2) and become more acidic. **Ocean acidification** adversely affects the lower levels of the Arctic food chain (in particular plankton), which are key to sustaining Arctic fish stocks, their prey and migrating whales.
- Thawing permafrost (itself a direct result of greenhouse gas emissions) leads to the release of more **greenhouse gases** from CO_2 captured in frozen soil and organic compounds, and methane emissions.
- **Long-range pollutants** including herbicides, persistent organic pollutants (POPs), mercury, radioactivity and black carbon are transported to the Arctic or discharged from melting ice and snow, causing them to accumulate in the Arctic food chain. Pollutants are still at safe levels in fish and shellfish but higher levels of POPs and mercury are found in marine mammals.
- Influx of **freshwater** to the Arctic basin from the Greenland ice sheet, and from melting glaciers and permafrost in northern Europe, could affect thermohaline circulation ([4]), which drives the North Atlantic current and exerts a strong influence on European weather and climate.

([3]) Albedo is a measure of how much light that hits a surface is reflected without being absorbed. White surfaces on snow and ice reflect most light and have a high albedo, while darker surfaces such as oceans absorb most of the light, indicating a low albedo.

([4]) Discharges of freshwater can affect the salinity of the upper layers of waters in the Arctic Ocean. This can affect the water exchange whereby warm waters brought into the Arctic Ocean from the Gulf Stream sink to the bottom because of temperature and salinity where the dense water then flows back to the world oceans.

for the rapidly changing situation in the Arctic through its imports of oil, gas, minerals, fish and other natural resources extracted from the region, the emission of greenhouse gases that contribute to rising Arctic temperatures, and long-range pollution including marine litter and plastics, and increased shipping and tourism.

However**, Europe and in particular the EU also plays a part in providing solutions** to many of these challenges through integrated policy responses. The EU policy for the Arctic (EC, 2016a), which compliments other EU policy initiatives, highlights potential responses, including:

- protecting and safeguarding the environment;
- mitigating climate change by addressing climate change impacts and providing support for adaptation;
- strengthening the knowledge base through satellite observation and continued research activities;
- supporting sustainable development through investment in innovation, infrastructure and regional cooperation; and
- engaging in international dialogue with Arctic and other partners on issues that require an international response.

To fulfil these roles, the EU has, among other policy initiatives, identified **the Arctic as a priority region in its Seventh Environment Action Programme** (EU, 2013a), the overall goal of which is to support sustainable development and safeguard natural capital. In this context, the EU has a role to play in continuing efforts to ensure the appropriate balance between challenges and opportunities arising in the Arctic region, and to strengthen the resilience of Arctic ecosystems and communities, and in supporting the wellbeing of Arctic inhabitants, particularly indigenous peoples.

As stated in *The European environment — state and outlook: sythesis report* (SOER2015) (EEA, 2015a), Europe and the Arctic face persistent and emerging systemic challenges linked to production and consumption systems, and a rapidly changing global context. Therefore, **achieving the EU and UN 2030 and 2050 visions (EU, 2013a/UN, 2015) requires systemic transition, driven by more ambitious actions on policy, knowledge, investments and innovation**.

Policy options are seldom straightforward and careful integrated planning is thus required. As such, the EU has an ambitious post-2020 plan to transform Europe into an efficient low-carbon circular economy by 2050. Under this plan, Europe would reduce the pollutants transported into the Arctic through air and ocean currents, reduce its imports of minerals and hydrocarbons from the Arctic region and act as a frontrunner in reducing greenhouse gas emissions. Some of these reductions are already taking place.

Besides being a region with low population density and economic activity, the economic downturn and fluctuations in world commodity prices have led to a slowdown in Arctic investments, and this has provided Arctic governments, Europe and the international community with more time to better: (1) carry out assessments on ecosystem resilience and functioning, and assess the boundaries for human activities; (2) anticipate the pace of change in the Arctic; (3) build better models and forward-looking scenarios for Arctic development; and (4) develop cleaner technologies and put in place safety standards, at both national level and regional level. At the same time, the downturn has allowed other economic sectors such as tourism, the service sector, renewable energy production and better transport and communication links to begin to be developed. **This window of opportunity should be taken advantage of** and the EU has valuable contributions to make.

To develop and implement integrated and coherent policies, better knowledge and understanding of the Arctic is essential. In that respect, the knowledge provided by Arctic States, the Arctic Council, the EU and other Arctic partners has played a valuable role in documenting Arctic changes, but **it is insufficient merely to document the change and more has to be done to mitigate the harmful effects**. Many drivers such as climate change or long-range pollution require an international response. National Arctic strategies among the Arctic States point to areas where further action is needed at national or sub-national level. Even at local level, changing conditions or economic activity warrant action in the form of planning, adaptation, regulation, enforcement or support.

Although we have yet to fully recognise and understand Arctic resilience, long-term effects and tipping points, scientific findings suggest that Arctic ecosystems, although undergoing change, are still coping with the pressures exerted on them and continue to provide vital functions and services for the region, and even humanity, given the Arctic's role in global climate regulation. However, **given warming forecasts, Arctic ecosystems are projected to stop doing so some time this century**, not least because the relevant stressors exacerbate one another and can have cascading effects.

It is imperative that EU and Arctic partners **work for continued ecosystem integrity** by regularly updating and adjusting policies in line with the emerging pressures to ensure the sustainable use of the Arctic's fragile natural capital. Furthermore, efforts that ensure that growth in the Arctic does not jeopardise ecosystem resilience have to be supported, just as development has to be planned with and for the benefit of the Arctic's people. EU and Arctic partners need to continue to address the systemic and transboundary nature of the challenges and implement environmental policies while developing integrated approaches to the environmental and health challenges arising in the Arctic region, so that economic opportunities do not come at the expense of the Arctic environment and the services and functions it provides.

Summary of policy options

In addition to the crosscutting issues and messages outlined above, there are seven areas in which Europe (the EU, EU Member States and to a certain extent non-EU member countries) can play a constructive role in the Arctic, in cooperation with Arctic partners. These, and the related actions proposed in Chapter 5, form the basis for the key messages readers should take away from this report.

Environment and health in the Arctic. Given that the Arctic and European environments are intrinsically linked, Europe has an interest in supporting efforts that contribute to strengthening ecosystem resilience, protection of biodiversity, improving health and living standards in the Arctic, reducing long-range pollution and marine litter, and regularly assessing the wider implications for Europe's environment.

Energy. The EU is currently a large importer of oil and gas from the Arctic, and the increased extraction of fossil fuels from the region goes against the objective of keeping global temperatures below the 2 °C target agreed under the United Nations Framework Convention on Climate Change (UNFCCC, 2015). This, and the severe Arctic impacts of global warming, require the EU to continue to transform its energy mix to include more renewable energy sources and to become less dependent on Arctic imports.

Fisheries. The EU is a major consumer of Arctic seafood products and needs to cooperate well with Arctic fishing states on the sustainable management of fish stocks and marine living resources, through establishing binding agreements on Arctic fisheries and for biodiversity in areas beyond national jurisdiction, as well as by promoting the establishment and connection of Marine Protected Areas.

Shipping. A large number of European ships operate in the Arctic, including cargo ships, passenger ships, fishing vessels and offshore supply vessels. In this context, Europe, the EU and its Member States should work towards setting ambitious targets and mandatory requirements for Arctic shipping and should support environmental and security monitoring.

Mining. Europe is a large consumer of minerals, including those imported from northern Scandinavia and north-west Russia in the European Arctic, and the EU can play a constructive role by promoting environmental, economic and social assessments, and best practices with regards to operations, waste management and accident response, as well as by supporting area-based management and implementing circular economy initiatives.

Strengthening the knowledge base. The EU has long contributed substantially towards Arctic research, but further efforts are required to identify and address gaps or weaknesses in the knowledge base, better integrate results and recommendations into the policy process, improve understanding of Arctic resilience and explore how EU policy objectives can best support the European Arctic region.

International cooperation and policy integration. The EU has identified the Arctic as a priority region and developed an integrated EU Arctic policy. In support of policy measures and engagement in regional fora, the EU should continue to assess the effectiveness of EU Arctic policy, including climate change mitigation and adaptation in the Arctic region and pushing for transitions in energy, mobility and food systems, as well as strengthening dialogue with Arctic partners.

1 Introduction

1.1 Purpose and scope

Five of the eight Arctic States (Denmark, Finland, Iceland, Norway, and Sweden) are European Environment Agency (EEA) member countries and the EEA therefore has an obligation to address the environmental state, outlook and risks posed to these states by changes in the Arctic. The EEA also has a cooperation agreement with Greenland with regards to sharing environmental information and seeking common solutions to safeguard the environment.

Moreover, given the EU's focus on the Arctic region through the Seventh Environment Action Programme (7th EAP) (EU, 2013a) and the integrated EU policy for the Arctic region (EC, 2016a), this EEA assessment is timely. It is intended to complement *The European environment — state and outlook: sythesis report* (SOER2015) (EEA, 2015a, which included an Arctic regional briefing (see Box 1.1), and the abovementioned EU Arctic policy by informing policymakers whose work will affect the Arctic region.

This report aims to bring key European considerations to the forefront, such as how Europe affects the Arctic environment and how changes in the Arctic affect Europe's environment and the ecosystem services upon which Europe depends. It also highlights the challenges and opportunities Europe should be mindful of.

The key messages and policy options arising from this report relate to EU polices, competences and legislative acts, and are primarily directed at EU institutions and EU Member States. There are also issues for consideration by non-EU EEA member countries, which require a common European or global response.

1.2 Methodology and outline of the report

A full understanding of the state of, and drivers and dynamics in, the Arctic does not exist. However, there are good attempts to expand the knowledge base or co-create knowledge in order to better guide policymakers. The EU and Arctic partners are working towards closing these gaps and introducing measures to safeguard the Arctic environment.

This report forms part of that work and draws on a large number of Arctic assessments, studies and indicators available to the EEA through the European Environment Information and Observation Network (Eionet) and our Arctic member countries, partners and networks. While the assessments and reports upon which the report is built are relatively recent, a number of the indicators in the report are fully up to date and provide the most recent description of the changing Arctic. Similarly new policy initiatives are included and put into an Arctic context. To this knowledge base a European lens has been applied to identify European perspectives and dimensions of relevance.

Box 1.1 Key challenges regarding the Arctic region identified in the EEA's SOER2015 report

The key challenges facing the Arctic region were summarised in the Arctic regional briefing:

- increasing economic development of the Arctic;
- global climate change and its rapid effects on the Arctic;
- policy developments and international cooperation related to the Arctic.

Source: EEA, 2015a.

In line with the EU Arctic policy, this report takes a circumpolar approach to the Arctic but tries to focus on the European Arctic. Topics of particular relevance to the European Arctic have been identified where possible, although European figures from many of the processes, trends and observed changes cannot be distilled from the circumpolar reports available to the EEA.

The report is structured similarly to the SOER2015. Framing the European Arctic, addressing the key trends and implications, the European footprint in the Arctic and megatrends affecting the region are presented first, including pointing to the main challenges and opportunities for Europe. Given that the ocean constitutes a large part of the Arctic, a marine section has been added to highlight crosscutting marine issues and environmental security aspects of European relevance.

There is an assessment of the policy context for European engagement and the socio-economic developments that drive Arctic change. Aspects of environmental integration and policy coherence and the priorities of the 7th EAP are considered, alongside the Arctic's role in the context of a transition and circular economy. Furthermore, the evidence base and assessment landscape, as well as relevant global reporting processes, are placed in a European and Arctic context.

There are reflections from an EEA perspective on the priorities of the EU Arctic policy, which focuses on environment and climate issues, sustainable development and supporting international cooperation and good stewardship. Finally, options for Arctic policy responses available to EU and Arctic partners are outlined.

Given that the report aims to capture the major trends of relevance to Europe — with regards to both challenges and opportunities — not all topics are covered; for example, forestry and land use have been excluded. Similarly, the references and linkages included here do not represent a comprehensive map of the evidence base and the assessment landscape, but rather point towards the latest or most relevant information available to the EEA at the time of writing.

In essence, this report is meant as a stocktaking exercise that Europe can build on when seeking to take a precautionary approach to Arctic development and a prudent and balanced move towards sustainable development.

2 Framing the European Arctic

2.1 Background

There are large differences between the countries in the Arctic in terms of size, population, economy, climate, culture, legislation and governance system, and this should be kept in mind when discussing the Arctic as a region or when addressing strategies and approaches towards sustainable development. Thus the Arctic region is not homogeneous and even within the European Arctic significant variations exist.

There is no major governance vacuum in the Arctic, as national legislation, bilateral agreements and international conventions and protocols apply ([5]). In the central Arctic Ocean, beyond any national jurisdiction, the UN Law of the Sea (UN, 2013) applies. So a comprehensive framework for governing relevant human activities has already been established. However, although policies are in place to address most harmful environmental impacts, both within the Arctic and globally, some impacts are not completely addressed and gaps exist. These include adding new harmful substances to multilateral environmental agreements (MEAs) like the Stockholm Convention on persistent organic pollutants or strengthening the protection of biodiversity beyond national jurisdiction.

The Arctic region is an area of growing strategic importance, and economic developments are accelerating that can be beneficial for the region's inhabitants and the global economy. Yet they will also have repercussions on the Arctic's fragile environment if not managed with care. It is therefore important to continuously monitor and assess the Arctic region, environment, its peoples and the linkages to global feedback systems.

Strengthening the knowledge base for policymaking is core to the EU, and the importance of the Arctic to Europe's environment has long been recognised. The EEA has also recognised the region's importance and published reports dedicated to the Arctic in 1997 and 2004 (EEA and NPI, 1997; EEA et al., 2004). The latest was produced in collaboration with the United Nations Environment Programme (UNEP) and the Arctic Council, addressing the question Why should Europe care? (EEA et al., 2004). In 2010, the European Commission conducted an EU Arctic footprint and policy assessment (Ecologic Institute, 2010) as a response to geopolitical and environmental changes in the region. In 2014, the EU funded a Strategic assessment of development in the Arctic (AC, 2014a) with recommendations on how the EU could respond to challenges identified in the assessment. More recently, the 2016 integrated EU policy for the Arctic region recognised the need to strengthen the knowledge base with regards to the changes occurring in the region and their local effects and beyond (EC, 2016b). In 2017, the EEA also published a report on Climate change, impacts and vulnerability in Europe 2016 (EEA, 2017), which includes perspectives on the European Arctic.

At national level, a dozen EEA member countries are involved in ongoing research and environmental monitoring and assessment work in the region. In particular, the EEA's five Arctic States have undertaken considerable national monitoring and assessment activities, as well as engaging in coordinated efforts under the auspices of the Arctic Council. An example is the assessment currently being undertaken by the Arctic Council on Adaptation Actions for a Changing Arctic (AACA), which seeks to integrate various impacts, drivers and changes and various adaptation needs, and to go beyond climate adaptation, initially at a regional level, including the Barents Region in Europe. These efforts, together with those of other Arctic partners and knowledge gained through the recent International Polar Year (IPY) in 2007-2008, have raised the level of understanding of the processes, changes and drivers at play, as well as establishing certain baselines and providing data, including some used in EEA indicators. However, further insights into feedback loops, resilience and limits to ecosystems' adaptive capacity, as well as spatial and temporal changes that enable more robust outlooks and models, are yet to be established. The Arctic States, together with other nations and the EU, are

([5]) Examples include the UN Framework Convention on Climate Change (UNFCCC), the UN Convention on Biological Diversity (CBD) and the UNECE Convention on Long-Range Transport of Air Pollutants (LRTAP).

continuing to address these needs and provide a better understanding of Arctic changes. This report will take stock of the current situation with particular emphasis on European perspectives.

2.2 The circumpolar and European Arctic

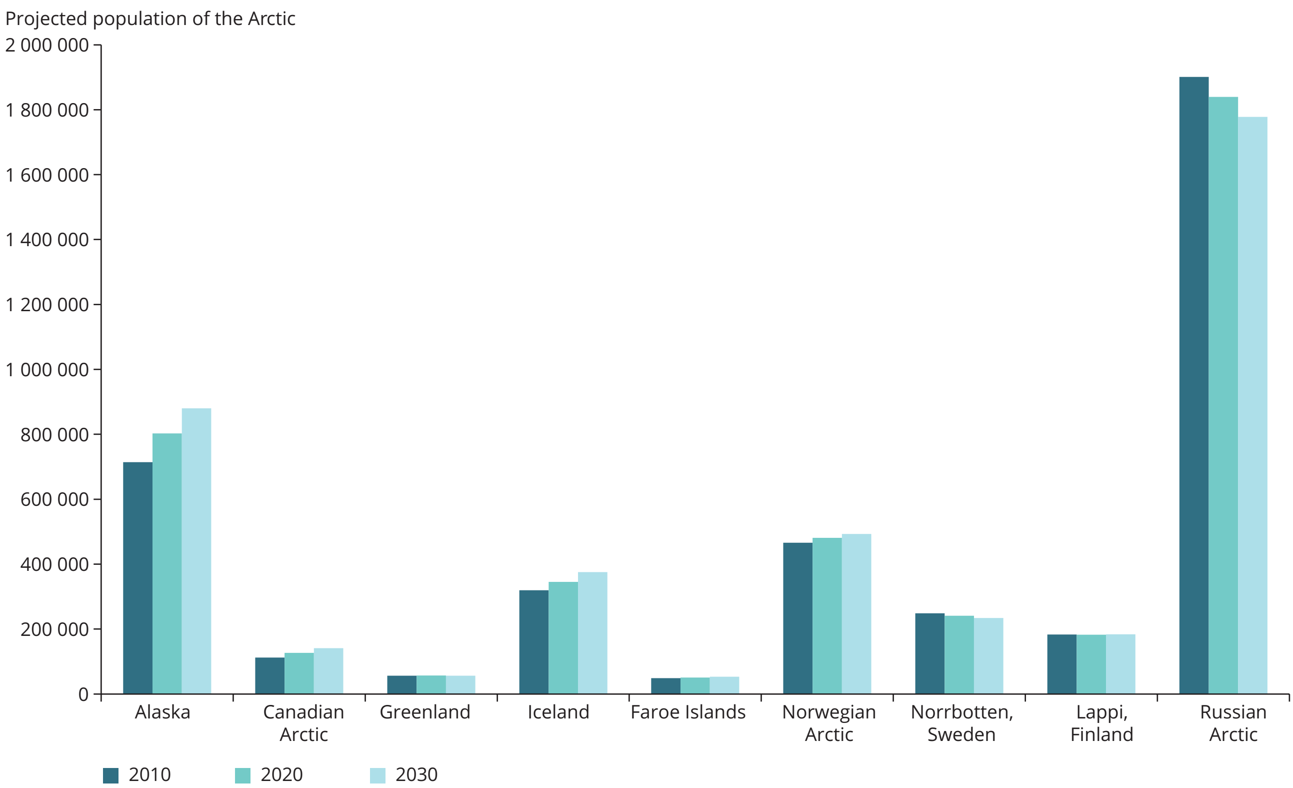
The **circumpolar Arctic region** consists of the partly ice-covered Arctic Ocean and land areas of the surrounding eight Arctic States: Canada, Denmark (including the Faroe Islands and Greenland), Finland, Iceland, Norway, Russia, Sweden and the United States of America (Alaska), as well as their shallow sub-regional seas, including the Barents Sea and Norwegian Sea in the European Arctic.

The circumpolar Arctic region is varied in terms of geography, topography, biodiversity, demography and level of infrastructure and development, and with regard to both the high Arctic, with its extreme environment, cold climate and lack of sunlight for parts of the year, and the rest of the Arctic. So while many parts of the Arctic are characterised by remoteness and low population density, others are more populated and developed.

A number of different and innovative governance structures are in place across the circumpolar Arctic, extending from typical government structures and institutions at the local, regional and national levels, to an increasing engagement with non-governmental organisations (NGOs) and indigenous peoples' organisations as well as international institutions. The Arctic governance systems have evolved and grown, in large part as a response to devolution and demands for greater regional autonomy, not least for the indigenous peoples of the circumpolar North.

After decades of growth, the population of the circumpolar Arctic has now stabilised at just over 4 million people and projections towards 2030 indicate only a modest increase of 4 % compared with a projected global population increase of 29 % (see Figure 2.1). However, population change is not even across the circumpolar Arctic, and the North American Arctic as well as Iceland are projected to see a population increase. Fennoscandia ([6]) is projected

Figure 2.1 Projected population trends in the Arctic from 2010 to 2030



Source: NCM, 2014.

([6]) Fennoscandia covers the Scandinavian Peninsula, Finland and the extreme west of the Russian Arctic.

to see a marginal increase while current population decline and emigration in the Russian Arctic is expected to continue (NCM, 2014). Exceptions to these trends are the Arctic indigenous peoples (or regions with large indigenous populations), who continue to have significant population growth because of younger age structures and higher fertility rates.

Demographic trends across the circumpolar Arctic described in the second Arctic human development report (NCM, 2014) are: (1) increased urbanisation and concentration of populations in many of the larger cities; (2) a diminishing number of people in the active workforce; (3) an ageing population with higher education levels; (4) decreasing household size; and (5) emigration of young people (in some areas particularly women), which adds to a skewed population distribution. It is furthermore a challenge that many of the younger inhabitants seeking education and employment in cities further south do not always return and provide possible advantages for local communities. In addition, the report has shown that the region continues to face significant challenges from emerging health issues, and persistent disparities in living standards and levels of education between indigenous and non-indigenous peoples ([7]).

However, the Arctic also has success stories to be shared, including the increasing use of indigenous knowledge in decision-making, a growing sense of cultural identity becoming a 'commodity' recognised locally and by external partners, and increasing indigenous participation in resource control and ownership in some parts of the Arctic, with Greenland and Nunavut territory in Canada as examples.

Economic development varies across the circumpolar Arctic, and the region as such does not act as an integrated region but rather as a region of different economies with similar characteristics. The impact of world market fluctuations on local economic development varies depending on the concentration of resources, the quality of deposits, the level of transport infrastructure, governance structure, royalty system, land rights and level of privatisation.

Across the region there are similar variations in the economic structure, combining large-scale natural resource production with small family-based production, subsistence economy or consumption supported by transfers from higher levels of government. The capital intensive production tends to be locally confined while the family-based production and services are small and scattered across the region. In real terms, the Arctic gross regional product (GRP) increased by 42 % between 2000 and 2010, with Russia making up more than 70 % of the share of the Arctic GRP (NCM, 2014).

There is no universally agreed definition of the Arctic, nor is there an agreed definition of the European part of the Arctic. For the purpose of this report, the **European Arctic** is defined as the zone between Greenland in the west and the Ural Mountains in Russia in the east (see Map 2.1). Within the European Arctic significant variations exist; the eastern part of the European Arctic (Northern Norway, Sweden and Finland) is characterised by higher population density, vibrant cities, economic activity and less sea ice cover due to the influx of warm Atlantic waters. This also applies to Iceland. The western European Arctic (around Greenland) is characterised by very low population density, permanent ice cover on land and partly at sea, and lower economic activity.

Similar to the circumpolar Arctic, the European Arctic is undergoing change that affects living conditions in the region, including thawing permafrost disrupting local infrastructure and affecting reindeer grazing lands; certain fish stocks migrating further north; invasive species outcompeting endemic species; altered breeding and living conditions for migrating species; increased ocean acidification affecting the lower levels of the Arctic food chain; and long-range transport of pollutants, black carbon, radioactivity and herbicides as well as discharge of historical deposition in melting ice/snow, all of which may enter the food chain. Some of these changes are addressed in Chapter 3 of the report.

More than 1 million citizens reside in the European part of the Arctic, including the Arctic's indigenous peoples, the Saami of northern Norway, Sweden, Finland and Russia, the Inuit peoples Kalaallit in Greenland ([8]), and the Nenets in Nenets Autonomous Okrug and the Yamalo-Nenets Autonomous Okrug in north-west Russia ([9]). Although the European Arctic is sparsely populated compared with most of Europe, the region's population plays an important role in the stewardship of the land, creating jobs and growth — and thus affecting living and health standards. The region's economy plays a substantial role in an international context given the exports of natural resources and economic activity within the region (see Map 2.2).

([7]) See more in-depth description of Arctic demographic changes in Megatrends (NordRegio, 2011) and the Arctic human development report II, (NCM, 2014).
([8]) Inuit people also reside in Canada and the United States (Alaska).
([9]) A small percentage of the Komi peoples are also found in this region.

Map 2.1 **The European Arctic and European Environment Agency (EEA) member countries and their affiliation to the Arctic Council, the main forum for discussing Arctic issues**

The Arctic Region in relation to European countries

- Arctic Region *
- European Arctic region
- EEA 33 member countries
- EEA cooperating countries and entities
- EEA member countries and Arctic Council member countries
- EEA observer countries to the Arctic Council

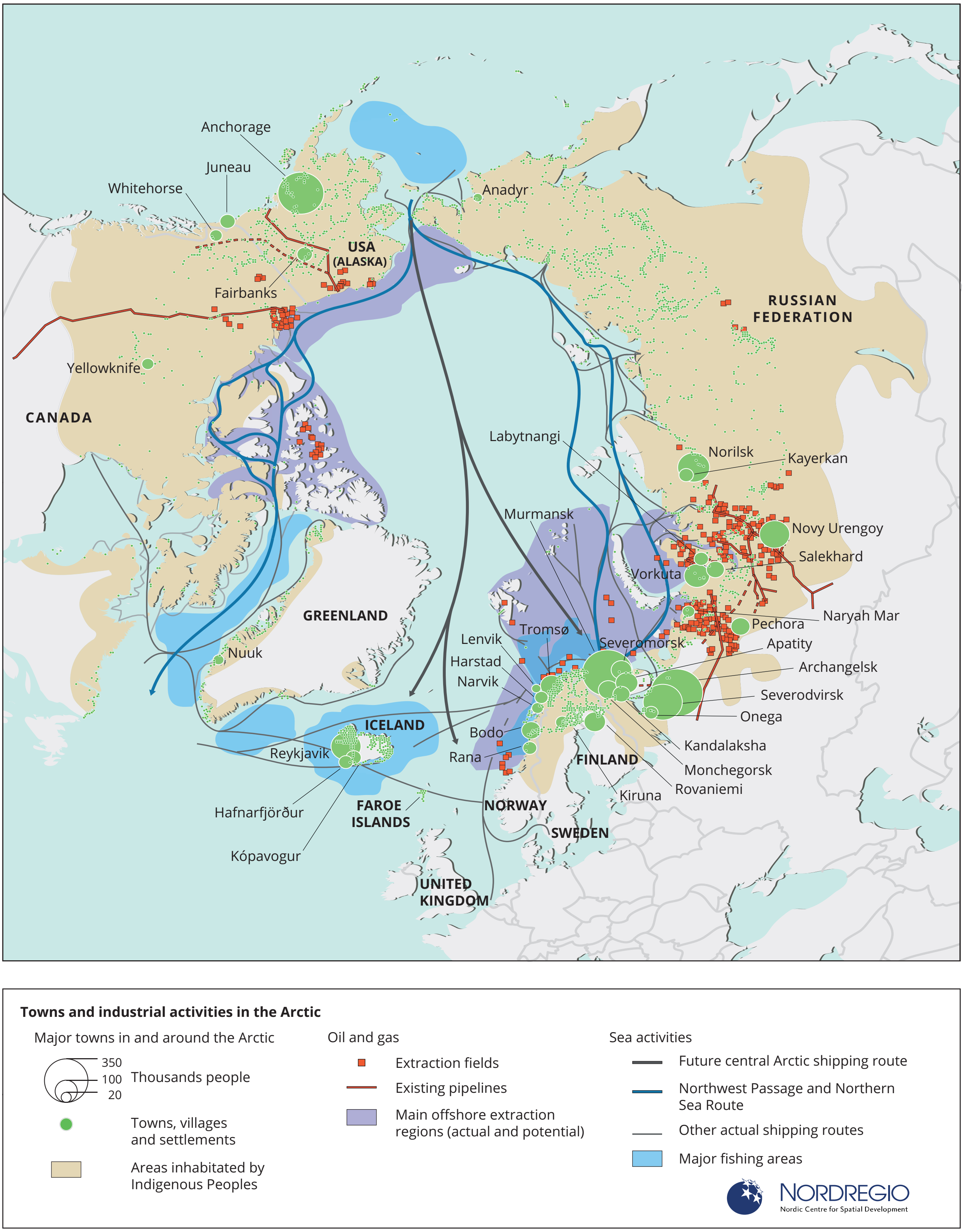
Note: * Definition of the Arctic by the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP).
For country groupings please see box page 5.

The European Arctic is a high-cost region because materials, goods and resources are far from markets and situated in a sparsely settled land or offshore, while the harsh environment influences economic development and affects living standards and access to social services. And although a predicted rise in commodity prices and possible reduced costs resulting from an opening Arctic caused by climate change may increase the profitability of resource development, the effects of environmental and climatic changes in the region may make it more costly to create economic development from the traditional resource base. This is because, while climate change may open the Arctic seas for transportation, fisheries and offshore development, changing and unpredictable sea ice conditions can be a hazard that limits development. Similarly, an increase in flooding, thawing permafrost or reduced snow and ice cover can shorten the lifespans of ice roads, destabilising roads, pipelines and infrastructures and thus increasing production costs even in areas with significant current activity. With regards to environmental, social and economic development, the European Arctic is thus facing challenges and opportunities similar to those in the rest of the circumpolar Arctic.

Photo: Reindeer herding is an important occupation for the Saami people, © Konstantin Vanujto

Photo: Seal hunting form part of the subsistence economy and dietary intake for Inuit people, © John McConnico

Map 2.2 Towns and industrial activities in the Artic



Note: Many parts of the Arctic are characterised by remoteness and low population density, others are more populated and developed. Major human development already exists in the European Arctic, including high population density, infrastructure and economic engagement, both on- and offshore.

Source: Adapted from the map 'Towns and industrial activities in the Arctic', Nordregio, 2011.

2.3 The policy context for enhanced European engagement

The importance of the Arctic to Europe's environment has long been recognised by the EU and the EEA's member countries. With regard to the policy and legislative aspects, the Arctic States for obvious reasons already have national legislation in place to regulate the economic development in the Arctic, and environmental monitoring has been taking place on their land and sea territories for decades. All five of the Arctic EEA member countries have national Arctic strategies in place, and even European countries outside the Arctic have launched national Arctic or polar strategies, policy papers, roadmaps or research programmes to address the challenges and opportunities in the region (see Box 2.1). Similarly, since 2008 the EU has developed an EU Arctic policy. Further demonstrating the European interest in and concern for the Arctic region, five EEA member countries are founding members of the Arctic Council and a further eight EEA member countries are observers in the Arctic Council ([10]) (see Map 2.1) and the EU has been invited to follow the work of the Council while its observer status application is reviewed. The EU furthermore maintains strategic partnerships with Canada, Russia and the United States, and has close partnerships with Norway, Iceland and Greenland (as part of the Kingdom of Denmark).

Box 2.1 National Arctic strategies, roadmaps, guidelines and policy frameworks

Europe

- **Denmark**: Strategy of the Kingdom of Denmark (including Faroe Islands and Greenland)
- **EU**: An integrated European Union policy for the Arctic
- **Finland**: Finland's strategy for the Arctic region 2013
- **France**: National roadmap for the Arctic and Arctic science strategy 2015-2020
- **Germany**: Germany Arctic policy
- **Iceland**: Iceland's Arctic policy
- **Italy**: Towards An Italian strategy for the Arctic, National guidelines
- **Netherlands**: Netherlands polar programme
- **Norway:** Norwegian High North policy
- **Poland**: Poland's policy towards the Arctic: Key areas and priority actions
- **Russia**: Strategy for the development of the Arctic zone of the Russian Federation and national security efforts 2020 and State programme 'Social and economic development of the Arctic zone of the Russian Federation 2020'
- **Spain:** The geopolitics of the Arctic region
- **Sweden**: Sweden's strategy for the Arctic region and Swedish environmental policy for the Arctic
- **United Kingdom**: UK policy towards the Arctic

Outside Europe

- **Canada ([11]):** Canada's northern strategy and Canada's Arctic foreign policy
- **India**: India and the Arctic
- **Japan**: Japan's Arctic Policy
- **South Korea**: Arctic Policy of the Republic of Korea
- **United States**: National Arctic Strategy

([10]) In addition to Arctic Council and EEA members Denmark, Finland, Iceland, Norway and Sweden, the following eight EEA member countries are observers to the Arctic Council: France, Germany, Italy, Netherlands, Poland, Spain, Switzerland and the United Kingdom.
([11]) Canada's Arctic policy is currently under revision, and is expected to be published in 2017.

Photo: © Arctic Council Secretariat/Linnea Nordström

Regionally, the Arctic Council, established in 1996, and its predecessor the Arctic Environmental Protection Strategy (1991) have been instrumental in assessing changes in the Arctic environment and subsequent impact on its peoples, and in making recommendations for policy responses on the basis of scientific assessments. Since 2011, the Arctic Council has also started adopting legally binding agreements ([12]). The Barents Euro Arctic Council, the Nordic Council of Ministers and the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) have similarly been active in regional cooperation, with various programmes supporting the Arctic region's peoples and environment. Internationally, a number of multinational environmental agreements (MEAs), many of which the EU is party to, have been put in place to regulate harmful substances (e.g. POPs or mercury), to regulate economic activities (e.g. the International Maritime Organisation (IMO) Polar Code for Arctic and Antarctic shipping), to provide guidelines for activities (e.g. offshore oil and gas) or to regulate greenhouse gases that significantly impact the Arctic region (e.g. the UNFCCC).

At the EU policy level, the Arctic was first acknowledged as a priority in 2007 ([13]) with the Commission Communication and Blue Book on the EU integrated maritime policy (EC, 2007) and later in 2008 by the High Representative's report on Climate change and international security (EC, 2008a), both of which identified the Arctic region as an area of concern and relevance to the EU. The Arctic had until then been addressed in a more piecemeal fashion through various marine, environmental, climate, regional, transport and research legislative acts, strategies and programmes. In 2014, the EU's 7th EAP identified the Arctic region and its environment as a priority area and from 2014 the EU maritime security strategy (EU, 2014) similarly embedded the Arctic region in the EU's policy framework.

Since the launch of the first Commission Communication on the Arctic region (EC, 2008b), the EU has been strengthening its Arctic coordination and in 2016, the European Commission and High Representative published a Joint Communication on an integrated EU policy for the Arctic (EC, 2016a) and submitted it to the European Parliament and the Council of the European Union. EU Arctic policy focuses on three overarching objectives, namely:
(1) strengthening the knowledge base to address the challenges from environmental and climate changes;
(2) contributing responsibly towards sustainable development in and around the region; and
(3) intensifying constructive engagement with Arctic States, local and indigenous peoples and partners regarding challenges that require an international response. More than 30 actions have been identified, focusing on research, innovation and strengthening the knowledge base in all three priority areas. In response to the Joint Communication, the Council adopted conclusions in 2016 (EU, 2016) broadly welcoming the EU Arctic policy, and the European Parliament adopted an own-initiative report and Arctic resolution in 2017 (EP, 2017).

The EU has demonstrated responsibility by contributing actively in the European Arctic through regional development policies and programmes, including INTERREG cross-border and transnational cooperation (e.g. the Northern Periphery and Arctic programme), the European Neighbourhood Instrument (ENI) cross-border cooperation (e.g. the Kolarctic programme) and the Northern Dimension cooperation with Russia, Iceland and Norway. The EU has also made big investments in satellite observation in the Arctic region, including CryoSat-2 and the Copernicus

([12]) The Arctic Council has adopted legally binding agreements on search and rescue (Arctic Council, 2011) and marine oil spill response (Arctic Council, 2013b), and an on Enhancing International Arctic Scientific Cooperation (Arctic Council, 2017a).

([13]) The European Parliament has however been a member of the Conference of Parliamentarians of the Arctic Region (CPAR) since its foundation in 1993. CPAR addresses topics such as maritime transport, education and research, human development and climate change. The most recent conference was held in Ulan-Ude in Russia in June 2016.

programme, as well as through its Framework Programme for Research and Innovation, Horizon 2020, which will significantly contribute to a better understanding of relevant developments and processes (in common with its predecessor, the FP7 research programme).

Furthermore, the EU has a number of policies that are not specifically aimed at the Arctic or its environment, but where the implications of the policies will be felt and have an impact in the region, including: (1) the Framework for climate and energy (EC, 2014d); (2) the EU biodiversity strategy to 2020 (EC, 2011a); (3) the EU engagement on sustainable development (EC, 2016c) in the context of the UN's 2030 Agenda and Sustainable Development Goals (SDGs); the ongoing work related to (4) green sustainable and inclusive growth (EC, 2010) and blue economy (EC, 2014a); and (5) the Roadmap to a resource efficient Europe (EC, 2011b). Similarly, the EU's common fisheries policy (CFP), the international ocean governance initiative (EC, 2016d) and offshore oil and gas regulation (EU, 2013b) are relevant for marine management in the EU and with its northern partners.

2.4 Global megatrends — the drivers of Arctic change

A global-to-European perspective is relevant for EU environmental policymaking, as Europe's systemic environmental challenges and response options are increasingly shaped by global drivers. Similarly a European-to-Arctic perspective is of relevance, as the two overlapping regions are bound to each other and the rest of the world through multiple systems, be they environmental, social, financial or through the flows of materials and natural capital. As a result, Europe and the Arctic's ecological and societal resilience ([14]) will be affected by a variety of global megatrends affecting the regions in the coming decades (see Figure 2.2), as highlighted in the 2015 Assessment of global megatrends (EEA, 2015b). Europe's relative size and influence on the global economy is expected to decline (EEA, 2015c), and this changing global setting presents both challenges and opportunities for Europe as well as for the Arctic.

The EU recognises that many environmental challenges are global and can only be fully addressed through a comprehensive global approach, and a 2050 vision that Europe should 'live well, within the planet's ecological limits' has been set out in the 7th EAP. The EU has also identified international cooperation as an overall objective in EU Arctic policy, and similar objectives for the region regarding environment, sustainable development and international engagement are set out by the eight Arctic States in their individual Arctic strategies, the mandate of the Arctic Council and in the Arctic Council's 2013 common Vision for the Arctic (Arctic Council, 2013a).

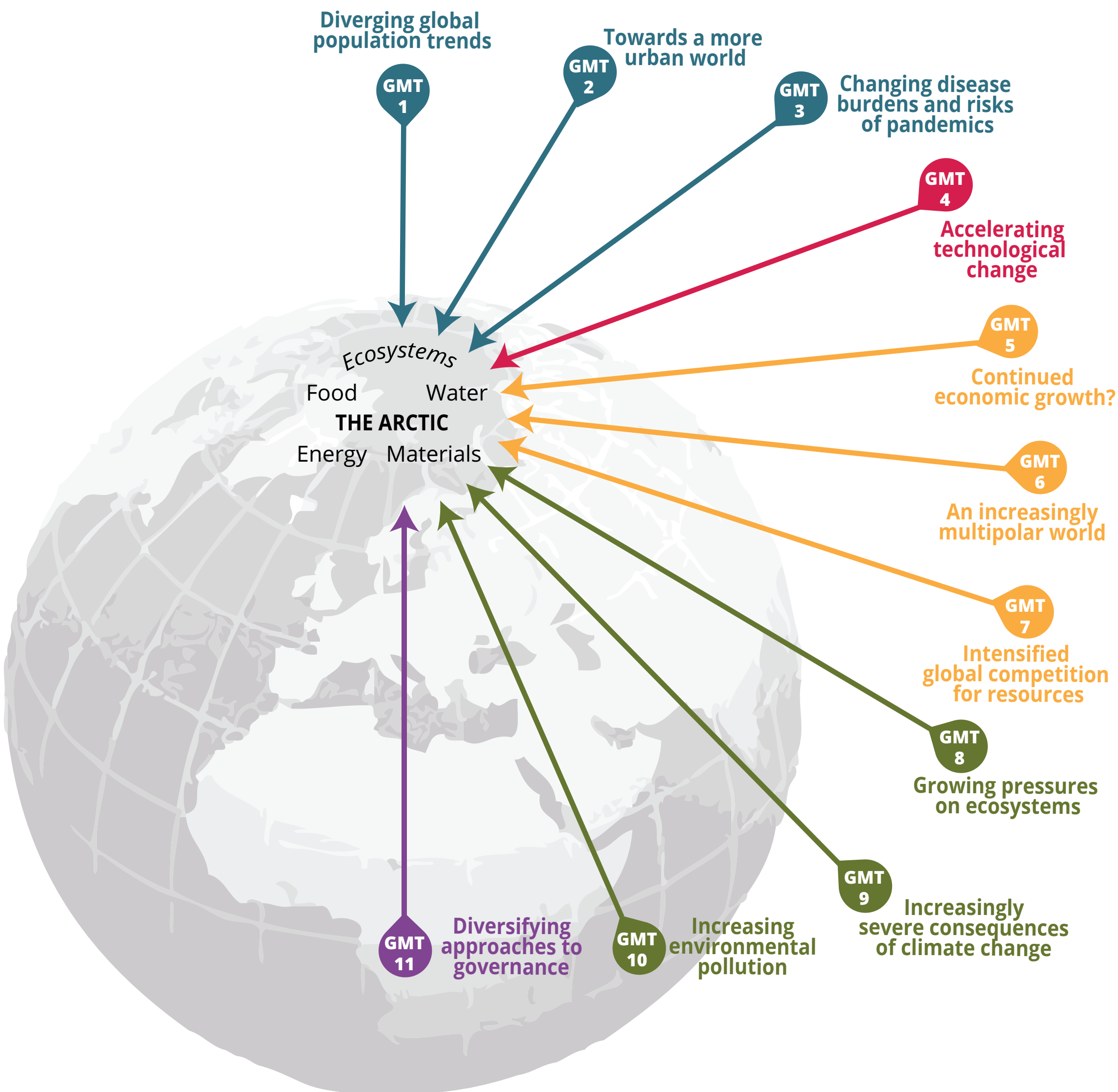
Global megatrends cut across economic, social, political, technological and environmental dimensions as well as temporal interconnectedness and interplay between various drivers and responses. It is therefore of importance to understand how they will shape or affect national or regional measures in the Arctic or in Europe, including systemic and potentially detrimental effects on the environment, human health or natural capital. Many of the drivers and trends that affect the Arctic region, the environment and its people are challenges that the Arctic States are not solely responsible for or can solve in isolation. An example is climate change, which is a major driver for changes in the Arctic. Although the Arctic States are responsible for a proportion of global greenhouse gas emissions, solving the problem cannot be tackled by these states alone. The same holds true for global population growth and associated growing demand for natural resources, changing trade patterns, world prices for key commodities (oil, gas and minerals) and increasing environmental pollution loads. Climate change is not the only or always the most salient driver of change in the Barents area; it interacts with socio-economic, political and cultural changes — and, in many cases, it exacerbates current challenges (AMAP, 2017a).

If Arctic nations do not, individually, collectively and in partnership with neighbouring regions such as Europe, seek proper mechanisms for incorporating global drivers of change into regional and local settings, any further large-scale economic development in the Arctic may exacerbate environmental pollution, cause ecosystem degradation and lower resilience to the brink of its tipping points. Similarly Europe needs to act responsibly by recognising and addressing its Arctic footprint and contribution to environmental pressures in the region, as current lifestyles and consumption patterns in Europe and other developed regions put excessive pressures on the Arctic environment.

However, the Arctic is also affected by a growing global middle class outside Europe, which increasingly adopts the resource-intensive consumption patterns of advanced economies. This will lead to long-range

([14]) Resilience is here understood as the capacity of social–ecological systems to effectively respond to change and continue to develop without losing key structure, function, feedbacks and identity.

Figure 2.2 **Global megatrends (GMT) affect the Arctic region**



Note: The EEA Assessment of global megatrends (EEA, 2015b) identified eleven global megatrends that affect Europe. These megatrends also, to a large degree, affect the Arctic region.

Source: Based on EEA, 2015b.

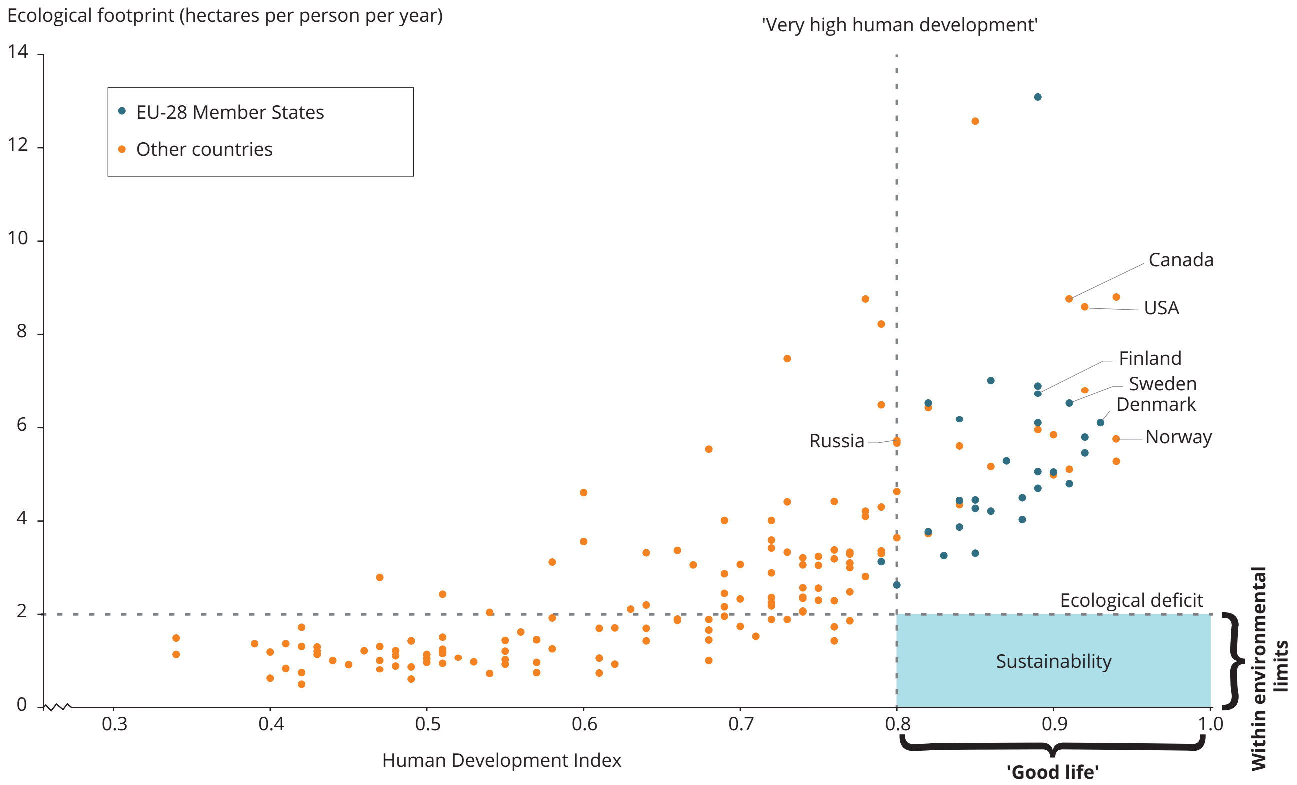
pollution affecting the Arctic and create local challenges from resource extraction and exports of food, energy and materials to world markets. Direct pressures on Arctic ecosystem resilience furthermore derive from point sources and land fragmentation due to expanding transport infrastructure, urbanisation and migration patterns.

These global trends with local impacts underline the need for action to reconfigure systems of production and consumption so that they operate within planetary limits and thereby ensure the wellbeing of current and future generations. In Europe, as in most of the Arctic states, efforts to manage environmental pressures, economic development and human wellbeing need to overcome the short-termism currently dominating political and economic thinking, and instead increase focus on embracing long-term, integrated and global perspectives.

Together, Europe and Arctic partners need to respond by seeking to shape global change in ways that mitigate and manage risks, and create opportunities as well as finding ways to adapt to changes by seeking to anticipate and avoid harm by strengthening the resilience of social, environmental and economic systems. Sustainable development is still an option in the vast and sparsely populated Arctic region, and responses should also include common initiatives that take advantage of the opportunities that arise as a result of the changes, such as the commercial opportunities associated with innovation, expanding global markets and prosperity to the benefit of both European and Arctic inhabitants. At global level, the 17 SDGs adopted in 2015 as part of the UN's 2030 Agenda, which the EU and Arctic States have subscribed to, acknowledge the global dimension and interconnectedness. The SDGs have the potential to supplement Arctic and EU efforts to address global megatrends, although they are not the full answer to ensuring sustainable development or integrated management in the Arctic. As a first step, the EU is now developing a set of indicators to measure regional progress towards the global targets.

Some Arctic States are further ahead than others when addressing core problems and implementing integrated ecosystem-based management plans. Regardless of the national governance level, improved regular monitoring and assessment capabilities are needed to support prudent policymaking in the region, including efforts by Arctic governments to develop Arctic strategies that fully recognise global megatrends and support the SDGs, and thus make protection of biodiversity and ecosystem resilience a high priority across sectors in Arctic policymaking. In particular, there is an obvious need to regionally assess planned or potential energy, fisheries, regional development and transport routes in the Arctic, before further industrial developments take away the window of opportunity for a prudent and balanced economic growth in the region, which respects the changing ecosystems and the planetary boundaries — the core message in the EU's 7th EAP. These efforts have to be made in cooperation with other international partners, including the EU.

Figure 2.3 Future development strategies need to embrace the concepts of sustainability and planetary boundaries



Note: The world cannot afford developing countries adopting the same unsustainable growth and consumption patterns of developed countries. All nations need system transition in order to achieve a sustainable development within the limits of the planet.

The Human Development Index is calculated using three components: education, life expectancy at birth and wealth. It is expressed as a value between 0 and 1, from less to most developed countries. The Ecological Footprint measures how much land and water area a population requires to produce the resources it consumes and to absorb its waste. The world biocapacity is the global productive area available on Earth (it decreases as population grows). Iceland is not included in the 2017 edition of the National Footprint Accounts by the Global Footprint Network.

Source: Adapted from © 2017 Global Footprint Network. National Footprint Accounts, 2017 Edition. Please contact Global Footprint Network at data@footprintnetwork.org for more information.

As outlined above and further substantiated in the SOER2015, Europe and the Arctic face persistent and emerging challenges linked to production and consumption systems and a rapidly changing global context. Achieving the EU and UN 2030 and 2050 visions requires system transitions, driven by more ambitious actions on policy, knowledge, investments and innovation. Doing so will present major opportunities to boost Europe's economy and employment, putting Europe at the frontier of science and innovation, and thus provide a positive influence on the European Arctic and beyond. But achieving the visions will furthermore require substantial European efforts at global level in supporting geopolitical stability and to bring forward development and raise living standards in developing parts of the world, through new technologies and efficient solutions that lower the ecological footprint rather than through outdated technologies that delay the transition into sustainable pathways (see Figure 2.3). Global environmental interconnectedness requires this to be applied in an Arctic context.

2.5 A snapshot of the EU's Arctic footprint

A number of concurrent changes are taking place in the Arctic. Much work has been undertaken in the past decades to monitor these changes in order to establish a better understanding of ecosystems, drivers and pressures, and to establish baselines for indicators and for predicting future trends and developments. Such efforts include monitoring and observation programmes and a number of International Polar Years (IPYs) (the most recent IPY was conducted in 2007-2008). Although the interlinkages and interplay are not fully understood, it is evident that a number of dramatic and rapid changes are occurring in the region and that ecosystem functions and resilience are being challenged.

Some of the pressures originate in Europe, including pressures associated with consumption in the EU. Depending on the type of pressure, between 24 % and 56 % of the associated total EU footprint occurs outside Europe (EEA, 2015a). The share of the environmental footprint of EU demand that is exerted outside EU borders has increased during the past decade for land, water and material use, as well as for air emissions. To a varying degree this footprint also affects the Arctic region, and in order to quantify and assess its Arctic impact, the European Commission compiled an EU Arctic footprint and policy assessment (Ecologic Institute, 2010) (see image on the right). The assessment, published in December 2010, indicated that the EU might be responsible for as much as 35 % of the global contribution to Arctic impacts. Some of the areas where the EU Arctic footprint is large include long-range chemical pollution, black carbon emissions and impact on fish stocks through imports from the Arctic States. However, the EU also has a positive footprint in the Arctic through efforts to: (1) reduce greenhouse gases that impact the region; (2) promote high-quality international standards applying to Arctic economic activities; and (3) foster employment in the Arctic through EU imports, regional cooperation programmes and research activities. Neither the Arctic States nor the Arctic Council has to date conducted such an assessment of their own impact on the region, although elements are addressed in some of the sector assessments of the Arctic Council.

Global megatrends predict increased demand for natural resources, some of which are expected to come from the Arctic, in particular as the region has large mineral deposits, significant oil and gas reserves and large fish stocks. The region furthermore holds vast amounts of freshwater and other renewable energy resources which can be used for energy-intensive industries, and the Arctic can provide transportation

Source: Ecologic Institute, 2010.

routes as well as cater to an increasing interest in cruise tourism. Many of the industries, shipping companies and tourists are expected to be European, which will affect the EU footprint in the Arctic.

However, the 2016 EU Arctic policy aims to reduce negative Arctic impacts through an integrated and coherent policy approach that links up with EU policies on renewable energy, cold technologies, reducing waste through a circular economy approach and initiatives aimed at the transport, energy and fisheries sectors. Given the EU and wider global impacts on the Arctic environment, it is important that Arctic nations engage with the EU and international partners when seeking long-term policy options, including binding policy options or international agreements when defining integrated solutions to the pressures affecting the Arctic. An example is climate change engagement through the UNFCCC. There is similarly scope for EU and the Arctic States jointly working towards applying the principles of circular economy and facilitating the required transitions.

2.6 Crosscutting marine issues of relevance

Given that a very large part of the Arctic region is covered by ocean ([15]) and that the EU acknowledged the Arctic Ocean as a priority in 2007 (EC, 2007), this section will address some general crosscutting marine issues in addition to the specific physiological aspects and socio-economic activities covered in Chapter 3.

While the Arctic Ocean is the smallest ([16]) and shallowest of the world's five major oceans, it is still up to 5.4 km deep and covers a huge area with little or no human activities directly affecting it. Sea ice cover and darkness for part of the year limit fisheries, while depth and extreme conditions exclude oil and gas extraction or mining activities, which currently take place only in the shallower subarctic regional seas. The Arctic Ocean is furthermore a semi-enclosed sea with two outlets, namely the Bering Strait and the North Atlantic Ocean (to the east and west of Greenland). Being a semi-enclosed sea is significant because this limits the turnover of water volume and influences water quality and the transport in and out of nutrients and contaminants. Furthermore, environmental and physio-chemical conditions can vary significantly in semi-enclosed seas, and thus affect important variables such as salinity, temperature, acidification, accumulation of pollutants and the ability to sustain a thriving food web.

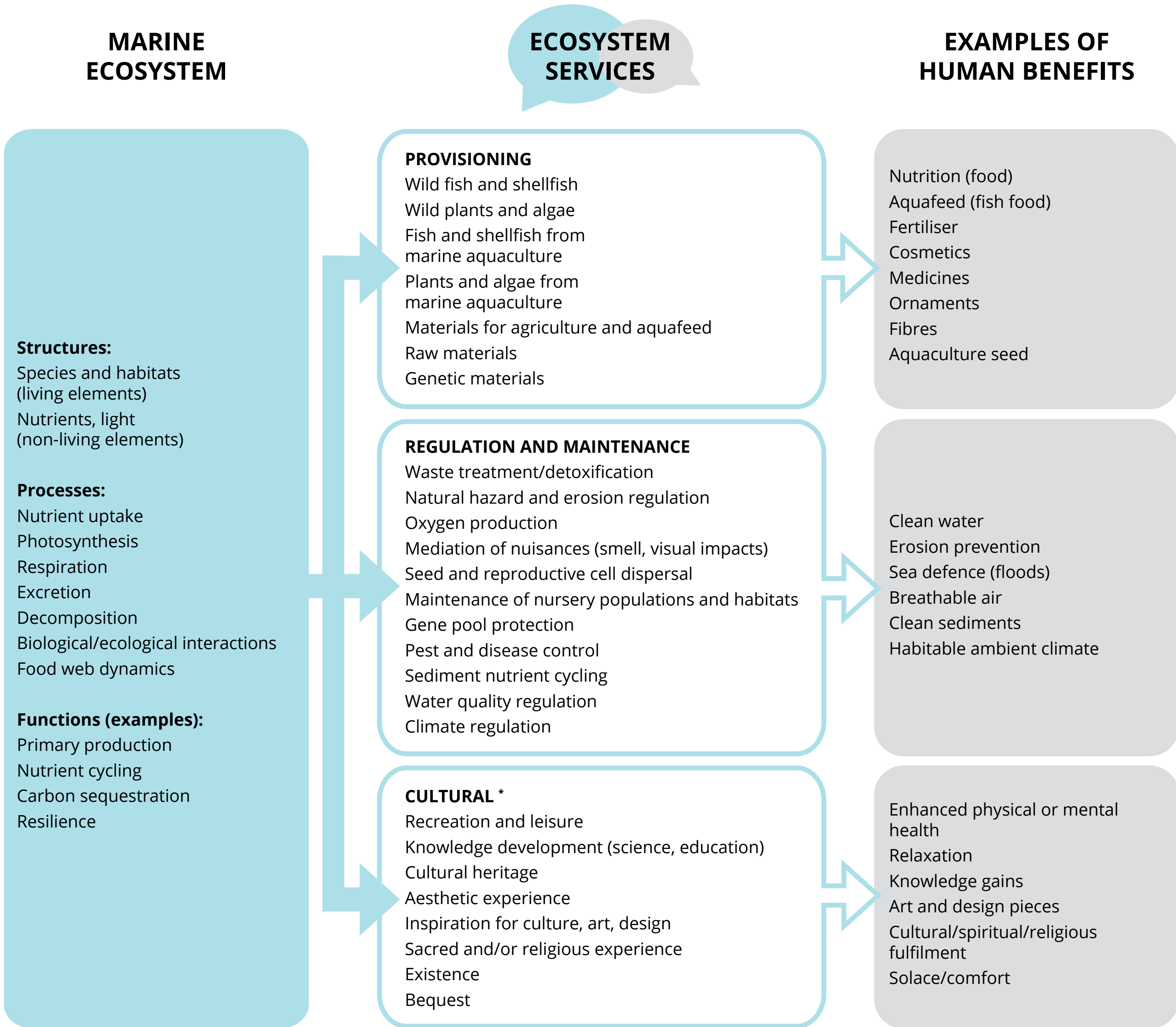
Our current knowledge of the Arctic Ocean is limited but it is recognised that Arctic biodiversity and ecosystems are under increasing pressure. Preservation of biodiversity and maintaining ecosystem services is fundamental to human wellbeing, as is continued access to natural resources and economic growth. Thus, if Arctic environmental conditions such as quality of air and water, biodiversity and natural resources are not properly managed, it could lead to future security implications due to a reduced ability to sustain people or keep economies healthy. Possible implications include food security, water security, environmental security and energy security. These security issues may affect the Arctic region and beyond. Even military security over access to marine resources could become an issue, although the Arctic is currently marked by low tension and the settlement of disputes in a rule-based manner. An overview of marine ecosystem services and links to societal benefits is presented in Figure 2.4.

Marine activities in the Arctic are primarily regulated through national legislation, as most of the current or planned activities take place within the 200 nautical miles exclusive economic zone (EEZ) of the Arctic coastal states. But international legislation also applies through, for example, the UN Convention on the Law of the Sea (UNCLOS) (UN, 2013) which regulates international waters. Nations that have ratified UNCLOS have the option to submit claims up to an additional 150 nautical miles of the sea floor (not the water column) beyond their EEZ ([17]), if scientific evidence supports such submissions. All Arctic States apart from the United States are party to UNCLOS and have sent either submissions or preliminary information for an extension of their continental shelves ([18]) (see Map 2.3).

The UN Commission on the Limits of the Continental Shelf (CLCS) was set up to assess submissions and it will in due course give its recommendations on the delimitation of the ocean floor in the Arctic. However, such recommendations are for guidance only. It is up to neighbouring states to agree bilaterally

([15]) According to the CAFF definition of the Arctic, 57 % of the Arctic is covered by marine areas.
([16]) The Arctic Ocean covers about 10 million km^2.
([17]) UNCLOS allows for the possibility of drawing the outer limits of the continental shelf further than 350 nautical miles from the baselines.
([18]) The United States has not signed UNCLOS but recognises most of its provisions as an articulation of customary international law, e.g. as stated in the Ilulissat Declaration of 2008 (Danish Ministry of Foreign Affairs, 2008). Canada has yet to make a formal submission but on 3 December 2013 sent preliminary information indicative of the outer limits of its continental shelf beyond 200 nautical miles in the Arctic Ocean.

Figure 2.4 Marine ecosystem services and links to societal benefits



Source: EEA, 2016a.

(or multilaterally depending on the number of overlapping continental shelf submissions) on the exact delimitation of the marine territories beyond their EEZs. This can take time and, as an example, the delineation of a disputed area in the Barents Sea between Norway and Russia, which was agreed in 2010, took 40 years to settle. The CLCS handles extension of continental shelf submissions in the order they are submitted, and given that the most recent submission from the Kingdom of Denmark regarding the shelf north of Greenland is currently number 76 on the list, it can be up to a decade before recommendations are finalised. Meanwhile, the CLCS might ask nations to submit further scientific evidence to support their submissions, and in 2015 Russia submitted additional evidence and adjusted the area submitted for its extended continental shelf.

The maritime areas under national jurisdiction — whether in EEZs or possible future extensions on the sea floor — are of significance when discussing the Arctic environment, as it will be the Arctic coastal nations that decide on the level of economic activity that will take place in these large areas. In the short term, this is mostly relevant in the shallower parts of regional seas, while in longer terms it will become relevant in the deeper part of the Arctic Ocean, as technologies are developed and become available for operators venturing into maritime areas. It will be up to individual Arctic States to determine which

Map 2.3 **2015 status of Arctic States' claims to an extended continental shelf under UNCLOS**

Maritime jurisdiction and boundaries in the Arctic region

- Internal waters
- Canada territorial sea and exclusive economic zone (EEZ)
- Potential Canada continental shelf beyond 200 nm
- Denmark territorial sea and EEZ
- Denmark claimed continental shelf beyond 200 nm
- Iceland territorial sea and EEZ
- Iceland claimed continental shelf beyond 200 nm
- Norway territorial sea and EEZ/ Fishery zone (Jan Mayen)/Fishery protection zone (Svalbard)
- Norway claimed continental shelf beyond 200 nm
- Russia territorial sea and EEZ
- Russia claimed continental shelf beyond 200 nm
- Norway-Russia Special Area
- USA territorial sea and EEZ
- Potential USA continental shelf beyond 200 nm
- Overlapping Canada/USA EEZ
- Russia-USA Eastern Special Area
- Unclaimed or unclaimable continental shelf
- Straight baselines
- Agreed boundary
- Median line
- 350 nm from baselines
- 100 nm from 2 500 m isobath (beyond 350 nm from baselines)
- Svalbard treaty area
- Iceland-Norway joint zone
- Main 'Northwest Passage' shipping routes through Canada claimed internal waters

Note: Explanatory notes and complementary information are available from the IBRU Centre for Borders Research: https://www.dur.ac.uk/ibru/resources/arctic.

Source: Adapted from © IBRU: Centre for Borders Research.

environmental protection standards, and which monitoring and enforcement levels, will apply to the maritime areas under national jurisdiction. It will also be up to Arctic nations to decide whether to designate shipping corridors with low environmental impact, or to close or limit shipping during the seasonal migration of whales. Currently, varying levels of environmental protection, monitoring and enforcement apply across the Arctic States through national legislation. When it comes to common approaches, the few precautionary measures established so far are non-binding guidelines on, for example, offshore oil and gas activities (Arctic Council, 2009a) or on preventing unregulated high seas fisheries. Common binding agreements have also been established through the Arctic Council as mentioned above. However, these agreements are remedial measures, and are not enforced or administered by the Arctic Council but are left up to the participating states to implement.

Increased attention to the opening seascapes in the Arctic Ocean over the past decades has led to a general perception that there is an ongoing race for the Arctic. This scenario does not, however, provide for a nuanced reflection of the situation, because most of the activity in the Arctic Ocean concerns research activities related to gaining scientific evidence on the ocean floor. After ratifying UNCLOS, Arctic coastal states had 10 years to send submissions on the extension of their continental shelves. Furthermore, it would be an exaggeration to describe the development as a race, because most economic activities take time to prepare, particularly in the Arctic, including time spent on exploration and taken for operators to obtain the necessary licences from the authorities in question (all Arctic states have regulatory processes in place for economic activities on their land and sea territories).

Since 2008, the economic crisis has also slowed economic activities, resulting in a more cautious investment climate with longer time horizons for major projects and investments. This includes European companies; Royal Dutch Shell's decision to suspend its Arctic drilling on the North Slope of Alaska, despite a USD 6 billion investment in exploration, licences and equipment, is a good example of companies' more cautious approach to Arctic adventures. In 2016, the Italian oil company ENI wrote down the value of the world's northernmost offshore oil field, Goliat in Norway, by EUR 710 million, and in its 2016 strategic document the French oil company TOTAL stated that the company will 'not conduct oil exploration or production operations in the Arctic ice pack' (TOTAL, 2016), to comply with the COP21 Paris Agreement. Russia's monopoly gas exporter Gazprom has decided to cancel plans to drill 12 exploration wells and conduct seismic mapping in the Barents Sea by 2025. Despite this slowdown, oil and gas production is still expected in decades to come as new licences are still being obtained by companies that plan to explore, e.g. in the Norwegian EEZ of the Barents Sea (see Section 3.3. on hydrocarbon exploration).

So rather than a race for the Arctic, or an invasion of investment-eager companies, the more appropriate description would be a tedious exploratory phase led by scientists and researchers in the north. And while international companies are looking north, the Arctic region is still overall seeing stable population levels despite the possible prospects for the region. However, despite the modest level of economic activity compared with elsewhere in Europe, environmental and social challenges exist in the marine domain.

Despite progress in some areas, the UN 2010 target of halting the loss of biodiversity was not met globally, including in the Arctic. The Arctic biodiversity assessment (CAFF, 2013a) highlighted the declining trends for the condition of both marine and terrestrial species. The importance of biodiversity and ecosystem services for economic development, human health and job creation has long been underestimated. In order to ensure that natural capital is preserved to support human wellbeing and sustain economic growth, Arctic states need to further implement ocean ecosystem-based management approaches, spatial planning, resource accounting and coherence among sector policies at all levels.

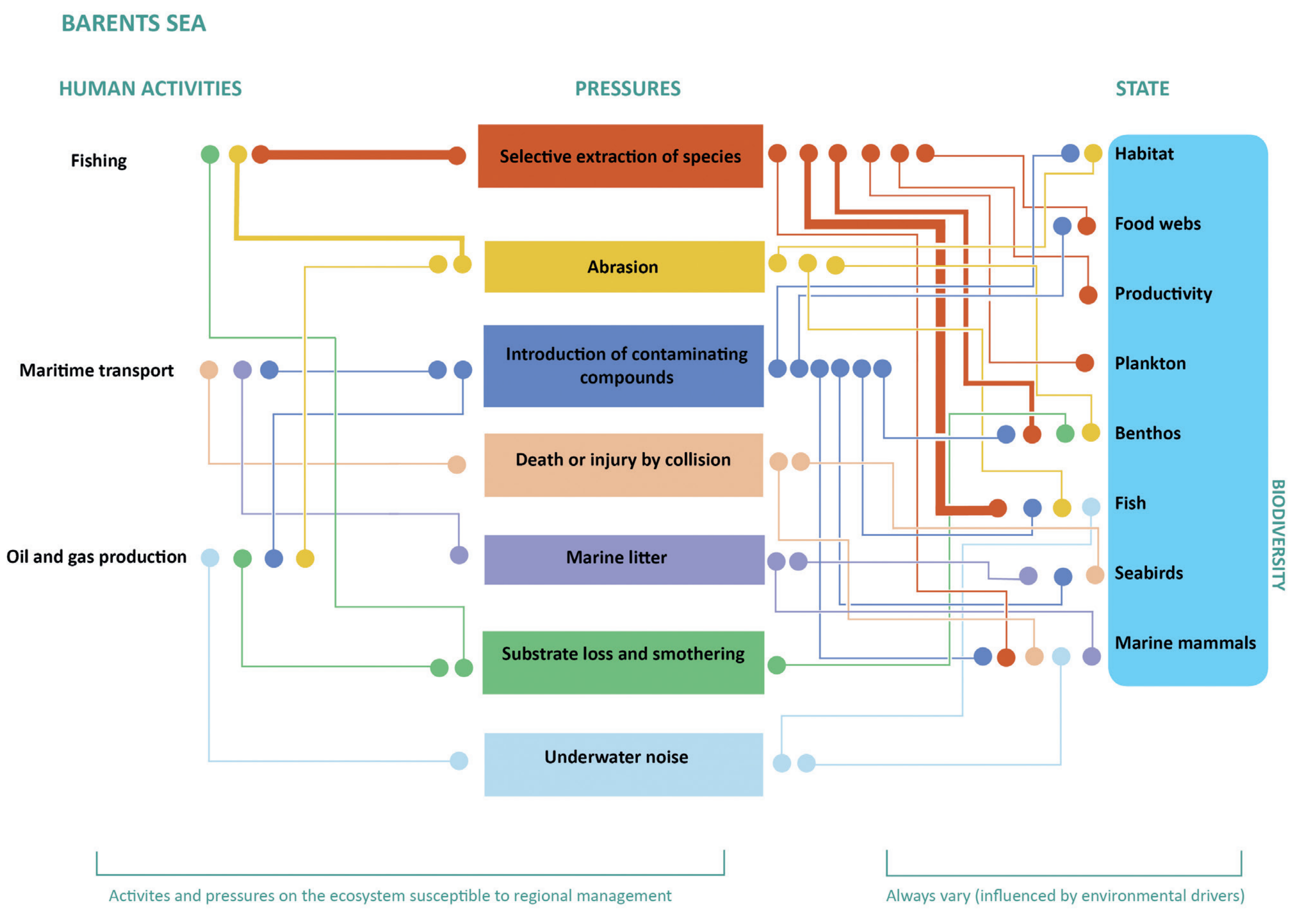
In this context, the CBD process to identify Ecologically or Biologically Significant Marine Areas (EBSAs) is a step in the right direction, as these are special areas that serve to support the healthy functioning of oceans and the many services they provide. Thirteen EBSAs were identified, covering 4.2 million km^2, or 22.7 %, of the Arctic marine area. Further work is similarly needed in the designation of Marine Protected Areas (MPAs) or Particularly Sensitive Sea Areas (PSSAs) in international waters, to avoid impacts on vulnerable Arctic species and to limit impacts on migrating animals such as birds, fish and marine mammals. In recent years, steps have been taken in this direction, with Arctic marine and coastal areas increasingly being protected, but MPAs still cover less than 4.7 % of Arctic waters (CAFF/PAME, 2017). This is well below the target of 10 % agreed to be implemented by 2020 under the Convention on Biological Diversity (CBD target 11). There are no designated PSSAs within the Arctic.

In April 2016, the international community, including the EU, agreed to develop a legally binding instrument for the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction, under UNCLOS. The agreement is a step forward in enhancing international ocean governance and once adopted the instrument will contribute to a more sustainable use of ocean resources, in line with the UN's 2030 Sustainable Development Agenda. The work aims at holding a formal intergovernmental treaty conference in 2018, and the elements to be covered by the instrument, which will apply to the Arctic Ocean, include marine genetic resources, area-based management tools such as MPAs, environmental impact assessments, capacity building and the transfer of marine technology. The same elements are addressed and supported in the EU's 2016 international ocean governance communication (EC, 2016d).

Our Arctic Ocean knowledge base is still generally poor and marine ecosystems are complex but our understanding of their state and functioning is constantly increasing. This increasing knowledge allows for better policy advice that integrates relevant elements of the ecosystem into management. In recent years increasing focus has been placed on an ecosystem approach to management of human activities in marine environments, whereby policies and ensuing management aim to encompass ecological, economic and social needs and outline trade-offs between different policy options to limit cumulative impacts. In the European Arctic, the Barents Sea ecosystem has been strongly influenced by fishing and aquaculture, maritime transportation of goods, offshore oil and gas activities and rising cruise tourism. Climate change and ocean acidification also affect the Barents Sea ecosystem. An overview of the Barents Sea ecoregion with the major regional pressures, human activities and state of ecosystem components was described by the International Council for the Exploration of the Sea (ICES) in 2016 (see Figure 2.5).

The use of our seas, including the Arctic Ocean and regional seas, must respect ecological boundaries to protect and value their potential for present and future generations. Therefore, policy ambitions for the

Figure 2.5 Barents Sea ecoregion overview



Note: Overview of the Barents Sea ecoregion with the major regional pressures, human activities and state of ecosystem components. The width of the lines indicates the relative importance of the individual lines

From an EEA perspective it can be argued that underwater noise should also be connected to maritime transport and fisheries.

Source: ICES, 2016.

economic growth of maritime activities in the Arctic region have to be aligned with policy targets for securing healthy, clean and productive seas. Simultaneously, they also require fundamental shifts in the systems that fulfil our societal needs and in the way we use ecosystem services. True cooperation among all stakeholders and wider societal engagement will be crucial to support this transition. The EU has important roles to play in this context, namely as:

- a knowledge provider for sound decision-making through research and satellite activities;
- a regulator of many companies operating in the region;
- a source of pollutants or climate forcers;
- a major importer of natural resources from the region; and
- an organisation able to support the establishment of protected area networks to ensure better conditions for habitats and migrating species.

The EU can furthermore foster a better dialogue between marine science and marine management to improve our understanding of the interactions between ecosystem resilience and human activities, which ultimately will lead to better maritime policy implementation and improve the state of the Arctic seas through improved management, including measures in relation to anticipated changes and uncertainty. In this context it should be mentioned that, under its process for regular reporting and assessment of the environment, the UN in 2015 completed the first World Ocean Assessment, a survey of global and regional marine environmental assessments, which included an assessment of the Arctic Ocean. In addition, the Arctic Council's Circumpolar Biodiversity Monitoring Programme (CBMP) launched a State of the Arctic Marine Biodiversity report in 2017 (CAFF, 2017), as part of implementing the Arctic Biodiversity Assessment recommendations and as included in the Arctic marine strategic plan 2015-2025 (Arctic Council, 2015). The increasing concerns regarding marine litter in the world's oceans is similarly an area that requires international responses and joint actions, in which the EU can play a leading role.

3 Challenges and opportunities from Arctic change

This chapter highlights some of the key trends, changes and effects in the Arctic region with regard to climate change, biodiversity, pollution and human activity, and the challenges and opportunities associated with the observed and projected changes. It is beyond the scope of this report to capture all aspects of Arctic change that individually or collectively have an impact in the region, and as a result some aspects have been excluded from this report: land fragmentation, unsustainable forestry and logging practices, quality of surface and marine waters and analysis of pressures from diffuse and point sources.

3.1 Arctic ecosystem resilience, connectivity and importance

The historical and cultural ties between Europe and the Arctic region are longstanding and Europe has for decades built its growth and development on natural resources extracted outside Europe, including from the Arctic. This dependency is set to continue in the short to medium term, both as Arctic resources such as minerals or fish are becoming increasingly accessible due to rapid climatic change, and because it will take time for the EU's efforts in transforming the economy on to a resource-efficient path, with less dependency on commodities and natural resources from other parts of the world, to take effect.

Monitoring this dependency and changes in the Arctic region, as well as assessing the wider implications for Europe's environment, its peoples and their health is thus of relevance to European and Arctic inhabitants. The same can be said for continuous and regular assessment of economic opportunities and promoting growth, innovation and improved living standards for the benefit of both regions.

Arctic ecosystems are facing multiple simultaneous stressors and rapid changes that can weaken ecosystem resilience and have severe consequences locally and regionally, as well as globally through cascading effects and feedback loops ([19]). Due to the abruptness and irreversibility of many of the changes, the sustainability of Arctic ecosystems and communities is increasingly challenged, particularly as new economic developments such as mining or oil and gas activities are locally adding to the ongoing environmental and climatic stressors on ecosystems.

An interim Arctic resilience report (Arctic Council, 2013c) provided an assessment of the potential for large shifts in ecosystem services that may affect human wellbeing, and illustrated some of the challenges and opportunities relating to resilience. In 2016, the final Arctic resilience report (Arctic Council, 2016) was published and it provides an assessment of environmental and social change and resilience, as well an overview of tools and strategies that can be used to assess and build resilience in the Arctic. The report identifies 19 tipping points or regime shifts in natural systems that may radically reshape the Arctic in the coming century. Furthermore, an Arctic Resilience Action Framework (Arctic Council, 2017b) for future Arctic work, along with practical options for actions to strengthen resilience and manage change, has been prepared under the auspices of the Arctic Council. In 2015, the Arctic Council (CAFF) in cooperation with UNEP and the World Wide Fund for Nature (WWF) conducted a scoping study exploring the economics of ecosystems and biodiversity (TEEB) in the Arctic, as a first step towards the mainstreaming of Arctic biodiversity and ecosystem services into policy and decision-making processes (CAFF, 2015).

Furthermore, three sub-regional reports, intended to describe and assess the effects of climate change and other major drivers of change and to inform decision-making with regard to adaptation measures, are being prepared by the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP)

([19]) An example of a cascading effect and self-enforcing feedback mechanism is the burning of fossil fuels. Through the release of greenhouse gases, this has led to a reduction of Arctic sea ice cover, which in turn is expected to lead to an increase in extraction of hydrocarbons once conditions are favourable, which again will result in further use of fossil fuels, which will accelerate a further opening of the Arctic though warming and further emissions of greenhouses gases (carbon dioxide and methane from thawing permafrost).

working group. Two of the regions studied, namely the Barents Sea region (AMAP, 2017a) and the Davis Strait/ Baffin Bay region (AMAP, 2017b), are relevant to the European Arctic. The three regional assessments and the planned overview report are part of the Arctic Council efforts on Adaptation Actions for a Changing Arctic (AACA).

Despite monitoring and observation efforts, environmental and biological baselines and thresholds are not fully established and understood, which makes management and planning efforts more challenging. Environmental standards, cross-border planning and the granting of economic licences are not always coordinated between Arctic States, which means that the environmental load could exceed harmful limits if multiple large-scale economic activities are introduced in an environment that is already undergoing rapid change. These are strong arguments for a precautionary approach, as management without full knowledge of the ecosystem boundaries or carrying capacity increases risks and uncertainties.

Thus, more research and knowledge innovation are needed to develop not only an understanding of each of the Arctic's many individual ecosystems, but also of the differences between them, their connectivity, components, thresholds, feedbacks and risks, as well as their accumulated global impact. This will contribute to a deeper knowledge of factors behind the resilience of some ecosystems and the feedback and cascade mechanisms through the interaction of food webs and ecosystem boundaries. For the Arctic States and Europe, developing a better understanding and sound knowledge base on the multiple ecosystem exchanges in the Arctic are key to understanding the interactions on local, regional and global scales and responding appropriately. These responses need to embrace ecosystem-based management approaches and actions towards maintaining and improving ecosystem functions and integrity (see Chapter 4).

3.2 Key environmental and climatic trends, changes and effects of relevance to Europe

It has been argued that we have entered the Anthropocene, the current geological age during which human activity is the dominant influence on climate and the environment. And, although human activities are increasing in the Arctic region, it is primarily through human-induced climate change that the Arctic region is currently most affected; it has been warming twice as fast compared with the global average in the past decades. This warming is having a profound effect on the Arctic cryosphere and the changes are predicted to have far-reaching impacts beyond the Arctic, affecting Europe and the rest of the world.

The changes in the cryosphere present a series of challenges, opportunities and risks that are still being studied and have yet to be fully understood with regard to feedback loops and albedo changes that can further amplify the impacts of climate change. This section of the report takes a closer look at some of these changes and trends and, in short, presents the environmental challenges associated with the change as well as the potential economic and social opportunities attributed to it. This section also addresses some of the related wide-reaching effects of these changes, not only for the Arctic inhabitants and the environment but also for Europe and globally.

It should be noted that the opportunities outlined in this chapter include local, regional and global perspectives, not all of which are encompassed by EU policy objectives but rather are in the nature of business or commercial interests. Thus, it is often preferable to focus on the environmental challenges and risks to ecosystem resilience and carrying capacity of the environment, rather than on the commercial opportunities associated with changes to the cryosphere.

3.2.1 Sea ice

The extent of Arctic sea ice has declined rapidly, especially in summer, since reliable global data became available in 1979 through satellite observations. Record low Arctic sea ice cover in September, which is the month the sea ice normally reaches its minimum, was observed in 2012 (see Map 3.1). The minimum sea ice cover in summer 2016 was the second lowest on record (jointly with 2007), while the winter sea ice cover in early 2017 was the lowest ever recorded (NSIDC, 2017a). Over the 1979-2015 period, the Arctic lost on average 42 000 km^2 of sea ice per year in winter and 89 000 km^2 per year in summer. The summer extent is now roughly half the size of the summer extent in the 1980s (EEA, 2016b).

In terms of thickness, the Arctic sea ice has also been losing thick multi-year ice and is increasingly being replaced by thinner 1-year ice from the previous winter (see Figure 3.1). In total it is estimated that up to 65 % of the total sea ice mass has been lost over the period 1975-2012 (AMAP, 2017c). Arctic sea ice is projected to continue to shrink and thin all year round. For high greenhouse gas emission scenarios, nearly ice-free summers can be expected before the mid-century and even as early as the late 2030's according to the latest assessment (AMAP, 2017c).

Map 3.1 Arctic sea ice extent

Arctic sea ice extent

- March median line sea ice extent 1981-2010
- September median line sea ice extent 1981-2010
- Area covered by sea ice in March 2013
- Area covered by sea ice in September 2012

ARCTIC PORTAL

Note: The Arctic sea ice reached the lowest extent in the satellite record on 16 September 2012. For comparison the median sea ice cover for the 1981-2010 for March (the month with sea ice maximum) and September (the month with sea ice minimum) are illustrated, along with the winter extent for March 2013.

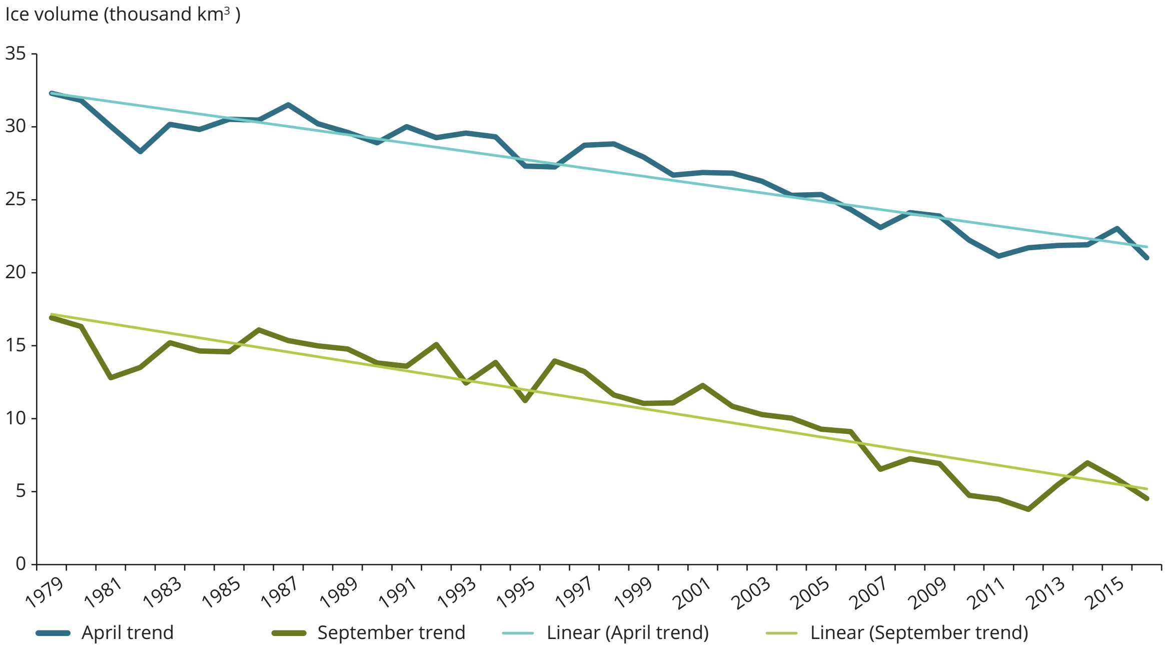
Source: Adapted from Arctic Portal, 2015.

Throughout the 21st century, there will still be substantial ice cover in winter due to dark cold winter months. For a high emission scenario, the Arctic could become ice-free year round before the 22nd century. The Barents region (the European high Arctic) is seeing the fastest rate of change in sea ice coverage — the Barents Sea has lost seasonal coverage at two to four times the rate of other areas (Laidre et al., 2015).

Environmental challenges and physical effects of reduced sea ice extent include:

- Open water absorbs more heat from the sun than reflecting sea ice. This ice-albedo feedback further reduces the ice cover.
- Open water affects the overturning circulation of cold and warm water through increased mixing of freshwater in the upper layer of the Arctic Ocean. This freshwater stems from run-off from melting of snow and ice on land and, to a lesser extent, from melting sea ice.
- Coastal erosion and damage to infrastructure in parts of the Arctic basin with sensitive coastlines will increase, because reduced sea ice results in bigger waves reaching the coasts.
- Open water absorbs more carbon dioxide (CO_2) from the air than ice-covered oceans. Reduced sea ice cover thus increases ocean acidification in the region and thereby affects the composition of the lower trophic layers of the food chain in the Arctic Ocean and sub-regional seas, including the European seas ([20]).
- Changes in light conditions and acidification impact on plankton and zooplankton, which are the base of the Arctic marine food chain. Changes in these species can have cascading effects throughout the ecosystem.
- Reduced sea ice cover affects animal species such as seal, polar bear and walrus, which depend on sea ice to rest, hunt and mate, and to give birth and feed their young (CAFF, 2013b).
- Decreasing sea ice extent and thickness makes the ice less robust and therefore prone to faster melting the following year.
- Reduced sea ice cover facilitates increased shipping, fishing and offshore natural resource extraction. Such activities can cause accidents, disturb breeding grounds or migration routes

Figure 3.1 Arctic sea ice volume, 1979-2016



Note: Trend lines and observation points for April (sea ice volume maximum) and September (sea ice volume minimum) have been indicated. Green line: Trend = – 2.6 +/– 1 [1 000 km^3/decade]; Blue line: Trend = – 3.2 +/– 1 [1 000 km^3/Decade].

Source: Schweiger et al., 2011; PIOMAS, 2017.

([20]) Barents Sea, Norwegian Sea and Greenland Sea.

of marine mammals ([21]), diffuse pollution loads (including black carbon) and stress sensitive ecosystems.

- Diminishing sea ice extent is being linked to changing weather patterns in the northern hemisphere due to changing high/low pressures over the Arctic Ocean and thereby amplifying oscillations in the jet stream causing more frequent and prolonged extreme weather events such as flooding or drought in northern Europe. The linkages are still being studied.

- Earlier break-up and reduced sea ice cover affect traditional livelihoods that are often dependent on sea ice for fishing and hunting.

Economic opportunities of a reduced sea ice cover include:

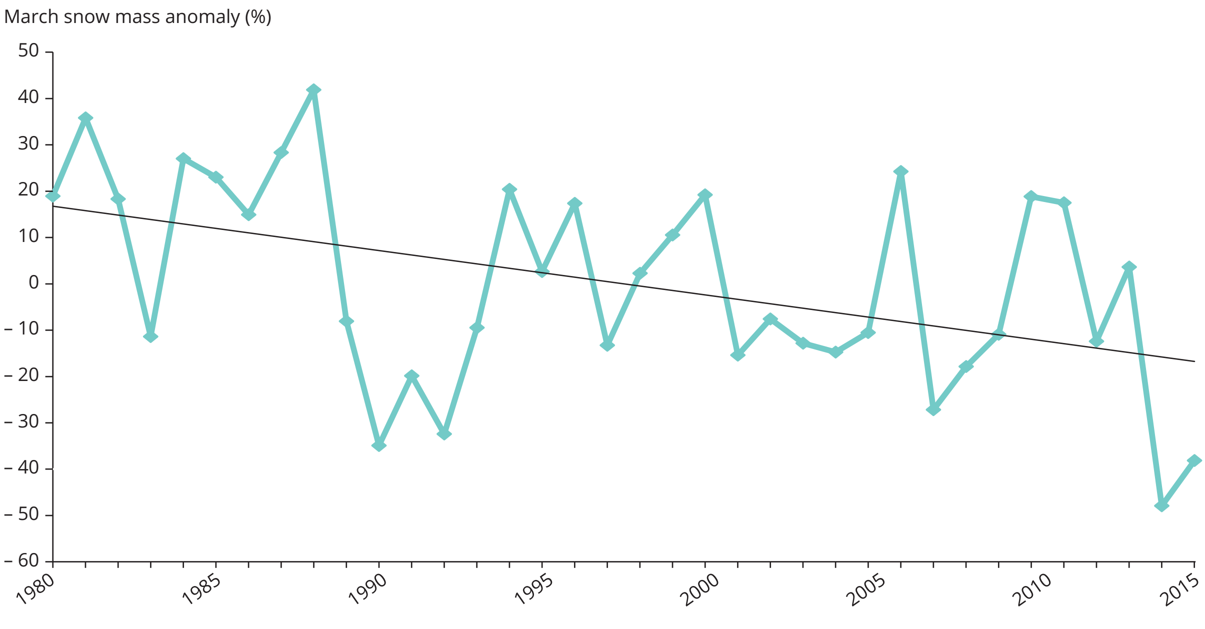
- Reduced sea ice cover increases access for shipping, fishing, offshore oil and gas ([22]), or mineral activities, as well as cruise ship tourism. However, the relationship between sea ice reduction and economic opportunities is not simple, as moving sea ice and icebergs, ice-formation on structures or vessels, bigger waves, low temperatures and light conditions still make operations very challenging in the Arctic Ocean.

- Many technologies to cope with the extremely cold conditions in the Arctic are yet to be developed and more importantly implemented, but this is an area for innovation potential.

3.2.2. Snow cover

The length of the snow season and amount of land covered by snow are important for plants and animals in the Arctic. A shorter duration of snow cover means a longer growing season for plants, which affects food availability for animals. Snow cover extent in the northern hemisphere has declined significantly over the past 90 years, with most of the reduction occurring since 1980. Snow cover extent in Europe decreased by 13 % on average for March and April and by 76 % for June over the period between 1980 and 2015 (EEA, 2016c) (see Figure 3.2). On average, across the entire Arctic, the duration of winter snow cover became 4 days shorter per decade in the period

Figure 3.2 Trend in March snow mass in Europe (excluding mountain regions)



Note: This figure shows the satellite-derived anomaly in March snow mass in Europe for the period 1980–2015 relative to the 1980–2012 average.

Source: GlobSnow, updated from Luojus et al., 2011.

([21]) Reduced sea ice might ease northwards movement for more mobile open-water species of marine mammals.

([22]) It should be noted that increased Arctic extraction of fossil fuels goes against the objective of keeping the global temperature change below the 2 °C target (UNFCCC, 2015) and may have adverse effects on the environment.

between 1972/1973 and 2008/2009 (AMAP, 2012). Models project further widespread reductions in the extent and duration of snow cover in the northern hemisphere and in Europe into the 21st century. Higher air temperatures in the Arctic have also led to an increase in 'rain on snow' (ROS) events, which lead to the creation of ice layers within the snowpack. A 2 °C global average warming translates into a 4-6 °C warming in the Arctic, while a 3 °C global average temperature could translate into a 6-11 °C Arctic warming, depending on the climate scenarios used (Seneviratne et al., 2016). The implications for snow and ice cover are obvious, as both are reduced when conditions change from freezing to non-freezing temperatures. Related to snow cover is the issue of ice cover on Arctic rivers and lakes, which play an important role for winter transport and tourism in many locations as well as for the functioning of local ecosystems.

Environmental challenges and economic, social and physical effects of reduced snow and ice cover include:

- Snow reflects solar radiation; Arctic areas with reduced snow cover absorb more solar radiation, raising local or regional temperature and resulting in further snow melt.
- Early or rapid melting of snow changes the amount and timing of freshwater flow during spring and summer months.
- Flora and fauna and their ecology change when no longer covered by snow for extended parts of the year, including increased competition with species from lower latitudes. Earlier blossoming of flora can lead to trophic mismatch with migrating birds.
- 'Rain on snow' events make it harder for grazing animals to reach plants through ice layers in the snowpack.
- Early seasonal snow melt can lead to increased incidence of droughts and wildfires.
- Increased number and duration of melt-off pools increase the likelihood of insect outbreaks in forests and tundra areas.
- The duration of ice roads on frozen rivers and lakes will be affected by earlier melt-off.
- Winter tourism and snow sports areas may be negatively affected.
- Hydropower generation might be affected by the timing of the snowmelt and associated water flows.

Economic opportunities of reduced snow cover include:

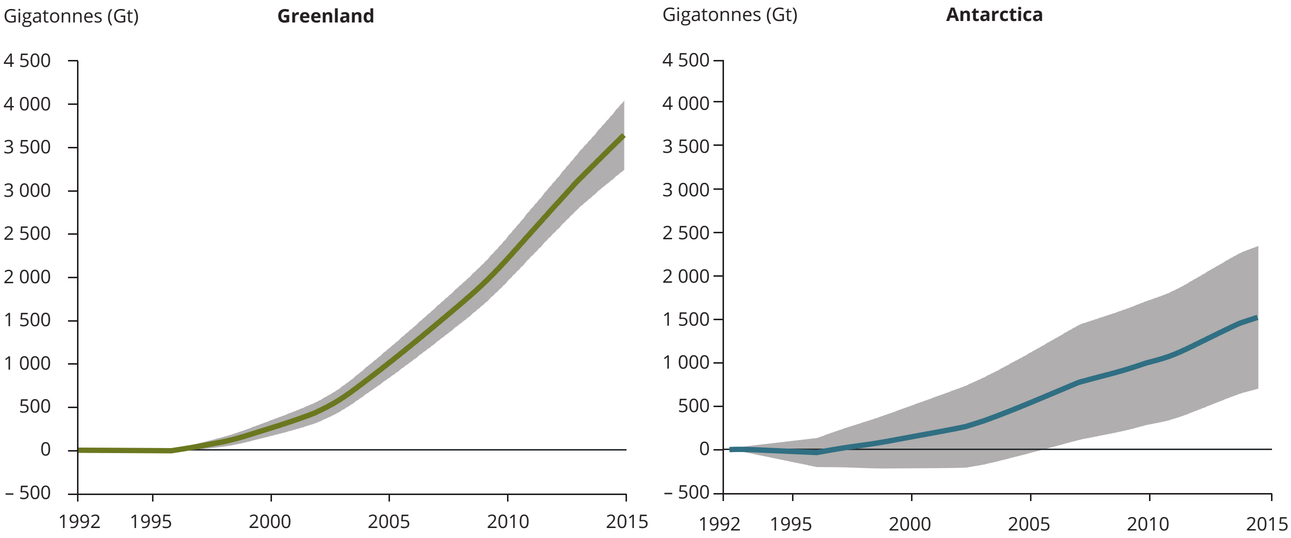
- Agricultural or forestry potential might increase with reduced snow cover, although this might impact traditional livelihoods and indigenous stewardship of the land.

3.2.3. The Greenland ice sheet and the European glaciers

The Greenland ice sheet is the largest body of ice in the northern hemisphere and plays an important role in the global climate system. The Greenland ice sheet has been losing ice at an increasing rate during the past two decades (see Figure 3.3). Thermal expansion of the world's oceans due to global warming was the most significant contributor to sea level rise (SLR), but the contributions from land-locked ice caps and glaciers have increased rapidly in recent decades. The Greenland ice sheet alone has contributed about one fifth of global SLR in the past decade. The average ice loss increased from 34 billion tonnes per year over the 1992-2001 period to 215 billion tonnes from 2002 to 2011 (EEA, 2016d). Model projections suggest the further decline of the Greenland ice sheet in the future but the uncertainties are significant.

The world's glaciers are losing mass at a faster rate than at any time in recorded history. European glaciers are losing mass, in the high Arctic, in Scandinavia and in the Alps, with losses observed to be accelerating in recent decades at many locations. The loss occurs by a combination of surface melt and run-off, iceberg calving and subsurface melting of the termini of glaciers that end in the ocean. The centennial retreat of European glaciers (including in the Alps) is attributed primarily to increased summer temperatures. However, changes in winter precipitation, reduced glacier albedo due to the lack of summer snowfall and black carbon deposition can influence the behaviour of glaciers, in particular on a regional and decadal scale. As for the European Arctic glaciers, the area of mountain glaciers and ice caps exceeds more than 420 000 km^2. Overall there has been a loss of ice mass in 21 of 24 glaciers, including loss and retreat from the Norwegian coastal glaciers. While some ice caps at higher elevations in north-eastern Svalbard seem to be increasing in thickness, the estimates for Svalbard as a whole show a declining mass balance. The only three European Arctic glaciers showing mass gain are all northern outlets of the Vatnajökull ice cap in Iceland (Jeffries et al., 2013). European glacier retreat is expected to continue in the future, with a decline in volume of between 22 and 84 %, compared with the current situation predicted by 2100 under a moderate greenhouse gas forcing scenario, and of between 38 and 89 %, under a high forcing scenario (EEA, 2016e).

Figure 3.3 Cumulative ice mass loss from Greenland and Antarctica



Note: The cumulative ice mass loss is derived as annual averages from more than 100 assessments. The uncertainty interval is estimated from the 90 % confidence intervals (5 to 95 %) of the individual studies. The ice mass loss from Antarctica is of relevance with regard to sea level rise (see Section 3.2.4).

Source: Shepherd et al., 2015, updated from 2012.

Environmental challenges and physical impacts of increased ice mass loss include:

- Ice mass loss has the potential to make a significant contribution to global sea level rise, particularly affecting coastal areas and low-lying island states in the southern hemisphere (see Section 3.2.4 on SLR).
- Increased ice flow through Greenland ice sheet outlet glaciers leads to an increasing number of icebergs discharged into waters around Greenland, creating hazards for shipping and tourism.
- Glacial meltwater run-off has negative effects by affecting freshwater supply, run-off regimes, river navigation and water supply for hydropower generation. Furthermore, it may cause natural hazards and damage to infrastructure along rivers affected by larger discharges of meltwater.
- The discharge of melted freshwater may affect the biological structure of flushed habitats.
- The discharge of freshwater can affect thermohaline circulation due to changes in the salinity of the upper layers of water in the Arctic Ocean. This can affect the 'pump' whereby warm waters brought into the Arctic Ocean by the Gulf Stream sink to the bottom where the dense water then flows back to the world's oceans ([23]). Thus, the freshwater discharge can disrupt the heat transfer in and out of the Arctic. Scientists are still studying the extent of this effect.

Economic opportunities that melting ice presents include:

- The run-off from both the Greenland ice sheet and European glaciers is a source of hydropower generation. This can be of particular advantage for remote villages far away from main power lines.
- Hydropower is suitable for power-intensive industries such as smelting aluminium. However, hydropower generation is dependent on stable long-term water flows, which might be adversely affected by retreating glaciers.
- Reduction in the Greenland ice sheet can open access to new deposits of mineral resources.

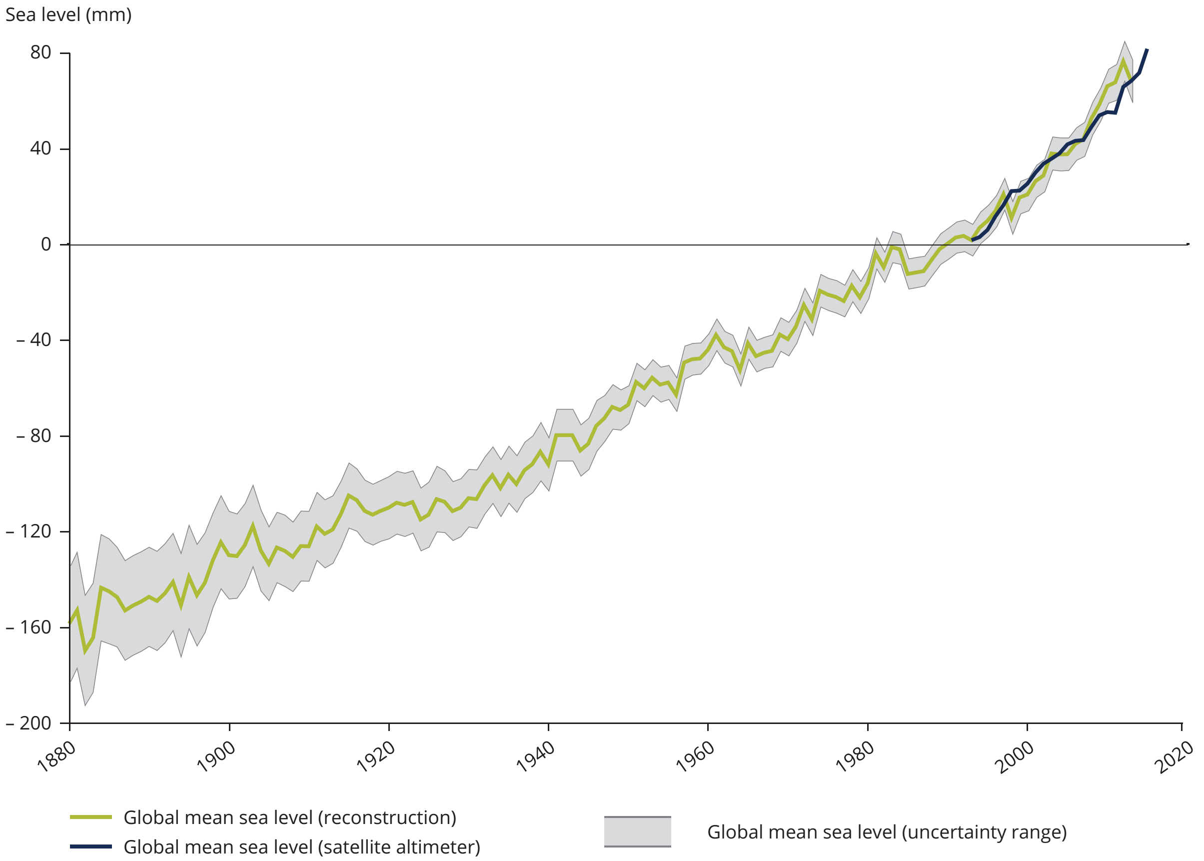
([23]) Also known as the North Atlantic Deep Water (NADW) formation affecting the the Atlantic Meridional Overturning Circulation (AMOC).

3.2.4. Sea level rise

Global warming has for many decades led to increasing SLR due to thermal expansion (i.e. warm water takes up more volume than colder water). Also, melting of land-locked ice, whether from glaciers or ice caps, is increasingly contributing to global SLR, as the melting shifts masses of water from land to the world's oceans (see Figure 3.4). The rise in sea level is not, however, restricted to the area where the ice loss is discharged, but rather spreads out globally.

Due to gravitational forces the ice loss from ice caps in the northern hemisphere results in larger SLR in the southern hemisphere and vice versa. This is of importance to Europe, as it will be ice loss from Antarctica that will affect European shorelines the most strongly. The Antarctic continent holds much more ice, and therefore water that could be released, than the Greenland ice sheet. If the Antarctic ice was lost completely it would result in a global SLR of up to 60 metres, while a complete ice loss of the Greenland ice sheet would result in an SLR of approximately 7 metres (NSIDC, 2017b; AMAP, 2011a). However, at the current rate of loss from the Greenland and the Antarctic ice sheets, this would take approximately 10 000-25 000 years. The current loss of ice from the Antarctic ice sheet is less than half that of the Greenland ice sheet (see Figure 3.3). The processes that determine (the future) stability of and loss from the two ice sheets are the subjects of intensive scientific studies [24].

Figure 3.4 Observed change in global mean sea level



Note: The figure depicts the rise in global mean sea level from 1880 to 2015, relative to the 1990 level, based on two sources. The green line shows a reconstruction for 1880 to 2013 from coastal and island tide gauge data. The uncertainty interval is shown in grey. The dark blue line shows a time series for 1993 to 2015 based on altimeter data from the TOPEX/Poseidon, Jason-1 and Jason-2 satellites. Corrections for the inverse barometer effect and glacial isostatic adjustment have been applied.

Source: Adapted from Church and White, 2011; Masters et al., 2012. Data supplied by Benoit Legresy (Commonwealth Scientific and Industrial Research Organisation (CSIRO)).

[24] It has to be taken into account that rising global temperatures may cause an increase in ocean water evaporation and therefore cloudiness, which could decrease incoming solar energy and cause temperatures to fall.

The global mean sea level (GMSL) rose by 19 cm from 1901 to 2013, at an average rate of 1.7 mm/year. The rate of SLR over the past two decades, when satellite measurements have been available, is higher at 3.2 mm/year. In its most recent assessment report, AR5, the Intergovernmental Panel on Climate Change (IPCC) projects that GMSL would rise a further 0.26-0.54 m by the late 21st century, for a low greenhouse gas emission scenario, and 0.45-0.81 m for a high emission scenario ([25]). In a recent assessment by AMAP it is even estimated that when all sources of SLR are considered (not just those from the Arctic), the rise in GMSL by 2100 would be at least 0.52 m for a greenhouse gas reduction scenario and 0.74 m for a business-as-usual scenario — these estimates are almost double the minimum estimates made by IPCC (AMAP, 2017c).

Some densely populated areas of Asia and many low-lying island states will be hardest hit. But Europe is and will also be affected (see Map 3.2). In addition to the EEA countries Iceland and Norway, 15 EU Member States have coastline that will be affected by SLR. It is estimated that the economic assets (including nuclear facilities) within 500 metres of the sea in EU Member States have an estimated value of EUR 500-1 000 billion. Furthermore some 47 500 km^2 of sites within 500 metres of the coastline in the EU are identified as having high ecological value (Ice2sea, 2014) and some 200 million European citizens live near the coastline (Eurostat, 2009). Most coastal regions in Europe have experienced an increase in absolute sea level as well as in sea level relative to land, but there is significant regional variation. Extreme high coastal water levels have also increased at many locations along the European coastline (EEA, 2016f).

Environmental challenges. From an environmental and socio-economic perspective, SLR can cause:

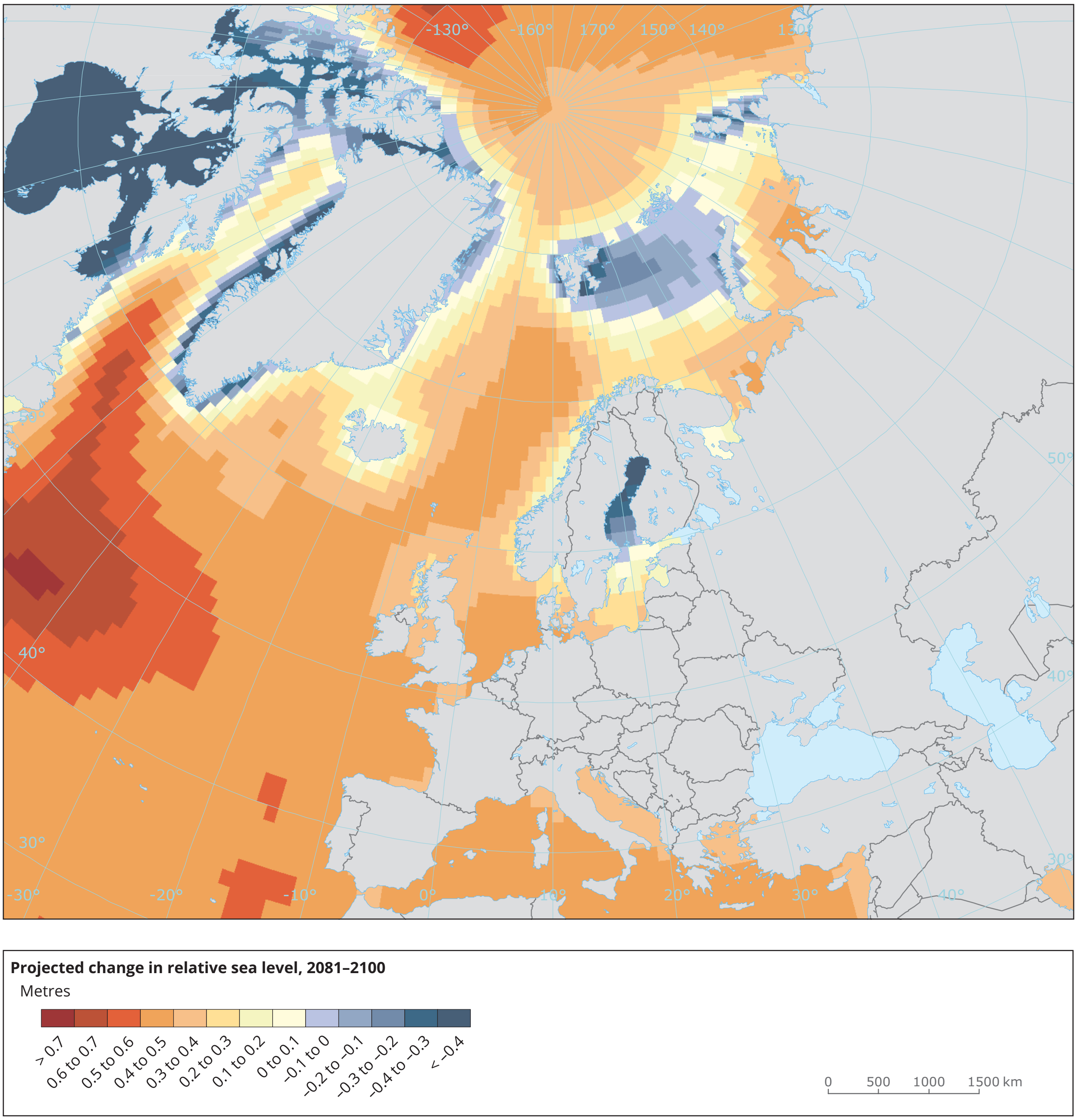
- major damage to coastal ecosystems and estuaries;
- increased erosion in coastal areas and estuaries inside and outside the Arctic;
- increased and/or persistent flooding;
- changing light conditions, which affect coral reefs, including cold coral reefs found in the Arctic ([26]);
- damage to infrastructure and installations and associated dispersion of harmful substances;
- displacement of people in low-lying areas, causing migration, local/regional tension over rights and access to land (mostly in regions outside Europe).

Economic opportunities. From an economic and social perspective, SLR can create opportunities for:

- There are no known advantages of sea level rise. Although construction firms outside the Arctic might stand to profit from having to increase dikes, barriers and coastal protection measures, and building new areas where people from flooded areas can repatriate, these opportunities do not in any way outweigh the costs of lost property or ecosystem change.

([25]) Further reading can be found in the EEA core set of indicators, Global and European sea level.
([26]) In addition to changing light conditions, coral reefs found in the Arctic are also affected by ocean acidification and salinity.

Map 3.2 Projected change in relative sea level in Europe



Note: The map shows the projected change in relative sea level in 2081-2100 compared with 1986-2005 for a medium-low emission scenario RCP4.5 based on an ensemble of CMIP5 climate models (IPPC, 2000). Projections consider land movement due to glacial isostatic adjustment (lands around the northern Baltic Sea have been rising since the last ice age) but not land subsidence due to human activities. No projections are available for the Black Sea.

Source: Adapted from IPCC, 2013 (Figure TS.23 (b)). Data were supplied by Mark Carson (ZMAW, Germany).

3.2.5. Permafrost

Large parts of the Arctic are covered by permanently frozen ground both at land and at sub-sea level (see Map 3.3). This layer, also known as permafrost, is a major component of the cryosphere, underlying 24 % of the northern hemisphere's land surface. The frozen layer can reach several hundred metres underground and it is only a top layer that thaws during the annual melt cycle (the active layer). Permafrost stores large quantities of water as well as carbon and methane made up of plant and animal remnants stored in soil for hundreds to thousands of years. Increased warming in the Arctic or in mountainous areas can thaw a deeper portion of the active layer or completely free an area of permafrost, transforming the area from a carbon sink into a carbon-emitting system.

Temperatures in the Arctic permafrost have risen by up to 2 °C over the past decades, and permafrost limits have retreated northwards by up to 100 km in parts of the Arctic. Warming regional seas in the Arctic are also seeing thawing of sub-sea permafrost. None of the climate projections in the latest IPCC AR5 include carbon emissions from thawing permafrost, despite it being estimated that Arctic permafrost stores as much as twice the amount of carbon stored in the atmosphere. These emissions can become a factor with regard to keeping the global temperature change below the 2 °C target, particularly as releases of methane, a greenhouse gas 34 times more powerful than CO_2 (IPCC, 2013) are emitted over vast areas, especially in the Russian Arctic tundra ([27]).

In areas with continuous permafrost, man-made structures have been designed and constructed to withstand the annual cycles of melt and may be founded on permanently frozen layers of soil. As the permafrost thaws or the active layer becomes deeper, man-made structures such as runways, roads, houses and pipelines may be damaged. This has major implications for the natural as well as the built environment. Thawing permafrost is thus costly for Arctic nations that would have to spend billions of euros to rebuild infrastructure. However the global cost can run into trillions of euros if large quantities of methane and CO_2 are released from permafrost, because climatic feedbacks could potentially result in crop failure, sea level rise, health impacts, etc., far away from the Arctic. Changes in and thawing of permafrost may also cause soil instabilities and disruptions, increasing the risk of landslides, drowning of forest trees, coastal erosion and hydrology changes. The projected change in northern hemisphere near-surface permafrost areas is presented in Figure 3.5.

Environmental challenges and socio-economic impacts from thawing permafrost include:

- Arctic infrastructure and transport systems, including oil and gas pipelines, roads, houses and airport runways, are faced with increased damage.
- Thawing permafrost alters ecosystems, vegetation types and associated animal life, as well as migration patterns of certain Arctic species.
- Thawing permafrost is a significant source of greenhouse gases, as thawing frozen soil and the subsequent decomposition of organic matter by microbes release CO_2 and methane greenhouse gases into the atmosphere. Tundra wildfires following thawing permafrost further add to greenhouse gas emissions.
- Thawing permafrost can release historical deposits of substances or harmful pathogens captured in older ice layers of the cryosphere, such as anthrax emerging from thawing permafrost in the Russian Arctic in 2016 ([28]).

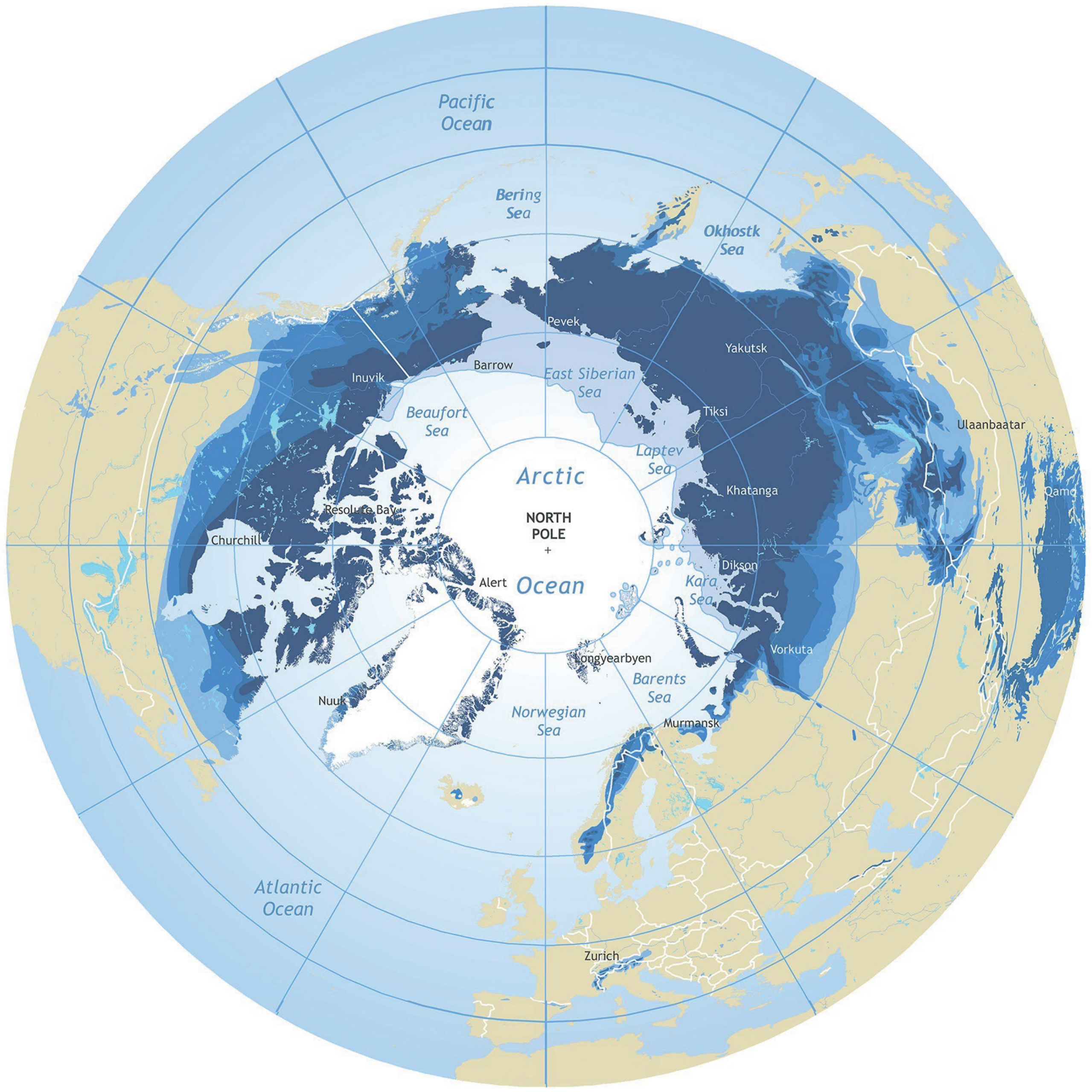
Economic opportunities from permafrost thaw include:

- Land areas with diminishing permafrost can be converted into arable land or forestry, if drainage or slope conditions are favourable. However, not many such opportunities exist in the European Arctic.
- Thawing permafrost can lead to an increase in availability and resource of potable water.
- Construction work may be necessary, associated with current infrastructure that has to be rebuilt or strengthened. However, although new and more climate-resilient installations might replace old and damaged buildings or infrastructure, the 'opportunity' seldom outweighs the costs of lost property or ecosystem change.

([27]) The AMAP study on Methane as an Arctic climate forcer (AMAP, 2015a) and Schuur et al. (2015) indicate that the current emission scenarios for Arctic methane will not significantly affect overall atmospheric greenhouse gas emissions. Other scientific articles suggest otherwise with regard to methane emissions from terrestrial and sub-sea sources (e.g. Schaefer et al., 2014; Schuur et al., 2015; Shakhova et al., 2015). Further research is required to produce more conclusive evidence.

([28]) Scientist fear that smallpox might also emerge, as the deceased from an epidemic in Siberia 100 years ago were buried in areas now hit by permafrost thaw and erosion.

Map 3.3 Permafrost in the northern hemisphere



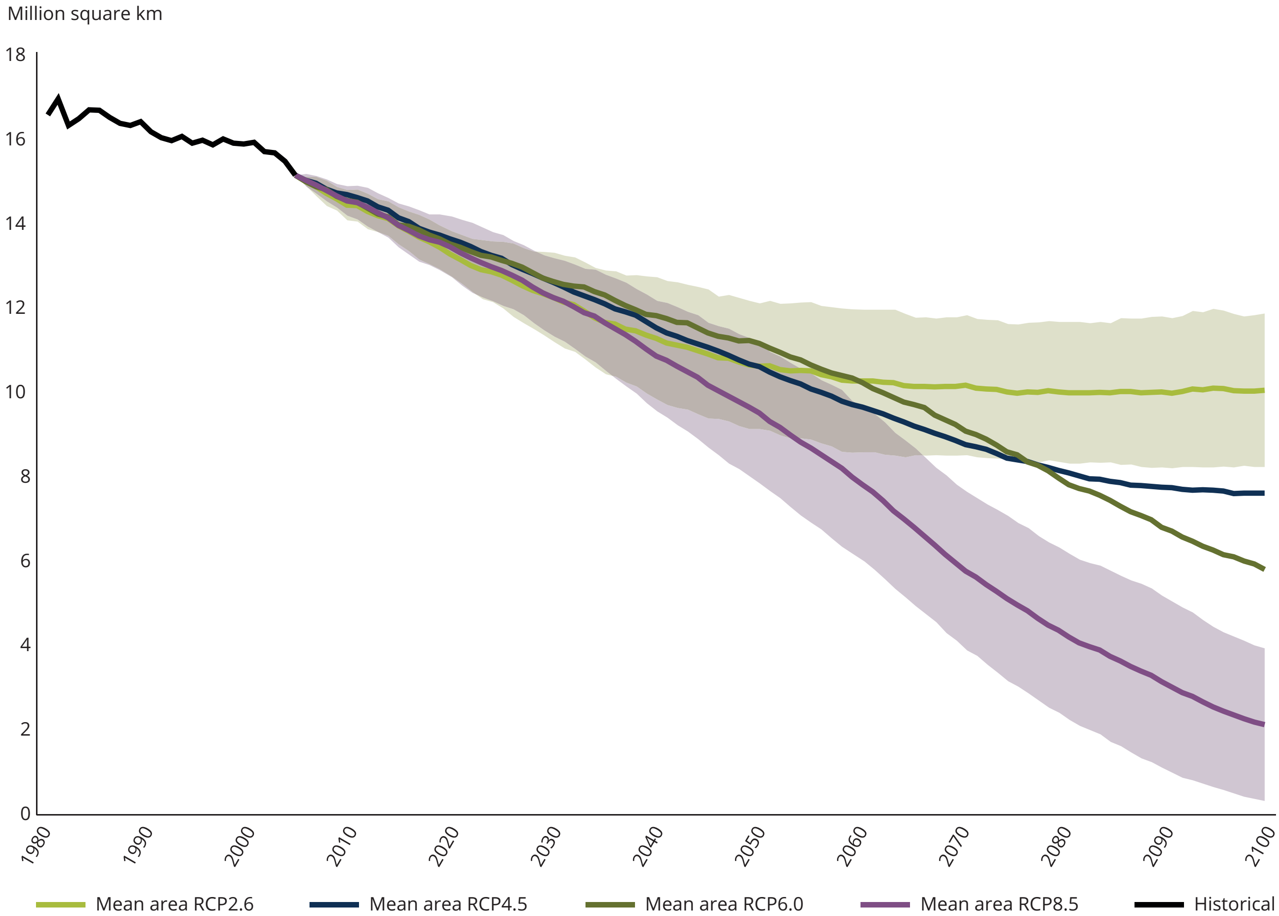
Permafrost in the Northern hemisphere

Durability

Continuous permafrost	Discontinuous permafrost	Sporadic permafrost	Isolated patches	Subsea permafrost

Source: © International Permafrost Association.

Figure 3.5 Projected change in northern hemisphere near-surface permafrost areas



Note: Projected change in sustainable near-surface permafrost for four representative concentration pathways (RCP) based on the CMIP5 model ensemble (IPCC, 2000). Solid lines show the model mean. For the highest and lowest RCP, uncertainty intervals comprising one standard deviation are also shown. Note that the projected reduction is for sustainable near-surface permafrost; it does not imply that deeper permafrost will disappear at a similar rate.

Source: EEA, 2016g.

3.2.6. *Ocean acidification*

Acidity is a fundamental property of seawater, as world oceans act as a carbon sink by producing carbonic acid when they absorb carbon released into the atmosphere or from sediments. As atmospheric CO_2 concentrations increase, more CO_2 dissolves into ocean water making the oceans more acidic. About 30 % of all CO_2 released by humans is now stored in the oceans (IPCC, 2014a). Overall carbon sequestration by the oceans significantly slows the accumulation of atmospheric CO_2, which affects climate change. This sink is primarily physical — the biological sink is considered insignificant — and without it the rate of anthropogenic global climate change would have been much higher than that already observed (Raven and Falkowski, 1999).

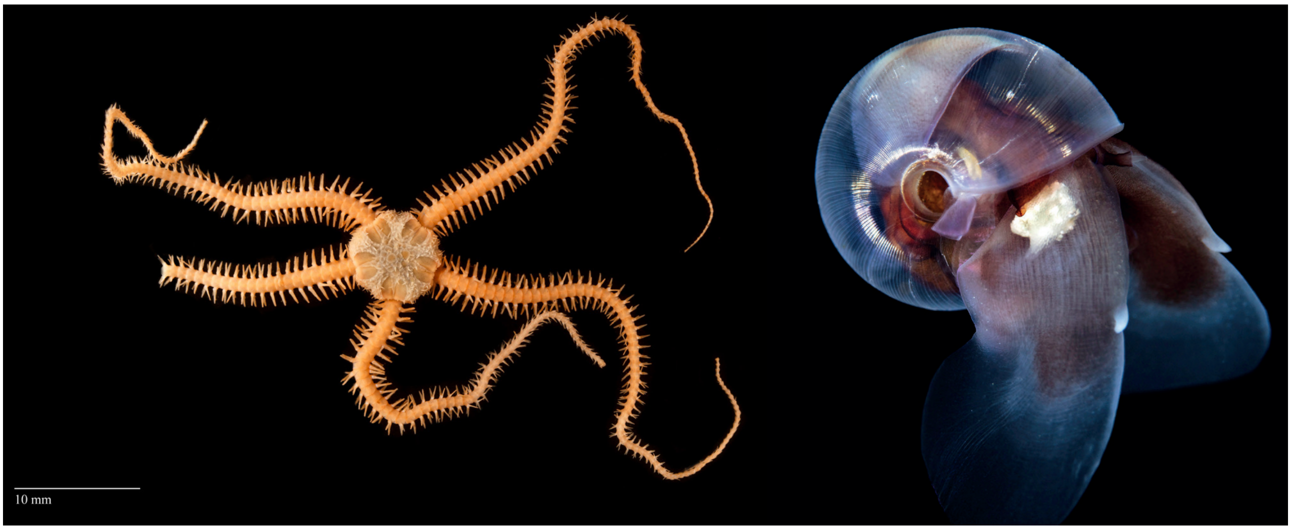
In recent decades, ocean acidification has been occurring a hundred times faster than during previous natural events over the past 55 million years. Global surface ocean pH has declined from 8.2 to 8.1 over the industrial era due to the growth of atmospheric CO_2 concentrations. Average surface water pH is projected to decline further to between 8.05 and 7.75 by 2100, depending on future CO_2 emissions (EEA, 2016f) (see Figure 3.6).

As cold water absorbs more CO_2 than warm water, Arctic waters are experiencing a widespread and rapid ocean acidification. Furthermore, the decreasing extent and duration of Arctic sea ice cover increases CO_2 absorption in the Arctic Ocean. Acidification is not uniform across the Arctic Ocean, as various factors such as sediments, sea ice cover, freshwater inputs and seaweed and plankton growth affect the process. In the European Arctic, the Nordic seas including Icelandic waters and the Barents Sea have experienced the most rapid acidification in surface waters, but deeper waters are also affected. The vulnerability of Arctic marine ecosystems and food webs is still uncertain due to lack of data, but good efforts by AMAP under the Arctic Council have provided new insights on Arctic Ocean acidification and its projections and impacts (AMAP, 2013). An update of this assessment is in preparation and will include case studies related to climate change.

Environmental challenges and socio-economic impacts arising from ocean acidification include:

- Changes in acidification have far-reaching effects on marine animals as well as other organisms and plants — and thus on human societies — as acidification can affect entire marine ecosystems and cause loss of resilience.

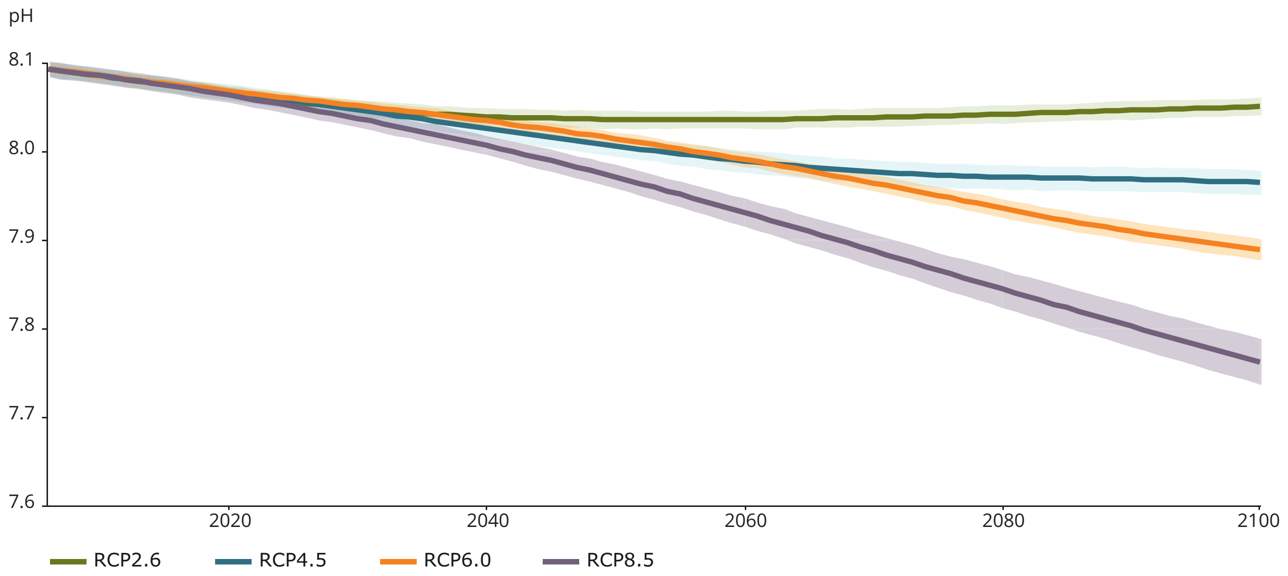
- Food webs are likely to be affected through: (1) the structure and composition of lower trophic layers changing to more acid-prone species that can endure living in more acidic environments; and (2) through changing availability of nutrients or essential trace elements (EPOCA, 2012; CBD, 2014). All will have cascading effects on fish, birds and mammals, through inability to respond by



Photos: Arctic ocean acidification can have effects on shell formation and organism growth which can have cascading effects on the delicate food web in Arctic waters. Two of the Arctic species that can be affected is the Brittlestar (*Ophiactis abyssicola*) right (and the Sea Butterfly (*Limalina helicina*) left.

Sources: © Olga Zimina, Greenland Institute of Natural Resources (left photo) and © Alexander Semenov (right photo)

Figure 3.6 Projected change in global ocean acidification



Note: The figure shows the projected change in ocean acidity for various emissions scenarios (RCPs) until 2100. The thick lines show the model average and the shaded areas the minimum to maximum range for each RCP.

Source: Adapted from IPCC, 2013 (figureSPM7(c)).

relocating to other areas or through competition from species able to adapt more quickly.

- Local and indigenous peoples might also be affected as changes in marine resources limit or change food availability.

- The current growth in whale-watching tourism could be affected, as impacts on krill in Arctic waters might affect migration patterns.

- In addition to atmospheric influence, thawing permafrost, and eroding coastlines and river banks are also releasing large quantities of organic carbon, which accelerates ocean acidification in the Arctic.

- Low levels of information on the effects of ocean acidification — either in isolation or in combination with other environmental stressors such as temperature, salinity and oxygen concentration — on keystone species and processes in the Arctic makes projections and scientific advice on policymaking very difficult.

- Fish stocks would be more resilient to ocean acidification if the combined stresses from overfishing, habitat degradation, pollution run-off, land use transformation, competing aquatic resource uses and other anthropogenic factors are minimised (AMAP, 2013). These stresses are, however, not likely to decrease in the near future.

Economic opportunities arising from ocean acidification are:

- There are currently no known opportunities associated with ocean acidification.

3.2.7. Biodiversity

The Arctic has, compared with temperate and tropical zones, less rich and varied biodiversity but more specialised species adapted to the cold environment. These include a number of iconic endemic species such as reindeer, polar bear, seal, narwhale, musk ox and the Arctic fox (see p. 48). The region plays an important role in a global and European context, as more than 50 % of the world's wetlands are in the Arctic and subarctic regions, which during the summer season contain more than half of the world's shorebirds, including 90 % of world geese populations. Arctic wetlands are furthermore important for carbon storage and water cycling. Arctic ecosystems and species are intrinsically linked to regions beyond, including Europe, and many Arctic seabirds and whales migrate great distances every year.

Arctic plants grow slowly due to short summers and cold conditions, and climate change is thus a major driver affecting Arctic biodiversity and ecosystems, including a greening of the Arctic. Certain areas in the Arctic are experiencing rapid change that challenges Arctic biodiversity (see Map 3.4), and particularly species which are sea ice-dependent or species finding it difficult to compete with subarctic species that may increasingly invade the Arctic, e.g. the snow crab. The Arctic is a varied region and the changes are not uniform, which means that some species thrive while others decline. For example, the mainland population of the Arctic fox has been in decline in the European part of the Arctic while the population is stable in North America. Polar bear populations are declining in some parts of the Arctic while increasing in others, and data deficiency makes trend analysis difficult across all of the species' circumpolar range.

The CAFF Arctic biodiversity assessment (CAFF, 2013a) has synthesised and assessed the status and trends of biological diversity in the Arctic and in some instances established baselines and presented examples of projections of future change. Some of the key messages from the assessment include: (1) that the global population of polar bears is predicted to decrease by 30 % in the next 45 years; (2) that the Arctic Ocean and regional seas produce (by weight) more than 10 % of global marine fisheries and 5.3 % of the world's crustacean catches; and (3) that northern plants are expected to lose up to 43 % of their current distribution under A2 and B2 climate change scenarios (IPCC, 2000). Many migratory birds that breed in the Arctic overwinter in Europe. This provides Europe with an opportunity to collect important monitoring data and thus support a better understanding of the changes to Arctic migratory bird populations.

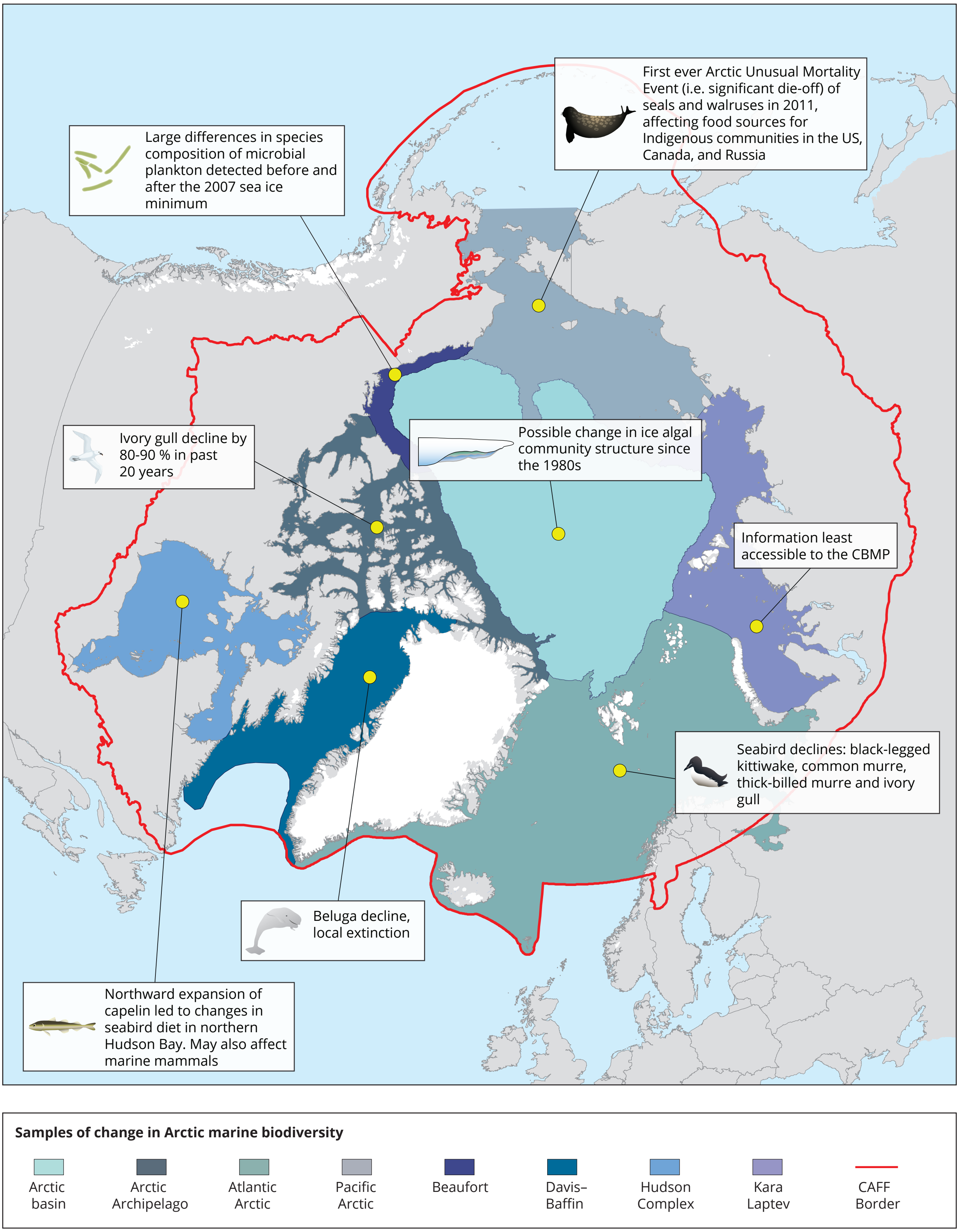
Environmental challenges and socio-economic impacts for Arctic biodiversity change include:

- Subarctic fish, algae and plankton are moving northwards, and new species are being observed in the Arctic. Invasive species are a threat to local ecosystems and endemic species.
- Highly mobile and migratory species are affected by the changes in the Arctic environment as well as pressures in areas outside the Arctic, including from long-range pollution.
- Arctic biodiversity is challenged by destruction of habitats, forestry, noise, accumulation of chemicals and, in some places, by overharvesting.
- Coastal areas and wetlands are affected by SLR, sedimentation, eutrophication and pollution that can affect species composition and food web structure.
- Pipelines and thawing permafrost are affecting grazing land of reindeer in the Sami area in Europe.
- Increasing risk of 'trophic mismatch', i.e. uncoupling the timing of different interdependent species. For example, the successful breeding of migratory birds depends critically on the phenology of snow melt and plant growth in the Arctic, which are changing.
- Infrastructure development such as roads or pipelines will result in direct and indirect disruption and disturbance to sensitive species.
- Arctic shipping and increasing development may allow invasive non-native marine organisms into the Arctic from unmanaged ballast water or on ship hulls and drilling rigs. Pathogens and disease vectors may also arrive with other invasive species.

Economic opportunities associated with biodiversity change include:

- Some commercial fish stocks are now expanding into Arctic waters, and retreating sea ice is opening up greater areas for fishing.
- Invasive species such as the king crab and snow crab have led to increased opportunities for the fishing industry in the northernmost part of Europe.

Map 3.4 **Arctic Marine Areas as defined by the CBMP, with examples of biodiversity change from each marine area**



Source: Adapted from CAFF, 2017.

- Certain mammals, insects and butterflies, as well as some birds, may flourish in a warming Arctic, although they are likely to be species expanding their range and invading the Arctic and thus threatening endemic species.
- Warmer temperatures and retreating permafrost are, from a long-term perspective, making agricultural production and forestry possible in new areas. Forests might also grow faster in a warming climate.

Photo: Large walrus on the ice (*Odobenus rosmarus divergens*), © vladsilver/istock.com

Photo: Polar bear (*Ursus maritimus*) on Sea ice, Franz Josef Land, Russian Arctic National Park, © Peter Prokosch/GRID Arendal

Photo: Arctic fox (*Vulpes lagopus*), © Rimante_Hegland/istock.com

Photo: Svalbard reindeer (*Rangifer tarandus platyrhynchus*) at Plateau mountain near Longyearbyen, Svalbard, © Peter Prokosch/GRID Arendal

Photo: Musk ox (*Ovibos moschatus*), © samsem67/istock.com

Photo: Narwhales (*Monodon monoceros)* © Paul Nicklen (NGS Image Collection), www.ourbreathingplanet.com

3.3 Socio-economic developments affecting the region

When discussing the Arctic environment — the state of the environment, pressures on the environment of ecosystems or the expected future impacts — social-economic activities need to be addressed in addition to the climatic and environmental changes in the region. These activities have the power to determine the fate of the Arctic environment as well as providing the base for jobs, economic growth and rising living standards and providing resources of the region to Europe and indeed the wider world.

The Arctic region is rich in natural resources but is a sensitive environment requiring prudent stewardship. Population density and economic activity vary significantly across the eight Arctic States, ranging from large areas with no human settlements or industry, both on- and offshore, to areas with larger, vibrant cities such as Tromsø and Murmansk, with large economic activities. So major economic activity already takes place in the Arctic, but the overall level of economic activity for the region as a whole is still relatively low compared with most of Europe. It is therefore difficult to substantiate alarmist claims that there is a rush for Arctic resources, that shipping lanes are being extensively used yearlong, that fishing is unregulated, or that oil and gas activities are conducted across the entire Arctic region at great risk to the environment.

Until now environmental impacts from Arctic economic activities have predominantly been local, although some activities have the potential to affect a wider region through accidental pollution or from harmful substances spread by wind and ocean currents. However, this also holds true for activities in the European environment, and the Arctic is not special in this sense, other than that safety and environmental standards must be higher because the cold climate makes pollution harder to break down. This can lead to accumulation of certain harmful chemicals in the ecosystem, and affect human health and wildlife. Unlike Europe, what is missing in the Arctic is an understanding of how ecosystem resilience and the carrying capacity of economic activities in the region are coupled with external pressures such as climate change and long-range pollution. Without such knowledge, more risks are associated with allowing multiple large-scale economic activities. Furthermore, large economic development activities often have conflicting interests between sectors or are at odds with local and indigenous lifestyles, hence it is all the more relevant to consult residents and to seek an ecosystem-based management approach before approving activities at sub-regional scale.

Although economic development is still ongoing, the expected Arctic boom in shipping, oil and gas extraction and mining has been less than that expected a decade ago ([29]). This is partly due to the financial crises in and after 2008 and the present low commodity prices of raw materials, but also because the region is still an expensive place to operate. When world prices do not meet development costs, investments are delayed or suspended. Cold and extreme conditions further diminish year-round operations, which affects the return on investment. Even if the potential for developing Arctic shipping routes or extracting natural resources is high, development still depends on high and stable world market prices, reliable and safe shipping routes, companies' willingness to invest and insurance companies' willingness to provide cover for such activities. These conditions have not been met and at present it does not look like the full economic expectations will be realised in the short term, at least when it comes to large-scale investments in the offshore oil and gas sector or regarding trans-Arctic shipping. Further limiting factors for a boom in economic development in the region include harsh conditions requiring special designs or additional site preparations, unpredictable ice pack or ice movement in Arctic seas, long supply lines, which require large inventories of parts, limited transport access, which can be dependent on ice roads, and higher wages and salaries required to induce personnel to work in the region. Of these factors, only the cost of shipping may be reduced due to climate change (NCM, 2014).

From a social point of view, the more modest economic growth in the region might delay local inhabitants' aspirations for growth, job creation and higher living standards, but the economic crisis and fluctuations in world commodity prices have also provided Arctic governments, Europe and the international community with more time to better assess ecosystem resilience and boundaries; anticipate the pace of change and transition; build better models and forward-looking scenarios for Arctic development; develop cleaner technologies; and put in place safety standards, at both national level and regional level. In addition, other less polluting economic sectors than hydrocarbon and mineral extraction might be developed and promoted such as tourism, the service sector, renewable energy production or communication links.

([29]) For example, trans-Arctic shipping through the Northern Sea Route grew from 41 ships in 2011 to 71 ships in 2013 but has since declined to 31 ships in 2014, 18 in 2015 and 19 ships in 2016. Similarly, oil and gas exploration off the coast in Greenland, Alaska and Russia has been suspended or postponed just as some exploration licensees cancelled.

Until planned circular economy and resource efficiency measures are fully implemented, the EU will, to a certain degree, still look to cater for its resource needs beyond its borders. Europe's consumption currently exceeds its own renewable natural resource production and 20-30 % of the resources used in Europe are imported (EEA, 2012). Continued economic growth and stability in Europe thus depends on imports from other parts of the world, including the Arctic region. In order to sustain future demands, a balanced approach to and management of Arctic resources is required, and the EU has a responsibility to support development that is sustainable and accommodates the resilience of Arctic ecosystems while promoting recycling and resource efficiency within Europe, in line with EU 2030 visions. The Arctic States have a natural interest in seeking the right balance between protecting the environment and ensuring economic and social development, both in meeting the growing global demand for resources and in finding sustainable national strategies for managing natural capital that will secure growth and job creation now and in the future, and for safeguarding the environment and human health.

However, the demand for Arctic resources creates a variety of challenges, and multiple issues and considerations that have to be incorporated into sustainable strategies and management plans. These issues include pressures on ecosystems from climate change, exploration of minerals and fossil fuels, increased transportation and shipping, overharvesting of key fish stocks, local and long-range pollution, pollution incidents from industrial activities and historical waste disposals, land fragmentation and impacts from infrastructure developments, decline in biodiversity and threat from invasive species, and pressure from tourism. This balance is hard to master.

Below is a brief introduction to some of these challenges that will have to be addressed nationally and collectively by the Arctic governments and their industries in addition to the global megatrends that must also be taken into account. Not all topics will be addressed in this report, and only a number of selected key socio-economic sectors will be presented here, based on availability of recent assessments and studies ([30]). A more comprehensive description can be found in the Strategic assessment of development of the Arctic — an assessment conducted for the EU in 2014 (Arctic Centre, 2014a).

It should be noted that the opportunities outlined in this section include local, regional and global perspectives, not all of which are encompassed by EU policy objectives but rather are in the nature of business or commercial interests. Thus, it is often preferable to focus on the environmental challenges and risks to ecosystem resilience and carrying capacity of the environment, rather than on the commercial opportunities.

3.3.1. Oil and gas

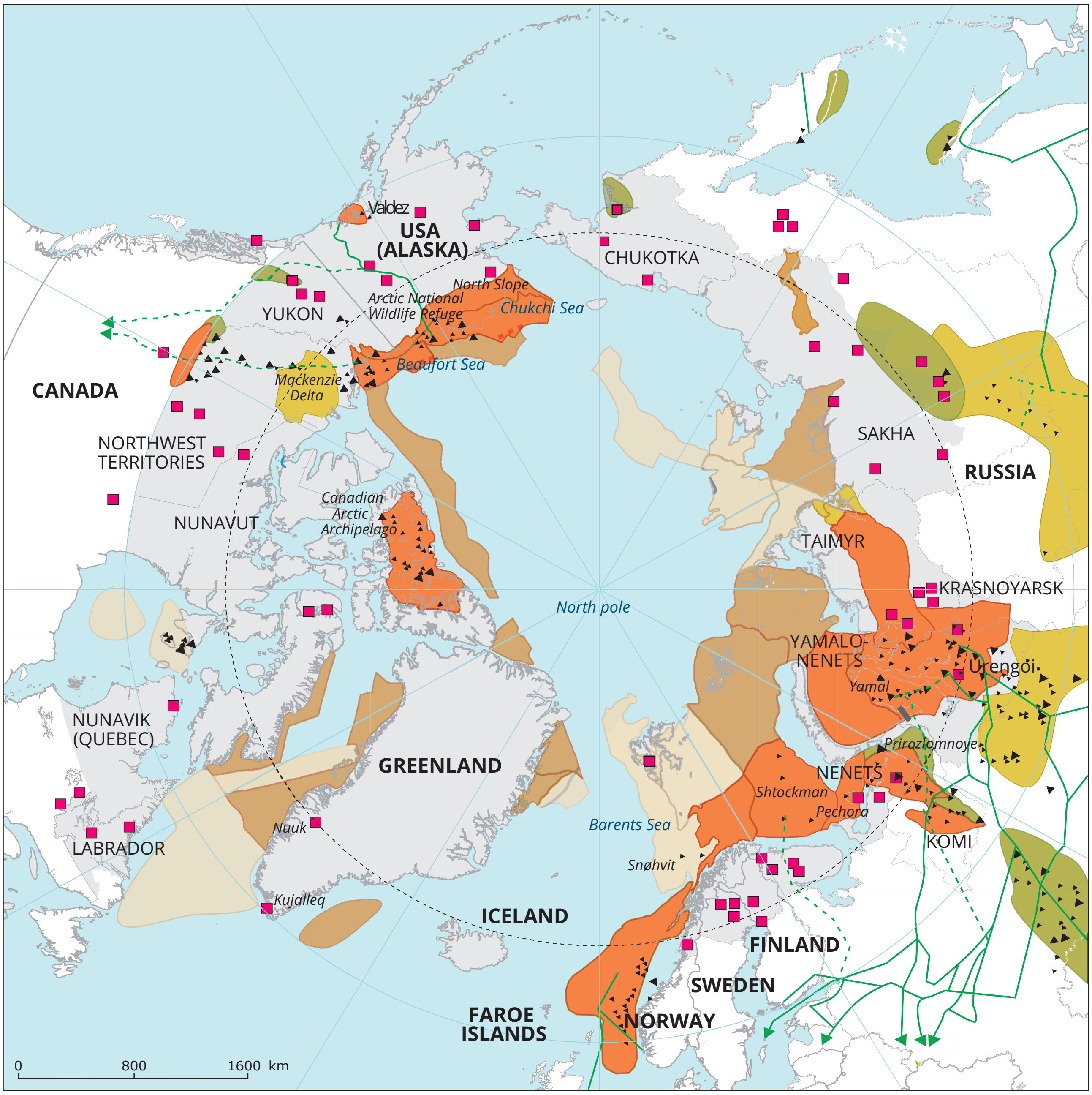
The global demand for energy is continuously rising despite efforts to reduce consumption, improve efficiency and shift to renewable energy resources. The Arctic has over the past decades seen an increase in the exploration and extraction of hydrocarbons to meet those needs, not least from Europe (see Map 3.5). Currently, 10 % of global oil and 25 % of gas production takes place in the Arctic. Most of this production comes from onshore fields, primarily in Russia, and to a lesser extent offshore fields in Alaska and Norway (SSB, 2011). The US Geological Survey in 2008 estimated that 30 % of the world's undiscovered and recoverable gas and 13 % of undiscovered and recoverable oil was to be found in the Arctic ([31]).

The financial crisis has slowed demands and, with oil prices well below levels seen a decade ago, oil and gas activities are currently being scaled back in some parts of the Arctic. Furthermore, the green shift in the global and European energy mix towards more renewable energy sources, which has gained further momentum since the 2015 COP21 Paris Agreement and COP22 in 2016 in Marrakesh, has resulted in a move away from fossil fuels and in particular from the most expensive, risky and inefficient Arctic projects, which are being cancelled or postponed indefinitely. However, regardless of current energy prices, a transition towards a more renewable energy mix will take time, and it is still expected that hydrocarbon extraction will increase in the Arctic, particularly gas from Norwegian and Russian onshore and offshore fields in the shallow coastal waters of the Barents Sea (see Box 3.1).

([30]) For example, tourism could have been included given the associated environmental risks of increasing tourism activities (CO_2 emissions from air travel and cruise ships, impacts on the local terrestrial environment and disturbance of sensitive habitats, etc.). But given the lack of comprehensive insights into these aspects, Arctic tourism has been omitted from this report.

([31]) The figures from US Geological Survey (Gautier et al., 2009) are based on statistical probabilities rather than proven available physical resources, and the estimates do not relate to the economic viability of the extraction of the estimated resources.

Map 3.5 **Oil and gas activities in the Arctic**



Arctic resources

Oil, gas and mining

- ▲ Oil and gas exploration and production sites
- ■ Main mining sites
- Main projected pipeline
- Main existing gas and oil pipeline
- Prospective areas and reserves

Potential oil and/or gas field *

- Medium (30-50 %), sea
- High (> 50 %), sea
- Medium (30-50 %), land
- High (> 50 %), land

Other features

- Arctic circle
- National/regional boundaries
- Arctic region defined as in Arctic Human Development report

NORDREGIO Nordic Centre for Spatial Development

Note: * Probability that at least one accumulation over 50 million barrels of oil or oil-equivalent gas exist after USGS.

Source: Adapted from Linus Rispling and Johanna Roto, Nordregio, 2015.

With the opening of Arctic waters due to climate change, attention may now turn to fields further offshore and at increasing depths, despite the risks involved in the demanding Arctic conditions with drifting ice, remoteness and darkness for parts of the year. Oil prices and advances in technology will be the determining factors on if or when these offshore fields will be taken into production. In this context it is important that all relevant actors apply provisions of the Espoo Convention on environmental impact assessments in a transboundary context and the complementing protocol on strategic environmental assessments by contracting parties. With regards to Arctic energy production, it is worth noting that coal extraction still takes place in north-west Russia and Svalbard in the European Arctic, although production is declining.

Environmental challenges and socio-economic impacts from hydrocarbon exploitation include:

- Utilising Arctic hydrocarbon resources will challenge the transition to a low-carbon society, as outlined in the 7th EAP, as it is recommended that two thirds of known global fossil fuel resources must remain in the ground if the UNFCCC's 2 °C target is to be achieved.
- Increased development of the natural gas sector, as well as renewable energy developments such as hydropower and wind power, are putting traditional livelihoods and practices such as reindeer herding, hunting/trapping and fishing under pressure, through pipeline development, dams and new production fields. Such challenges need to be considered and mitigated, especially in the

Box 3.1 Oil and gas development in the Barents Sea

Following the 2010 agreement between Norway and Russia on the demarcation of the border in the Barents Sea and the Arctic Ocean, Norway has offered new production areas as well as rebates on Norway's special hydrocarbons tax for firms exploring for oil in the area. The two countries signed an agreement on exchange of seismic data in 2016. Negotiations on a so-called Full Fold seismic deal for their joint border areas in the Barents Sea are ongoing, which will enable seismic vessels to cross the borderline with their streamers in order to map all adjacent waters. In 2016, the 23rd licensing round on the Norwegian continental shelf led to 10 new production licenses, all located in the Barents Sea (Norwegian Petroleum Directorate), and in 2017 the Norwegian government announced that it proposes to include a total of 93 Barents Sea blocks in the 24th licensing round.

Photo: The Goliat Platform in Hammerfest, a joint venture between ENI (Italy) and Statoil (Norway), before being put in place in the Barents Sea, © Eni Norge context of vulnerabilities characteristic of the Arctic environment and Arctic communities.

- Existing pipelines can become more hazardous with thawing permafrost.

- Oil and gas operations in the Arctic increase air pollution and greenhouse gas emissions, including methane emissions and sulfur compounds from gas flaring as well as black carbon emissions.

- Offshore, large-scale activities influence fishing grounds and migration of sensitive marine animals, including noise disturbance from seismic testing. Effects on the seasonal migration patterns is particularly worrisome, as Arctic ecosystems are sensitive, the breeding season is short and the intensity- and timing-related effects of oil and gas activities can therefore be severe.

- Getting the extracted hydrocarbons — in the form of gas, oil or liquefied natural gas — safely out of the Arctic and delivered to consumers further south, e.g. in Europe, presents a set of environmental, social and legal challenges that industry and government have to manage.

- Although technological advances have been made and environmental safety standards are high, there is still little experience on how to handle Arctic oil spills in or under ice-covered waters. The IMO is drafting a guide to oil spill response in snow and ice conditions, however, it will be a challenge to convert knowledge into experience without jeopardising the fragile environment.

- There is no guarantee that companies are using the newest technology and best practices available, which can affect secure and environmentally sound operations.

- Developing the renewable energy sector may be at odds with the need to protect landscapes and seascapes in the region.

Economic opportunities and socio-economic aspects associated with hydrocarbon exploitation include:

- Growth in the Arctic oil and gas sector creates employment opportunities and economic development in the Arctic region, which are welcomed by many Arctic inhabitants and regional governments.

- Low oil prices are currently halting a number of developments despite companies having spent large sums of money on time-limited exploration licences. This halt can be a window of opportunity to better assess the resilience of Arctic ecosystems and to develop better technologies for operating in the extreme conditions in the region, particularly as it can be up to 10-20 years between the exploration phase and the start of actual production in the Arctic.

- While moving towards renewable energy sources, natural gas might gradually replace coal- or local diesel-powered heat production and in this way reduce CO_2 emissions (although this might be offset by flaring at gas production sites which causes greenhouse gases emissions).

- The region has the potential to further develop renewable energy primarily for local consumption and to a lesser extent for exports, provided that energy grids are adequately connected: Iceland has geothermal heat and power production, Greenland and Fennoscandia have hydropower and the potential for wave power, and the circumpolar Arctic has solar power potential during the summer months.

3.3.2. Fisheries

Most of the fishing in the Arctic is carried out in the coastal seas, as key commercial fish stocks including cod, herring, capelin, haddock and shrimp are located in the shallow regional seas where light and nutrients create the best conditions (see Figure 3.7). The Arctic marine shipping assessment (Arctic Council, 2009b) estimated that some 1 600 fishing vessels operate in Arctic waters. A considerable part of the commercially harvested species mentioned above are concentrated in the European part of the Arctic, in the Barents and Norwegian Seas (see Map 3.6). Furthermore, extensive fish farming, primarily of salmon, takes place in coastal areas in the Arctic.

The Arctic biodiversity assessment (CAFF, 2013a) identified 63 fish species as 'Arctic', but there is insufficient scientific data on all of these species. The International Union for Conservation of Nature (IUCN) estimates that some 95 % of them have yet to be evaluated for threat status and for fish quotas to be established. As regards regional fishery management organisations, the European Arctic is covered by the North East Atlantic Fisheries Commission (NEAFC), and a bilateral management plan for the Barents Sea has been established between Norway and Russia.

In 2015, the five Arctic coastal states signed a voluntary declaration concerning the prevention of unregulated high seas fishing in the central Arctic Ocean. Although the declaration aims to stop their fishing fleets from exploiting the central Arctic Ocean, it does not apply to other states, some of which have industrial fishing fleets operating around the Arctic. Once the declaration was signed, the US chair of the Arctic Council took the initiative to bring in five other parties (China, the EU, Iceland, Japan and South Korea) to explore the interest of participants in extending the declaration to cover non-coastal states ([32]).

Although the entire Arctic basin has been less intensively overfished compared with other regions of the world, primarily because of ice cover and extreme weather conditions, recent studies have indicated that, when small-scale and local catches are included, total catches from parts of the Arctic region are 75 times higher than those reported to the Fisheries and Agriculture Organization of the United Nations (Zeller et al., 2011).

Environmental challenges with Arctic fisheries include:

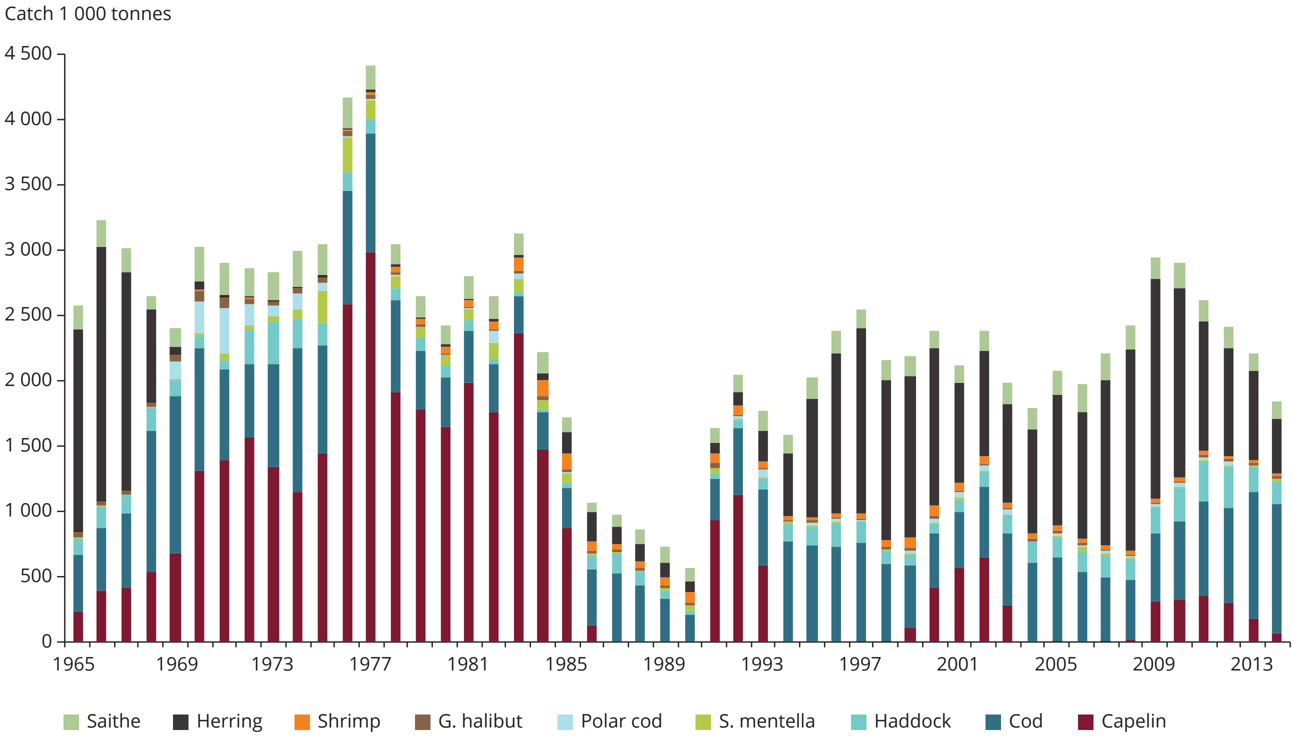
- Overfishing or changes to fish stocks present a major challenge for local and indigenous coastal communities in the Arctic, as fish is often the primary source of income and food.
- Damage to seafloor habitats is likely to increase with growing maritime activities such as fishing or hydrocarbon extraction.
- Increased fishing efforts combined with climate change, which has pushed the distribution of certain fish species further north and opened up room for invasive species, is placing pressure on fish stocks and the Arctic marine environment.
- Pressures and disturbance from increasing economic activities from shipping, oil and gas extraction, sand and gravel extraction and offshore wind farms affect spawning and feeding grounds for key commercial fish stocks.
- Warmer waters caused by climate change can affect spawning and feeding grounds for fish stocks.
- Ocean acidification is changing the Arctic species composition, particularly through changes of phytoplankton (the main base for any marine food chain) from calcium to siliceous skeleton species, but also through changes to zooplankton.
- Although Arctic fish are still relatively clean and healthy, pollution from chemicals, marine litter and shipping are increasingly becoming a problem (AMAP, 2015b), from local discharges via river run-off and from coastal industrial sites and shipping, as well as from long-range pollution through oceanic and atmospheric currents from distant sources, including Europe. Ironically many of the Arctic fish and shellfish caught are exported and end up on European dinner tables.
- Not all fishing vessels have ICT platforms to download and use the multilayered information, charts and services necessary for operating in Arctic waters.

([32]) At the time of writing, the discussions were still ongoing. The EU is working towards a binding agreement that would put in place: (1) a precautionary approach; (2) a collaborative scientific process to collect data on the marine ecosystem of the central Arctic Ocean; and (3) a clear trigger mechanism to set up a regional fisheries management organisation if necessary. This would stand in contrast to the non-binding agreement currently included in their declaration by the five Arctic States).

Economic opportunities and social aspects associated with Arctic fisheries include:

- Diminishing sea ice and commercial fish stocks migrating further north create fishing opportunities in areas that are currently unexploited.
- The fishing moratorium in the central Arctic Ocean, newly established by the five coastal states, presents a window of opportunity to conduct scientific research into fish stocks and sustainable catches before fishing fleets risk overexploiting stocks. Similarly, models of ecosystem-based management, integrated management plans and ecosystem resilience can be further developed to aid scientific recommendations with regard to sustainable fisheries in both the central ocean and the adjacent regional seas.
- Current fish prices and demand for fish products are a driver for blue growth in the fisheries sector, particularly in the Barents Sea in the European Arctic, where the price of 5 kg of salmon in 2016, for example, was higher than that of a barrel of crude oil.

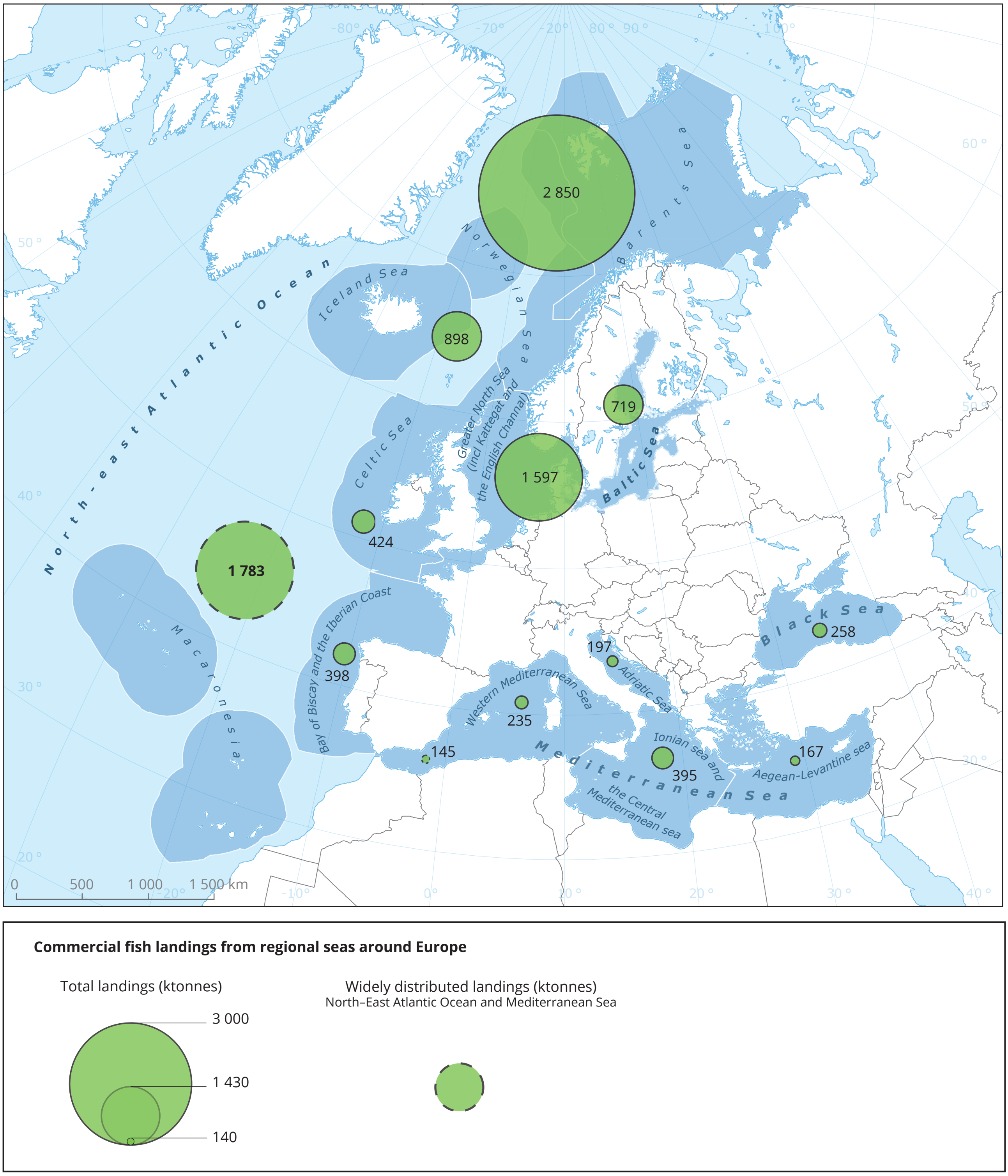
Figure 3.7 Total catches of the most important stocks in the Barents Sea



Note: The catches in the graph are including catches in all of ICES area IIa, i.e. along the Norwegian coast south to 62° N) from 1965–2014. Catches of Norwegian spring-spawning herring outside ICES area IIa are also included. In addition, minor catches of other stocks are taken in the Barents Sea

Source: Based on ICES, 2015 (Figure 3.1).

Map 3.6 Commercial fish landings in European regional seas



Note: The poroportion of fish landings from Arctic waters is considerable compared to the rest of Europe. Landings data for all fish stocks are from 2010, given the availability of data for the Mediterranean and Black Seas.

Source: EEA.

3.3.3. Shipping

The Arctic Marine Shipping Assessment (Arctic Council, 2009b) estimated that some 6 000 vessels annually sailed in Arctic waters ([33]) and predicted numbers to increase in decades to come. The vast majority of the current traffic is composed of ships resupplying Arctic communities, moving natural resources out of the Arctic or providing cruise tourism. Most of this destinational traffic takes place in the coastal areas of the regional seas surrounding the Arctic Ocean. At present only a very small part is trans-Arctic shipping from the North Atlantic to the Pacific Ocean through the Northern Sea Route, along the Russian coast or through the North-west Passage in Canadian waters. For comparison, annual trans-Arctic shipping through the Northern Sea Route grew from 41 ships in 2011 to 71 ships in 2013 but declined to 31 ships in 2014, 18 in 2015 and 19 in 2016, while annually some 17 000 ships pass through the Suez Canal (which is undergoing expansion) and 15 000 ships through the Panama Canal (this is expected to rise to 28 000 after an extra canal opened in 2016).

The continuous sea ice melt may increase Arctic shipping, however, in particular for destinational shipping but also in time for trans-Arctic shipping as well as fishing and local usage, when the navigational season becomes extended and new areas become ice-free. With increased shipping activity comes increased maritime activity from inspection and naval vessels carrying out fishing inspections, environmental enforcement and search and rescue operations. Thus overall shipping numbers are expected to increase and Europe has a role to play, as traffic is high in the European Arctic (see Map 3.7). It is therefore often ships servicing or departing from Europe that affect the environment, and that are likely to cause spills or be in need of search and rescue ([34]). It is even likely to be a European ship coming to the rescue. Although only icebreakers for research and tourism purposes currently sail to the North Pole and central Arctic Ocean, traffic through the central Arctic Ocean may eventually be possible during the summer months if the current decline in sea ice continues. Shipping activities in winter, with darkness and extensive ice cover, are expected to remain low. However, shipping in the European part of the Arctic is expected to remain higher all year, as the North Atlantic current keeps this part of the Arctic ice-free even in winter.

The IMO has, to a certain degree, addressed international concern about the protection of the polar environment and the safety of seafarers and passengers with the mandatory Polar Code, for ships operating in Arctic and Antarctic waters, which entered into force on 1 January 2017. Its requirements, which were specifically tailored for the polar environments, go above and beyond those of existing IMO conventions such as those covering marine pollution (MARPOL) and safety (SOLAS) by including mandatory standards that cover the full range of design, construction, equipment, operations, training and environmental protection matters. The code prohibits or strictly limits discharges of oil, chemicals, sewage, garbage, food wastes and many other substances.

Environmental challenges and socio-economic aspects associated with increased shipping include:

- Ballast water may bring non-native species into Arctic waters.
- Black carbon emissions transported by air may be deposited on snow and ice, accelerating melting. Black carbon is also dissolved in the water column.
- There may be effects on marine mammals, in particular migrating whales, or disturbance of sensitive breeding grounds.
- Noise pollution may affect marine mammals and fish.
- Accidental and illegal intentional spills. These effects are likely to increase when ship traffic increases.
- Increased shipping brings challenges with regard to marine planning, as the needs of other economic sectors such as fishing, oil and gas activities, offshore wind farms and MPAs all have to be accommodated and new port facilities constructed.
- Arctic shipping is challenged by a lack of updated sea charts and only a small portion of the Arctic Ocean and regional seas has been properly mapped. Surveillance and communication can be a further challenge with regard to human safety as well as environmental impacts from accidents.
- Challenges even exist with icebreaker escort through northern sea routes, as insurance is hard to obtain, the cost of icebreaker escort is high (USD 200 000 per escort) and getting the necessary Russian permits can take weeks.

([33]) Smaller fishing boats and naval vessels were excluded from the assessment.
([34]) 'European' in this context means ships owned, registered or calling at European ports (even if some are flagged outside Europe, e.g. in Panama).

- Although the coastal states have increased cooperation through agreements in the Arctic Council, search and rescue capabilities in the Arctic are a huge challenge nationally and collectively, as available rescue ships are few and far between.

- Increased marine activities impact coastal Arctic communities, especially indigenous peoples whose traditional ways of life are closely linked to the marine environment.

- An increasing number of large cruise vessels are entering Arctic waters but not all are properly equipped and designed, or used to operating in ice-covered waters, which increases the likelihood of accidents.

- Increased numbers of cruise ships can lead to increased pollution including black water (sewage), grey water (sinks, laundries, showers, etc.), oily bilge water and black carbon air emissions.

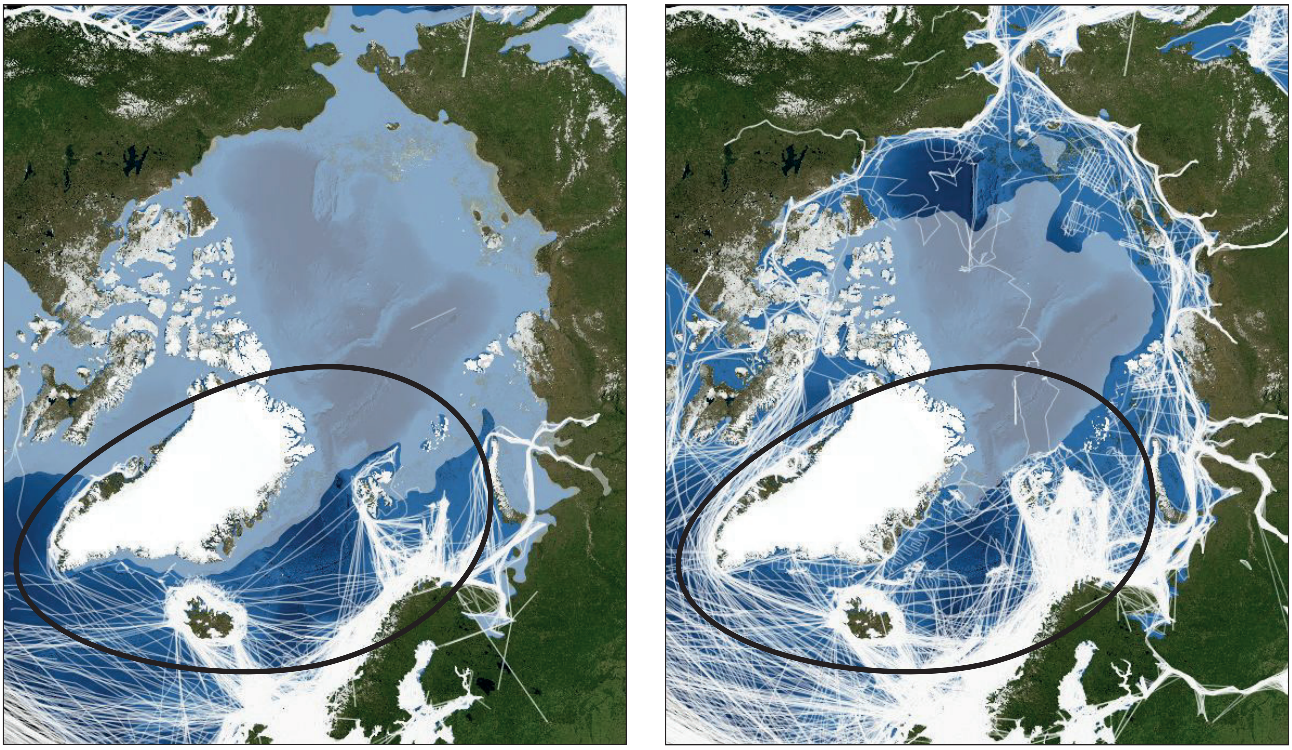
- Trans-Arctic shipping is challenged by structural constraints, including international shipping logistics, limitations to the number of months the shipping lanes are navigable, annual variability and the demand for stable and predictable delivery.

Economic opportunities associated with Arctic shipping include:

- Increased trans-Arctic shipping can bring substantial reductions in fuel costs due to the shorter travel distance from Europe to Asia. For example, a journey from Rotterdam in Europe to Yokohama in Japan can be reduced from 11 212 to 7 825 nautical miles, a saving of 30 %. Given the

Map 3.7 Arctic shipping in 2016

January | **September**



Arctic shipping 2016

Land | Sea | Ice sheet | Sea ice extent | Ship traffic | European Arctic

Note: A large proportion of Arctic shipping takes place in the European Arctic, with associated risks of accidents, pollution and disturbance to ecosystems and migrating marine mammals and birds. The maps show all ship traffic and the extent of sea ice in January 2016 (left) and September 2016 (right).

Source: www.Havbase.no (extracted 18 December 2016).

importance of timing for container shipping, which often does not use ice-strengthened vessels, bulk carriers of mineral ore, oil, gas and grain are more likely to use the Arctic route in the summer months.

- A reduction in overall shipping distances can lead to lower ship emissions and thus reduce pressures on the marine environment and improve human health, although the improvements will be along existing routes, which may see less traffic, rather than along Arctic shipping routes ([35]).
- Increased shipping will create job opportunities in the Arctic, in both destinational and trans-Arctic shipping, in servicing ships in current ports and in building new infrastructure in the region as well as in increased need for mapping services, surveillance and communication. In the European Arctic, Iceland has placed increased focus on future shipping potential and is looking to invest in deep water harbours to service predicted trans-Arctic shipping. Russia has also approved a plan for development of the Northern Sea Route which aims to increase capacity by a factor of 20 before 2030.
- Following the entry into force of the new IMO mandatory Polar Code on 1 January 2017 ([36]), the ship-building industry can expect to see new orders as ice-strengthened vessels have become a requirement for operating in Arctic waters ([37]).
- Crew members also need training for working in Arctic conditions, an expertise currently centred in Arctic nations and ship operators.
- Insurance companies stand to gain from activities in the Arctic.
- Although concentrated in specific regions such as Svalbard, Greenland and southern Alaska, cruise tourism is on the rise in the Arctic and an increasing number of tourists enter the Arctic on ever larger cruise ships, creating jobs in various service sectors as well as in preparedness and response capabilities.
- In 2023, the Trans-European Transport Networks (TEN-T) will be reviewed. This offers opportunities for extending rail and road connections to accommodate increased trans-Arctic shipping. In the meantime, the extension of the relevant core network corridor may be considered, to connect parts of the core network to the Arctic region.

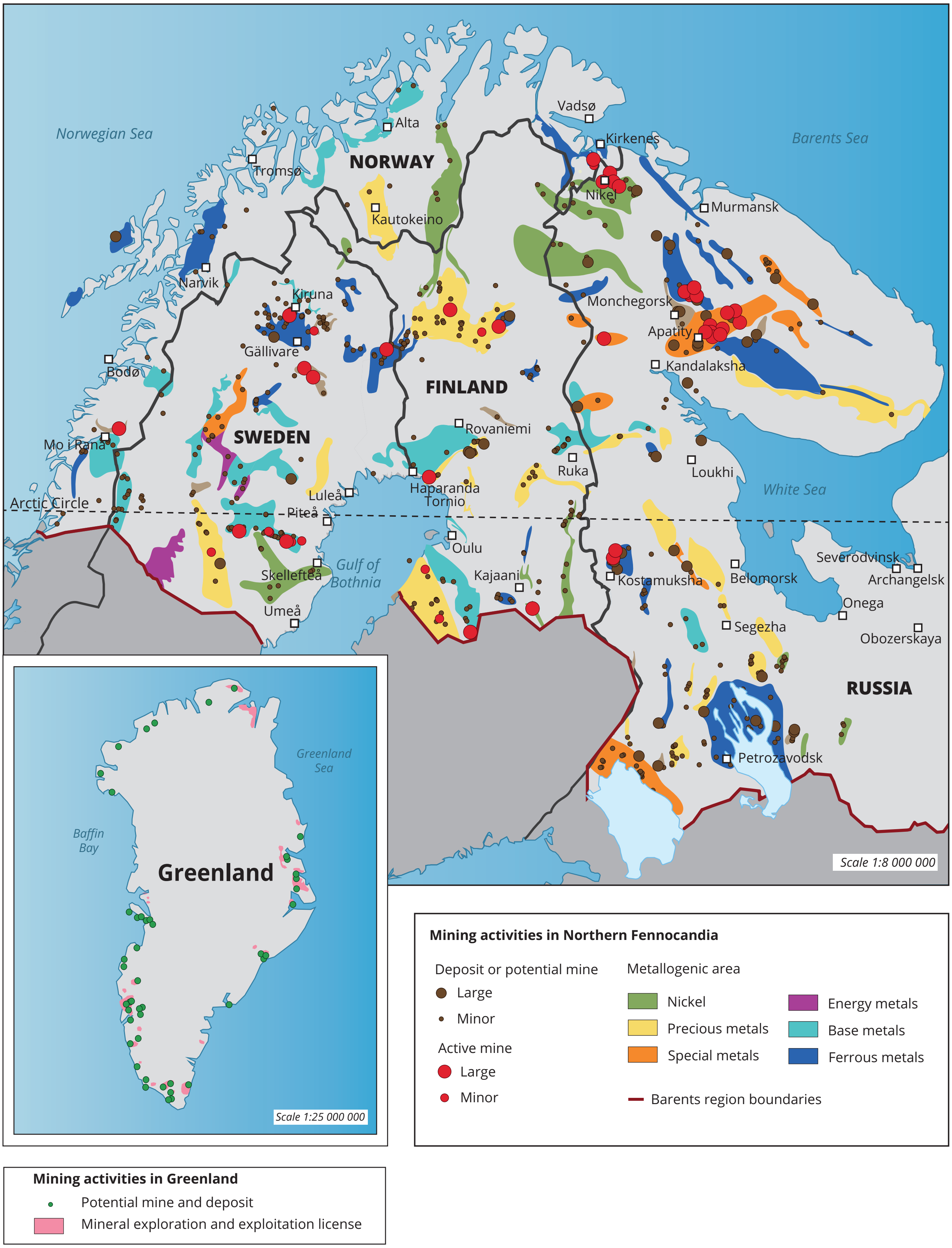
3.3.4. Mining

Global and European demand for mineral resources is growing and the Arctic region has for decades been catering for part of this demand. Despite remoteness and varying degrees of infrastructure, the Arctic has a large number of operating mines, including 110 in the Barents region of the European Arctic. More can be expected, as the Barents region holds vast amounts of mineral resources, including some 500 identified mineral deposits (see Map 3.8). The raw materials found in the Arctic include nickel, gold, zinc, copper, lead, iron, platinum and rare earth minerals, which are key components in electronics. Coal mines are also in operation in the European Arctic including in Svalbard. Although in past decades rising commodity prices increased interest in further mining activities, more recent falls in commodity prices have resulted in a slowdown. Projections, however, expect demand and therefore prices to go up again.

In 2011, Sweden and Finland supplied 28 % of the EU's gold production, 27 % of its zinc, 17.5 % of its silver and 11 % of its copper. Norway also has a large number of mines and some 60 % of the Norwegian production of zinc, cobalt, copper, stone, etc., is exported. Iceland has few mineral resources, but, because of abundant geothermal and hydropower, it has three current and two planned aluminium smelters, to which raw materials are shipped. In the European Arctic, Greenland also has large deposits of minerals, including gold, rare earth elements and uranium, although Greenland's only gold mine has now ceased production. The biggest mining activity in the European Arctic takes place in north-west Russia where extensive extraction and production takes place, in particular on the Kola Peninsula and in Karelia, with the deep water port of Murmansk used to ship nickel, iron, aluminium and apatite ore abroad.

([35]) Shipping contributes with greenhouse gases, including CO_2, which has detrimental effects regardless of where it is emitted.
([36]) Some of the expected environmental benefits from the Polar Code can be found on the IMO website.
([37]) The expected new vessels built for Arctic operations will be bulk carriers and, to a lesser extent, passenger vessels. Container vessel traffic is not expected to grow in the Arctic due to strict requirements on time of arrival at the port of destination, which may not be met due to variable weather and ice conditions in Arctic waters. Often container ships are not ice strengthened and cannot operate in Arctic conditions.

Map 3.8 **Mining activities in the European Arctic**



Source: Adapted from Arctic Centre, 2014a.

Environmental challenges and socio-economic aspects with mining activities include:

- Mining activities often conflict with other land uses, such as reindeer herding, tourism, fishing and hunting, and may interfere with sacred lands of indigenous peoples.
- Operations affect wildlife, habitats and migratory paths.
- There are possible associated health implications through contamination of drinking water resources, air pollution and the accidental release of hazardous chemicals used in production.
- Mining sites are not always restored after production has ended, which may have long-term detrimental effects on the local environment.
- Impacts of mining sites, including open-pit mining, are not limited to the local area, and the transport of material and partial refining also has to be taken into account.
- Climate change causes permafrost to thaw, and precipitation and run-off to increase. Deposits of mine tailings in areas of thawing permafrost are prone to wash-out of pollutants. A warmer Arctic is also limiting the number of days ice roads are available in the winter season.
- Mining activities can involve challenges when it comes to land use rights or revenue sharing.
- In certain areas of the Arctic, access to skilled labour can be an issue and large numbers of foreigners will have to be brought into small communities.
- Attracting foreign investments requires stable prices and operating conditions. Inadequate infrastructure must often be factored in by investors too.

Economic opportunities and social aspects associated with Arctic mining include:

- Growing demand for raw materials may lead to more small- or large-scale mining activities in the Arctic, creating job opportunities and higher living standards, and diversifying economic revenue in the region. Local spending can increase, public infrastructure can be improved and revenues for public budgets increased, thereby allowing for investments in public facilities such as schools and medical services.
- Increased economic activity can facilitate capacity building and transfer of skills as well as counterbalance the demographic change by which many people currently leave the Arctic.
- In the European Arctic, year-round ice-free waters mean that mining ports in Narvik, Kirkenes and Murmansk provide marine transport possibilities throughout the year, and emerging trans-Arctic shipping routes to Asian markets. However, this could lead to a lower utilisation of the Swedish railways that are currently used to move raw materials.
- By developing the mining sector in the European Arctic, EU countries may have the opportunity to secure access to critical raw materials in case of politically motivated embargos or shortage of delivery from Asian markets.
- Future resource production is likely be concentrated, as it is today, in regions of lower cost (existing production allows the use of existing infrastructure, which lowers investment costs), or in places with low taxes and efficient regulation. This is an opportunity for the mining sector but, from an environmental perspective, there are also certain limited benefits to restricting production to fewer sites rather than spreading it over larger areas. This is because of infrastructure requirements associated with the establishment of new production sites.

3.3.5. Health and pollution in the Arctic

Generally the Arctic environment is considered clean and pristine. However, contamination is also found in Arctic sediments, water columns, in the air and in the food web. Intensified economic activities in the Arctic have both positive and negative environmental, social and regulatory consequences. While possibilities for economic growth, job creation and higher living standards can be an opportunity for local inhabitants and European companies, finding the balance between environmental protection and economic development remains a challenge. Regardless of the aspirations for economic growth and improved living and health standards, it has to be recognised that the scope for economic activities in the Arctic is generally low and opportunities are often limited.

According to the European Chemicals Agency, the number of chemicals in use in the EU alone is greater than 30 000 and is growing by around 300 each year. Some of these chemicals reach the Arctic through long-range atmospheric transport, in water currents and to a lesser extent in migratory species. In particular, POPs ([38]) accumulate in the food chain and may reach harmful levels in humans, as well as in top predators.

While concentrations of certain contaminants have declined in some parts of the Arctic, others are influenced by multiple factors and do not show clear trends. In general, long-range transported pollutants such as the legacy POPs that have been regulated or banned, e.g. by strengthening the LRTAP convention on long-range transboundary air pollution and by the Stockholm Convention, have declined and are thus of less risk to human and ecosystem health (AMAP, 2009, AMAP, 2017d). However, more newly regulated POPs such as brominated flame retardants and fluorinated compounds are still found in the Arctic environment.

Newly emerging compounds are generally found at lower concentrations. A new assessment on chemicals of emerging Arctic concern shows that additional international and national regulation is needed to reduce the increasing amounts of emerging chemicals in the Arctic (AMAP, 2017d). Air pollutants such as sulfur oxides, nitrogen oxides, volatile organic compounds and particulate matter are also found in the Arctic environment, and increased economic activity can increase these forms of air pollution.

Mercury is similarly posing a health problem in the Arctic and, despite efforts to reduce emissions in Europe and North America (see Figure 3.8), AMAP assessments have shown that levels of mercury in the Greenlandic population as well as in wildlife are still high (AMAP, 2011b, 2011c, 2015b). The EU and the Arctic States played a role in setting up the global, legally binding instrument on regulating mercury, which hopefully will lead to less mercury being found in the Arctic ([39]).

Arctic conditions vary and the extent to which local and indigenous peoples are affected by pollution levels similarly vary. Wildlife studies indicate that the European Arctic is among the most polluted areas within the circumpolar Arctic. In the European Arctic in particular, indigenous peoples' health can be affected, as their traditions, cultures and livelihoods are more interconnected with the land, environment and local food sources. The Sami peoples in northern Europe traditionally rely on reindeer herding and fisheries, while the Inuit in Greenland have a close relationship with coastal environments and seals, whales and fish make up a significant part of the traditional diet.

Increasingly marine litter, including microplastics (fragments of plastic less than 5mm in diameter), is brought into the Arctic by ocean currents and rivers. There is evidence to suggest that microplastics share characteristics of traditional POPs, including their environmental persistence and potential to accumulate and cause adverse effects in fauna that ingest them (AMAP, 2017d). Because of their complex makeup, microplastics cannot be evaluated with the current approaches used by international conventions, although efforts under UN and OSPAR are targeting the issue of marine litter.

Environmental challenges and health aspects in the Arctic include:

- Increasing economic activity and intensity is often accompanied by pollution loads, e.g. from flame retardants, pharmaceuticals, detergents, solvents and lubricants.

- Local unsustainable waste disposal practices, diffuse pollution loads through river run-off and discharges from contaminated sites all contribute to an increasing pollution load in the Arctic.

- Pollution is brought into the Arctic through ocean and wind currents from sources far away from

([38]) Persistent organic pollutants include toxic polychlorinated biphenyls (PCBs), DDT and dioxins. The health risks to ecosystems and humans include disruptions to immune, hormone and reproductive systems (AMAP, 2016).
([39]) Ratification of the Minamata Convention is currently ongoing.

the Arctic, including Europe. These include POPs, pesticides, mercury and marine litter/plastics.

- Cold temperatures slow biological processing and cause harmful substances to degrade more slowly. Some pollutants thus accumulate in the relatively simple Arctic food webs, resulting in high concentrations of harmful substances in top predators, including POPs such as DDT, PCBs and perfluorooctanesulfonic acid (PFOS).

- Heavy metals accumulate and pose a dietary risk to humans in areas where marine food sources and in particular top predators (such as seal, tooth whale and polar bear) are eaten in larger quantities. Accumulation of mercury in whale meat and seal liver is of concern, for example, and advice is given to pregnant women in Arctic communities where diet is primarily derived from local marine food items ([40]), which might affect their children's intellectual capacity, motor functions, blood pressure and heart rate. In adult men, semen quality can also be affected.

Photo: Point sources and historic deposition of harmful substances can cause local pollution problems in the Arctic, © Brendan Killeen

- While domestic mercury emissions have been declining in all Arctic States except Russia, long-range transport from sources far from the Arctic, including coal burning in Asia and artisanal and small-scale gold mining in developing parts of the world, mean that overall levels in the Arctic remain a concern.

- Contamination of food sources can cause cancer, affect the immune system and increase the risk of type 2 diabetes in Arctic inhabitants.

- Climate change may lead to increased levels of pollution in Arctic ecosystems, as the increasing annual melting of snow and ice in summer leads to large releases of substances captured in the cryosphere over the winter period or through historic deposition in older ice layers (AMAP, 2017d).

- Climate change has, more recently, even led to harmful pathogens emerging from historical depositions, including anthrax in the Russian Arctic in 2016 (see also Section 3.2.5).

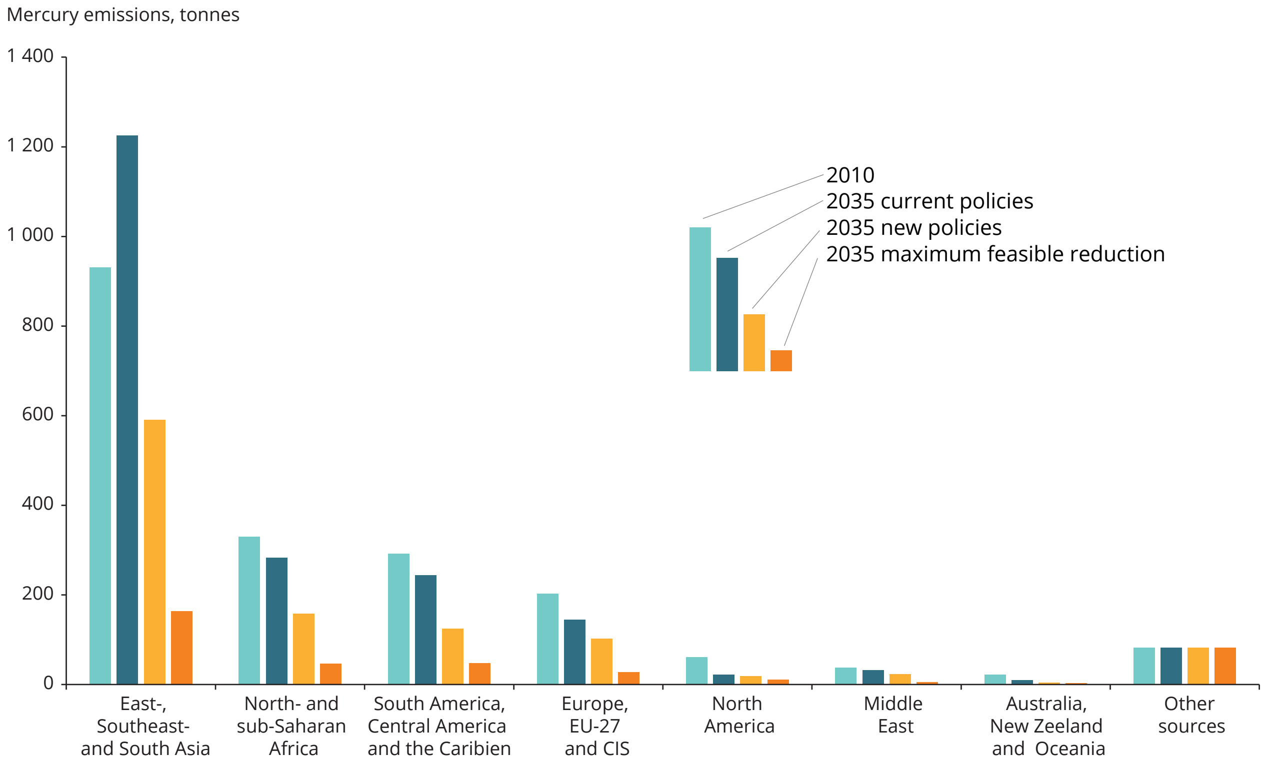
- Under the REACH Regulation, industry is required to provide information on the risks that chemicals pose to human health and the environment. Nevertheless, the time it takes to produce evidence regarding the relationship between chemical exposure and associated health outcomes often delays policy measures to minimise exposure.

- There is a time lag between reduced emissions in the source regions and observed declines in the Arctic environment. It is thus a challenge to provide rapid screening and monitoring in the Arctic and accompanying policy action and measures adopted by the international community, including the EU.

- The resilience and carrying capacity of Arctic ecosystems, which determine the flow of ecosystem services upon which local residents rely, are not fully understood. This is a challenge when determining the level of economic activity to be approved and factored into local and regional planning and management plans.

([40]) Formulating public health advice on contaminants in food is complicated in the Arctic, as traditional diets play a key role in people's social, spiritual and cultural identity, while also providing excellent nourishment, vitamins and minerals, and helping to protect against several diseases (AMAP, 1997).

Figure 3.8 Regional mercury emissions under different mercury abatement scenarios



Note: Current and future levels of mercury atmospheric pollution on a global scale. 'Other sources' than anthropogenic indicated in the figure includes mercury emitted from volcanoes and geothermal sources and re-emission processes of historically deposited mercury over land and sea surfaces. Results obtained during the performance of the EU GMOS (Global Mercury Observation System) project. Further elaboration on the definitions of used emissions scenario (current policies, new policies and maximum feasible reduction) can be obtained through the Copernicus Publications on behalf of the European Geosciences Union.

Source: Pacyna et al., 2016.

Economic opportunities and socio-economic health aspects include:

- Through increased economic activity and a growing labour market, living standards can be raised leading to better housing, diets, connectivity (physical or through better access to the internet) and recreational activities.

- Increased socio-economic activity can lead to increased buying power, which can create a demand for more varied and healthy food options among local residents, although high prices remain a challenge.

- Advances in telecommunications can lead to an increase in the share of the Arctic population with access to e-health, i.e. online face-to-face sessions with doctors or practitioners. Furthermore social media can be used as a tool for communication on health risk messages in the circumpolar north.

- There has, in recent years, been extensive work done on characterising Arctic people's exposure to chemicals via biomonitoring. This wealth of data provides opportunities for researchers investigating exposures and potentially related health effects for Arctic communities.

4 Responding to Arctic change

4.1 Europe's role in the Arctic and the Arctic's role in Europe

Many EU policies and legislative acts affect the Arctic directly or indirectly. In an Arctic context specifically, the EU Framework for climate and energy (EC, 2014b) and the 7th EAP (EU, 2013a) are relevant. Both share a 2030 horizon and, although both policy instruments are applicable only to EU Member States, they have implications for the Arctic region ([41]).

The EU Framework for climate and energy targets and policy objectives aim to help the EU achieve a more competitive, secure and sustainable energy system and to meet its long-term 2050 greenhouse gas reductions target. The 'Clean energy for all' package, a set of policy initiatives and legislative proposals, outlines the overall EU 2030 targets, which are: (1) a 40 % cut in greenhouse gas emissions compared with 1990 levels; (2) at least a 27 % share of renewable energy consumption; and (3) at least 27 % energy savings compared with the business-as-usual scenario (EC, 2016e). The EU's efforts to shift from fuel sources towards low-carbon technologies, thus decarbonising the energy sector, will be of importance for the Arctic, which is significantly affected by climate change. The EU transition will furthermore reduce the impacts of black carbon that is transported by air from Europe to the Arctic. Job creation in the renewable energy sector is also of relevance to the Arctic region.

The priorities of the 7th EAP are to: (1) protect, conserve and enhance natural capital; (2) promote a resource-efficient, green and low-carbon economy; and (3) safeguard citizens from environment-related pressures and risks to health and wellbeing. Furthermore, the aim of the 7th EAP is to enhance understanding of the systemic challenges facing Europe and to respond to them in a way that will see a transition of energy systems, mobility systems, food systems, etc. The 7th EAP identifies the Arctic as a priority region for the EU (see Box 4.1) with good reason, because this overlapping region plays a significant role in Europe's environment and with regard to natural capital and

Box 4.1 The EU's Seventh Environment Action Programme: global and neighbourhood cooperation required for common challenges

Article 98: Many of the priority objectives set out in the 7th EAP can only be fully achieved as part of a global approach and in cooperation with partner countries, and overseas countries and territories. That is why the Union and its Member States should engage in relevant international, regional and bilateral processes in a strong, focused, united and coherent manner. Particular emphasis should be given to the Black Sea and the **Arctic regions**, where there is a need for intensified cooperation and increased Union involvement, including through membership of the Convention on the Protection of the Black Sea against Pollution and by gaining permanent observer status in the Arctic Council, in order to address new and shared environmental challenges. The Union and its Member States should continue to promote an effective, rules-based framework for global environment policy, complemented by a more effective, strategic approach in which bilateral and regional political dialogues and cooperation are tailored towards the Union's strategic partners, candidate and neighbourhood countries, and developing countries, respectively, supported by adequate finance (EU, 2013a).

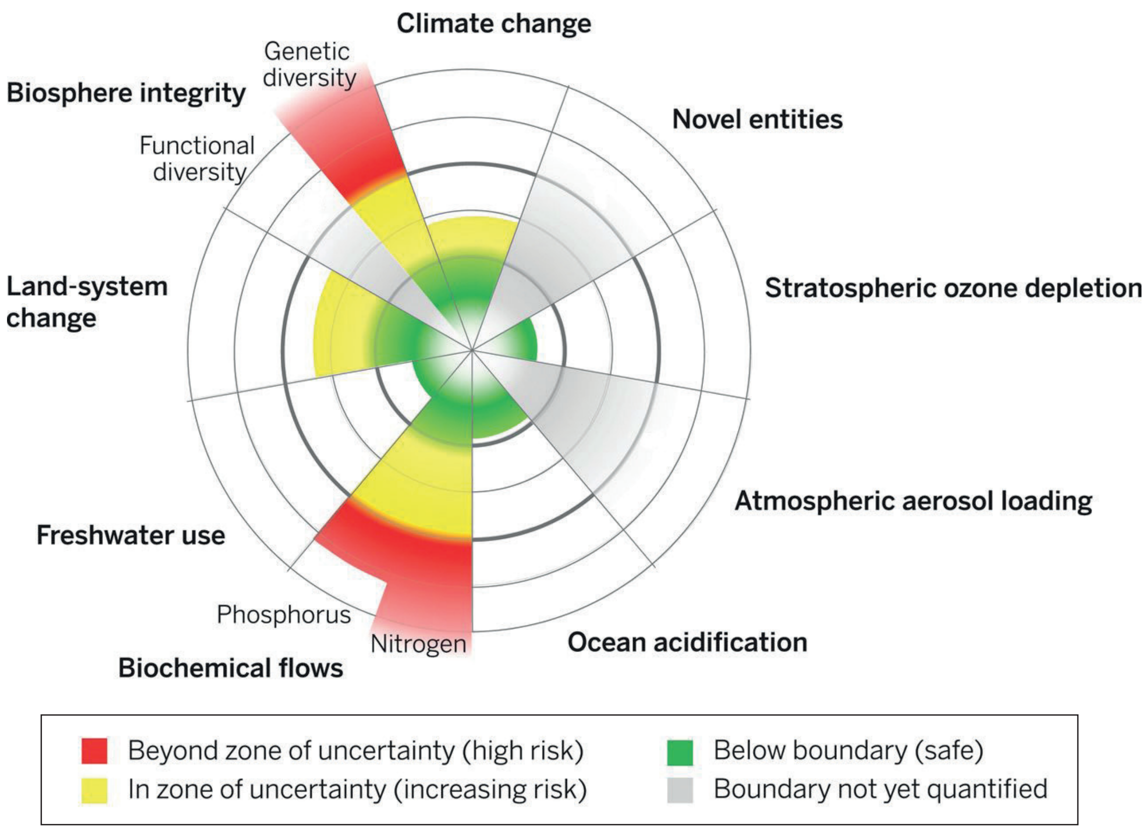
([41]) Norway has adopted some EU environmental and marine legislation, and thus takes part in coordinated responses.

the transition to a low-carbon economy. The Arctic's role in Europe and Europe's role in the Arctic are furthermore recognised and addressed by the EU and many European countries that have developed national Arctic or polar strategies, policy papers, roadmaps or research programmes to address the European–Arctic nexus (see Section 2.3).

The title of the 7th EAP, 'Living well, within the limits of our planet', refers to the planetary boundaries concept, whereby there are limits to growth and consumption because ecosystems are linked and may eventually break down and stop delivering vital ecosystem services if one or more of the key nine planetary boundaries is crossed (see Figure 4.1). In this context, the Arctic is significant in regulating the global climate, with regard to maintaining biosphere integrity, in the vast natural resources it contains, in providing livelihoods and homes to millions of people as well as in the intrinsic value of its endemic species, landscapes and seascapes. The Arctic is in many ways becoming the symbol of the age of the Anthropocene (in which humans are determining the future of other species for generations to come) because the observed changes in the Arctic are so rapid and widespread and the repercussions profound and global in nature.

In order to operate within the limits of the planet, it is becoming increasingly important to recognise the significance of ecosystem services and natural capital in the context of governance and management, but also in the context of economic decision making. Because some economic sectors (e.g. fisheries) are often dependant on these ecosystem services, while other sectors can negatively impact on the ecosytems that deliver them (e.g. oil, gas and mineral exploitation). Although it makes business sense to prevent degradation of the foundations the business is built on, this is not always reflected in reality and companies often overlook the risks, opportunities or responsibilities with regard to maintaining biodiversity and ecosystem services. These aspects therefore need to be better accounted for along the value chain by putting the costs of biodiversity loss or ecosystem degradation next to the income from economic activity. Without this, the estimated wealth of natural capital might be lower than when fully accounting for the value of often unique biodiversity, culture, tourism and the

Figure 4.1 The nine planetary boundaries identified for safe operating space for humanity



Source: Steffen et al., 2015.

role of certain ecosystems in the climate system, all of which are of high relevance to the Arctic.

A difficult challenge for European and indeed Arctic environmental governance arises from the fact that environmental drivers, trends and impacts are increasingly globalised (see Section 2.2). International cooperation is required to reduce greenhouse gases and pollution (POPs, mercury, etc.) as well as to regulate safety and environmental standards for shipping, manage migratory species and address marine litter, transboundary air pollution, short-lived climate forcers such as black carbon, ocean acidification, etc. In each of these challenges facing the Arctic, the EU and its Member States can play an important role.

In order to achieve real decline in pressures on the environment, including on fragile Arctic ecosystems, global society must undergo a number of transformations with regard to energy systems, mobility systems, food systems, consumption and production cycles, etc. Recalibrating existing policy approaches can make an essential contribution to such transitions, although it will be challenging because the relevant transitions are long-term, unpredictable, multi-level and multi-sectoral, and involve multiple scales and multiple actors. In Europe, including the European Arctic, the 2030 vision of the 7th EAP is no longer simply an environmental one, if indeed it ever was. The environmental vision it incorporates is inseparable from its broader economic and societal context. Unsustainable use of natural capital not only undermines the resilience of ecosystems, but also has both direct and indirect implications for health and living standards. Current consumption and production patterns enhance our quality of life but paradoxically put it at risk at the same time. Growth and job creation have raised living standards but depletion of natural capital continues to jeopardise good ecological status and ecosystem resilience. Biodiversity loss, climate change and chemical burdens create additional risks and uncertainty.

It is in everyone's interest — Arctic inhabitants, Europeans and global populations — that the widest possible scope of international cooperation and consent are sought when it comes to environmental and climate-related matters, and that such cooperation is rules-based and built on binding agreements. A number of fora exist to facilitate progress on different aspects of activities and environmental protection in the Arctic region. In some of these, the EU Member States and EEA member countries are represented and negotiating while, in others, the EU is merely an observer. Key to them all is that Arctic governments should continuously strive to lead the way by introducing prudent, timely and appropriate measures built on guiding principles, such as the precautionary principle or the polluter pays principle, while still allowing for economic development, job creation and improving local livelihoods.

Levels of environmental protection and regulations on industry are not at the same level for the eight Arctic States. And while it is recognised that ecosystems do not respect political borders, integrated management plans in line with the ecosystem-based management approach are not yet the norm across the circumpolar Arctic. The Arctic Council is focusing on further developing ecosystem-based management approaches, including national use in implementation. Thus, there is a need for more integrated approaches that acknowledge the concepts of ecosystem management, natural capital, ecosystem services, life-cycle thinking and ecological footprints, because these concepts embrace many of the key components needed for development that is sustainable and balanced when it comes to both the challenges and opportunities facing the Arctic region. These concepts are critical when it comes to constructing viable and long-term solutions that will sustain economic growth (traditional growth, green growth or blue growth concepts) at the same time as ensuring ecosystem resilience and human development in the Arctic. The EU has experience to offer in this context through the approach taken in the 7th EAP, EU Arctic policy, ocean governance and SDG communications.

Key to discussing economic growth and integrated management is not only recognition but also raising the current level of understanding of the resilience of Arctic ecosystems. Without an understanding of the carrying capacity or potential tipping points, increasing large-scale human activities may potentially start processes that have deep and profound impacts on other parts of the globe and weaken the social resilience of Arctic communities. And as ecosystem responses can have decadal time lags, this makes Arctic management and risk abatement even more challenging. Some of the impacts and vulnerabilities resulting from climate change in the Arctic region and wider Europe are addressed in further detail in the 2017 EEA publication Climate change, impacts and vulnerability in Europe 2016 (EEA, 2017).

When considering sustainable development approaches in the region, it is important to acknowledge the growing demand among the Arctic populations — indigenous or otherwise — for economic development, improved living conditions and higher health standards. Creating job opportunities and allowing for industrial activities are not necessarily incompatible with safeguarding the environment, as long as appropriate measures are in place to protect the environment and to avoid accidental effects from increased use of living and non-living resources. Growth can also be sought in sectors outside the extraction industry, including the blue economy supported by the EU, although marine activities also present environmental challenges to sustainability, e.g. through increased emissions or impacts on ecosystems.

When seeking such opportunities, it is similarly important to respect and take into account the culture, languages and local and traditional practices of indigenous peoples before starting new major economic activities. Indigenous peoples are often open to economic development in the Arctic as long as they are consulted and stand to benefit financially, and provided that new social and cultural living conditions or environmental implications do not jeopardise their traditional livelihoods and access to, for example, fishing, hunting or reindeer herding. Indigenous peoples have a long tradition of adapting to changing living conditions; retaining their role as stewards of the land, and adapting to economic development, is a challenge they can meet if their views and concerns are properly respected and addressed. The EU has initiated an annual dialogue with representatives of the indigenous peoples of the circumpolar north (and not only from the European Arctic) in order to foster better discussion on issues of concern and increased cooperation. The EU has furthermore established an Arctic Stakeholder Forum, reaching out to both governments and the private sector, which aims at streamlining the use of EU funding in the Arctic and identifying common investment priorities.

4.2 The evidence base and assessment landscape

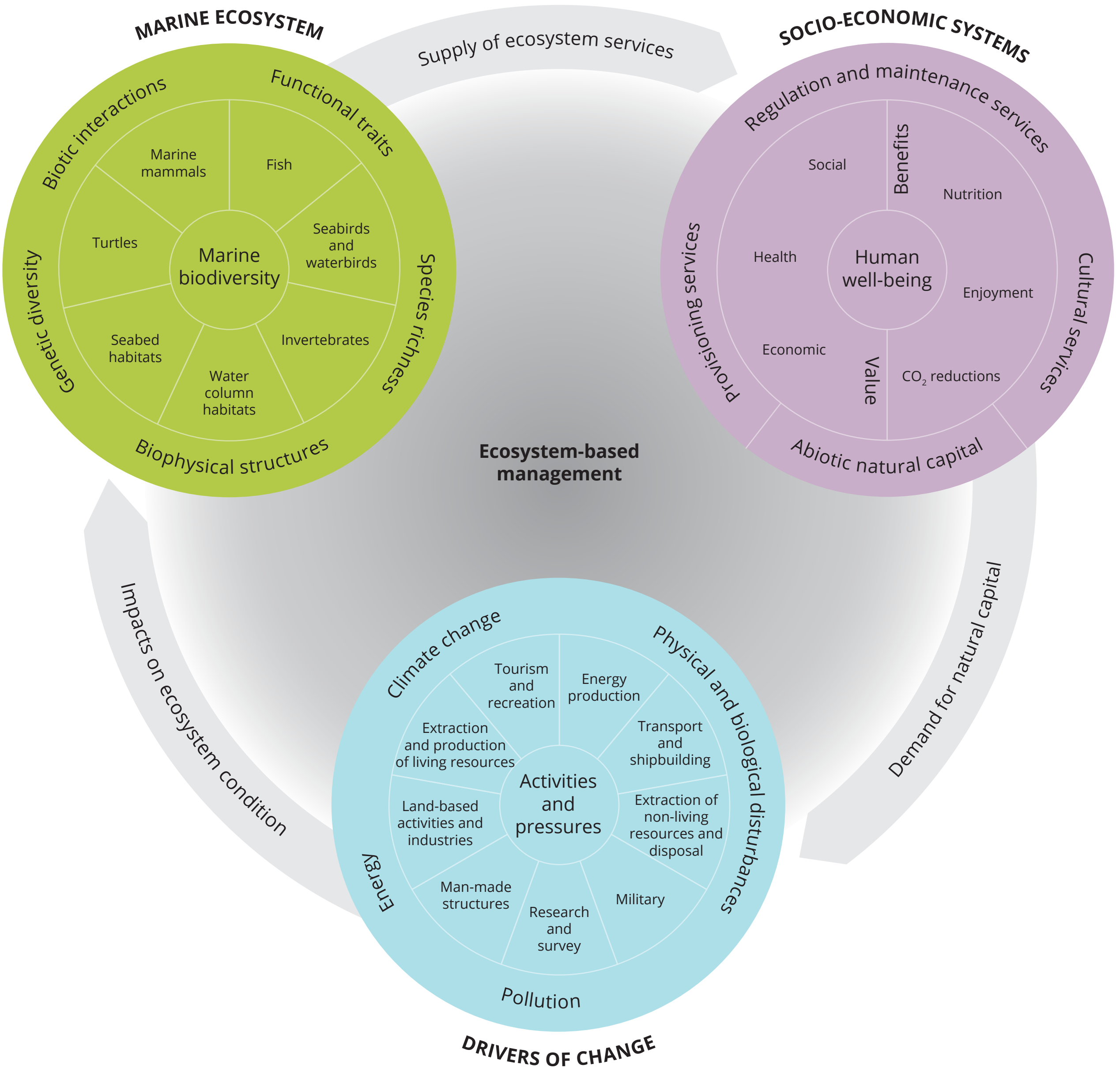
Information and knowledge are the building blocks used for regular assessments of the Arctic environment, including detecting trends, supporting model predictions and developing outlooks for policymaking. The Arctic is the region of the globe where climate is changing the most rapidly. Although our knowledge of the region is expanding, many gaps still exist regarding baselines, feedback systems, resilience and ecosystem response to multiple drivers. In order for the Arctic stakeholders to put themselves in a better position to anticipate changes rather than respond to them, further sustained observations and improved understanding of local, regional and global processes are required.

For decision-makers to have access to the best available information, further efforts are required to sustain and develop data collection, information and knowledge flows, including near real-time data, and to make regularly updated Arctic indicators available. This will provide stronger evidence for early interventions and preventative actions, supporting enforcement efforts and enhancing the overall management of the Arctic's natural capital. The awareness of unknown or unpredictable effects of current actions (or inactions) — due among other things to large time lags, some of which extend into decades — further increases the calls for more knowledge in order to devise appropriate strategies, manage risks and reduce uncertainty. This applies to global decision makers as well as to Arctic decision-makers; global and European decision-makers need to be provided more regularly with comprehensive integrated assessments of the state and outlook of the Arctic environment, and the consequences of actions and inactions. Similarly, Arctic decision-makers, including at regional and local level, should be made aware of global trends that will affect their region, because they are often responsible for approving and managing economic activities taking place on land or in territorial waters.

Expanding the knowledge base on sustainable development and resilient Arctic communities and ecosystems can also help in meeting many of the challenges facing the region, and provide much-needed support for ecosystem-based management approaches and ecosystem services (see Figure 4.2), all while securing economic growth and societal wellbeing for Arctic inhabitants, including indigenous peoples. This is the vision outlined in the UN's 2030 Agenda for Sustainable Development.

Over the past two decades much effort has been made into Arctic observation and monitoring. This includes the activities of the Arctic Council working group CAFF, undertakings by the CBMP covering marine, freshwater, terrestrial and coastal ecosystems, and the first Arctic biodiversity assessment (CAFF, 2013a). Since being established in 1991, AMAP — another working group under the Arctic Council — has dealt with monitoring and assessing global pollution (POPs, mercury and radioactivity) in the Arctic as well as observing changes in the Arctic cryosphere (AMAP, 2011a) and climate change impacts on Arctic Ocean acidification (AMAP, 2013). In the marine domain, work on better understanding the ecosystem-based management approach, designating and creating a network of MPAs and efforts to protect the marine environment from shipping and other sectors have been carried out by the Arctic Council working group Protection of the Arctic Marine Environment (PAME). These Arctic Council peer-reviewed scientific circumpolar assessments are based on national monitoring programmes, and policy recommendations are brought forward to Arctic ministers and other relevant decision-makers, including the EU.

Figure 4.2 Towards ecosystem-based management



Source: EEA, 2015d.

Since 1979, European satellite observations — in particular through the CryoSat and Copernicus programmes — have also given a boost to observational efforts. The IPY in 2007-2008 provided much information on both the Arctic and the Antarctic, and the global linkages. Together with the work of the IPCC (IPCC, 2014b) and the science community, including important work led by the EU's research programmes (Sixth Framework Programme (FP6), Seventh Framework Programme (FP7) and Horizon 2020), the International Arctic Science Commission (IASC) and other Arctic partners, these efforts have raised the level of understanding of the processes, changes and drivers at play. Data collection and providing valuable information and establishing baselines for future trend analysis by both Arctic States and non-Arctic states have similarly been improved. And through Arctic Council assessments on the Arctic environment and climate, guidance has been provided to national and joint policy developments on specific ecosystem components.

Despite these efforts, there are still many unknowns when it comes to the state of the environment and

Box 4.2 European satellite observation in the Arctic

The European Space Agency (ESA), the European Commission and European states, have provided a large contribution to observation and monitoring efforts in the Arctic, and recently the EU launched its Space Strategy for Europe (EC, 2016f), which is of relevance to future work. Below is a brief overview of the European input to better understanding Arctic change and providing services for operators in the region.

The ESA's **CryoSat-2 satellite** carries a sophisticated radar altimeter that acquires accurate measurements of the thickness of floating sea ice so that annual variations can be detected. It also surveys the surface of ice sheets accurately enough to detect small changes. CryoSat-2 is orbiting Earth at an unusually high inclination, reaching latitudes of 88 °N or 88 °S, thereby covering most of the polar regions.

One of the findings from the satellite's precision measurement capabilities is that, between 2011 and 2014, Greenland lost around one trillion tonnes of ice, corresponding to a 3 mm rise in global sea level.

Photo: CryoSat-2 satellite (ESA), © ESA–Pierre Carril

The **Copernicus space programme** (formerly known as Global Monitoring for Environment and Security, GMES) is an EU-wide programme that supports policymakers, businesses and citizens with improved information. Copernicus integrates satellite observations, in situ data from ground stations and airborne and seaborne sensors, and modelling, to provide reliable and up-to-date information on land cover, the marine environment, the atmosphere and climate change, as well as support to emergency management and security. Added value service providers can build on these public services to provide targeted information for specific public or commercial needs, resulting in new business opportunities, job creation, innovation and growth as well as better information about the state of the planet. The range of applications is wide and includes environmental protection, management of urban areas, regional and local planning, agriculture, forestry, fisheries, health, transport, climate change, sustainable development, civil protection and tourism. The EEA plays a key role in the technical coordination of the Land Monitoring Service and in coordinating in situ observations. In the global context, Copernicus is an integral part of the Global Earth Observation System of Systems (GEOSS).

Copernicus
Europe's eyes on Earth

The **CryoLand space project** (using data from Copernicus) addresses challenges from changing water flows and availability (EC, 2015a). On a daily basis, snow and ice updates are needed by stakeholders such as hydropower companies, hydrological and meteorological service providers, climate-monitoring bodies, environmental agencies, road, rail and river authorities, geotechnical construction companies, avalanche-warning centres and ecologists. To provide these potential users with the information they need, the CryoLand project has developed a process to first receive data from a network of satellites, combine it with ground-based measurements, and then make these data accessible in customised online applications.

biodiversity, growth in economic activities, social indicators, predicting the rate of change and assessing or forecasting ecosystem responses. This is due to a lack of comprehensive long-term monitoring with widespread coverage in the Arctic. But, given the significant cost involved — due to the huge area to be monitored, remoteness and extreme operating conditions — this is not surprising. The result is a relatively fragmented and non-regular reporting, particularly at regional level, on both the state of the environment and the drivers affecting it, which makes environmental management and planning in the Arctic more complicated. In particular, this is because reliable models that mirror observed changes and accurately predict future trends are still missing, e.g. those predicting sea ice extent.

Apart from the abovementioned CBMP, which has a fixed frame of reporting on Arctic biodiversity, and AMAP, which for many years has reported on pollution effects on wildlife and human health as well as Arctic climate change, there is currently no legally mandated requirement or framework to regularly report on Arctic change and produce assessments at the circumpolar or European Arctic scale. Nor is there any such requirement applying to specific sectors or topics, such as regular shipping assessments, oil and gas assessments, fisheries assessments or broader assessments of the state and outlook of the circumpolar Arctic and its sub-regions. Assessments are conducted under the auspices of the Arctic Council only if consensus can be reached between the eight Arctic States.

It may be considered useful to establish a regular reporting mechanism that is linked to global reporting streams, such as the Global Environment Outlook process and UN World Ocean Assessment, whereby the EU and non-Arctic states can also support the process and share data and observations. Also at the global level, the 17 SDGs adopted by the UN in 2015 as part of the 2030 Agenda can be of use in developing agreed targets, indicators and associated reporting cycles (see Figure 4.3), because both the Arctic States and the EU (EC, 2012a) have committed to support the SDGs process.

The Arctic Council and IASC have jointly established an observation network, Sustaining Arctic Observing Networks (SAON), which aims to promote long-term monitoring of key parameters and facilitate data and information sharing between Arctic nations and other international actors, including community-based monitoring efforts. The vision is that such a network can improve the level of knowledge when it comes to key trends, drivers and describing the effects of human activities. To be successful, the work has to be integrated into ongoing environmental cooperation and monitoring efforts in neighbouring regions, such as Eionet in Europe, the Arctic Observing Network (AON) in North America and the UNEP-led Global Environment Outlook (GEO), to build on existing building blocks and avoid duplication of monitoring efforts. Given the global importance of Arctic issues and the international nature of Arctic research, it is beneficial that SAON includes non-Arctic states and organisations in the pursuit of improving Arctic monitoring and research capabilities to support regulatory stability and more effective governance. In this context, the EU and its Member

Figure 4.3 United Nations 17 Sustainable Development Goals (SDGs)

Note: The 17 UN Sustainable Development Goals (SDGs) was adopted in 2015 as part of the global 2030 Agenda. The SDG's also apply to the Arctic region. The EEA supports the Sustainable Development Goals.

Source: United Nations, 2015.

States can play a role by supporting the initiative by GEO to make SAON its Arctic branch and part of the GEO Cold Regions Initiative (Yubao et al., 2015) in the work programme leading up to 2025.

The majority of Arctic observational efforts are carried out via operational monitoring by the Arctic states, although data and information also come from international research programmes as well as from local and indigenous knowledge. All sources play their part in the puzzle and indigenous knowledge and citizen science are currently underused sources of information. The data generated by monitoring programmes become more valuable the longer the programmes run, because trends and projections become more solid. With more than two decades of monitoring data, some of the Arctic Council working groups such as CAFF and AMAP are now in a better position to assess the relative success of the various policies aimed at, for example, reducing Arctic pollution. Policies whose effects may now be assessed include past decisions to ban certain pollutants that were being detected in the Arctic, such as DDT, or to regulate them (POPs, PCBs) through international conventions and agreements. By measuring what governments must manage, these long-term monitoring efforts now provide stronger evidence of policy effectiveness when it comes to improving the health of people and wildlife in the Arctic.

European countries have long experience and traditions of environmental regulation and monitoring, just as those countries and the EU have large funding programmes for research and innovation efforts. The recent EU Arctic policy, which seeks to improve the knowledge base and to support sustainable development in the region, recognises these efforts specifically. The EU has also conducted a Strategic assessment of the development of the Arctic and an Arctic gap analysis report (AC, 2014a, 2014b) to help guide EU engagement in the region, with regard both to filling gaps in knowledge and to facilitating development in the region. Improving the EU's responses to global megatrends and Arctic change depends on credible information on possible future developments and choices in the face of global risks and uncertainties. In other words, Arctic information and perspectives need to be mainstreamed into long-term regional and global policies.

The EU has for the last decade been one of the largest funders of polar research through a large number of projects. Under the FP7 (2007-2013) around EUR 200 million was invested in Arctic research, which provided useful results for climate mitigation and adaptation policies, environmental protection and health-related issues, as well as development of economic activities (EC, 2012). The EU is also supporting the development of and international access to Arctic research infrastructures (terrestrial research stations, remote and in situ observing systems, vessels, etc.) throughout the whole region, with relevant cooperation activities with all non-EU Arctic countries. This complements efforts under the Shared Environmental Information System whereby sharing of environmental data and information is promoted. The EU structural funds have also supported innovation and research activities in the Arctic during the 2007-2013 programming period and the current programme from 2014-2020 is continuing these efforts.

The EU research programme running from 2014-2020, Horizon 2020, has continued the Arctic engagement, including though the development of a comprehensive European Polar Research Programme (EU-PolarNet) to improve coordination and streamlining of international research priorities and programmes, and use of European resources for Arctic research. Within Horizon 2020 and the European Partnership Instrument, there are possibilities to further develop the Arctic theme. Arctic science and research could to a greater degree be coordinated across all three pillars of Horizon 2020 (excellent science, industrial leadership and societal change) in order to increase synergies. Establishing an Arctic focus area in the Horizon 2020 work programme for the remaining period may also be an option to increase Arctic research engagement.

In addition to research programmes, the EU has also engaged in a Transatlantic Ocean Research Alliance with Canada and the United States, which in time will create synergies and efficiency gains. The alliance has decided to invest in a broad package of Arctic research activities in the Work Programme 2016-2017 of Horizon 2020. The package comprises three Arctic topics and is worth EUR 40 million, and three large research projects were started in 2016. All projects are based on large transnational consortia, extending beyond the Transatlantic Ocean Research Alliance. The INTAROS project, with a budget of approximately EUR 15.5 million, will extend, improve and unify Arctic observation systems, including community-based ones, contributing to filling critical gaps and creating an integrated data access platform. The projects APPLICATE, with a budget of approximately EUR 8 million, and BLUE-ACTION, with a budget of approximately EUR 7.5 million, will explore through complementary approaches the predictability of Arctic climate and its impact on climate and weather at lower latitudes, improving models, contributing to the design of appropriate observing systems and leading to the co-design of better climate services with stakeholders. A new call in 2017 will address the challenges from thawing permafrost. In 2016, the EU furthermore engaged in strengthening marine data and information in the Arctic through the European Marine Observation and Data Network (EMODnet) (see Box 4.3).

Challenges still remain and some of the gaps that Arctic partners and the EU should address are captured by the Third International Conference on Arctic Research Planning (ICARP) Roadmap for the future (ICARP, 2016) as well as in the Joint Statement from the Arctic Science Ministerial meeting held in September 2016 in the United States. They include:

- improved polar predictions on sea ice extent, for example, and the effects of Arctic warming;
- improved models on climate change and sea level rise, and further data to support such models;
- more regular assessments on biodiversity and ecosystem resilience;
- human health aspects related to a changing Arctic, including knowledge about the cumulative effects on humans and Arctic wildlife of multiple stressors from climate change and pollution, including black carbon;
- more monitoring data from the winter season (most scientists operate in the summer);
- more information on fish stocks in the central Arctic Ocean.

To facilitate such efforts the international community and relevant stakeholders should consider:

- increasing scientific cooperation and research funding;
- making better use of remote sensing and drones;
- improving exchange of data and information (including translation of Russian data), for example through the Arctic Biodiversity Data Service (ABDS) and in future through the SAON initiative;
- making better use of data from industry and operators in the region;
- making better use of citizen science and indigenous knowledge to support operational monitoring efforts.

Box 4.3 European Marine Observation and Data Network (EMODnet)

EMODnet
European Marine Observation and Data Network

Long-term sustainable economic growth is a high priority in the EU, and in particular developing an economy based on knowledge and innovation. The marine and maritime sector or 'blue economy' has been identified as having great potential for making a major contribution towards meeting Europe 2020 objectives. In order to achieve the goals of the blue economy the EU has taken initiatives to improve the collection and accessibility of marine data. Public bodies in the EU together spend more than EUR 1 billion a year collecting data on the marine environment. Instead of each agency collecting data separately for its own purposes, the EU is moving towards a new paradigm, in which data are collected once and are used for many purposes, whereby costs can be reduced, innovation encouraged and marine knowledge improved.

As part of EU Marine Knowledge 2020 and EMODnet, the European Commission has initiated a process to determine gaps in data and observation systems and priorities for an observation system that supports the delivery of sustainable growth and innovation. A number of sea basins surrounding Europe are being studied with regard to whether or not the right data are being collected. One of the sea basins identified is the Arctic Ocean, where the data overview is designed to:

- assess various parameters (e.g. water temperature, currents, nutrients);
- identify the purposes for which data are used (e.g. marine spatial planning, assessment of (potential) MPAs, assessment of navigational risks);
- identify how the data meet the needs of users (e.g. fisheries managers, coastal protection authorities and national authorities responsible for the Marine Strategy Framework Directive (MSFD), ports, shipping, offshore energy exploration and pipeline laying).

The preliminary results of a data adequacy report (IMARES, 2016) point to a number of Arctic data gaps that need to be filled or strengthened, including fisheries data, river flows, alien species and phytoplankton distribution. A final report to the EU is expected by 2018.

Source: EC, 2016g.

In order to develop a comprehensive view of Arctic change, it is essential to take into consideration environmental, social and economic dimensions while seeking integrated approaches. So in addition to the climate and environmental aspects outlined above, extended and regular monitoring and research are also required when it comes to fisheries, shipping, oil and gas extraction, tourism and demographic changes. To meet such needs, the EU-PolarNet initiative is reaching out in 2017 to the global polar and ocean business community to identify opportunities to collaborate on data collection in support of improved science and sustainable development. More effective engagement with non-Arctic partners is also beneficial, particularly with the EU and observer countries and organisations in the Arctic Council. It is furthermore meaningful to continuously engage and involve Arctic inhabitants and indigenous communities in priority setting and in the co-design and co-production of research and development of wider initiatives. Sharing results and disseminating new knowledge to local communities should be taken for granted, but this is not always the case.

4.3 Integration and policy coherence in Europe

Many national, bilateral and international measures and instruments are currently in place for regulating activities and safeguarding the environment in the Arctic. However, like most regulations, these policy measures and frameworks can be strengthened, streamlined, implemented and managed in a more integrated manner in order to limit human impacts on the environment, strengthen sustainable development and raise living standards, as well as to avoid undermining future economic growth by eroding natural capital. In order to support such efforts, strengthened governance structures represent a way forward, including closer cooperation between the Arctic nations and the international community.

Seeing that international cooperation efforts are essential to tackle Arctic environmental issues, it is important that this be more explicitly acknowledged by the Arctic States and that non-Arctic states and partners are further included in this endeavour. Steps in this direction have recently been taken under the auspices of the Arctic Council, the main forum for Arctic discussions, although observer countries and organisations' involvement and influence are kept at working group level and not in the selection of initiatives. That said, the Arctic Council does not have the status of an international organisation and it is more a decision-shaping forum than a decision-making organisation, although some binding agreements have been adopted (see Section 2.1). The approach of seeking regional solutions with international partners can bring added value in addition to efforts to reach agreement through international bodies and conventions with lower or limited Arctic State influence. However, a more optimal approach would be to improve in parallel: a meaningful engagement through the Arctic Council and subsidiary bodies as well as addressing Arctic issues and concerns in international fora such as the UNFCCC, the CBD, the IMO, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the World Trade Organization (WTO), UN Environment, the Sendai Framework for Disaster Risk Reduction (UNISDR) and the OSPAR Commission.

It also has to be recognised that although most of the Arctic basin is covered by the Arctic coastal states' EEZs, there is a central part of the Arctic Ocean that will continue to be an area beyond national jurisdiction and in which the international community will have a legitimate interest regarding its conservation and sustainable use. International cooperation is therefore unavoidable and international solutions are required. Efforts are now under way in the UN to establish a legal instrument to protect marine biodiversity in areas beyond national jurisdiction, which would include the central Arctic Ocean. Furthermore, as outlined in Section 3.3, the EU and Arctic partners (in a five + five format) are discussing a binding international agreement preventing unregulated commercial fishing in the high seas area of the central Arctic Ocean. These initiatives contribute towards a more integrated management of natural capital and help avoid passing on to future generations the risks from today's inadequate governance of natural resources.

The EU and its Member States have an important role to play in facilitating sustainable development in the region and minimising negative impacts on the Arctic environment. Faced with the impacts and challenging outlook of a changing Arctic, and the knowledge that Europe is contributing to a number of negative changes, robust scientific understanding for better policymaking is needed alongside strengthened existing regulations. It should also be recognised that Europe contributes to positive developments including job creation, education, infrastructure and regional development. Achieving sustainable development in the Arctic while maintaining or strengthening ecosystem resilience will rely heavily on continuous monitoring of how increasing human activity is affecting the region's fragile environment, as well as devising coherent and integrated policy responses, some of which require international engagement and commitment. This narrative is the backbone of the EU Arctic policy adopted by the European Commission and European External Action Service in 2016.

The EU Arctic policy has been in development since the first EU Arctic Communication (EC, 2008b). While the three overall objectives on safeguarding the environment, supporting sustainable development and engaging in international cooperation have remained the same, the actions, integration and coherence with relevant policies have been strengthened since 2008. The policy framework captures the key EU policies of relevance to the Arctic region and its development, including environment, climate, energy, transport, fisheries, research and innovation, marine and maritime, cross-border cooperation and social policies. An Arctic in transformation and the EU's responsibility in support of positive responses are in the forefront, and the framework gives an overview of the positive contributions the EU can make. Thus, the EU has long recognised and acted on its Arctic responsibility, including in the 7th EAP, and some of its Arctic engagements to date are highlighted in Box 4.4.

Specific environmental challenges, which often present themselves with local effects and impacts, have in the past been dealt with through targeted policies and specific instruments. The new challenge for Arctic governments, in collaboration with the EU and other international partners, is to balance the need for resources, economic growth and raising living conditions with the less visible (and perhaps less obviously immediate) need for supporting, regulating and ensuring that the services that ecosystems provide are maintained and the human-made systemic risks

Box 4.4 Elements of the EU's ongoing Arctic contribution

- ***Fighting climate change***: The EU is on track to meet its greenhouse gas reduction target of 20 % by 2020 compared with 1990. It is committed to achieving a 40 % reduction by 2030 and has endorsed a long-term objective of reducing its emissions by 80-95 % by 2050 compared with 1990. This commitment and the COP21 Paris Agreement on intensifying actions and investments through nationally determined contributions (NDCs) will significantly contribute towards reducing climate change and related impacts in the Arctic. Adaptation to climate change is also part of the Paris Agreement and relates to enhancing resilience to the adverse impacts of climate change in the Arctic; adaptation also includes tapping into the opportunities brought about by climate change.
- ***Investing in sustainable development in the north***: The EU provided more than EUR 1.14 billion to develop the economic, social and environmental potential of the Arctic regions of the EU and neighbouring areas for 2007-2013. The regional development and regional cooperation programmes funded by the European Regional Development Fund (ERDF) are worth mentioning here, and include ongoing investments during the 2014-2020 programming period as well as the Arctic Stakeholder Forum, aimed at streamlining the use of EU funding in the Arctic and identifying common investment priorities.
- ***Shipping and maritime safety***: As almost 90 % of EU external trade is carried out at sea, the EU has significant experience in shipping, shipbuilding, satellite navigation, search and rescue and port infrastructure development.
- ***Reducing future uncertainties and monitoring changes in the Arctic region***: The EU, through the FP7, has contributed around EUR 200 million of EU funds to international research activities in the Arctic since 2002, excluding the individual contributions from EU Member States. The structural funds have similarly supported innovation and research activities in the Arctic.
- ***Reducing pollution***: The EU has also continued to play a prominent role in international efforts to reduce pollution from POPs, through both the Stockholm Convention and the UN LRTAP convention. An initiative on addressing black carbon in the Arctic was launched in late 2016 (EC, 2016h).
- ***Research on the Arctic environment***: The Commission has carried out a pioneering assessment of the EU's current and future Arctic footprint, the EU Arctic footprint and policy assessment (Ecologic Institute, 2010). This shows that the EU has a significant impact on socio-economic and environmental aspects of the Arctic region, including biodiversity, transport, energy, fisheries and climate change. A number of EU research projects concern the impact of climate change on the Arctic region's ecosystem and on key economic sectors. Other projects are studying the evolution of the Arctic sea ice cover, glaciers and ice sheets, including the impact that their loss is having on sea level. A project involving all Arctic countries produced a first-ever harmonised assessment of soil conditions in the region, the Atlas of northern circumpolar soils (JRC, 2008). Several projects have been involved with boosting research infrastructure in the region, including by building on the INTERACT network of 70 terrestrial field bases scattered around the region. Other research projects benefiting from EU funds (e.g. CLEAR and ArcRisk) are filling critical knowledge gaps on the impact of transboundary pollution on the health of Arctic populations. An overview of Arctic research funded by the EU was produced in 2014 (EC, 2014c). The most recent initiatives from 2016 include the Horizon 2020-funded projects to extend, improve and unify Arctic observation systems, including community-based ones (INTAROS), and the APPLICATE and BLUE-ACTION projects.

and vulnerabilities that threaten ecosystem resilience are reduced. The continued global over-exploitation of natural capital cannot continue and strategies on how to counteract and phase out damaging practices and activities are crucial components in the pursuit of development that is sustainable and that will provide continued economic growth for the Arctic region and its people. As this cannot be tackled through integrating environmental concerns in individual sector policies alone, increasing emphasis needs to be placed on holistic approaches to strengthening ecosystem resilience and building adaptive capacity.

In response to socio-economic and ecological interactions, the EU is increasingly formulating its environmental policies in a three-step timeframe to cover a mixture of short-term targets, mid-term ambitions (2020-2030 objectives for environment and climate, for example) and long-term visions (a 2050 vision of societal transition, informed by the concepts of planetary boundaries, green economy and resilience of society and ecosystems). The concrete policy measures that make up these three steps include a range of policy initiatives introduced by the EU. These aim at improving sustainability through the implementation of an integrated ecosystem-based approach to management. An example of the EU three-step approach is in the marine and maritime domain, where initiatives include the integrated maritime policy and its 'environmental pillar', the MSFD, the CFP, the EU biodiversity strategy to 2020 and the 7th EAP. With its experience in the marine area, the EU can provide a good example among the Arctic States of how such integrated policy development could be deployed in the Arctic, not least because current efforts coordinated through the Arctic Council tend to be more focused on assessing, studying and describing challenges and less on how to collectively address and tackle them. Similarly, the EU efforts on strengthening resource efficiency and moving towards a circular economy that reduces waste and emissions (EC, 2015b), as well as recent steps on developing a strategy on plastic that addresses issues related to production, use and end of life (including plastics in the marine environment), are of relevance to the Arctic environment, and thus areas for further cooperation.

In addition to seeking better integration and policy coherence within the EU, the EU is furthermore acting as a bridge in linking the Arctic to Europe, the pan-European area and the global reporting processes under UNEP. This regional cooperation on assessing environmental impacts is needed to strengthen forward-looking planning and to devise international responses to systemic change, which becomes more visible through global assessments. A coordinated approach towards the principles for collecting and sharing environmental information across regions is also needed to provide a sound knowledge base for policy development and decisionmaking, including initiatives to support the UN 2030 Agenda and 17 SDGs from 2015 (see Section 4.1).

Photo: Ilulissat, Greenland, © Nikolaj Bock

5 Conclusions

5.1 A need for an integrated response

Arctic change takes many different forms: environmental, demographic, economic, cultural, political and changes in living standards and wellbeing. Thus a variety of responses are required, some of an integrated and coherent nature, to meet multiple needs. Conflicting agendas often arise if policy response addresses only individual dimensions of change, and self-enforcing feedback mechanisms may be created.

Most of the changes observed in the Arctic, as well as current and future economic activities, have a European dimension to them, although Canada, Russia and the United States also play their part. These changes and economic activities include: (1) ships sailing to/from or though Arctic waters, providing Europe with goods and services and calling at European ports; (2) European companies extracting minerals or hydrocarbons in the Arctic; (3) European fishing vessels catching and landing Arctic fish; (4) European tourists going to the Arctic and/or travelling with European tour operators; (5) accidents and oil spills involving European ships and oil rigs, and European ships coming to the rescue or taking part in the clean-up operation; (6) long-range pollution and marine plastic in the Arctic that originated in Europe; and (7) European emissions of greenhouse gases, and imports of energy and goods which cause emissions elsewhere. European emissions in particular are impacting the Arctic region severely.

Given that it overlaps with and has direct impacts on the Arctic, the EU has a role to play in efforts to ensure an appropriate balance between challenges and opportunities arising in the Arctic, as well as in supporting development that is not at odds with traditional livelihoods and cultural practices, e.g. facilitation of innovative financial instruments for eco-innovation. **The EU has an ambitious 2030 plan for transforming Europe into an efficient low-carbon circular economy and by doing so Europe will reduce its Arctic footprint**, through reducing pollutants brought into the Arctic through air and ocean currents but also through reduced imports of minerals and hydrocarbons from the Arctic region. The EU is also working to strengthen the resilience of Arctic communities and supports the wellbeing of Arctic residents, in particular respecting the rights and involvement of indigenous peoples.

When it comes to some of the economic drivers of change in the Arctic, the EU has a responsibility to act in a prudent manner by, for example, ensuring policy integration and by strengthening the knowledge base to guide policymaking and EU engagement in activities affecting the region such as fisheries, extraction of hydrocarbons, shipping and mining. The Arctic sub-regions differ substantially, and policy options and recommendations for the European Arctic may not be relevant to other parts due to different living conditions, environmental standards, government structures and local traditions.

Some of the overall conclusions and take-home messages from this report are summarised below:

- The Arctic region is undergoing rapid change and is affected by a number of drivers and pressures, including: climate change; decline in biodiversity; threat from invasive species; long-range pollution (coupled with pressures from economic development such as exploration for minerals and fossil fuels); increased transportation and shipping; comprehensive fishing efforts; local pollution from industrial activities and historical waste disposals; land fragmentation; infrastructure developments; and tourism. These multiple stressors do not act in isolation but often exacerbate one another, leading to cumulative impacts greater than those from individual activities or stressors. **Collectively, these changes challenge ecosystem resilience, and Arctic species and inhabitants**, particularly indigenous peoples, all of whom and which will have to adapt to pressures and rapid transformation in both the environment and living conditions.

- It is in European and global interests to **limit the changes occurring in the region** as well as to support Arctic residents in adapting to the ongoing transformations. The EU can play a constructive role in the years to come by supporting activities that: (1) support sustainable development; (2) are adjusted to local and regional conditions; and (3) are aligned with the precautionary principle and do not add further pressure for a fragile region already seeing rapid change and impacts of human activities. The EU and its Member States need to continue their approach of addressing the systemic and transboundary nature of the challenges, take account of emerging pressures and effectively implement environmental policies while developing integrated approaches to the environmental and health challenges arising in the Arctic region so that economic opportunities do not come at the expense of ecosystem resilience, natural capital and ecosystem services.

- In recent years, economic crises and fluctuations in world commodity prices have caused a slowdown in Arctic investments and this has provided Arctic governments, Europe and the international community with **a window of opportunity, and more time** to better: (1) assess Arctic ecosystem resilience, natural capital and boundaries for human activities; (2) anticipate the pace of change; (3) build better models and forward-looking scenarios for Arctic development; and (4) develop cleaner technologies and put in place safety standards, at both national and regional levels. The slowdown has furthermore allowed a diversion of focus on resource extraction towards emerging sectors such as tourism, the service sector and renewable energy production, as well as improving transport and communication links.

- We have yet to fully recognise the state of the Arctic environment and long-term effects on it, and **continued efforts to monitor and assess changes are needed** to ensure a sustainable use of the Arctic's fragile natural capital. The EU, together with the Arctic States and their international partners, has to work tirelessly to ensure that growth in the Arctic does not jeopardise already stressed ecosystems, just as efforts have to be directed towards promoting development that is planned with the people of the Arctic, and benefits them. In this context, the EEA can play a constructive role by regularly reporting, through assessments and indicators, on trends in the Arctic environment of relevance to Europe.

5.2 Policy integration options

In addition to the overall messages, a number of policy options related to the environment and climate change, and where the EU and European states can play a role in addressing Arctic challenges and opportunities in the years to come, arise from this report. The policy options summarised below are primarily directed at EU institutions and EU Member States because they often relate to EU policies, competencies or legislative acts. However, a number of issues raised are also of relevance to non-EU countries because they require a common European or global response.

Environment and health

Changes in the Arctic will affect Europe, just as Europe is affecting the Arctic. Europe therefore has an interest in looking to the Arctic and assessing the wider implications for Europe's environment. In this context, the EU and its Member States along with Arctic partners can play a constructive role in the following ways:

- Take further action in Europe and internationally to reduce impacts from long-range pollutants, such as marine litter, mercury emissions and black carbon emissions.
- Undertake regular integrated assessments in supporting efforts to raise understanding of the interplay between local effects and global megatrends; reduce uncertainties and better project future trends; and identify suitable policy responses.
- Promote further research on ecosystem services and natural capital in the context of international ecosystem accounting approaches and valuation of ecosystem services. Facilitate environmental accounting for the Arctic in line with the UN System of Environmental and Economic Accounts (SEEA) and related sub-systems.
- Work towards mainstreaming Arctic biodiversity by incorporating biodiversity objectives and provisions into sectoral and cross-sectoral policies, plans and programmes at all levels, including international standards, agreements, action plans, operations and tools related to the development of the Arctic.
- Improve weather forecasts and climate predictions to provide better services for those who live and work in the Arctic as well as those living in the lower-latitude regions, e.g. by supporting an international action plan to improve predictions of weather, climate and ice conditions in the polar regions by the World Meteorological Organization (WMO), better known as the Year of Polar Prediction, which will take place from mid-2017 to mid-2019.

Environment and health (cont.)

- Support states in designating further protected areas onshore and offshore in the Arctic. Connecting European and Arctic MPAs and the Natura 2000 network could be explored ([42]), as well as supporting an ambitious legal framework for the conservation of and sustainable use of marine biodiversity in areas beyond national jurisdiction.
- Facilitate initiatives aimed at improving Arctic health and living standards, including better housing, diets, connectivity, e-health and understanding people's exposure to harmful substances accumulating in the Arctic food chain.

Arctic energy

Europe is a large importer of hydrocarbons from the Arctic. Increased extraction of Arctic fossil fuels goes against keeping the global temperature change below the 2 °C target. While the EU and its Member States transforms its energy mix towards renewable energy sources, it can play a constructive role with Arctic partners in the following ways:

- Facilitate the development of renewable energy in the Arctic, e.g. hydropower, solar power, wind power and wave power.
- Study and mitigate negative impacts on the environment and traditional livelihoods such as fishing or reindeer herding from renewable energy developments such as hydropower and wind power.
- Support replacement of the many local diesel generators across the Arctic with renewable energy sources and/or ensure the connectivity of regional energy grids.
- Promote high standards across the Arctic region and ensure that best available techniques are implemented for European companies' operations in the Arctic, if extraction cannot be avoided.

Arctic fisheries

Europe is a major consumer of Arctic sea products and thus has an interest in ensuring good cooperation with Arctic fishing states in sustainable management of fish stocks and marine living resources. Furthermore, the EU supports a blue growth agenda and a significant part of this relates to the fishing and aquaculture industry. In this context, the EU and its Member States can play a constructive role in the following ways:

- Participate and engage in international and regional regulatory frameworks and safety standards, and combat incentives for unsustainable fisheries and illegal, unreported and unregulated (IUU) fisheries in the Arctic.
- Facilitate fisheries research and sharing of information, including local and indigenous knowledge from the large fishing communities in the Arctic.
- Improve management of fisheries through reform of the CFP, further develop fisheries governance at international level and contribute to the EU's ocean governance objectives and the UN's SDGs through agreements with non-EU countries (an external dimension of the CFP).
- Support expanding the 2015 Arctic non-binding agreement on a fishing moratorium in the central Arctic Ocean towards a binding agreement that puts in place a precautionary approach and a collaborative scientific process to collect data on the marine ecosystem of the central Arctic Ocean, and that also contains a clear trigger mechanism to set up a regional fisheries management organisation (RFMO) and a regional sea convention if necessary.
- Continue to improve existing legislation with regard to authorisation of fishing vessels that operate in Arctic waters and ensure that they meet the same, or even higher if deemed necessary, environmental standards for operating in EU waters.
- Further develop monitoring systems for changing fish distribution in the Arctic to support multinational fishery agreements in managing fish stock distributions and thus support the blue economy.

([42]) Both to halt the loss of regional biodiversity and also to support migrating species, many of which come from Europe or use Europe as a corridor.

Arctic shipping

The EU and its Member States and its Arctic partners can play a constructive role in the following ways:

- Shape international standards and set ambitious targets and mandatory requirements through international conventions and regulations, e.g. through the IMO, including measures related to heavy fuel oils in Arctic waters (both for on board combustion and as cargo) and reducing black carbon emissions from shipping. The promotion of an ambitious second phase of the IMO Polar Code should be ensured.
- Strong enforcement of port and flag state obligations including ensuring compliance with the Polar Code applicable to ships operating in ice-covered waters.
- Support designation of shipping corridors with low environmental impact, or consider limiting or banning shipping in sensitive areas during the seasonal migration of whales.
- Continue supporting Arctic satellite systems for better satellite-based Earth observation systems, e.g. through CryoSat and the Copernicus sentinels. These should cater to both environmental and security monitoring needs by facilitating hydrographic mapping, oceanographic observations, weather forecasts, ice charts and ice models, ship surveillance and vessel tracking, and search and rescue capabilities, as well as helping to improve Arctic communication.
- Support efforts to reduce black carbon emissions from shipping, including research and monitoring activities, updating and maintaining inventories, and putting in place appropriate measures and management plans.
- Cooperate with the Arctic Council working group PAME on assessing impacts from cruise tourism.

Arctic minerals

Europe is a large importer of natural resources and minerals, including from the European Arctic which has a number of actives mines in Fennoscandia. In this context the EU and its Member States can play a constructive role in the following ways:

- Support the collection of data through Horizon 2020 and the sharing of mining data and knowledge through the European Innovation Partnership on Raw Materials. A record of mineral raw materials of the Arctic region could be established.
- Ensure that environmental, economic and social assessments are taken into account in future developments and that special attention is given to local issues and indigenous rights.
- Promote the adoption of a full value chain perspective, in which every stage from exploration through to mining, transport, processing, production and recycling is included to address the social and environmental externalities. This would cover both the demand side from, for example, European consumers and the supply side from, for example, EU companies and local communities in the European Arctic.
- Support the use of best available practices with regard to operation as well as management of waste materials, as well as plans regarding prevention, preparedness and response to accidents involving dangerous substances.
- Support area-based management, which limits or prevents mining activities in particularly sensitive or ecologically important areas, e.g. deep-sea mining.

Strengthening the knowledge base

Europe has long been a major contributor to Arctic research and innovation, and in this context the EU and its Member States can play a constructive role in the following ways:

- Address uncertainties and the dynamic nature of interplay between social systems, economic development and ecosystems in the Arctic to improve understanding of systemic change and identify policy options. Similarly various baselines need to be established and integrated assessments carried out, preferably aligned with internationally agreed reporting cycles. Supporting commonly agreed Arctic indicators and targets would be helpful in this regard.

Strengthening the knowledge base (cont.)

- Continue to be a leading force in conducting and coordinating Arctic research activities with regard to better assessing environmental and climatic changes, but also support research, science and innovation regarding development of cleaner technologies for Arctic conditions. The EU-PolarNet initiative on shaping research priorities and bringing together European research infrastructures plays an important role in this context.
- Form still more accurate predictions about the consequences of global climate change and those of local Arctic climate change on climates at lower latitude.
- Promote openness, access and coherence across research programmes and databases, and foster a dialogue on the establishment of a common open monitoring database.
- Facilitate better use of community-based monitoring and indigenous knowledge in environmental and climate assessments in the Arctic, in particular through development of methodologies and validation processes, and harmonisation of data and information from such sources — both in the context of supporting operational monitoring efforts and in scientific activities.
- Support efforts to produce regular assessments to guide EU policymaking, reduce uncertainties and better project future trends.
- Collect results and recommendations from EU research programmes and incorporate them in a consolidated and comprehensive manner into the policy process.
- Establish an Arctic focus area for the remaining period of the Horizon 2020 work programme to increase Arctic research engagement.
- Support a thorough assessment with Arctic partners that identifies gaps or weaknesses in the current knowledge base that need to be addressed to ensure good stewardship in the region. In this regard better alignment between EU and national research programmes and objectives could be sought in order to create synergies, avoid duplication and reduce costs.
- Facilitate research activities to improve understanding of interactions between species, habitats and cumulative impacts, and of how Europe's various environmental policy objectives can best support the European Arctic region.
- Help explore the opportunities for using natural capital accounting approaches in analysing the links between economy and environment in the Arctic region.
- Foster data collection and sharing by industry operating in the region to strengthen the knowledge base and support safe, responsible and effective industry operation in the Arctic, and develop and coordinate cooperation between industry and the research and observation community.
- Continue working towards easing administrative burdens for researchers' cross-border cooperation, to enhance cooperation with the EU's Arctic neighbours. In this context, the EU might co-sign the Arctic Council agreement on Arctic scientific cooperation from 2017, and further related initiatives.

International cooperation and policy integration

The EU has adopted an integrated EU Arctic policy and a number of EU Member States — as well as close partners Norway and Iceland — have now developed national Arctic strategies and policy frameworks (see Box 2.1). In this context, the EU and its Member States can play a constructive role in the following ways:

- Continue to develop the EU Arctic policy in light of rapid changes and, together with EU Member States, devise appropriate long-term monitoring efforts and coherent policy responses.
- Continue efforts to mitigate climate change, push for transitions in energy, mobility and food systems and in implementing adaptation efforts in response to climate change, thereby limiting impact in the Arctic region.
- Work towards ensuring that not only EU environmental and safety standards are upheld for EU companies operating in the Arctic, but that any Arctic-specific environmental and technical standards, best practices and guidelines are applied, as these might differ from EU standards.

International cooperation and policy integration (cont.)

- Continue driving regional development forward, supporting infrastructure development through roads, rail, telecommunications and linking the European and Arctic energy grids; support the service, food and tourism sector and provide alternative growth and job opportunities to the extractive industries, in particular through the European structural and investment funds.
- Develop an Arctic business dialogue and engage with the Arctic Economic Council, in order to address the concerns of Arctic residents and operators in areas of European relevance or EU competency.
- Develop further information platforms with regards to Arctic-related activities, and better channel Arctic knowledge to the appropriate European Commission services, developing EU policies that will affect the region, thereby strengthening the integration of Arctic concerns into all policy domains. This includes conducting regulatory impact assessments and public consultations.
- Continue and strengthen the regular dialogue with Arctic environmental NGOs and indigenous peoples' organisations (circumpolar), e.g. through the annual Arctic indigenous peoples' dialogue. The Saami people and the Kalaallit (Greenland Inuit) are the only Arctic indigenous peoples living partly on the territory of the EU Member states Denmark, Finland and Sweden, and although the EU does not give preferential treatment to any groups, it has certain obligations regarding the rights of indigenous peoples that can be explored and developed.
- Strengthen cooperation between researchers, businesses and government, building public–private partnerships for multi-purpose infrastructure, to address the high costs of Arctic infrastructure.
- Develop a dialogue for better coordination of efforts with the relevant activities and assessments initiated by the Arctic Council in order to facilitate synergies and avoid duplication of efforts.

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Further reading

To further frame the European perspectives of a changing Arctic, the following reports, scientific assessments, EU policy documents and agreements form part of the knowledge base. Some are directly referenced in this report while others are not but provide context, insights and further information to Arctic discussions.

EEA products and sources

- *Climate change, impacts and vulnerability in Europe 2016*, EEA, 2017
- *The European Environment — state and outlook report, Global megatrends*, EEA, 2015
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- EU PolarNet, EU funded research infrastructure coordination, H2020
- Arctic Climate Change, Economy and Society (ACCESS), FP7-funded project, 2015
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- Ice2sea, EU FP7 funded project on sea level rise from Polar Regions and mountains, BAS, 2014
- International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT), FP7
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Arctic Council assessments and products

- Agreement on Enhancing International Arctic Scientific Cooperation, Arctic Council, 2017
- *Chemicals of Arctic Emerging Concern 2016*, AMAP, 2017
- *Snow Water Ice and Permafrost in the Arctic (SWIPA)*, AMAP, 2017
- *Adaptation Actions for a Changing Arctic (AACA) — Barents Area overview*, AMAP, 2017
- *State of the Arctic marine biodiversity*, CAFF, 2017
- *Temporal Trends In Persistent Organic Pollutants in the Arctic*, AMAP, 2016
- *The Arctic Resilience Report (final report)*, Stockholm Environment Institute, 2016
- Circumpolar Biodiversity Monitoring Programme, CAFF, 2015
- *Human Health in the Arctic*, AMAP, 2015
- *Adaptation Actions for a Changing Arctic (AACA), Draft report*, Arctic Council, 2015
- *Framework for a Pan-Arctic Network of Marine Protected Areas (MPAs)*, PAME, 2015
- *Framework for Action on Enhanced Black Carbon and Methane Emissions Reductions*, Arctic Council, 2015
- *Black carbon and tropospheric ozone and methane*, AMAP, 2015
- *Assessments of human health, trends in POPs and radioactivity in the Arctic*, AMAP 2015
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- Joint Statement, Arctic Science Ministerial, 28 September 2016, Washington, DC, USA
- Arctic Observing Summit 2016 — Conference Statement
- Ship Data, Northern Sea Route Information Office, 2015
- The International Polar Year (March 2007 to March 2009)
- Integrating Arctic Research — a Roadmap for the Future, Third International Conference on Arctic Research Planning (ICARP), 2015
- *Environmental Security in the Arctic Ocean*, NATO Science for Peace and Security Series C: Environmental Security, Springer, 2013
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