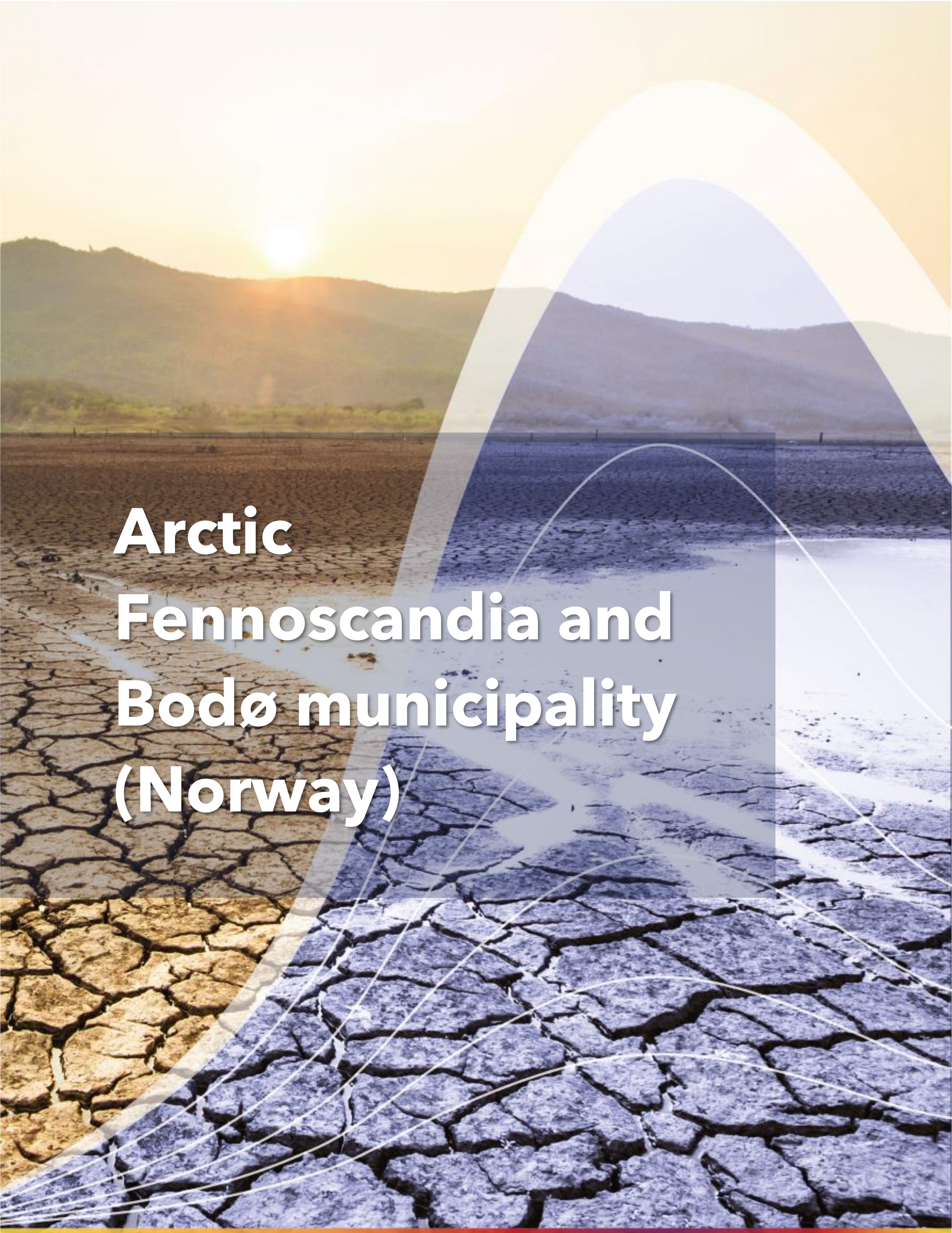
Arctic Fennoscandia and Bodø municipality (Norway)



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D4.1 Four review reports on key overshoot adaptation challenges in Iconic Regions and Cities: Arctic Fennoscandia and Bodø municipality (Norway)

Deliverable lead beneficiary: NRI
Authors: Annika E. Nilsson and Amsale Kassahun Temesgen (Arctic Fennoscandia);

Internal Technical Auditor	Name (Beneficiary short name)	Date of approval
Task leader	Annika E. Nilsson (NRI)	18.08.2022
WP leaders	Tiago Capela Lourenço (FC.ID) Annika E. Nilsson (NRI)	30.08.2022
Coordinator	Inga Menke (CA)	31.08.2022
Project Office	Sophie Rau (AI)	31.08.2022

Abstract:

Impacts of overshooting the Paris Agreement temperature thresholds will materialise globally but be particularly consequential for vulnerable regions. This report represents the initial stocktaking of overshoot adaptation challenges in one of the four Iconic Regions and Cities in focus for PROVIDE: Arctic Fennoscandia, with a focus on Bodø, Norway

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Glossary

Unless otherwise stated, the terminology in the report follows conventions developed by the IPCC WGII.

CONCEPT	DESCRIPTION
Adaptation challenges	Factors that make it harder to plan and implement adaptation actions.
Adaptation opportunities	Factors that make it easier to plan and implement adaptation actions, which expand adaptation options, or that provide ancillary co-benefits.
Adaptive capacity	The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
Ecosystem service	Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food, fibre, or fish, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, *livelihoods,* service provision, *ecosystems,* and environmental resources.
Overshoot	Pathways that first exceed a specified global warming level (usually 1.5°C, by more than 0.1°C), and then return to or below that level again before the end of a specified period of time (e.g., before 2100). Sometimes the magnitude and likelihood of the overshoot is also characterized. The overshoot duration can vary from at least one decade up to several decades.
Risk	The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change.
Tipping point	A level of change in system properties beyond which a system reorganizes, often abruptly, and does not return to the initial state even if the drivers of the change are abated.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Executive Summary

The 1.5°C Paris Agreement long-term temperature goal sets ambitions for global climate action to avoid the most devastating impacts of climate change. However, under current emissions trajectories, overshooting 1.5°C is a distinct possibility.

Even if we only temporarily exceed 1.5°C in the near term, we could still cross climate thresholds in ways that would severely limit our adaptation options. This would impact people and places around the world, but nowhere will this be felt more than in vulnerable regions.

To date, adaptation and urban planning do not routinely consider the implications of temporary overshoot of 1.5°C and what this would mean for sea level rise, extreme heat, extreme weather events, flooding and their impacts locally or for whole regions. To bridge this gap, the PROVIDE project is undertaking research on temperature overshoot scenarios and their expected impacts, so we can better understand under which conditions these impacts can be avoided.

This report looks at adaptation challenges in four iconic case study regions and cities:

- Arctic Fennoscandia, with a focus on Bodø, Norway.
- the Iberian Mediterranean, with a focus on the Lisbon Metropolitan Area.
- the Upper Indus Basin, with a focus on Islamabad.
- The Bahamas, with a focus on Nassau.

The findings are based on the review of relevant literature and stakeholder workshops undertaken by in-region experts, along with analyses of the structural profile of the urban environments in focus.

The four regions are very different, both in climatic and socioeconomic settings, but all are experiencing the consequences of climate change, including risks connected to more frequent and more serious severe weather events. Examples range from deadly heatwaves, hot and dry summer with forest fires, and extreme precipitation events that lead to flooding and increased risk for landslides (and avalanches). Whole ecosystems are also changing and could eventually vanish in response to shifts in the climate, including snow and ice habitats, agroforestry, and coral reefs. In the cities in focus, the built environment has often reduced the capacity of the natural environment to buffer the impacts of climate change, including intensive precipitation and extreme heat.

A common feature for all iconic regions – despite their differences – is that impacts from a changing climate are exacerbated by socio-economic factors, such as inequalities and lack of financial and human capital. Furthermore, pressures from urbanisation and migration makes adaptation more challenging. Lack of adequate adaptation governance and incentives is another common feature. These social factors affect adaptive capacity and thus create “soft” limits of adaptation.

There are also significant similarities between the adaptation challenges faced by the iconic cities. In all four cities, vulnerability to various climatic risks have increased because of anthropogenic activity, such as the urbanization of coastal areas, construction leading to discontinuity of green-blue structures, and the intensity of the built-up space. All four places have possibilities to address their respective climatic risks, but they also face challenges related to a high degree of private land ownership along with governance regimes without sufficient coherence for the needs related to climate adaptation and mitigation.

Arctic Fennoscandia and Bodø Municipality, Norway

The circumpolar Arctic is warming three times as fast as the global average. While the rate of warming varies across the regions, Arctic Fennoscandia is facing very rapid warming with shorter and more unpredictable winters as well as increasing precipitation. The long-term implications for subarctic ecosystems are severe and affect all the services that they provide in terms of food, materials, and health.

Key climate hazards and adaptation challenges:

- Increased precipitation and runoff.
- Warmer and drier summers, followed by the increased frequency of forest fires.
- Changing marine ecosystems with impacts on fisheries.
- Multiple pressures on the landscape and increasing competition for land, where reindeer herding is particularly vulnerable.
- New pathogens and diseases.

Local and regional impacts of climate change have the potential to affect national economic interests (forestry and fisheries), but stakeholders also highlight non-economic losses related to culture and wellbeing, such the loss of winter leisure activities.

In general, adaptive capacity is high and some adaptation efforts are underway but there are concerns about lack of awareness, lack of appropriate incentives and directives, and lack of action. Participants in the regional stakeholder workshop also raised concerns that the pace of change could challenge the capacity for both funding and innovation.

While web-based tools are available to access locally relevant information about climate impacts, there is a need for more knowledge support for adaptation, especially at the local level. The major policy instrument for adaptation is spatial planning, with specific local and regional responsibilities.

Adaptation must account for multiple pressures, including expansion of renewable energy production and mining, and conflicting interests. Limits of adaptation are often shaped by a combination of biophysical and social factors.

The analysis of urban spatial structure has focused on the city of Bodø, Norway. Bodø is a small and compact city surrounded by coast, high mountains, and forests. It has a multifunctional built-up centre, and peripheral residential areas with a suburban structure. Bodø is planning a new urban quarter on the former grounds of a military airport, which will radically change the structure of the town and create opportunities for sustainable and climate-resistant development.

As of today, the city's green space is very fragmented and mostly private, but it could play a big role in mitigating potential risks, for example, flooding from extreme levels of precipitation. The creation of strong green-blue corridors could play an important role in buffering the flow of water and help its infiltration into the ground, but the fragmentation of available spaces makes this a complex task.

1. Introduction

1.1. The PROVIDE project

Overshooting the Paris Agreement temperature thresholds is a distinct possibility. Potential impacts would be global in scope, with consequences which may be particularly severe where changes are abrupt, irreversible, or adaptation limits are exceeded. The aim of the EU-funded project, *Paris Agreement Overshooting – Reversibility, Climate Impacts and Adaptation Needs* (PROVIDE), is to create climate services that incorporate comprehensive information on impacts under overshoot pathways from the global to the regional and local urban level, directly feeding into adaptation action. This includes:

- Producing global multi-scenario, multisectoral climate information that integrates and quantifies impacts across scales.
- Providing comprehensive risk assessments of overshooting by assessing climate system uncertainties and feedbacks, and the potential (ir)reversibility of climate impacts.
- Co-developing a generalizable overshoot proofing methodology for adaptation strategies to enhance adaptation action in response to overshoot risks.
- Identifying and prioritizing overshoot adaptation needs in four highly complementary case study regions.
- Integrating the project outcomes into a PROVIDE Climate Service Dashboard, designed to complement established climate service platforms.
- Interacting and collaborating with a wide variety of stakeholders, to ensure usability and wide dissemination of project results and outputs.

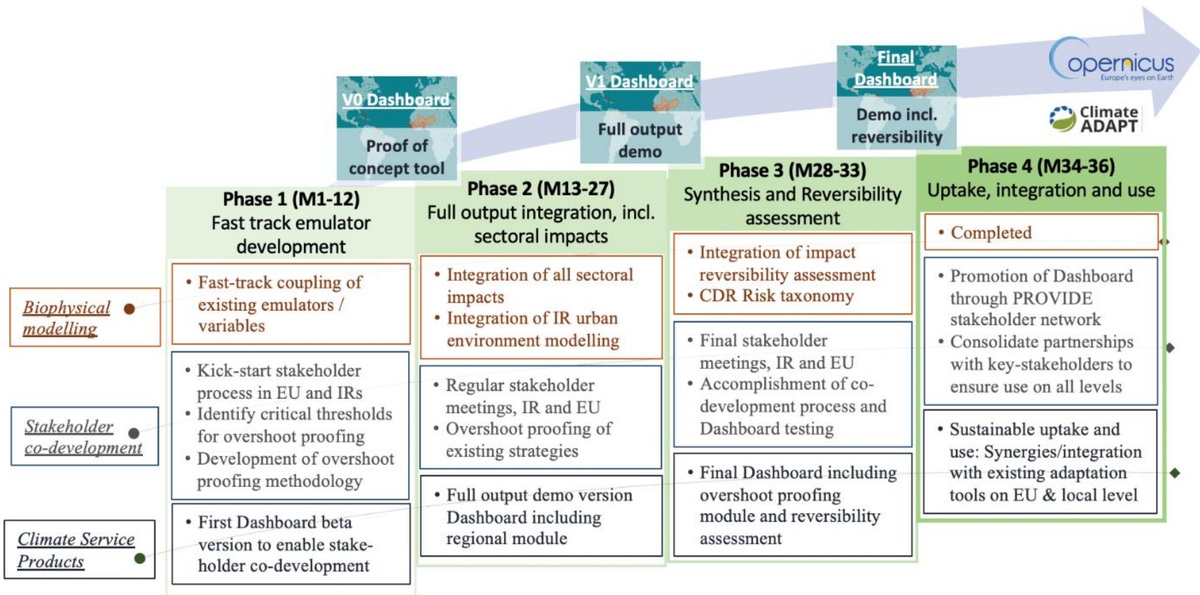

Figure 1.1. The PROVIDE project at a glance.

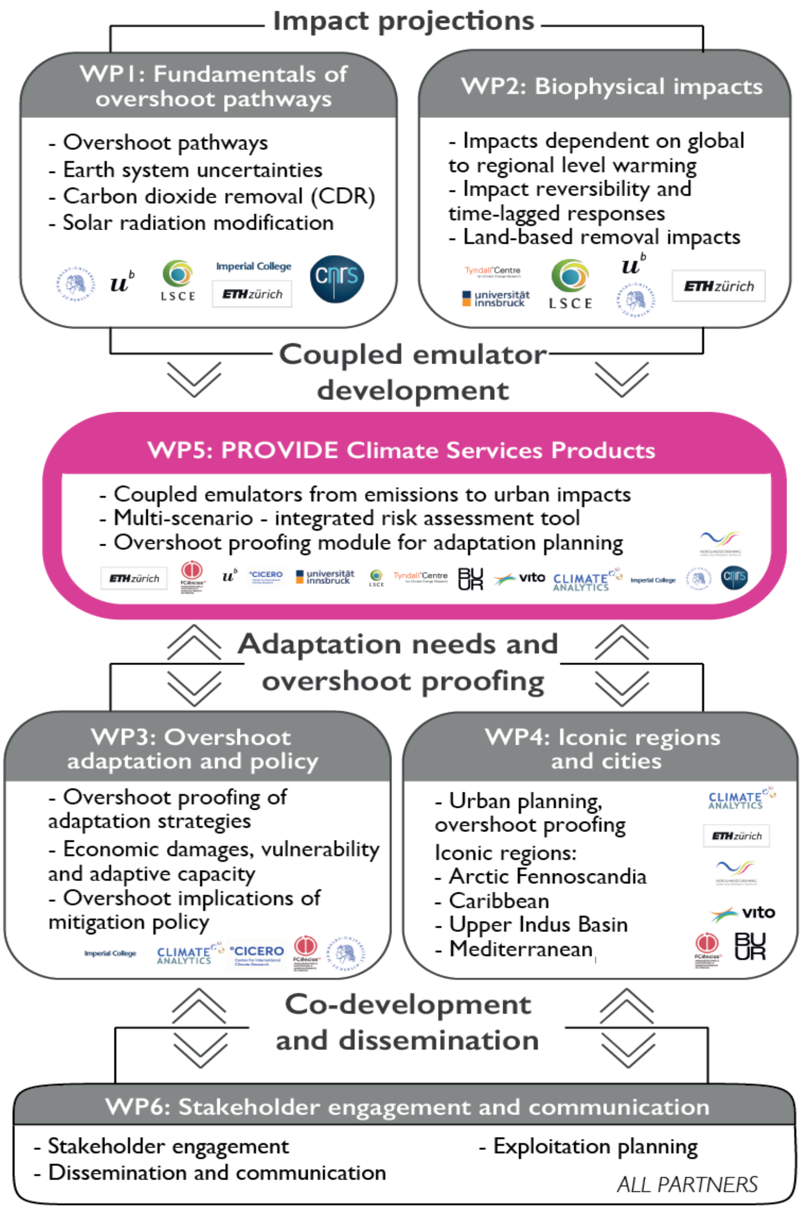

Figure 1.2. PROVIDE is organized in interlinked work packages.

1.2. Iconic Regions and Iconic Cities (WP4)

PROVIDE assesses regional and local impacts of overshoot pathways and the required adaptation responses in four Iconic Regions (IR), including a focus on selected urban environments within those regions. These regions and cities are places where physical risks overlay with specific socio-economic vulnerabilities. The Iconic Cities (IC) were selected to serve as places where the PROVIDE Overshoot Proofing Methodology can be co-developed with local and regional stakeholders. They will provide entry-points for raising awareness about the need for enhanced adaptation action under overshoot scenarios and offer a practical testbed for generalisable urban planning approaches.

Figure 1.3. Region in focus for PROVIDE.

The regions and cities in focus for PROVIDE are:

1. Arctic Fennoscandia, with a focus on Bodø, Nordland County, Norway.
2. Iberian Mediterranean, with a focus on the Lisbon Metropolitan Area, Portugal.
3. Upper Indus Basin, with a focus on Islamabad, Pakistan.
4. The Bahamas, with a focus on Nassau.

The IRs span over diverse climate zones, different environments, and different social and cultural contexts. They thus represent different adaptation challenges. Nevertheless, some conclusions are relevant across the regions, which will be particularly important for developing a generalizable overshoot proofing methodology and a Climate Services Dashboard that is credible and useful in a wide range of contexts.

2. Arctic Fennoscandia and Bodø municipality, Norway

Lead author: Annika E. Nilsson, Nordland Research Institute

Contributing authors: Amsale Kassahun Temesgen, Nordland Research Institute and Miechel De Paep, BUUR Part of Sweco

2.1. Introduction to Arctic Fennoscandia

Arctic Fennoscandia is here defined as the northernmost counties of Norway (Troms and Finnmark,[1] and Nordland), Sweden (Norrbotten and Västerbotten) and Finland (Lapland). In the west, northern Norway faces the Norwegian Sea and in the north the Barents Sea. In the east both Norway and Finland share borders with Russia. Despite the high latitude, the climate is sub-Arctic, with mean annual temperatures ranging from -2°C inland to up to +6°C along the west coast (1960-2015) (Eide et al. 2017). The seasons are distinct with snow and ice in the winters. Sunny summer days often reach +20°C, but occasionally feature temperatures close to +30°C.

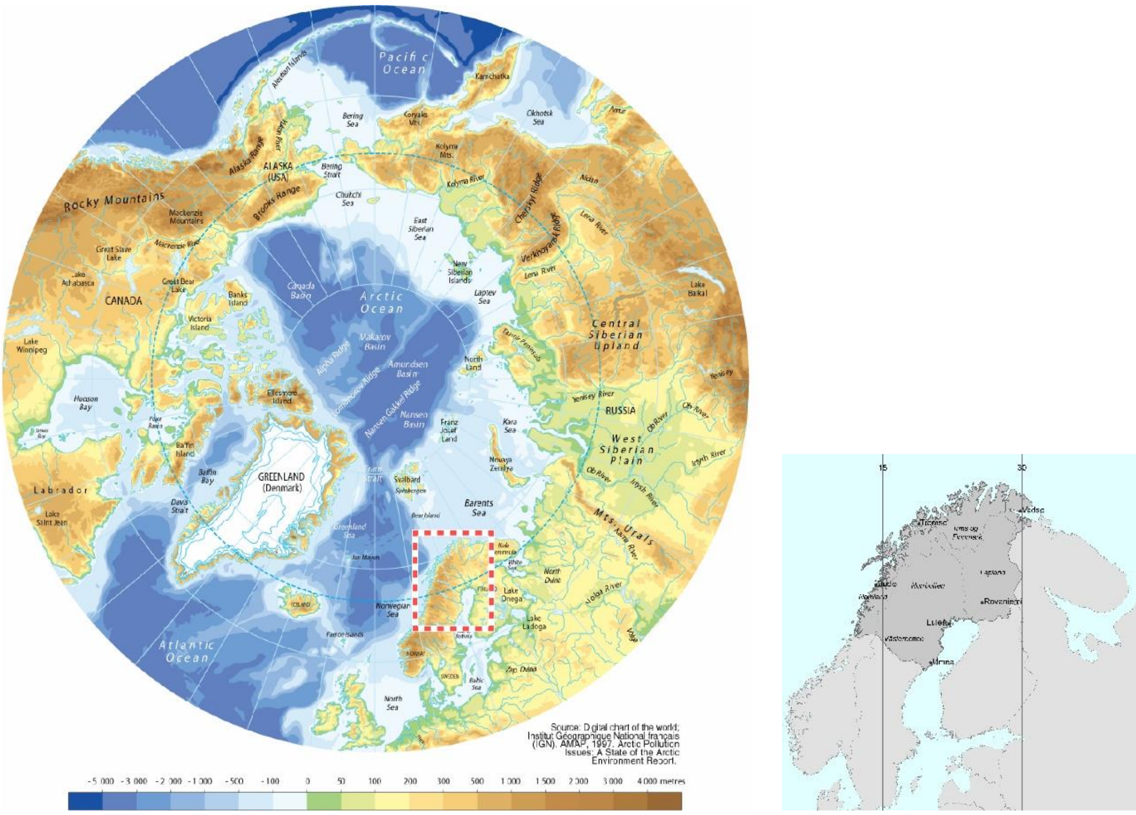

Figure 2.1 The circumpolar north (left) and Arctic Fennoscandia with the northernmost counties of Norway, Sweden and Finland (right). Based on maps produced by AMAP and barentsinfo.org.

2.1.1. Landscapes, ecosystem services, and natural resources

The region's landscape is shaped by the last glaciation with deep fjords along the western and northern coasts, and the inland rich in lakes and wetlands. The western areas are mountainous and include mountain glaciers, which have been receding in recent years

[1] The two counties of Troms and Finnmark were merged in 2020. Earlier statistics list data separately.

(Benestad et al. 2017). The terrestrial biomes include tundra in the inland north but is otherwise dominated by boreal forest. For a detailed description of the region's physical and ecosystem features, see Eide et al. (2017).

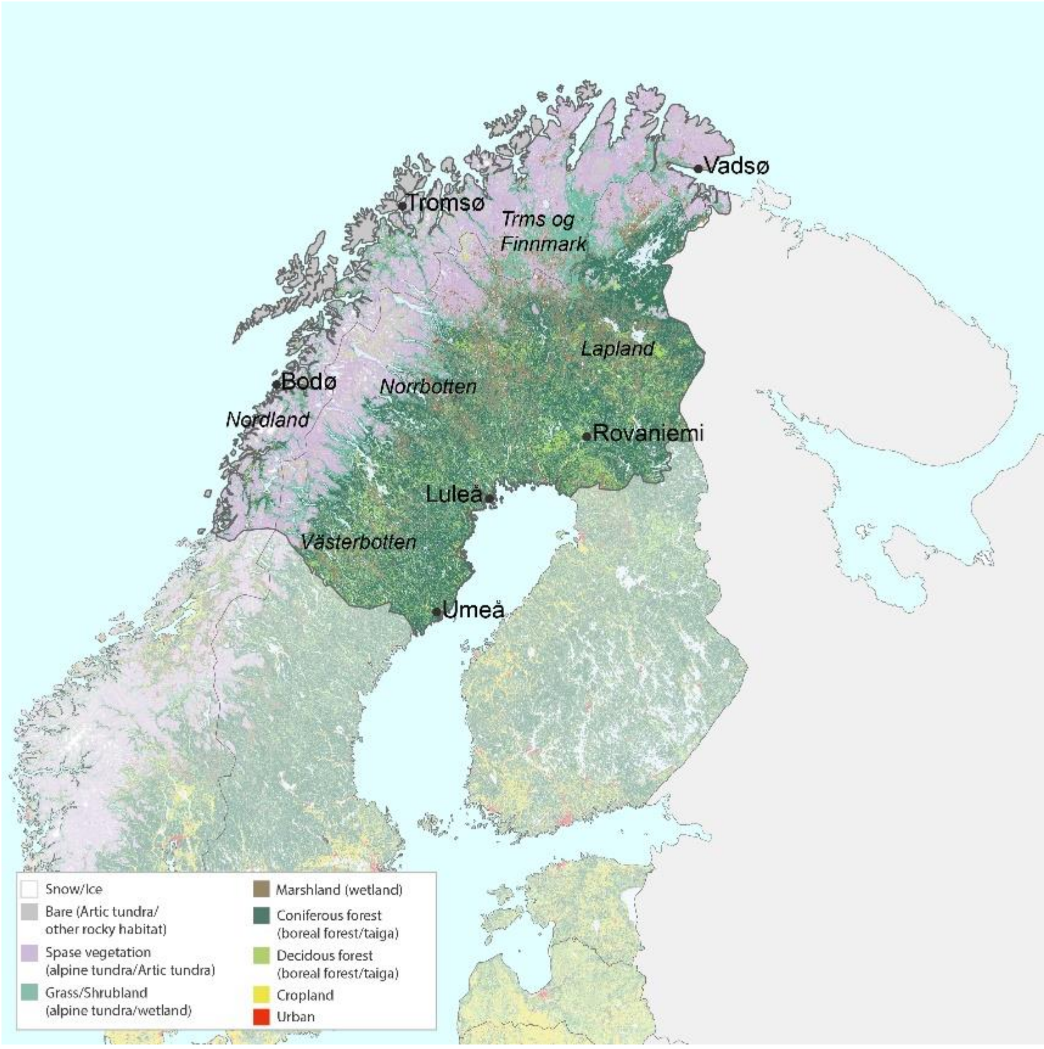

Figure 2.2 Ecozones in Arctic Fennoscandia. Reproduced from (AMAP 2017).

The region's marine ecosystems are highly productive because of the interplay of nutrients and light in the marginal ice zone. They support globally important fisheries, with the EU as a major importer (Koivurova et al. 2021; Constable et al. 2022).

Other ecosystem services include the provision of raw material for the forestry industry. Forests also provide gracing land for reindeer and moose, where reindeer herding is a cornerstone in Sámi culture. Berries, mushrooms, fish, and game are other important ecosystem services. Food provisioning is closely linked to cultural services (well-being, identity, knowledge) not only for the Sámi but for many other people in the region. Agriculture accounts for only a small part of economic activities, where the most important ecosystem service is grass for animal feed. Grassland and forage cropping support dairy farming and sheep production (Eide et al. 2017). In Norway, Nordland, Troms, and Finnmark together account for about 13% of all grass and about 6% of the national meat production (Asheim and Hegrenes 2006). There is also some cultivation of potatoes and vegetables.

Many of the landscapes of Arctic Fennoscandia are attractive for tourists and important for a growing tourism industry, where ski tourism is highly dependent on climate conditions that affect the lengths of the snow season (Finnish Ministry of Agriculture and Forestry 2014).

Regulatory ecosystem services include carbon storage and water purification (Nordic Council of Ministers et al. 2012). A scoping study to assess the economic importance of Arctic ecosystems concluded that health values of ecosystem services are often overlooked as are social and cultural attributes (CAFF 2015).

The landscapes of Arctic Fennoscandia provide energy resources, including hydropower from damming most of the large rivers during the 1900s. In recent decades, wind power has expanded and now includes large wind power parks, with plans for further expansion. The region is rich in economically valuable ores that have supported a large mining and steel industry. The region has been targeted by the European Union as important for the future supply of critical minerals for the European market and for the transition to non-fossil energy systems (European Commission 2020, see also Glomsrød et al. 2021b). Oil and gas production is important for Norway, where the northward expansion of offshore drilling has been facilitated by declining sea ice but is controversial as it is perceived as a threat to fisheries and vulnerable ecosystems and at odds with reducing the production of fossil fuels (Glomsrød et al. 2021b).

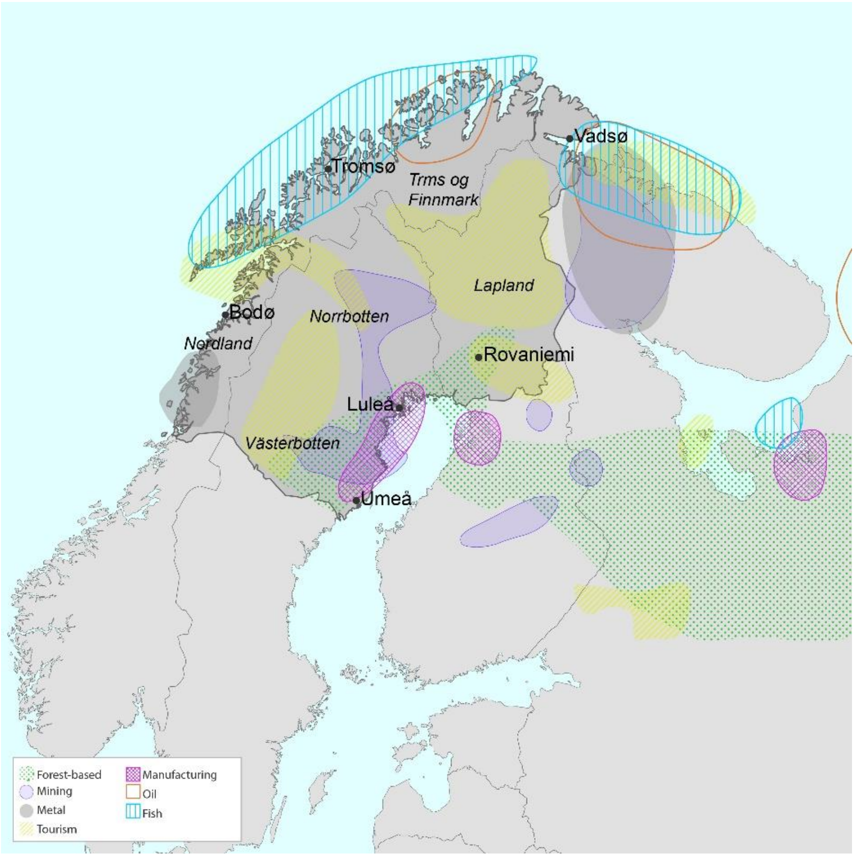

Figure 2.3 Overview of industries in the Barents area. Reproduced from AMAP (2017).

The national importance of the region's industry has led to relatively well-developed infrastructure compared to many other parts of the Arctic. The railroads, roads, ports, and airports are also important for the tourism industry and facilitate the further expansion of extractive industries.

The expansion of industrial activities has led to increasing land use conflicts among competing interests, where the extraction of resources and energy compete for land with reindeer herding, preservation of biodiversity and iconic landscapes, the demand for undisturbed recreational areas, and defence-related interests. In a ruling by the Supreme Court of Norway, wind power in a site for reindeer herding was stopped due to its negative impact on Sámi reindeer herding culture (Supreme Court of Norway 2021).

2.1.2. Population

Compared to other parts of Norway, Sweden and Finland, Arctic Fennoscandia is sparsely populated but nevertheless feature several medium-sized cities. The current demography is shaped by in-migration of early settlers as well as by people who moved north as the region was industrialized in the 20th century. The Indigenous Sámi and other early settlers are now in minority, but with relatively large share of the population in Finnmark (Heleniak 2014). The relationships between minority peoples and majority society have been shaped by a long history of interaction as well as coercive nationalization policies of integration into majority society (Eide et al. 2017). The industrial development and focus on fisheries have led to a male-dominated labour market, which is reflected in a higher proportion of men to women than the national averages (Heleniak 2014).

Since the latter part of the 20th century, mechanization of major industries has led to fewer jobs, followed by outmigration and urbanization as many young people leave for education and jobs elsewhere. Consequently, there are fewer and older people inland and in smaller communities, while some of the region's cities have benefitted, especially those that provide higher education and a more urban lifestyle. Overall, life expectancy is high in a global perspective and infant mortality low. More than a fourth of the population have completed tertiary education. Disposable incomes are more similar to the national indicators for Norway, Sweden and Finland than in some other Arctic region (Duhaime et al. 2021).

Even with attempts at diversifying the region's economy, its development and local population dynamics are tied to extractive industries with their boom-and-bust cycles. In Norway, the oil and gas industry has played an important role for some municipalities that serve as hubs for prospecting and production in the Barents Sea (Loe and Kelman 2016; van Bets et al. 2016). In Sweden and Finland, mining and related industry have shaped some settlement patterns. The expectation of increasing demand for renewable energy and metals is currently driving a new wave of demand for skilled labour to work in mines, the construction of battery factories, and with new fossil-free steel production.

Table 2.1. Selected social and economic indicator for Arctic Fennoscandia based on ECONOR 2020 (Duhaime et al. 2021).

Region	Population	Population growth 2012-2018	% females*	Life expectancy	Infant mortality per 1000 live births	Tertiary education	Disposable income USD-PPP
Finnmark	76167	0.5	49.3	79.8	5.0	28.0	24323
Troms	166499	0.8	49.1	81.7	1.8	32.9	25375
Nordland	243335	0.3	49.3	81.1	3.0	26.8	23536
Norrbotten	250497	0.1	48.8	81.1	2.9	27.8	22889
Västerbotten	270154	0.6	49.3	82.0	2.7	26.5	21717
Lapland	178522	-0.4	50.0	80.5	2.9	26.7	22314

2.1.3. Governance

Governance follows the same pattern as in the rest of the Fennoscandian countries, with a combination of central governments in the capitals further south (Oslo, Stockholm, and Helsinki respectively), regional governance structures, and municipal governments. The regional structures include the national governments' regional representation as well as regionally elected governments, with different areas of responsibility. Local governments have a relatively strong control over local development and responsibility for land-use planning (Eide et al. 2017).

Norway, Sweden, and Finland can be characterized as Nordic welfare democracies but also have their own national features based on the importance of different economic sectors. Since, the end of World War II, peace has reigned in the region and crossing borders between Finland, Sweden and Norway has not even required a passport. However, the Covid-19 pandemic made the borders very real, due to heavy restrictions on border crossings, which have affected job commuting and places that have economies based on cross-border shopping. The borders to Russia are tightly controlled.

The region is of military strategic importance due to its closeness to Russia. In recent years, it has witnessed increasing military posturing from both Russia and the West. Norway is part of NATO, while Sweden and Finland collaborate with NATO, including joint exercises, and have applied for NATO membership in May 2022.

2.2. Introduction to Bodø municipality, Nordland County, Norway

Nordland county is 500 km long and stretches from Trøndelag county in the south to Troms and Finnmark county in the north. It borders Sweden in the east and the Norwegian Sea in the west. The county is divided in five different regions: Helgeland, Salten, Ofoten, Lofoten and Vesterålen (Thorsnæs 2022).

Bodø municipality is the regional capital in Salten with a population of 52,560 (Statistisk Sentralbyrå 2021). Bodø is Nordland's largest city in terms of population and the administrative centre of Nordland county (Bodø kommune, 2018). It has a steady population growth, and it is expected that the population size will grow to 56,601 in 2030 and to 60,281 in 2040 (ibid). About 90% of the population lives in densely populated areas while 2.3% live on farms.

Bodø municipality covers 4,827 km^2 (including territorial waters). The land area is about 1,395 km^2 including islands and the mainland. Land area is divided as follows: forest 40%, agriculture 2%, fresh water 6%, city and built-up area 1%, industry areas 0.10%, and open/uninhabited land 46% (Bodø kommune, 2018).

Bodø is a coastal municipality with an 802 km long coastal line (ibid). As described by Bodø municipality, "[T]he nature is varied from coastal areas to high mountain peaks" (ibid, p.14). The municipality has two national parks and 18 other protected areas with a range of other conservation values. One such area is Saltstraumen, which is the world's strongest tidal current.

Bodø municipality has won the nomination to be the European cultural capital in 2024 (Bodø 2024 2021). The municipality has heavily invested in cultural activities the past few years resulting in a significant growth of the cultural sector.

2.3. Climate risks

2.3.1. Expected climatic changes in Arctic Fennoscandia

The Arctic climate is changing rapidly with the increase in annual mean surface temperatures three times higher than the global average between 1971 and 2019. Impacts are apparent with sea ice loss and melting glaciers, while long-lasting spells of extreme cold have almost disappeared. The changing climate has fundamental implications for ecosystems, with consequences for carbon cycling and biodiversity. Climate models project that annual mean surface temperatures in the Arctic may rise to 3.3-10^{o}C by 2100, depending on future emissions. Most projections point to a mostly ice-free Arctic in September (the month of the sea-ice minimum) before 2050 (for reviews, see AMAP 2021a; Constable et al. 2022; Meredith et al. In press).

Within the circumpolar Arctic, there are large regional variations. In Arctic Fennoscandia, temperature increases are projected to be larger in the north-eastern part with 5-5.5°C by 2100 (RCP4.5) and smallest along the Norwegian west coast with 2.5-3.5°C, as illustrated by the climate scenario tool provided by the Swedish Meteorological and Hydrological Institute (SMHI 2021). The warming is most pronounced in wintertime. At the end of the century, most of Arctic Fennoscandia may no longer feature a subarctic climate and typical environments may only be present in smaller areas at high altitude (Bednar-Friedl et al. 2022, p. figure 2.4). By 2040, most of the region is likely to experience temperature increases of 1.5-2.5°C.

Precipitation will increase, especially along the Norwegian west coast, and more is expected to fall as rain in seasons when snowfall has been the normal. Especially problematic is wintertime rain on top of snow, which can create a layer of ice that grazing animals have difficulties getting through (locked pastures) (Risvoll and Hovelsrud 2016). Another concern is that the intensity of precipitation is expected to increase (Benestad et al. 2017).

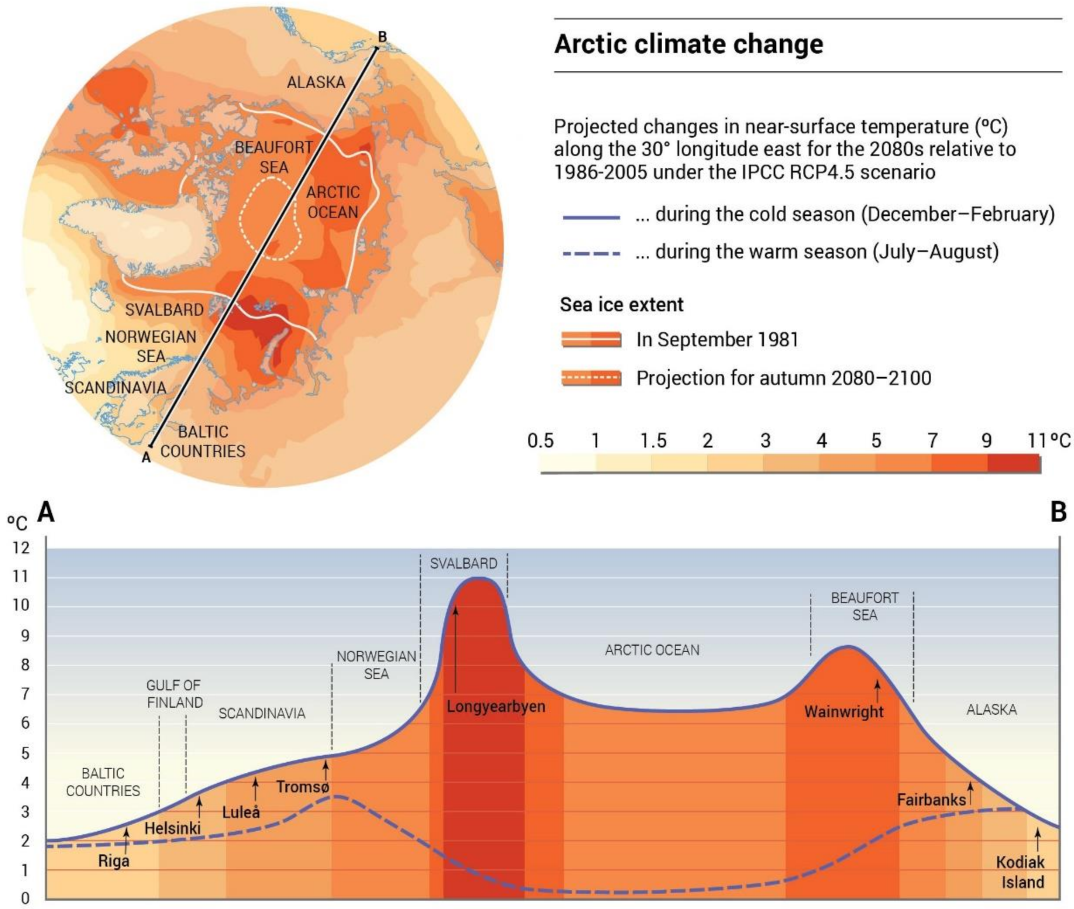

Figure 2.4 Projected changes in Arctic sea-surface temperatures. Reproduced from https://www.grida.no/resources/13335. Cartographers: Philippe Rekacewicz and Nieves Lopez Izquierdo.

2.3.2. Weather-related hazards – regionally and locally

Many weather-related hazards in Arctic Fennoscandia are connected to low-pressure systems accompanied by strong winds, high waves, and heavy precipitation (as rain or snow). The consequences include difficult traffic conditions as well as threats to physical infrastructure, including risks for power outages, which has prompted demands on upgrading the distributions network (Finnish Ministry of Agriculture and Forestry 2014). Heavy precipitation also creates conditions that increase the likelihood of avalanches and rockslides (Benestad et al. 2017) and increase the risk for the breaching of dams that are used in mining operations to store polluted water (Finnish Ministry of Agriculture and Forestry 2014).

Changes in the frequency and intensity of low-pressure systems are difficult to predict, but a slight increase in the frequency of deep cyclones over the Barents Sea is consistent with a northward shift and increase in storm activity in the Arctic in recent decades (Benestad et al. 2017). A special type of extreme low-pressure systems (polar lows) with sudden hurricane force wind occurs in the Norwegian and Barents Sea, predominantly in the cold season, and pose a threat to shipping, fishing vessels, coastal infrastructure, and offshore activities.

With many rivers and large seasonal variation in runoff, flooding is relatively common. It becomes a hazard when snowmelt and heavy rainfall coincide and/or when the breakup of ice in rivers lead to ice dams. The likelihood of precipitation causing flooding is exacerbated when the ground is frozen or when artificial surfaces hinder water from penetrating the ground.

In summers, longer warm and dry periods are expected, including conditions where summer thunderstorms can start forest fires. Climate change is expected to increase not only the length of the fire season but also the number of lightning events. The risks can be further compounded by pest damage to the forest creating a high fuel load (AMAP 2021b). Forest fires can pose a direct hazard to people and infrastructure but also significant economic losses for forest owners. They are an important source of black carbon to the Arctic atmosphere (AMAP 2021b).

2.3.3. Other climate-related changes of societal significance

A warmer climate will have long-term effects of ecosystems and human activities. For example, the snow season will become substantially shorter. Over the past 30-40 years, the length of the snow season has declined by 2-5 days per decade, mostly because of earlier snowmelt (Benestad et al. 2017). Declining snow cover may accelerate the extinction of vascular plants, mosses, and lichen (Constable et al. 2022). It also affects the hydrological cycle and hydropower, where the flow is likely to become more even over the year. It furthermore leads to a shorter season for winter tourism.

The warming leads to a longer growing season, with an additional 10-30 days, with the most impact along the North Atlantic and Barents Sea coast. This will affect both natural ecosystems and the potential for horticulture and agriculture in a region where temperatures and frost-free days have been limiting factors. For natural ecosystem, warming will lead to a northward shift of the forest at the expense of tundra biomes, but changes in specific places will also depend on precipitation and soil moisture.

In a circumpolar perspective, warming permafrost is a major concern for the integrity of infrastructure, hydrology, and emissions of greenhouse gases that have previously been held captive in the ground. Arctic Fennoscandia features some areas of discontinuous permafrost that are very sensitive to changes in climate, with consequences for hydrology and biodiversity.

Figure 2.5 Warming permafrost affects carbon storage and hydrology. At Stordalsmyren, the discontinuous permafrost is monitored by researchers at the nearby Abisko Research Station. Photo: A. Nilsson

A warmer climate creates more favourable conditions for animals that have previously been limited by cold winters. These include insect pests that affect forestry (such as bark beetles) and animals that carry disease agents, such as tick-borne encephalitis, Lyme disease, and tularaemia.

The expected increase in warm days during the summer may not appear as an imminent concern in a region where many people welcome the warmth. However, prolonged warm periods create challenges to maintain reasonable indoor temperatures in hospitals and facilities for elderly care, with increasing needs for air conditioning.

The marine environment is responding to the changing climate and declining sea ice with changes in timing of the spring bloom, altered food web dynamics, and the appearance of more southern species, including invasive species. Sea birds that rely on the marine food web are especially sensitive to the timing of the spring bloom and many marine mammals are sensitive to changes in the sea ice. Ocean acidification is an additional concern. Cascading and interacting effects of climate change impacts may affect access to and productivity of future fisheries (Constable et al. 2022).

2.3.4. Exposures to climate change and related hazards

2.3.4.1. A range of activities that depend on weather conditions

Arctic Fennoscandia features a variety of economic activities that are exposed to climate and weather-related hazards, including those that directly dependent on ecosystem services, such as herding, fisheries and forestry, as well as nationally important extractive industries and energy production. The region's infrastructure is relatively well developed, but also highly exposed to weather-related hazards. Table 2.2 summarizes some of the direct and indirect impacts on of climate change and provides examples of implications related to adaptation. In several sectors, adaptation actions are already underway as reactions to observed changes, but awareness and capacity varies (Hovelsrud and Amundsen 2017).

Table 2.2. Examples of potential impacts of climate change on different activities in Arctic Fennoscandia. The examples as primarily based on the Arctic Council assessment Adaptation Actions in a Changing Arctic. Perspectives from the Barents Area (Hovelsrud and Amundsen 2017; Turunen et al. 2017). See also Table CCP6.6 in IPCC WGII (Constable et al. 2022).

ACTIVITY	DIRECT IMPACTS	INDIRECT IMPACTS	IMPLICATIONS FOR ADAPTATION
ACTIVITIES THAT DEPEND ON ECOSYSTEM SERVICES			
Herding, hunting and gathering	Decreasing snow cover and changing snow quality Increasing frequency of rain-on-snow events	Changing vegetation (less herbs more brush) Lack of access to adequate forage	Reindeer herding becomes more challenging, with impacts of Sámi traditional livelihoods
Agriculture	Longer growing season Wetter conditions		Increasing potential for local agriculture and horticulture. Need for drainage
Forestry	Longer growing season Less severe winters but with potential increase of high winds Shorter season of frozen ground Warmer and drier summers	Potential for higher productivity Increased risk for storm damage and insect pests Greater risk for damaged ground during harvesting Increased risk for forest fires	New demands on forest management New demands on preparedness and response in relation to storm damage and fires
Coastal fisheries	Warmer water Ocean acidification	"Atlantification" of the marine ecosystem as southern species move further north	New demands on fisheries management
Marine aquaculture	Warmer water Extreme temperatures Storms	Potential for parasites shifting range and increased risk for harmful algal blooms	
Freshwater fisheries	Changing ice season and warmer water	Changing water quality	
Tourism	Shorter snow season	Arctic tourism may have a competitive advantage compared to ski areas further south but may nevertheless need to adjust to a shorter season	Need to rethink business model to include more summer tourism
ACTIVITIES THAT DEPEND ON ABIOTIC SERVICES			
Hydrocarbon extraction	Declining sea ice Changing risk for icing	Changing conditions for shipping and offshore hydrocarbon activities	More offshore extraction and related shipping require more attention to pollution control and to search and rescue capacity

Hydropower	Shorter snow season Changes in the amounts and seasonality of precipitation		Potential for more even flow in hydropower dams Need for attention to dam safety
Wind power	Changing in weather patterns that affect winds		
Mining	Changing precipitation patterns		Need to reassess water management and dam safety New demand on climate proofing in environmental impact assessment
ACTIVITIES THAT DEPEND ON TECHNICAL SERVICES AND INFRASTRUCTURES			
Shipping	Declining sea ice Extreme winds	Longer shipping season	Increased need for preparedness and response to meet growing activities and extreme weather events
Road, railroads, and airports, energy supply	Increased risk for extreme precipitation events Warming permafrost	Increased risk for flooding, avalanches, and landslides. Increased risk for heavy snow loads	Need for risk assessments, preparedness and response to flooding, avalanches, and erosion events. Need for upgrading energy transmission infrastructure
Water and sanitation infrastructure	Extreme precipitation/overflow	Disease-causing agents	Need for re-dimensioning
Housing	Long warm spells more likely Changes in extreme winter conditions		Increasing need for cooling of buildings, especially in health and elderly care Need to assess structural integrity demands in relation to snow load
CROSSCUTTING CONCERNS			
Human health	More warm days Longer warm season More days with icy conditions	Risk for heat stress Increased risk for animal and water-borne pathogens Increased risk for slippery conditions causing falls and fractures	

A context of multiple drivers of change

The impacts of climate in Arctic Fennoscandia takes place in a context of multiple drivers of change and often constitute one of multiple pressures on ecosystems and activities (Finnish Ministry of Agriculture and Forestry 2014; Expertrådet för klimatanpassning 2022; Österlin et al. 2022). The drivers of change range from external factors, such as global demand for resources, to regional processes of change, such as shifts in the demographic structure. Many drivers of change are influenced by decisions that are taken elsewhere, in corporate board room or in political assemblies at national, EU, and international levels.

In participatory scenario exercises, local and regional actors have highlighted drivers of change that they consider relevant for shaping the local future in the Nordic Arctic (Nilsson et al. 2017a, b; Nilsson and Sarkki 2023). In addition to the impacts of climate change, common themes include expectations of market demand (natural resources and energy but also tourism), politics and power relations (especially local decision-making power and the lack thereof), demographic trends (especially out-migration), and technology (especially in relation to connectivity and remote operations). Less prominent in the local discussions but important in shaping the region's history and increasingly relevant at present due to conflicts between Russia and the west are geopolitical interests and related security concerns (Nilsson et al. 2019). The region's role in energy production combined with the transition away from fossil fuels is likely to become an important driver of change in the region (Nilsson et al. 2021). It takes place in a situation of increasing land-use conflicts and social tensions (Koivurova et al. 2015; Bay-Larsen et al. 2018; Beland Lindahl et al. 2018; Zachrisson and Beland Lindahl 2019), along with calls for more holistic impact assessment processes (Karvinen and Rantakallio 2019; Nilsson et al. 2021). Conflicts in relation to environmental protection are also becoming more common, for example in relation to water management and protection of biodiversity, including Natura 2000 sites. Reindeer herding requires extensive land for grazing but increasingly finds earlier grazing grounds disturbed by other activities in ways that also challenges adaptation to changing grazing conditions (Turunen et al. 2017; Fohringer et al. 2021; Österlin et al. 2022). An example is the situation facing the Sámi community Leavas whose reindeer migrate in the vicinity of the mining town Kiruna in inland Norrbotten and where more than a third of traditional grazing land has disappeared (Fohringer et al. 2021).

Figure 2.6 Adaptation to climate change takes place in a context of multiple pressures on the landscape, including the expansion of wind power. Photo: A. Nilsson

2.3.5. Climate-related risks in Bodø municipality

Expected climate-related changes in Bodø municipality include higher temperatures, sea level rise, more frequent extreme weather, and an increase in precipitation (Bodø Kommune 2018). Bodø municipality's Risk and vulnerability analysis outlines the following expected changes towards 2100 (ibid, p.14):

- A sea-level rise of 63 cm for Bodø/Skjerstad
- Return of storm surges:
    - 20 year – 276 cm
    - 200 year – 398 cm
    - 1000 year – 312 cm
- Change in yearly precipitation: 15-25% increase. The increase is highest in the winter (24%) and least in the summer (8%).
- Change in annual temperature: 2.0°-3.0°C increase.

Extreme weather is a part of life in Nordland. It is common to get warnings of storms and heavy precipitation. With climate change, more frequent extreme weather is expected, with more frequent strong winds due to the warmer weather in the Norwegian Sea, although wind-intensity is not expected to change. Bodø municipality's climate risk analysis expects "strong storms with up to full storm in the gusts, with a maximum of up to 45 meters per second in the centre of Bodø. The risks connected to strong winds vary with wind direction, wind strength, location, and a number of other local conditions. Combinations of strong winds and heavy precipitation are the largest the challenges for the municipality. Strong wind from southwest can squeeze water from the Norwegian Sea into the Vestfjord and generate storm surge in Bodø harbour" (Bodø Kommune 2018, p. 15). Another climate risk is storm surges (an increase in water levels including waves and flooding towards land in addition to the usual tide changes) that can coincide with tidal fluctuations and cause extensive flooding (ibid).

With increased precipitation, there is an increase in the frequency of landslides. A shorter winter season, increased precipitation, and an upward movement of the snow and treeline is a recipe for more frequent avalanches (ibid).

Most of the registered landslides in Bodø happen around the Misværfjord causing damages to buildings and human life. The road network that pass along the foot of mountains could also be at risk (Statens vegvesen, 2019). Moreover, potential landslide towards Skjerstadfjorden could create a tsunami with significant consequences for Bodø (ibid). If Bodø starts to attract more tourists in the skiing season, accidents in connection with avalanches may increase (ibid).

Quick clay is another source of risk , where quick clay landslides along watercourses could trigger landslides, especially in seasons with high precipitation and water levels (Statens Vegvesen 2019).

Figure 2.7 Icy sidewalk in Bodø a few days after a winter storm. Photo: A. Nilsson

2.4. Adaptive capacity

The literature on adaptive capacity includes a range of suggested determinants and indicators but without consensus on methods for assessments (Siders 2019). The IPCC defines adaptive capacity as "the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences." Working Group II has developed an analytical framework focusing on opportunities and constraints on adaptation. Opportunities are factors that make it easier to plan and implement adaptation actions, which expand adaptation options, or that provide ancillary co-benefits. Constraints are factors that make it harder to plan and implement adaptation actions (Klein et al. 2014).

In the literature on resilience in the Arctic, Kofinas et al. (2013) highlight the importance of natural capital, social capital, human capital, infrastructure, financial capital, knowledge assets and cultural capital for both adaptive and transformative capacity, a notion that was further elaborated in the 2016 Arctic Resilience Report (Nilsson et al. 2016). Other conceptual framings in the Arctic literature relate to vulnerability (Hovelsrud and Smit 2010), resilience (Arctic Council et al. 2016), and adaptation options (Hovelsrud and Amundsen 2017).

2.4.1. Regional assessment of adaptation opportunities and constraints

Using the IPCC framework and drawing on insights from literature, the following summary highlights important adaptation opportunities and constraints in Arctic Fennoscandia.

2.4.1.1. Adaptation opportunities

Awareness raising

A regional initiative to raise awareness and involve a broad group of stakeholders in adaptation was the Arctic Council assessment Adaptation Actions for a Changing Arctic that was finalized with an in-depth scientific report in 2017 (AMAP 2017). Also relevant is the Arctic Resilience Report (Arctic Council et al. 2016), which was followed up in the Arctic Council's Arctic Resilience Action Framework (Arctic Council 2017). Climate change has also been in focus for the Barents regional cooperation, specifically in its Action Plan on Climate Change, updated in October 2021 (The Barents Euro-Arctic Council 2021).

As in other parts of the Arctic, Arctic Fennoscandia features a general trend of increasing stakeholder participation research, especially in relation to Sámi reindeer herding. An example is collaboration between natural scientist and Sámi in mapping the local impact of climate change in locations that are critical for the reindeer (Rosqvist et al. 2021).

Capacity building

There is extensive research on climate change and adaptation in Arctic Fennoscandia (for review, see AMAP 2017) as well as sector-specific projects, e.g., focusing of forestry management (Keskitalo et al. 2016). Business-as-usual attitudes nevertheless dominate management practices (Andersson and Keskitalo 2018). Among coastal fishers in northern Norway, "facing whatever comes" is a common attitude and discrepancy between scientific understanding of climate change and perceptions based on experience may prevent the activation of adaptive capacity (Bay-Larsen and Hovelsrud 2017). For ocean fisheries, where fish stocks change their range in response to climate change, lack of knowledge is not necessarily the key concern but rather if management regimes and quota systems would allow for catching the new species (Tiller and Richards 2018). These examples suggest that data and research may not be the limiting factor but rather the social capital that would allow those most likely to be affected to actively engage with adaptation rather than carrying on as usual.

There is also a growing trend of Indigenous-led research and research with strong Indigenous participation, partly related to reindeer herding but also addressing the broader context of change in the region and its implications for adaptation. An example is a review of adaptation actions by Degteva et al. (2017). For reindeer herding, the activities of the International Centre for Reindeer Husbandry support reindeer herders across the circumpolar north and provides a network for exchanging knowledge that has historically been mainly local knowledge.

Tools

The tools for predicting future climate change at scales relevant for local and regional stakeholders have improved greatly, as have the interfaces for communicating the results of climate modelling. An example are web-based tools for reviewing likely changes in winter and summer temperatures, temperature extremes, zero crossing, days with extreme precipitation (SMHI 2021; Climateguide.fi). The weather services provide warning systems, for example for flooding and extreme warm weather.

National and regional agencies and organizations provide some support and guidance documents for municipalities. An example is the guidance to risk and vulnerability analysis available through the Nordland County website together with projections for changes in temperatures, precipitation, and future levels for storm surges in Nordland (County Governor of Nordland). In Sweden, the website "Klimatanpassningsportalen" serves as gateway to a multitude of resources as well as opportunities for networking (Klimatanpassning.se) and in Finland Climateguide.fi serves the same purpose. However, the Swedish Expert Council for Climate Adaptation has identified a need for further coordinated support from national agencies to the county level and from the county level to municipalities in providing and interpreting available information, motivated by an assessment that lack of adaptation action is still often connected to insufficient knowledge about methods and tools (Expertrådet för klimatanpassning 2022).

Policy

Arctic Fennoscandia is covered by Norwegian, Swedish, or Finnish national governance frameworks for spatial planning, which includes adaptation planning, for details, see

Section 2.4. The coastal areas of northern Norway are furthermore covered by a plan for integrated ecosystem-based management for Lofoten and the Barents Sea, with the latest update in 2021 (Norwegian Ministry of Climate and Environment 2015). Several other policy areas are also relevant for adaptation, including sector-specific policies for management of natural resources, environmental policies, and policies related to Indigenous peoples' land rights. Whether current policies represent opportunities or constraints to adaptation varies, but in Sweden, the need to strengthened adaptation goals and incentives has been identified as a priority (Expertrådet för klimatanpassning 2022).

Learning

Experience and opportunities for learning vary depending on the capacity of individual municipalities. However, opportunities for learning have been available through collaboration and partnerships with research institutes and universities. Some examples are the Norwegian Research Centre on Sustainable Climate Change Adaptation (NORADAPT) and projects such as "Barriers for climate adaptation and local and regional levels," and "Unpacking Climate Impact Chains. A new generation of climate change risk assessments."

Innovation

The capacity for technical innovation is generally high in the Arctic Fennoscandia with northern universities often focusing specifically on Arctic conditions. The region is currently seeing an expansion of industrial activities along with a need for improved transport and energy infrastructure, which may benefit other sectors of society as well. In relation to reindeer herding, new infrastructures and the expansion of new industries can be a constraint rather than an opportunity, but there are also examples of innovative use of new technologies, for example the use of GPS collars in combination with traditional knowledge to better understand the behaviour and grazing preferences of reindeer (Kuoljok 2020).

2.4.1.2. Adaptation constraints

Physical and biological constraints

Cold and long winters have always constrained the plants and animals that can thrive the north and thus the activities that depend on them. Many Arctic species are long-lived with slow reproductive rates, which makes genetic adaptation to new conditions slow. The major response of wild species is therefore likely to be relocation as they spread to new areas, but success will also depend on the pace of climate change. Moreover, nutrient availability, soil quality, and soil moisture may limit relocation. The presence of the northern coast is a physical constraint for the northward shift of terrestrial biomes (Callaghan 2005).

Ice is a physical constrains for some activities but can also offer access to places and transport routes. The expected decline in ice will change both the presence and the nature of this physical constraint, for people, other animals, and plants, including ice-specialized species, such as ice algae and some seal species. For marine mammals, fish, and seabirds, the timing and locations of ice breakup-associated algae blooms affects food supply at a critical time of the year, where feeding opportunities will change as the ice-edge shifts northward (Barber et al. 2017).

The expansion of industrial activities, both inland and along the coasts, may create physical constrains for adaptation for animals and plants as well as for activities based on ecosystem services if the natural ecosystems are disturbed or destroyed.

Economic and financial constraints

Arctic Fennoscandia is a comparatively rich region in a global as well as an Arctic perspective (for details, see Glomsrød et al. 2021a). However, most earnings from extractive industries leave the region. Many municipalities face economic constraints due to high costs caused by large distances, which often combine with declining tax base as the population ages and declines. As highlighted in a stakeholder workshop, funding for adaptation activities is often lacking.

Human capacity

Lack of education is not a general constraint for adaptation in Arctic Fennoscandia. That said, access to education differ depending on where you live, causing many young people to leave rural and inland areas and draining them of people and knowledge that would be vital for adaptation.

Traditional Indigenous knowledge is important for Sámi activities and its importance increasingly highlighted. However, experiential knowledge from earlier generations is not always adequate for addressing situations caused by completely new weather patterns and climate conditions (Ministry of the Environment and Statistics Finland 2017).

Governance/Institutions/Policy

Arctic Fennoscandia is integrated in countries with well-functioning democratic institutions, but decision-making processes are nevertheless challenged by conflicting priorities and regional-national tensions from a history where narratives of the north have been guided by national rather than local interests (Sörlin 1988; Bravo and Sörlin 2002). Furthermore, there is lack of trust is legal processes related to environmental impact assessment for new industrial activities (Nilsson et al. 2021). While adaptation is an institutionalized policy goal in all three countries, a report from the Swedish Climate Adaptation Expert Council highlight that current incentive structures are inadequate and that there is a need for more coordination and clarity regarding responsibilities (Expertrådet för klimatanpassning 2022).

Information/Awareness/Technology

The region features world-leading expertise in relation to its major industries and access to relevant technologies or potential for developing new technical solutions is generally not a constraint for adaptation. Compared to many other parts of the Arctic, infrastructure is well developed but distances are large and not all people are equally well connected, especially in relation to internet infrastructure and collective transport options.

Social/Cultural constraints

A constraint to addressing adaptation challenges are social tensions related to cultural backgrounds, rights of the Indigenous Sámi people, and conflicts over land and resource rights. As in many other parts of the Arctic, the loss of Indigenous languages is an important concern (Degteva et al. 2017).

2.4.1.3. Sector-based assessment of adaptive capacity

The sector-based summary in this section builds on information in the following reports Adaptation Action for a Changing Arctic. Perspectives from the Barents Area (AMAP 2017), Första rapporten från Nationella expertrådet för klimatanpassning (Expertrådet för klimatanpassning 2022), Finland's National Climate Change Adaptation Plan 2022 (Finnish Ministry of Agriculture and Forestry 2014), and various other sources.

Activities that depend on abiotic services

The region's engineering-based industries (energy, mining, and steel industry) generally have access to high financial capital and technical knowhow, but adaptive capacity may be partly constrained by lack of awareness about the potential impacts of climate change, as indicated by a lack of attention to climate change in impacts assessment. These industries are often supported by strong institutions and organizations. Their financial capacity can vary over time and depend on global markets.

Activities that depend on ecosystem services

Forestry and fisheries are sectors supported by a strong institutional base for knowledge and learning, but where path dependencies in norms, practices and policies can act as constraints. For large actors, financial capital is not a major adaptation constraint, while the financial situation for small businesses can be more precarious and limit the capacity to invest. Activities that depend on ecosystem services are highly exposed to impacts of climate change, including risks for ecological tipping points that may affect economic viability of some businesses. They also face pressures from competing interests. For example, there is a highly charged discussion in Sweden about forestry practices and the relative importance of using the forests as carbon sinks and protection of biodiversity or as a source of building material and biofuels.

In the tourism industry, businesses are small and have relatively weak institutional backing. However, the structure of the sector makes it nimble in the face of change, for example expanding summer tourism when winter activities are negatively impacted by as climate change.

Reindeer herding is highly exposed to climate change impacts and to pressures on land use from other activities at the same time as practitioners often lack financial capital. Furthermore, the institutional frameworks with lack of or weak land rights can constrain adaptation. Increasing international collaboration and recognition of Indigenous rights is likely to play an important role for future development. Small-scale fisheries face similar constraints regarding financial capital and regulatory frameworks that can hinder adaptation.

Activities that depend on technical services

Mobility and communication depend on a range of actors with different responsibilities, where northern regions are not always prioritized in allocation of financial capital, unless the development is linked to industrial needs. The situation varies between different countries depending on policy decisions. It also varies within the region, where people and activities along the coasts are generally better connected to technical infrastructures than people living inland.

Constraints related to municipal infrastructures, such as water, sewage, and public buildings vary depending on financial capacity (the tax base), and where human capacity and the capacity for learning and awareness raising can also be affected by the population size and structure. These challenges are often greater in small municipalities, where the responsibility for local climate-sensitive infrastructure may become heavy in relation to the available resources.

2.4.2. Adaptive capacity in Bodø municipality

Adaptation opportunities for Bodø municipality include an increasing awareness about the need to adapt and the fact that it engages in research projects to increase its internal capacity. Practical work to map the need for specific adaptation measures have started, including attention to drainage systems that play a key role in managing runoff, where current infrastructure is inadequate already in the present climate. Bodø will also be able to take advantage of growing network activity among municipalities in Nordland County and national initiatives to improve capacity. Despite these opportunities, participants in PROVIDE's stakeholder workshop in Bodø pointed to several limitation in adaptive capacity, including lack of awareness and lack of funding for adaptation measures.

2.5. Adaptation governance

Governance and policies related by climate adaptation in the Arctic Fennoscandia were recently reviewed in the report *Adaptation to Climate Change in The Baltic Sea and Arctic Regions. Governance and Policy Tools across Counties* (Berninger et al. 2021) and in an analysis of Adaptation options in the report *Adaptation Action for a Changing Arctic. Perspectives from the Barents Area* (Hovelsrud and Amundsen 2017). Unless otherwise indicated the following summary builds on these reports.

2.5.1. Norway

At the national level, climate adaptation in Norway is governed by the National adaptation strategy: Climate change adaptation in Norway (Norwegian Ministry of Climate and Environment 2013) and by the Climate Change Act, which includes annual reporting requirements related to adaptation. The principle is that responsibility is placed with the actor that is usually responsible for the task or function that is sensitive to impacts from climate change, ranging from individuals and businesses to sectorial organizations and authorities.

At the national level, three institutions account for a significant amount of knowledge production and dissemination regarding climate and expected changes: Norsk Klimaservicesenter (KSS), the Norwegian Water Resources and Energy Directorate (NVE), and the Norwegian Mapping Authority (Kartverket) (Miljødirektoratet 2019). Moreover, the Norwegian Environment Agency, the Norwegian Directorate for Civil Protection (DSB), and NVE have special responsibilities for cross-sectoral facilitation of knowledge and practice on climate change adaptation while the Norwegian Environment Agency has a coordinating role at the national level (ibid).

The county governor is responsible for local and regional follow-up of the government's policy and coordinates prevention and preparedness at the regional level. The county governor gives guidance and supervises county councils and municipalities. County councils have responsibility for regional planning, for giving planning-guidance to municipalities, and for ensuring that planning contributes to achieving political goals (ibid).

At the local level, major responsibilities fall on the municipalities within their overall responsibilities for societal development, infrastructure, and spatial planning. The legal framework for planning is the Planning and Building Act, which requires municipalities to take climate considerations in their planning, and the Central Governance Planning guidelines that describe how adaptation should be included. Klimatilpasning.no is a website with tools, case studies and information on adaptation aimed at municipalities (Miljødirektoratet).

Responsibility for adaptation within specific sector rests with sectoral agencies where three agencies have developed their own adaptation strategies, including the Norwegian Environment Agency, the Directorate of Fisheries, and the Norwegian Water Resources and Energy Directorate (NVE). In 2018, an updated assessment of consequences of climate change was presented (CICERO and Vestlandsforsking 2018).

In addition to the formal governance, adaptation is supported by several forums and networks, including the natural hazards forum ('Naturfareforum') aimed to strengthen the collaboration between national, regional, and local actors with a focus towards reducing vulnerabilities to natural hazards (Miljødirektoratet 2019). Furthermore, the network 'I front: Kommunenettverk for klimatilpasning' aims to be an arena for knowledge and competence development on adaptation to climate change and to further the work done by municipalities in the area (Miljødirektoratet 2020). The network is coordinated by the Norwegian Environment Agency and includes 13 city-municipalities from all counties in the country (Bodø is one of the 13 municipalities).

2.5.2. Sweden

Sweden adopted its current National Climate Adaptation Strategy in 2018 (Swedish Ministry of Environment and Energy 2018). Responsibility for implementation is shared across several government agencies, where the National Board of Housing Building and Planning has a coordinating role for physical planning. At the regional level, responsibility of adaptation falls on the County Administrative Boards, which must have their own adaptation plans and have responsibility to follow up on adaptation at the municipal level. The municipalities have responsibilities under the Planning and Building Act but no obligation to develop specific adaptation action plans. The County Administrative Boards and the sectoral agencies are supported by The Swedish Meteorological and Hydrological Institute (SMHI). The National Adaptation Strategy is to be updated every five years based on review by a national expert council for adaptation. Its first review, released February 2022, concluded that organization of adaptation is not sufficient, and that stronger incentives and sharp governance tools are needed, with focus on implementation of adaptations measures (Expertrådet för klimatanpassning 2022). The report provides a detailed description of relevant actors and calls for coordination across administrative and geographic boundaries.

In addition to the formal governance framework, there is a network of 28 national agencies and 21 county administrative boards that aims to strengthen society's adaptive capacity. Information relevant for adaptation is accessible through the Swedish Climate Change Adaptation Portal (klimatanpassning.se), while climate services are available through SMHI (2021).

2.5.3. Finland

Finland was one of the first countries on the world to adopt a policy to guide climate change adaptation. In accordance with the Climate Change Act, Finland must adopt a national adaptation plan every ten years (Ministry of the Environment and Statistics Finland 2017). The current plan – National Climate Change Adaptation Plan 2022 – was adopted in 2014 (Finnish Ministry of Agriculture and Forestry 2014). In addition, there are several sectoral plans or programs, e.g., related to environmental administration, agriculture and forestry, transport and communication, and defence. Responsibility for coordination across government ministries rests with the Ministry of Agriculture and Forestry. There is also a Monitoring Group on Climate Change Adaptation (Ministry of the Environment and Statistics Finland 2017). While the government is responsible for securing vital societal functions and for promotion of adaptation in cooperation with municipalities, businesses, citizens and organizations, the responsibility for adaptation action rests primarily with practitioners. At the regional and local levels, adaptation can be included in regional and municipal climate strategies, and even if these are mainly focused on mitigation, many municipalities have included adaptation. The national land-use guidelines that were adopted in 2008 include objectives related to adaptation, such as restrictions on building in flood-prone areas. Municipalities have responsibility for planning in relation to flood risk in urban areas while the government's decree on flood risk management regulates management of river basins (Ministry of the Environment and Statistics Finland 2017). The web portal ilmasto-opas.fi (climateguide.fi) includes a section on adaptation, and good practices from municipalities sorted by sector.

2.5.4. International

2.5.4.1. Barents regional cooperation

The northernmost counties of Norway, Sweden and Finland are part of the Barents Regional Council, which also includes neighbouring regions of Russia. The region is also in focus for the intergovernmental cooperation in the Barents Euro-Arctic Council (BEAC). The cooperation in the Barents Euro-Arctic Region was launched in 1993 with an overall objective to support sustainable development. BAEC has recently updated its action plan on climate change with the aim of supporting knowledge sharing across the different working groups (The Barents Euro-Arctic Council 2021). However, the Barents regional cooperation is currently suspended due to Russia's war in Ukraine.

2.5.4.2. Circumpolar cooperation

Norway, Sweden, and Finland are members of the circumpolar political collaboration in the Arctic Council, together with Canada, Kingdom of Denmark (Denmark / Greenland / Faroe Island), Iceland, United States and Russia. The Arctic Council also includes the Sámi Council and five other Indigenous Peoples' organizations as Permanent Participants. The Arctic Council has addressed climate related concerns through several scientific assessments, including recurring assessments of the impacts of climate change. It has also carried out three regional assessments focusing on climate adaptation, including a report on adaptation action in the Barents area (AMAP 2017). All Arctic Council activities were suspended in March 2022 due to due to Russia's war in Ukraine. A decision to start some activities but to continue to exclude Russia was taken in June 2022.

2.5.4.3. European Union

Sweden and Finland are members of the European Union and Norway collaborates closely with the EU on many issues via partnership agreements and membership in the European Economic Area cooperation. The EU's adaptation strategy adopted in February 2021 (European Commission 2021) is thus highly relevant for Arctic Fennoscandia, as are all other EU regulations that affect climate change and/or adaptive capacity Spatial structural and strategic profile of the Bodø municipality.

The city of Bodø is a compact port town with a grid structure centre and most facilities concentrated near the port. Its current structure developed following bombings during the Second World War. In the second half of the 20th century, rapid suburbanization caused the built-up area to increase, especially along the coast. This peripheralization ended in the 21st century with a policy that favours densification in the centre. At the same time, a plan emerged for the redevelopment of the current military airport as a new and sustainable urban district.

This urbanized area of Bodø is located on the more fertile and permeable soil within Bodø municipality, which is located along the coastal zone (see Section 2.2). The higher areas are rockier, wilder and for large parts protected as nature reserves. The ecological value here is high and the scenic quality makes Bodø a unique place. However, a lot of space claims converge in the coastal zone; buildings take up the largest part, but this is also one of the only places suitable for agriculture and where run-off (rain and snow melt) water can infiltrate. The remaining agricultural activities have been protected from further urbanization since 2000 but are too limited to provide food for the city. Bodø's water system consists of many small streams descending from the mountains in the north towards the coast. Because of space limitation in the urbanized area, many streams have been diverted underground.

At the municipal level, by far the largest part of the area is nature, with only 2.5% is built environment. Within the built areas, the proportion of public green space is limited to a number of fairly small park areas. The centre itself is heavily paved, while the surrounding areas have a suburban morphology with low building density and large private gardens. The city has good, multi-modal accessibility and all the necessary amenities, which are spread throughout the centre and beyond.

2.6. Insights from stakeholder engagement workshop

2.6.1. Workshop purpose and setting

The first PROVIDE stakeholder engagement meeting in the Iconic City of Bodø took place on 9th March 2022. The program included presentations from the PROVIDE team, Bodø municipality, Nordland County Council, County governor, along with interactive exercises and group discussions to map local knowledge and gather feedback. Invitation had been sent to representatives from the business sector, civil society, public agencies, and politicians. Twelve people attended the workshop, which was facilitated by three members of the PROVIDE team.

2.6.2. Observations of climate ongoing adaptation efforts

After a few introductory words, the participants were invited to share a personal experience of how climate change is affecting their lives. Several people expressed a sense of worry for the impacts of climate change, and some noted a sense of loss that the “winter is disappearing.” There were comments about having the most important job working with climate change issues. Some stated that they experienced that weather systems have shifted and changed unpredictably, and one participant described how a particular type of fish he used to catch has now almost disappeared.

Presentations from the municipality and the county illustrated how impacts and adaptation efforts are already underway. One example is a plan to handle surface water runoff, where Marit Elveos from Bodø Municipality described how the natural creeks have been led through pipes and the system now often overstrained, sometimes leading to overflow of untreated sewage as well as the flushing of litter to the sea. Furthermore, urbanisation has reduced the natural absorption capacity of the ground and there is a need to increase green areas in the city to better handle surface runoff, which benefits well-being in the city. Bodø has not yet experienced extreme precipitation, so, the effects and damages of truly extreme rainfalls are unknown. Elevos highlighted that adaptation measures require resources and that while there is money to do evaluations there is not enough funding to act on the results of the evaluations.

Figure 2.8 Bodø municipality collaborates with a local school to map current flooding risks and consequences. Photo: Bodin Videregående skole.

Nordland County Council is responsible for ensuring that municipalities follow state planning guidelines and has also initiated collaborations and networks across regional and municipal boundaries. see Section 2.3.7. Charlotte Alexander Lassen from Nordland County Council also described several knowledge-building initiatives, including a new statistics bank for climate and environment data hosted at the County Council's website (www.nfk.no) and a strategy document that guides planning processes in municipalities. They also plan to develop a regional Risk and Vulnerability Analysis (ROS) for Nordland County that will include climate change impacts.

The municipal and regional plan-strategy includes consideration of expected climate changes and will also shed light on vulnerability related to ecological sustainability, including attention to destruction of ecosystems, species extinction, natural hazards, threats to livelihoods, and conflicts. The new regional plan-program represent s new policy area for the county and includes new concepts such as carbon-rich areas and areal-budgeting, where the council will develop regional plans and plans for water management.

2.6.3. Future risks and potential thresholds

A joint mapping of future vulnerabilities and risks at the local level generated a long list of issues, ranging from physical hazards and ecosystem changes to economic issues and cultural well-being. They included impacts on ecosystem-depended livelihoods, such as the impacts of warmer seawater on aquaculture, impacts on reindeer herding from locked pastures due to ice, and the northward shift of fish species. Other issues were threats to infrastructure and life due to flooding, landslides, and avalanches. Infrastructure near the coast, including new developments, will also be exposed sea-level rise and more powerful westerly storms. Severe weather was also a concern in relation to conditions for fishing. Another set of concerns related to health and identity, including the loss of snow and wintertime leisure activities and the loss of reindeer. Furthermore, some participants pointed to economic challenges such as adjustment crises in industry and lack of funding. Finally, one person noted that many people don't care.

In another exercise, the participants were asked to highlight potential thresholds for adaptation. While it generated some of the same concerns of loss of ecosystems, changing landscapes, and the loss of the winter, it also included attention to the risk that it would not be possible to keep pace with the changes, e.g., when the lag in renovation of pipes cannot keep up any longer, when it becomes too expensive to prevent damages, when opportunities for innovation are lost, and when we accept losses. The examples thus pointed to a need for attention to how thresholds can relate to and interplay across social, economic, and climate-related factors.

2.6.4. Digital tools for adaptation planning

The notion of environmental dashboards is familiar to Bodø municipality, which is engaged together with a private company in a project aimed at developing digital solutions by compiling environmental data from several sources and making them easily available. They also supplement existing data sources with new sensors and new real-time data. The data includes energy use, waste disposal, traffic, air quality, and the weather, among others.

After a presentation of the PROVIDE dashboard, participants expressed an interest in its further development and need for such solutions, but it was also clear that they were not aware of digital tools that are already available to get information about further climate change under different scenarios. The on-site evaluation of the workshop highlighted a need for analysis and for visualizations to increase insights and understanding and as a base for planning.

3. Structural and strategic profile: Bodø, Norway

Main author: Miechel De Paep, BUUR Part of Sweco
Contributing authors: Raluca Davidel and Mario Doneddu, BUUR Part of Sweco

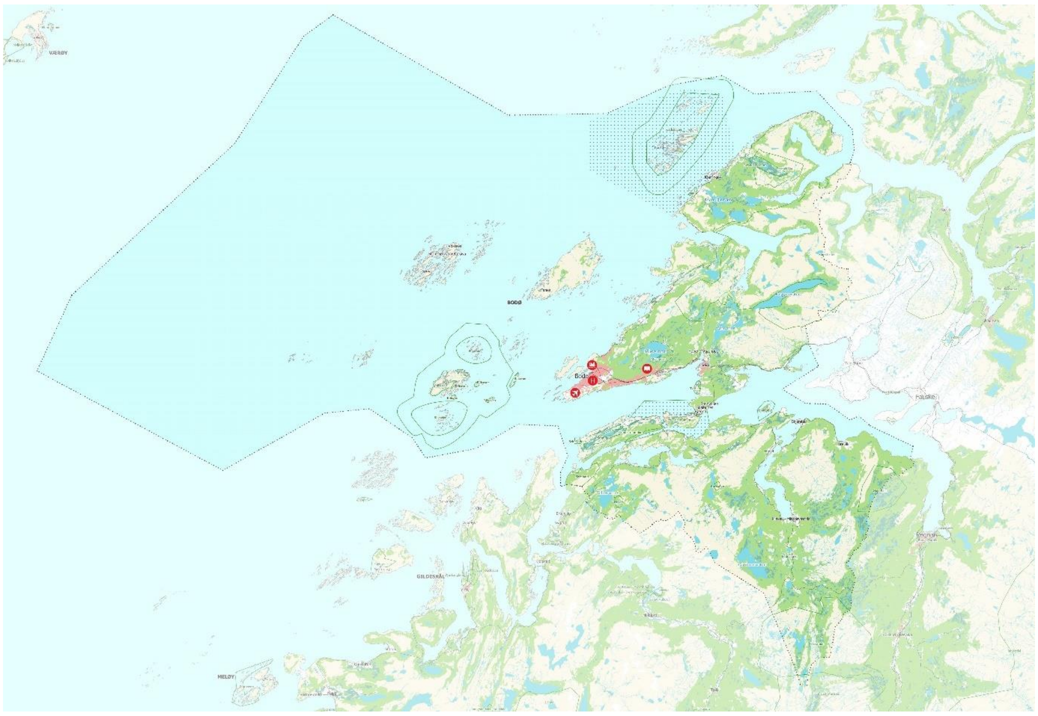

Figure 3.1 Base map Bodø municipality, image by BUUR/PoS 2022

Figure 3.2 Base map Bodø urban zone, image by BUUR/PoS 2022.

3.1. Introduction

Bodø is a city in northern Norway, in Nordland County, with a population of almost 53,000 people and an area (on land) of almost 1400 km^2 (for more general info, see Section 2.2 Introduction to Bodø Municipality, Nordland County, Norway). That huge area is in contrast with the compact town itself, located on a flat peninsula surrounded by sea, mountains, islands, and fjords.

The place where Bodø is located has a history that dates back to the Vikings. However, the current town did not flourish until the 19th century, as a small city focused on fishing and sea trade. Around 1900, the harbour and breakwater were constructed, an important milestone for the urban development. At that time, the town had about 6,000 inhabitants, living in colourful wooden houses, organized according to a square grid parallel to the coastline. The city had a compact structure and was surrounded by swamps and farmland. Along the harbour were the main larger buildings: warehouses, church, hospital, schools. However, during World War II, Bodø was almost completely razed to the ground during a German bombing raid: up to 80% of the houses were destroyed. The reconstruction lasted until about 1960. The town was rebuilt and enlarged, with wider streets but a similar square grid as before. Several main axes were created, and the centre received a number of central plazas and parks. The general building height was increased to three storeys, the area reserved for commercial functions increased. The centre remained focused on the harbour (Marthinussen & Bjørklund 2017).

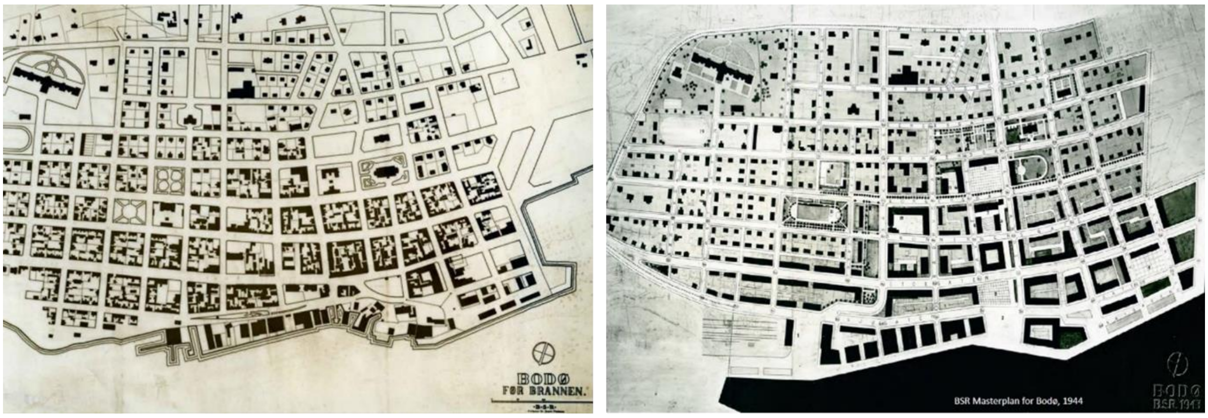

Figure 3.3 Bodø before the bombing in 1940 (left), and the plan for reconstruction in the 1950s and 1960s (right) (Marthinussen & Bjørklund 2017, pp. 31-32)

At the same time, a large NATO airport was built south of the city, which soon occupied more than half of the peninsula. Bodø also grew rapidly in area and population. A large merger with the adjacent municipalities increased the surface of the municipality to the present area. The urban area grew mainly eastward and northward, along the coastline. In the south, the airport blocked further growth, and inland the mountains made growth impossible. In Mørkved, east of the centre, a new university campus was founded around which an entire city district grew. Northwards, new suburban neighbourhoods were built. However, Bodø's horizontal growth was halted in 2000 to avoid urbanizing the remaining (flat) open space. Since then, Bodø has mainly focused on densification of the centre. In three blocks along the harbour, high-rise was allowed, one hotel tower has already been realized. At the same time, work was done on urban renewal with the construction of the new library and concert hall right next to the water. The building, with its sober but stylish architecture, gives the entire waterfront a new elan. Another important evolution is that more housing is being allowed in the centre, which also increases the liveliness.

Figure 3.4 Bodø city in 1950 (left) and in 2000 after the expansion towards the east and north (right) (Marthinussen & Bjørklund 2017, p. 33).

In 2012, the decision was made to move the NATO air base to Trondheim. Although a disaster for the local economy in Bodø, this decision also creates new opportunities. A new, civilian airport will be built more to the south, so that a significant part of what is now NATO territory can be redeveloped as a new, mixed-use city district – covering almost the same area as the current city centre.[2]

Bodø is a relatively small town, in an imposing landscape. With its plans for urban renewal and expansion, it is playing a pioneering role in Norway. At the same time, these plans represent a unique opportunity to prepare the city for the future: radically opting for sustainable urbanism and climate security. The climate risks for the urban area are well known and include sea level rise, higher probability of extreme storms, heavier precipitation with an impact on rainwater runoff and risk of flooding (see also Sectionr 2.3.5 Climate-related risks in Bodø municipality). None of these risks represent significant danger to residents today. Nevertheless, it is crucial that the projects planned today for the Bodø of (the day after) tomorrow, consider this changing future.

3.2. Structural profile

3.2.1. Soil and topography

The urban area of Bodø lies on a fairly flat peninsula, but the rest of the municipality has a much more jagged relief with quite a few mountains. One third of Bodø's territory is above 300 m sea level, one third below 60 m (see Figure 3.5). Most of the municipality consists of rocky ground with large boulders and not very fertile soil. Water permeability is also low (see Figure 3.6 and Figure 3.7). On the peninsula, the soil consists of sediments left by the sea with higher permeability. This zone, like the flatter coastal zones elsewhere in the municipality, is also more fertile, and so are some of the valleys carved by glaciers during the last ice age.

The subsoil of Bodø consists of various rocks from different time periods, the most important being lime, sandstone, granite and quartzite. In the northern part of the municipality, we see a lot of quartzite and slate, in the south gneiss and granite dominate.[3]

[2] For more information, see https://bodo.kommune.no/planprosesser/horing-og-offentlig-ettersyn-kommunedelplan-for-hernes
[3] See https://geo.ngu.no/kart/berggrunn_mobil/

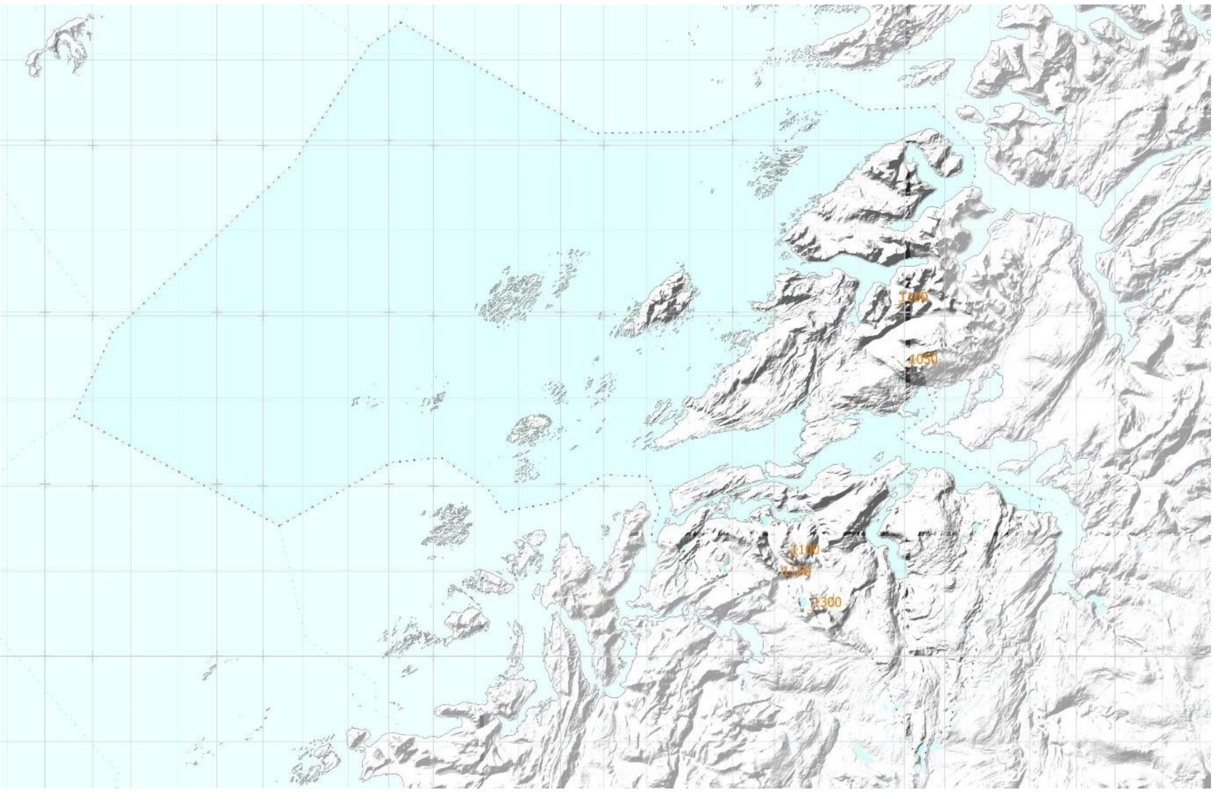

Figure 3.5 Topography, image by BUUR/PoS 2022

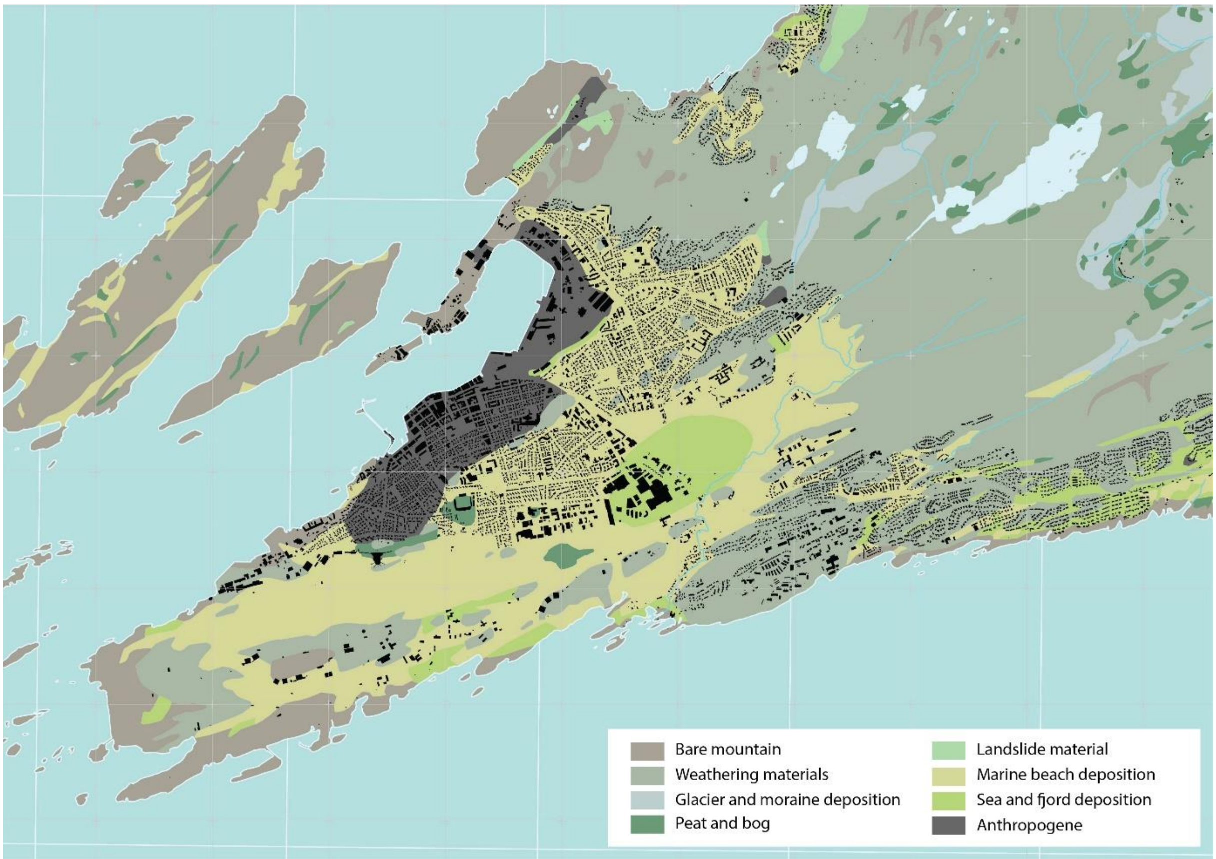

Figure 3.6 Sediment map, image by BUUR/PoS 2022

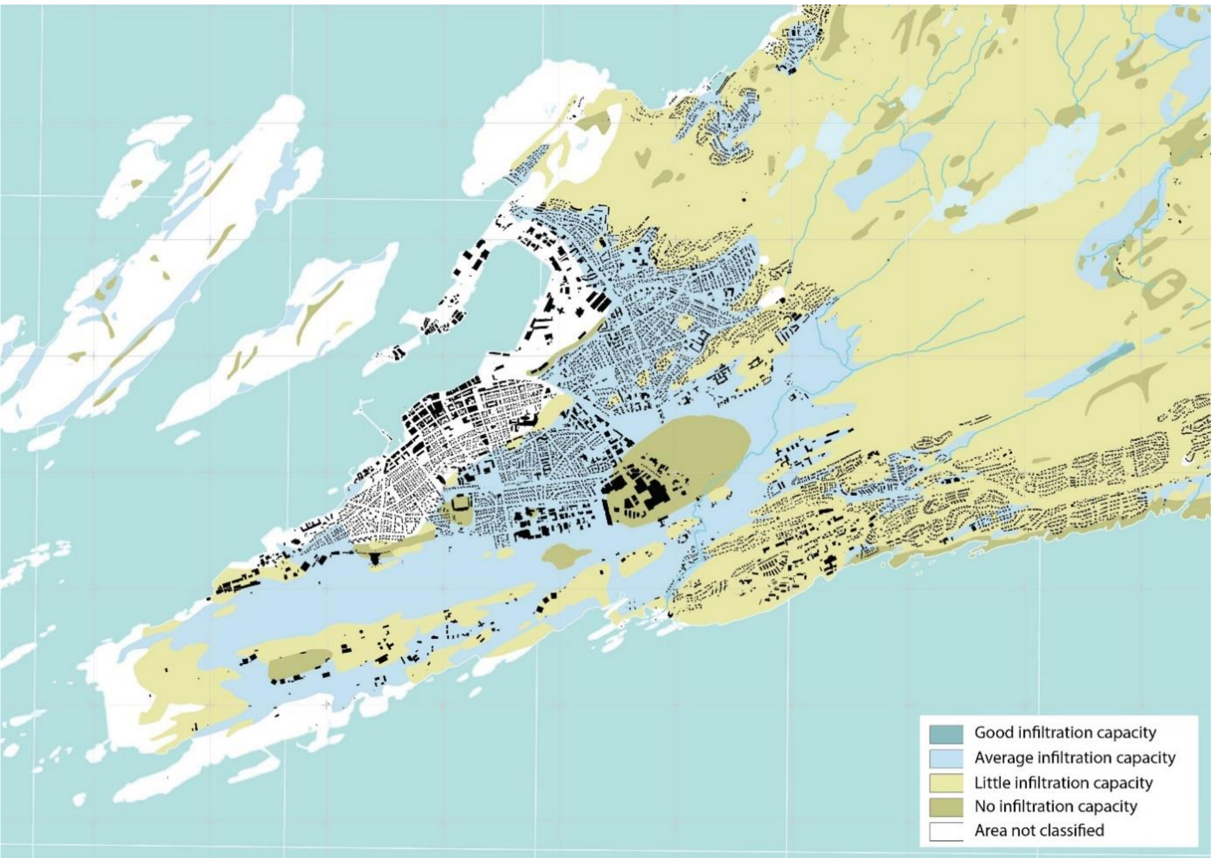

Figure 3.7 Soil infiltration capacity, image by BUUR/PoS 2022

3.2.2. Water

Bodø has many water-rich areas, with lakes and an extensive network of small streams and rivers. These have a high nature value and are also attractive for recreation and fishing. As visible in Figure 3.8 and Figure 3.9, there is not really a single catchment area, but the water network consists of numerous small streams that flow directly from the higher, mountainous areas to the sea. These streams are fed by rainwater and meltwater. Whereas in the natural zones these streams are very numerous and widely branched, in the urban area of Bodø we see a much lower density of open streams. In the urban area, rain and melt water is mainly drained through the urban sewage system and only to a limited extent along natural, open watercourses.

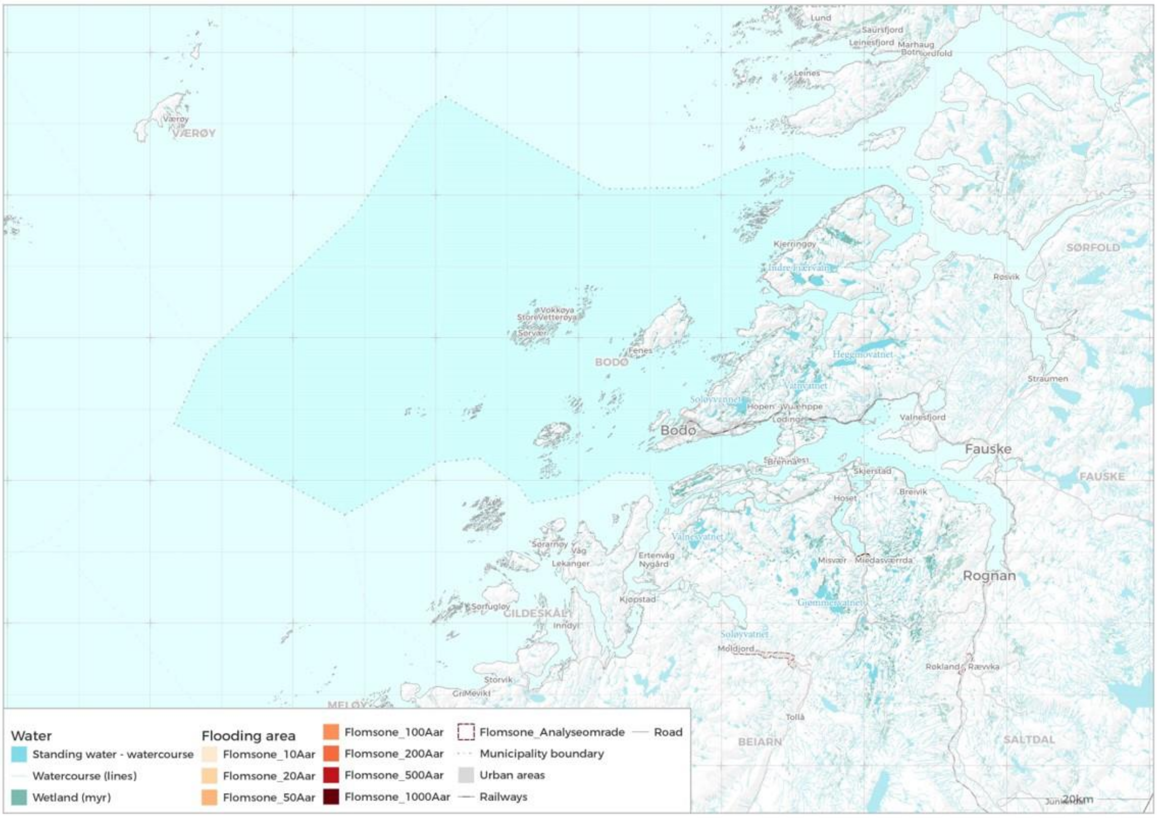

Figure 3.8 Water system Bodø municipality, image by BUUR/PoS 2022

Figure 3.9 Water runoff streams city zoom, , image by BUUR/PoS 2022

3.2.3. Land cover

The municipality of Bodø, with its enormous size, consists for a very large part of undeveloped space. Only 2,5% of the municipality's surface is built-up space, another

2,5% is used for agriculture. 88,9% of the surface is nature, including 39,1% forests. The remaining 6,1% are open waters, like lakes and rivers.

The most intensively used space, for construction and agriculture, is on the peninsula and in the flatter coastal zones. Some wetlands are also used for agriculture. After several decades of horizontal growth, the boundary of the urban area is now clearly defined and forms a compact island amidst the open space.

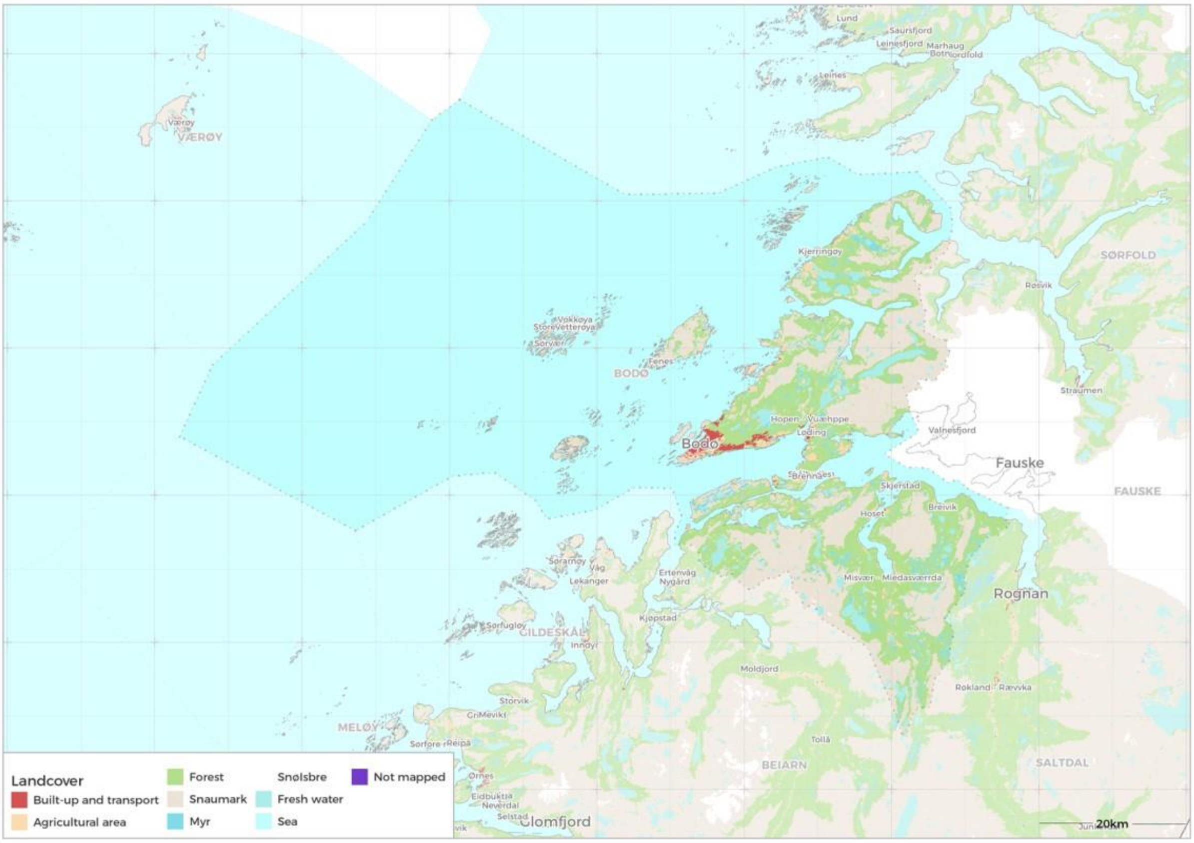

Figure 3.10 *Land cover map (municipality), image by BUUR/PoS 2022*

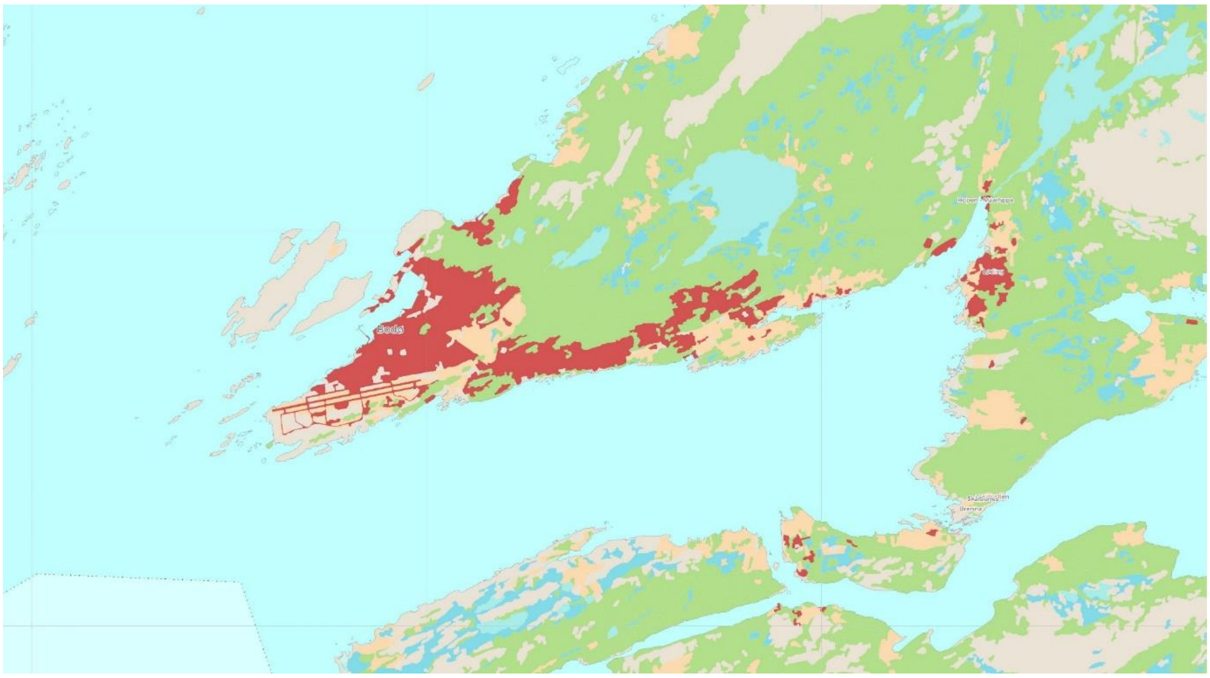

Figure 3.11 Land cover map (city zoom), image by BUUR/PoS 2022

3.2.4. Ecology[4]

The natural areas in the territory of Bodø have regional and national importance and are diverse in character, offering very different habitats, including coastal zone and fjords, mountainous areas, lakes, and wetlands. However, most of the nature in Bodø is culturally influenced, through agriculture and reindeer husbandry, fishing, recreation, forestry (and deforestation), among other things.

The most popular area for nature, sports and recreation is Bodømarka, with an area of about 150,000 ha – this is the whole area north and north-east from the city centre. It includes large forests and lakes, but also hiking and bike trails, areas for weekend and holiday homes, fishing zones. Central in Bodømarka is the Soløyvatnet lake.

The municipality of Bodø contains (parts of) two national parks.[5] In the north lies Sjunkhatten National Park, a water-rich, mountain landscape that is glacier formed and very diverse. In the south Bodø touches upon Saltfjellet – Svartisen National Park, Norway's largest natural park that is also mountainous and contains the largest glacier of the country. Next to the national parks, Bodø contains many natural reserves of different character. Many are located in the wetlands and are protected habitats for birds, like Straumoya, Loddvatnet or Strandavassbotn. Some natural reserves are coast-related, like the dune reserve Fjaere or the coastal system of Skjelstad. Also, a lot of islands are protected, like Bliksvaer and Karlsoyvaer, both with coastal wetlands that are real bird paradises and Ljonesoya that is a reserve for Eider ducks. In the south of Bodø there are also valuable birch forests with orchids.

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[4] Information from the Kommunedelplan Arealdel 2022-2034 (Bodø Kommune 2022) and the Grønnstrukturplan for Bodø Kommune (Bodø Kommune 2017)
[5] https://bodo.kommune.no/miljo-klima-og-naturbruk/naturmangfold/verneomrader/ (2022)

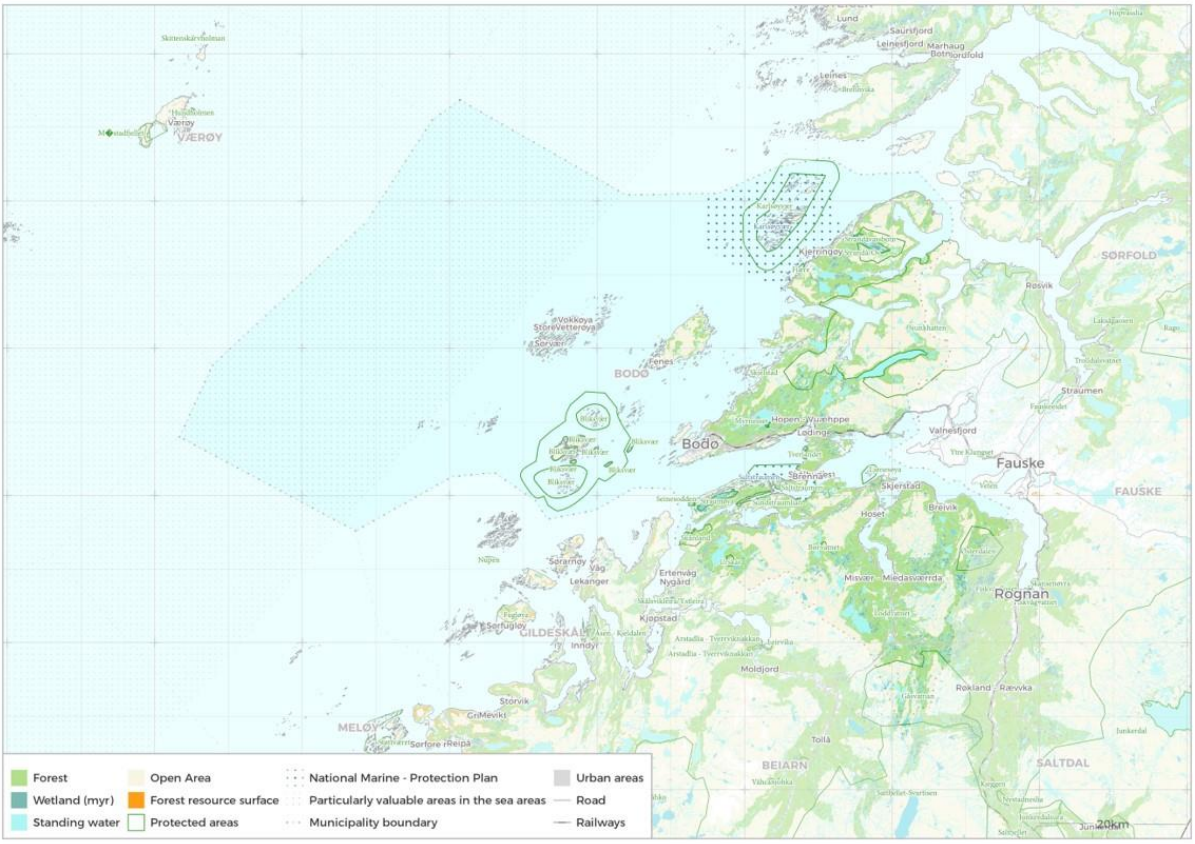

Figure 3.12 Map of ecotopes and natural protection zones, image by BUUR/PoS 2022

The inhabitants' access to green spaces in Bodø was analysed in 2017.[6] The study looked at which urban areas had access within 200 m to sufficiently accessible green spaces of min. 500 m². The analysis shows that the green spaces in the urban area are sufficiently distributed to cover a reasonably large part of the population. In addition, most residents also have quick access to the large green areas outside the city, such as Bodømarka and the green areas along the coast. However, the green areas in the city centre do not form a continuous network and are mainly isolated fragments.

[6] See Grønnstrukturplan for Bodø Kommune (Bodø Kommune 2017)

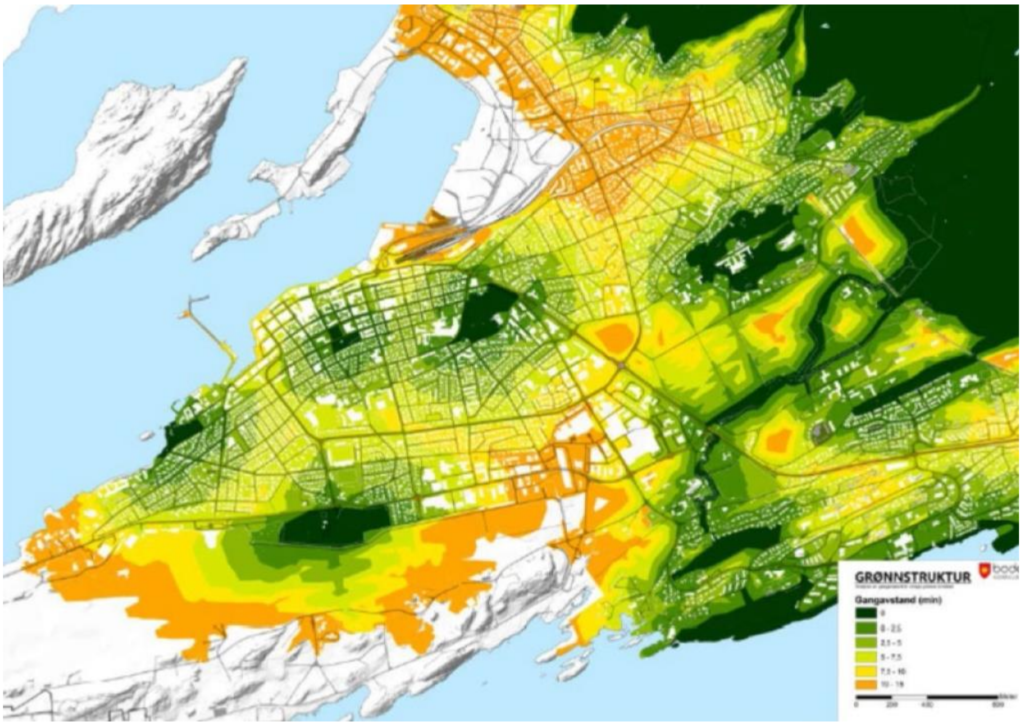

Figure 3.13 Existing green structure and access to green in the urban area (Bodø Kommune 2017, p. 27)

3.2.5. Agriculture[7]

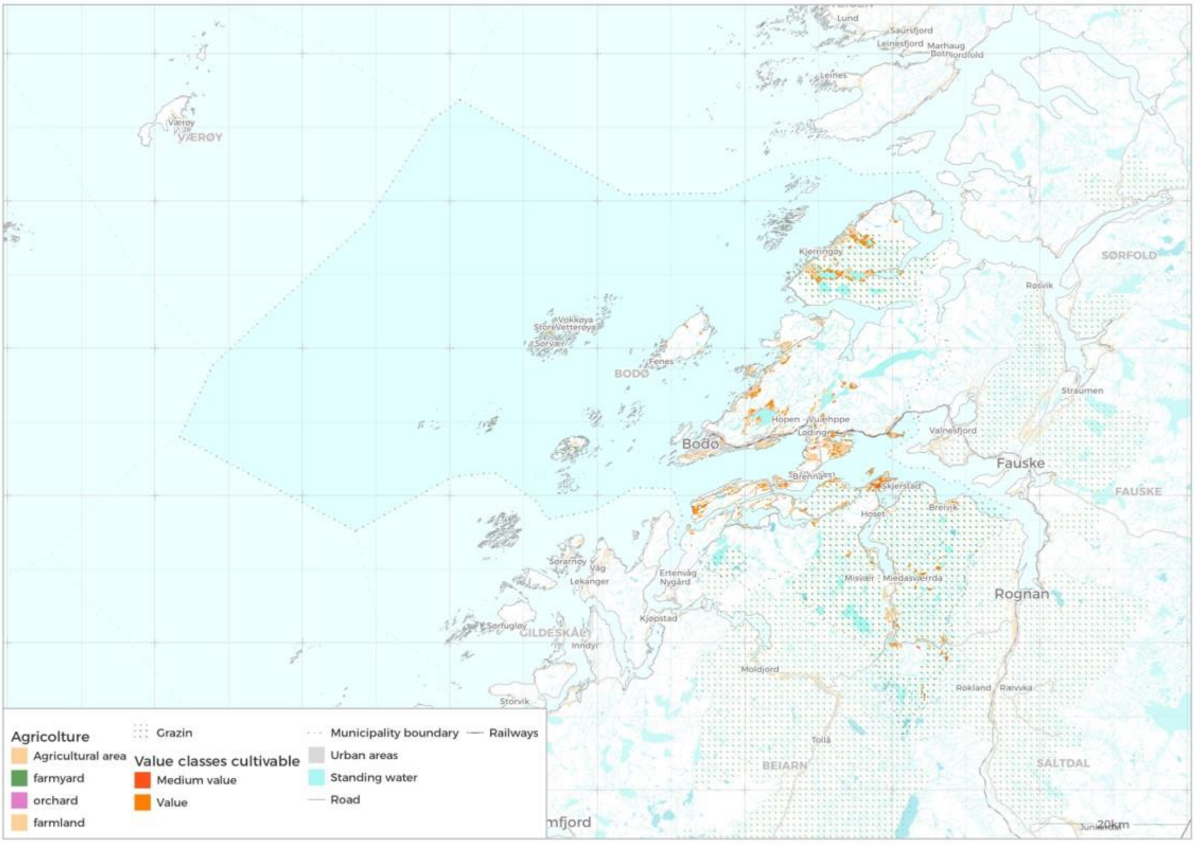

Figure 3.14 Map of agricultural uses, image by BUUR/PoS 2022

The little space in Bodø used for agriculture (2,5% of the entire surface of the municipality) is strictly protected from further urbanization by the KPA 2022 (Bodø Kommune 2022). Most of the agricultural land in the Nordland County is used as grassland for livestock. In Bodø, a special role is played by the areas Fjær and Godøynes which have an important cultural significance as traditional rural villages with a small-scale parcel structure as little islands in a forested landscape.

Figure 3.15 Agriculture with a cultural significance: Fjær (left) and Godøynes (right) (Google Maps 2022)

[7] Information from the Kommunedelplan Arealdel 2022-2034 (Bodø Kommune 2022)

Of specific interest is also the agricultural zone Rønvikjordene,[8] right next to the urban area of Bodø. It lies in the south of the district Rønvika and has an agricultural history of over 100 years. It has seen a lot of development pressure in the past decades but managed to survive and is now protected as a local food supply at short distance from the city centre, also for educational purposes. Another area for urban agriculture is Andelslandbruk in the neighbourhood of Fenes.

Figure 3.16 Rønvikjordene agricultural zone (Google Maps 2022)

An important point of interest for agriculture are also the reindeer grazing zones, with the most important in Duokta (between Sørfolda and Saltfjorden) and in Saltfjellet. Bodø is of particular interest to reindeer in winter, due to the milder climate in the coastal zones, but the mountainous zones are also popular in spring and summer. Besides the specific grazing zones, there are also the migration routes that are of great importance. Reindeer herding is both of economic and cultural importance in the area.

Other important economies are forestry and fishery. Almost 14% of the productive forest area in Norway lies in Nordland County, and 33% of the timber from broad-leaved forests comes from this county.[9]

3.2.6. Transport networks[10]

Bodø is well connected to several transport networks, but the large distances between the city and other urban areas makes travelling time consuming. The main highway that makes north-south connections in Norway is the E6, passing the municipality at around 50 km from the city centre. Via this highway, there are around 650 km to get to Trondheim, the closest big city. But also visiting smaller, more adjacent cities always demands large distances to be covered. Due to this, Bodø is a quite car-oriented city, with 26,000 passenger vehicles registered for 53,000 inhabitants – including 12% electric cars.

Other important transport means for longer distances are of course the airport and the ferry connections. Bodø is an important regional hub for transportation of people and goods, with the port and airport as major pillars. As a regional port hub, Bodø has fast boat connections to most of the adjacent islands, and a ferry to the Lofoten Islands around 80 km away from the coastline.

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[8] See also https://no.wikipedia.org/wiki/R%C3%B8nvikjordene (2022)
[9] https://www.ssb.no/en/jord-skog-jakt-og-fiskeri/jordbruk (2022)
[10] Information from the Kommunedelplan Arealdel 2022-2034 (Bodø Kommune 2022)

Bodø train station is the terminus for the Nordlandsbanen that follows the E6 and offers one day or one night train to Trondheim, and regional and local train connections to Mosjøen and Rognan.

For local transport, there is a modern bus network between the centre and the surrounding villages. Efforts are also being made to improve the bicycle network. The largely flat profile of the urban area fosters cycling, but weather conditions and strong winds create a major barrier.

This translates in a modal split that is dominated by car use (62% of all displacements) and a low use of bicycles (9%). Also, public transport is not very popular for internal displacements (5%). Walking counts for 24%.[11]

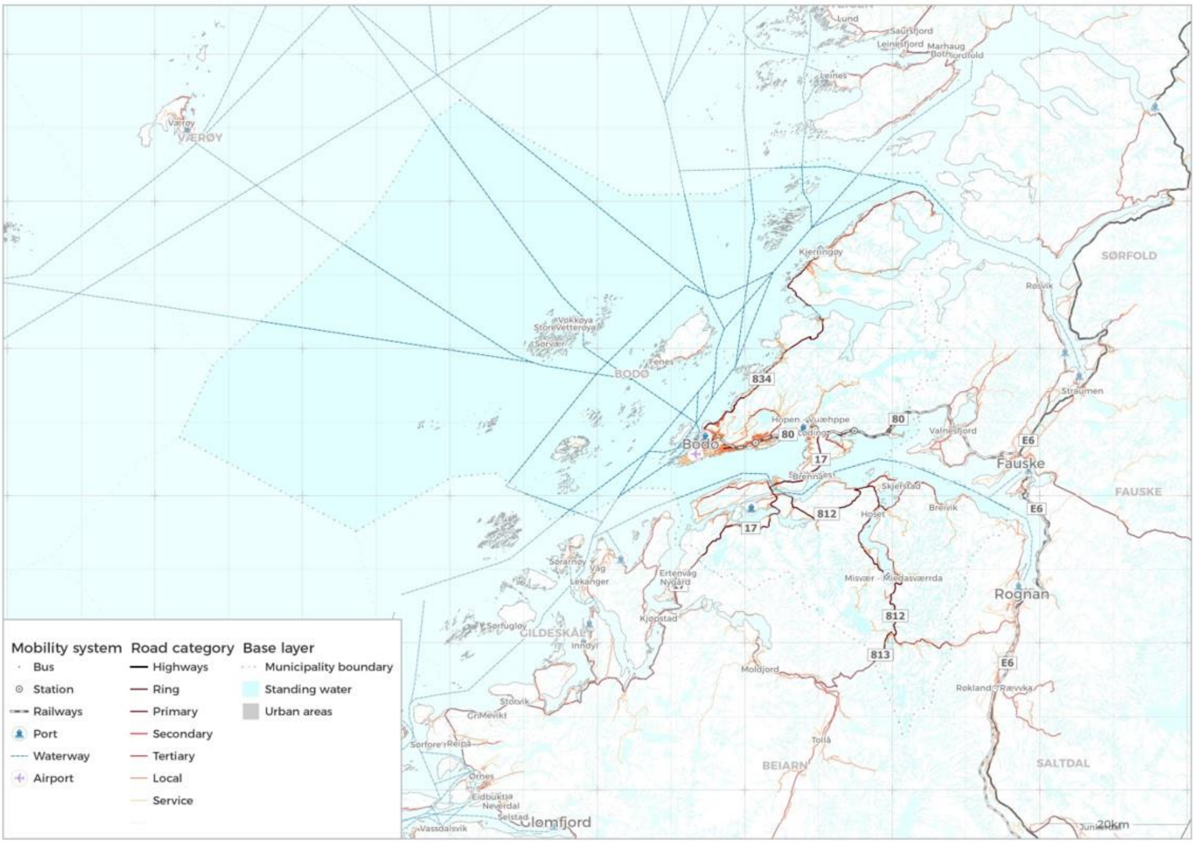

Figure 3.17 *Map of transport networks, image by BUUR/PoS 2022*

3.2.7. Land Use

The entire built-up area of Bodø municipality contains 831 ha of residential land and 288 ha of economic zones. Recreation, schools and other public facilities count for 337 ha. Of the public space, 1410 ha is used for transport and other infrastructure and 212 ha are green and/or recreational spaces.[12]

The urban area of Bodø is clearly structured. The centre at the harbour contains the highest building density and most mixed functions, such as commerce, hotels and

[11] Klima- og energiplan (Kommune Bodø 2018)
[12] https://www.ssb.no/en/natur-og-miljo/areal (2022)

restaurants, the town hall and the cathedral, the library and cultural centre, and a number of schools. Other important functions are located more outside the centre: the railway station in the northeast, the Nordland Hospital just below, more to the south an extensive school and sports campus. Both to the north and to the southwest, the port contains important economic zones. In addition to industry, quite a few large-scale retail centres and even recreational functions have settled here. A similar mixed zone is located in the southeast of the centre, along the entrance road Rv 80, with in addition to classic large-scale retail also a big shopping mall (City Nord), a sports hall and the swimming pool. Here you also find the aviation museum, directly linked to the airport.

The urban neighbourhoods outside the centre are mostly residential in character, with supporting functions such as schools and commerce for daily use. Mørkved is also home to the main campus of Nord University. Around the campus, a residential district has also developed here, which is one of the few districts in Bodø that also continues higher up the hills.

Bodø is strongly committed to urban renewal. Since the decision was taken to stop the horizontal growth of the city, they follow a polycentric growth model, which focuses on four central locations: the centre, the new district Hermes, the new airport and associated economic zone and the commercial zone around City Nord.[13] Especially in the centre the focus lies on urban renewal, with the redevelopment of the waterfront (including the already realized new library and cultural centre) and the refurbishment of the shopping street Storgata.

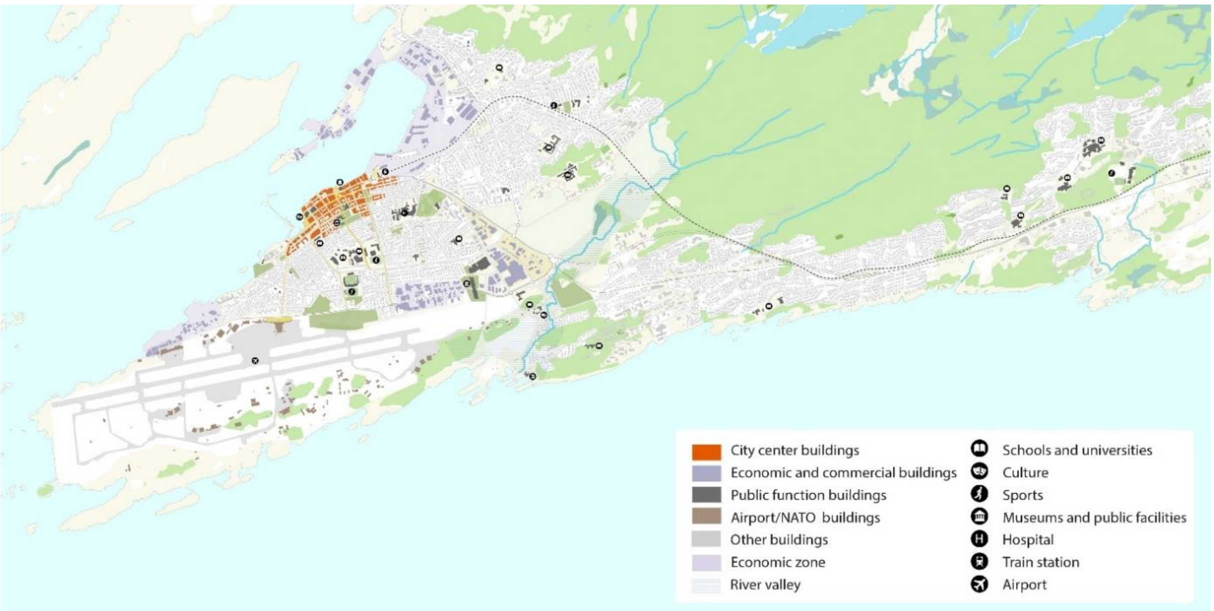

Figure 3.18 Urban structure of the urban area, image by BUUR/PoS 2022

[13] Marthinussen & Bjørklund (2017)

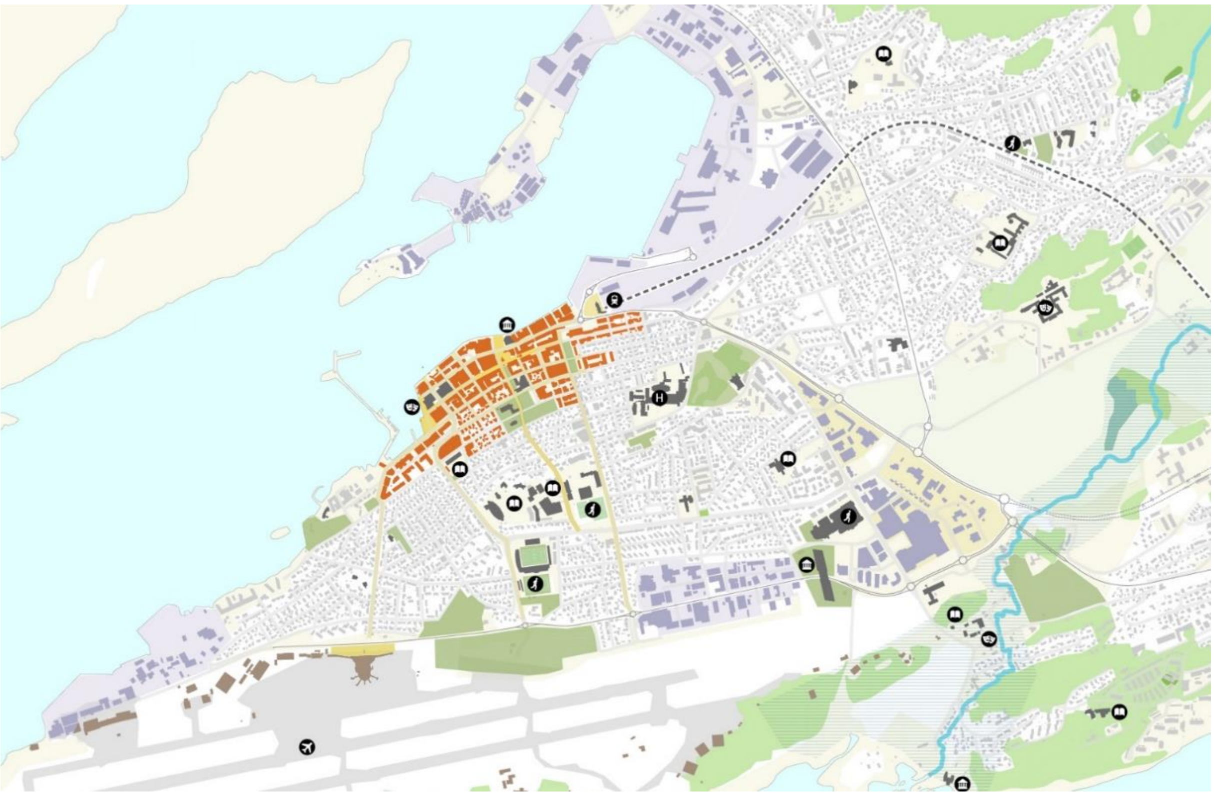

Figure 3.19 Urban structure of the city centre, image by BUUR/PoS 2022

3.2.8. Building morphology

Apart from the waterfront zone and the adjacent central building blocks, most of the buildings in Bodø are rather small scale and low rise. 66% of residents live in detached houses (open or semi-detached), 27% live in apartments. The average family size per home is 2.09 residents. In addition, the municipality has about 2700 vacation homes, scattered throughout the open space.[14]

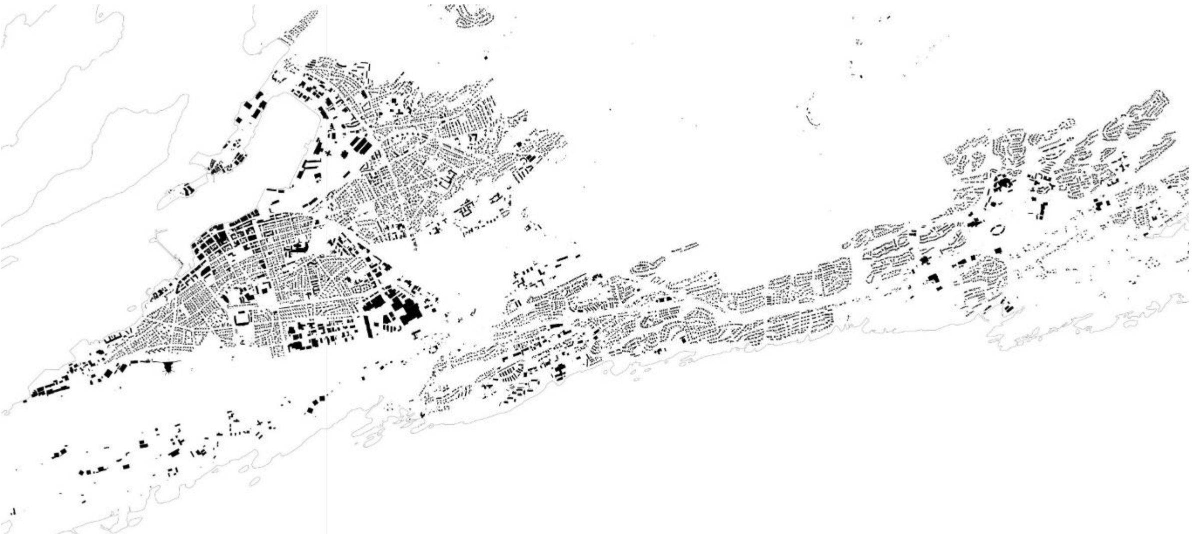

Figure 3.20 Building morphology in the urban area of Bodø, image by BUUR/PoS 2022

[14] Kommunedelplan Arealdel 2022-2034 (Bodø Kommune 2022), p. 11

In the city centre, a square grid defines the layout of the streets and buildings. Close to the waterfront the building blocks are densely built, leaving little space for inner courts and without much green space. Further outside, the buildings blocks are built with up to eight single, mostly freestanding houses on private plots. These blocks are much greener, including sometimes large trees. In a few cases there are larger buildings integrated in this tissue, like public facilities or small-scale apartment buildings.

Figure 3.21 Urban building blocks with high density (up left), single housing in the urban grid (top right), scattered individual houses in a suburban style (bottom right) and single housing compounds with collective public space (bottom left) (Google Maps 2022)

Outside of the centre, the grid structure is less defining and many of the more suburban districts have typical curvy roads and a more organic building structure, adapting to the topography. Also, here the large majority of the houses are freestanding single-family houses, sometimes interspersed with larger facilities, small clusters of row houses or small-scale apartment buildings.

Figure 3.22 The morphological structure of the suburban districts east of the centre

Figure 3.23 The morphological structure of the urban grid in the city centre

3.2.9. Population density

85%, or 45,000 of Bodø's 53,000 inhabitants live in the urban area. In addition, 3,200 residents live in Løding and 2,300 in Skivika and Løpsmarka. The remaining 1,500 people are scattered in smaller village centres such as Skaug, Kjerringøy, Saltstraumen, Misvær and Skjerstad.[15] The entire municipality has a density of approximately 40 inhabitants / km^2.

Bodø currently has an annual growth rate of 1% (approx. 500 new inhabitants per year), but this is expected to decrease to approx. 0.7% per year (approx. 350 additional inhabitants).[16] The KPA 2022 sets a clear objective that this growth should be concentrated in the city centre and the new district Hernes (p. 8).

[15] Kommunedelplan Arealdel 2022-2034 (Bodø Kommune 2022), p. 10
[16] Kommunedelplan Arealdel 2022-2034 (Bodø Kommune 2022), p. 6

In the new urban district of Hernes, a development is planned with about 15,000 additional homes and economic functions for about 20,000 additional jobs.

3.2.10. Governance and spatial planning

Much of the information included in this report, is derived from various planning documents published by Bodø Municipality. The city has an active and well-organized set of planning instruments, of which the areal municipal plan (Kommunedelplan Arealdel, Bodø Kommune 2022), green structure plan (Grønnstrukturplan, Bodø Kommune 2017) and climate and energy plan (klima- og energiplan, Bodø Kommune 2018) are the main ones for spatial planning. These documents contain a great deal of information about the city's structure and challenges and formulate important ambitions but are rarely compelling visual or even cartographic documents. Ambitions are rarely put on a map, nor are they otherwise communicated in a recruiting way. The spatial plan contains a technical zoning plan, but no structure plan or other more strategic plans.

Things are different when it comes to the master plan for the new district of Hernes. Here numerous visions, design proposals and graphic concepts have been elaborated, which convey a great ambition and also manage to make it tangible. At present it is still unclear which concrete choices will be made and what the new district will look like exactly, but the sustainable ambitions are very clear.

A similar ambition is also evident in the various international collaborations Bodø is involved in, such as European research projects, but also the ISOCARP conference in Bodø in 2017. What concrete results these collaborations deliver for local residents is not yet entirely clear.

However, the planning practice in Bodø shows that important and positive decisions have recently been made that strongly support the sustainable development of the city. Especially admirable is the clear decision to stop the horizontal growth of the urban area and resolutely opt for densification in the centre.

3.3. Strategic profile

3.3.1. Local climate risks[17]

Climate change is expected to increase the average temperature in Nordland by about 5°C by the end of the century, especially in winter. At the same time, rainfall will increase by about 15% and the severity of precipitation will also increase. The expected rise in sea level until 2100 is between 16 and 54 cm[18].

In this chapter we look at two specific climate risks in more detail and examine the spatial regulatory systems that play a role in adaptation strategies for these risks. In doing so we try to identify how these systems function today and whether they are capable of performing their regulatory function – and where this is less or not the case, what weaknesses cause this and what opportunities there may be to (partially) remedy this.

The two climate risks we are looking at are flooding from increased precipitation (both fluvial and pluvial flooding) and flooding from rising sea levels.

[17] See also chapter 2.3.5 "Climate-related risks in Bodø municipality"
[18] Kommunedelplan Arealdel 2022-2034 (Bodø Kommune 2022), pp. 23-24

3.3.2. Sea level rise

3.3.2.1. Adaptation strategies

Coastal cities such as Bodø are obviously sensitive to sea level rise. In general, three broad groups of adaptation strategies can be distinguished: (physical) protection measures, risk avoidance through changing land use and disaster management. [19]

- (Physical) protection measures
  - construction of new infrastructure
  - adaptations to buildings
  - natural buffers such as wetlands
- Risk avoidance through land use change
  - new developments only outside risk zones
  - relocation of activities and infrastructure away from risk zones
- Disaster management
  - modelling & risk analysis
  - warning systems
  - emergency plans
  - insurance

Initially, we examine the regulatory system formed by the coastline, and the extent to which it can act as a (physical) protective belt.

3.3.2.2. Regulation systems: coastline

A crucial role here is played by the coastline and how it is shaped. Figure 3.24 shows how the coastline in Bodø looks like today. The map makes a distinction between the urbanized coastline, with quays, buildings and other built structures encroaching right up to the coastline, and the more 'natural' coastline. For not urbanized sections of the coastline, a distinction has been made between the rockier segments and those that consist of beaches, wetlands and/or mouths of streams. This distinction was done based on visual desktop research and is just a preliminary analysis. In the case of the latter, the difference in elevation is likely to be very limited but may involve natural buffering through nature-based solutions. Although highly subject to tides and extreme weather events, these types of coastal habitats are adaptive by nature and can "grow" through sediment supply and are less subject to erosion. For the rockier segments, this is also possible, but further research is needed to better map them.

[19] https://eri.iu.edu/erit/strategies/sea-level-rise.html (2022)

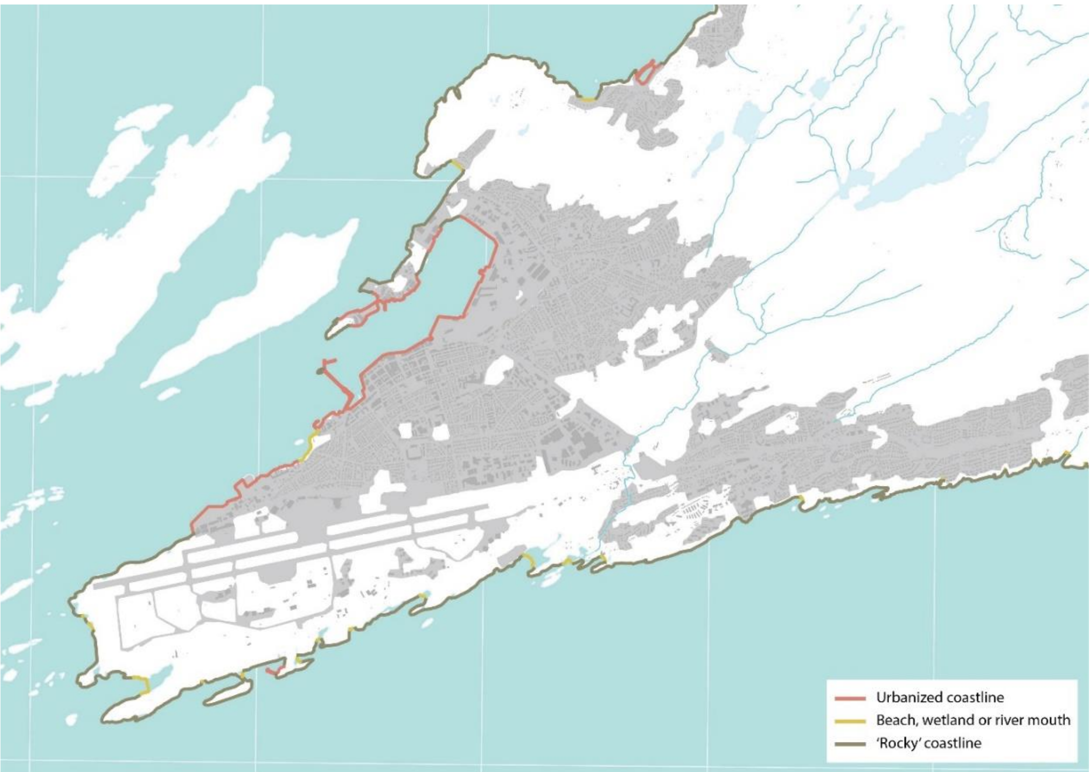

Figure 3.24 Preliminary analysis coastline peninsula Bodø, image by BUUR/PoS 2022

The urbanized segments present two concrete risks. On the one hand, the exposure of buildings and people is highest, because the built-up area here has often advanced directly until the coastline. On the other hand, they consist of 'grey infrastructure', which can provide high protection but is not adaptive and can lead to immediate catastrophic consequences if it fails in extreme conditions. Again, additional research is needed to get a better idea of the exact design of this coastline and the existing system of breakwaters, dikes, and quay walls.

Currently, the urbanized segments are mainly located on the north side of the peninsula, the neighbourhoods in the southeast respect a large distance from the coastline and here there is no harbour infrastructure. The current airport also respects this distance. How this situation will evolve in the future with the realization of the new urban district and the rebuilt airport more to the south of the peninsula is currently unknown but should be included in the study in order to fully assess future risks.

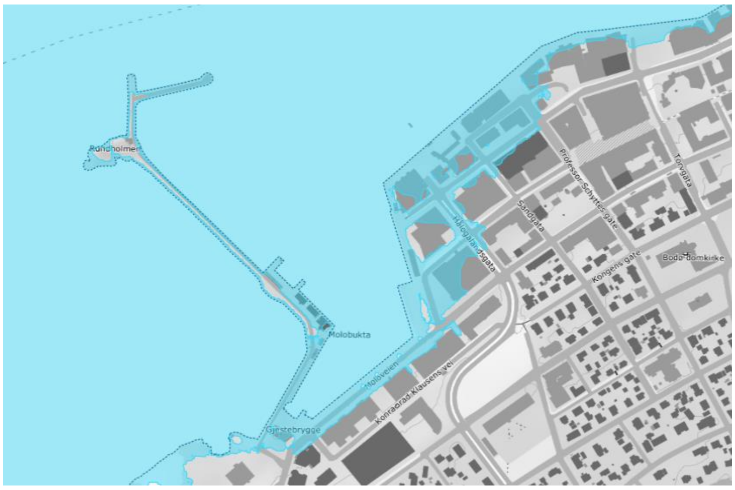

Figure 3.25 Sea level rise and risk areas

Recently, an analysis of Bodø's exposure to coastal flooding has been carried out for the harbour area (see Figure 3.25).[20] More information on the methodology and the concrete results would greatly help to advance the research on this regulation system.

In order to optimally map the vulnerability of this regulation system, additional information on sea currents and on the concrete predicted sea level rise in the different climate overshoot scenarios is also needed.

3.3.3. Pluvial and fluvial flooding

3.3.3.1. Adaptation strategies

The expected increase in precipitation amounts, both average and during extreme weather events, brings an increase in the risk of pluvial and fluvial flooding in Bodø, especially in the urban area on the peninsula. Here, runoff precipitation from the city's paved surfaces meets precipitation water discharged through open or channelled waterways.

Adaptation strategies for this type of flooding, consist of both measures to protect against the floods themselves, and strategies that reduce the amount of rainwater runoff, such as buffering and natural infiltration. In certain circumstances, accelerated drainage can also be a solution.[21]

- Flood protection
  - protection measures on building scale
  - physical protection infrastructure
  - temporary (emergency) protection
  - warning systems
  - insurance
- Water buffering
  - lakes, ponds & wetlands

[20] https://www.an.no/bodo/var/varoy/deler-av-bodo-sentrum-kan-sta-under-vann-om-70-ar-sjekk-om-stormflo-kan-ramme-deg/s/5-4-909154 (2022)
[21] https://eri.iu.edu/erit/strategies/flooding.html (2022)

  - water squares & other urban above ground buffering
  - storage sewers & other underground buffering
  - rainwater harvesting & storage
- Infiltration
  - increasing soil permeability (reduction of impermeable surfaces)
  - natural buffering systems
  - bioswales & infiltration strips
  - underground infiltration systems (horizontal/vertical)
- Drainage
  - improving above ground drainage (deepening rivers)
  - above ground drainage systems
  - underground reverse drainage (including infiltration)
  - underground drainage systems

Initially, we are investigating the 'green-blue' network on the Bodø peninsula to examine how the green space of Bodø is structured and what role it can play for infiltration but possibly also for buffering rainwater.

3.3.3.2. Regulation systems: green-blue network

Bodø is a very green municipality with extensive nature reserves occupying most of its surface area. A green character also prevails in the urban area itself. This is primarily due to the morphology of the buildings, which largely consist of detached houses on fairly large, green-filled plots. This set of gardens plays an important role in the green character of the urban area but is probably strongly fragmented by fences and the paved areas of buildings, garden sheds, terraces, parking lots. Obviously, the streets also form a barrier in this network. Without a detailed study it is not immediately possible to determine how much the fragmentation weighs on the climate adaptive and regulating character of this garden landscape. From experience with garden landscapes in other cities, we can expect that the cooling character of the gardens is high, but the biodiversity rather average to low due to intensive maintenance and mowing management. Soil permeability is usually high in gardens, but they play only a partial role in rainwater buffering because rainwater from paved surfaces (traffic infrastructure, roofs) is usually drained into the sewer system and does not infiltrate into gardens.

In between are other, more public green areas such as public parks and bigger green areas within the urban tissue, for whom it is difficult to assess if they have a public or a private character. Other green spaces are the ones related to infrastructure (along roads and crossings, on parking lots, ...) that are smaller in size but form a bit more continuous network, being connected to the infrastructure network.

Areas with very little green space, and therefore very low soil permeability, are mainly the centre and some of the economic zones at the port and along the Rv80 road and the airport. The centre is very densely built up and the rigid grid structure of the building blocks leaves little room for greenery. The economic zones have a much lower building density, but here it is mainly the extensive car parks, road infrastructure and paved storage areas that provide a very low proportion of green space.

Figure 3.26 Analysis of the green areas on the urban peninsula: together they cover a large area, with only locally (downtown, industrial zones) large, petrified areas, image by BUUR/PoS 2022

So, in general it can be stated that Bodø has a very green character, also within the urban area. If the small-scale, individual gardens are omitted from the map though, the green network presents a much more fragmented picture, with few green structures that can play a role as a green corridor. Also, the role of the green spaces as a buffer for rainwater is unclear. If the private gardens are not part of such a system, it will be too limited in size and not even enough distributed.

Within the green urban network, water streams do not play a major role. Most of the natural streams have been covered up and there are no clear green-blue corridors present in the urban tissue where this can be undone rapidly. However, this is definitely a strategy that needs to be further investigated. The most continuous green structures are the ones connected to the road infrastructure. These can play a role for water infiltration but are usually too narrow to be developed into real green-blue corridors.

One real green-blue corridor exists however, along the river that runs from Rønvikjordene to its southern mouth in the sea. Large parts of this corridor are still intact and form an important natural area (also used for food production). Further investigation will be necessary to understand better how the corridor crosses the road infrastructure and the more built-up areas in the south, to see if there are improvements necessary.

Figure 3.27 However, most of the green space in the urban area of Bodø seems to consist of private green space; private gardens and other green areas that fulfil a garden function. Here, permeability and biodiversity can be used, but the chances for water buffering are limited, image by BUUR/PoS 2022

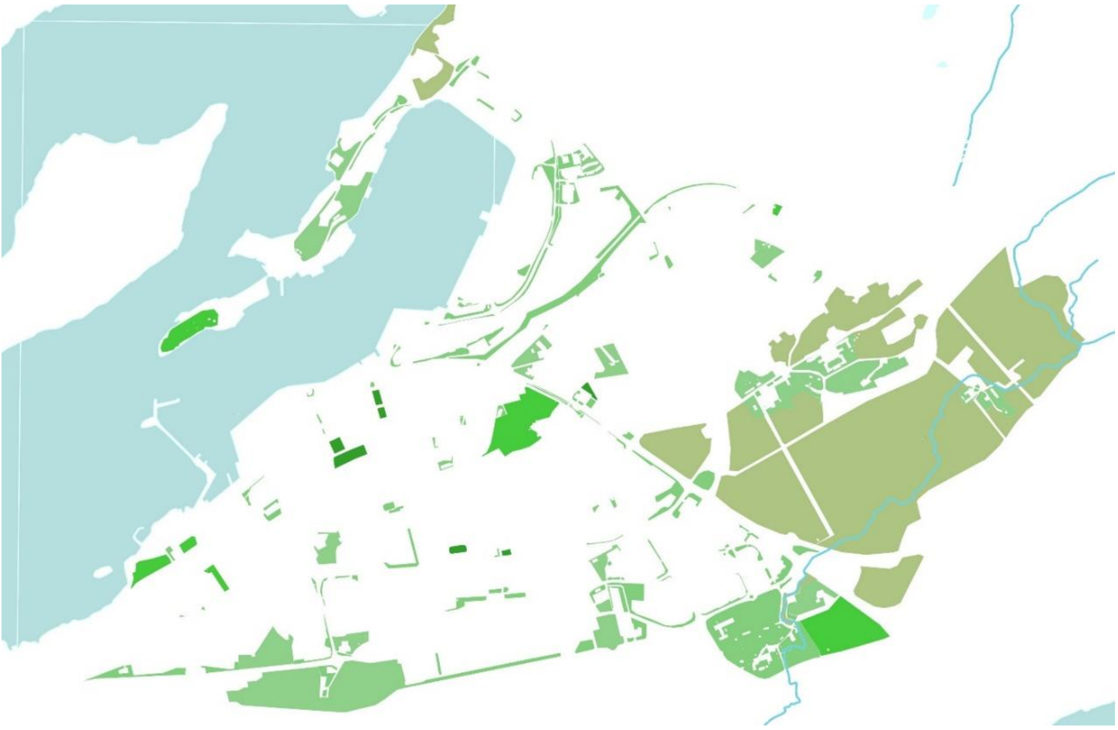

Figure 3.28 The green spaces with a more public character (parks, but also green spaces along road infrastructure and (public or private) parking areas) have a greater chance of being used for water buffering, provided they are well designed so that the functionality of the space can be maintained. This also applies to green areas outside the urbanized area, but here there is a risk that water buffering will conflict with agricultural use, image by BUUR/PoS 2022

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