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WHITE PAPER

Climate Change Adaptation in the Nordic Countries

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INTRODUCTION

For many decades, climate policy debates focused on how to curb greenhouse gas emissions. This remains an urgent priority, but it is also clear that some warming – at least 1.5°C above pre-industrial levels – is now inevitable due to historical emissions, and even more is likely given the slow pace of mitigation. Thus it is will be crucial to adapt to changing conditions.

In a global context, the outlook for the Nordic region is relatively favourable: climate change impacts are not expected to be as severe as in many other parts of the world (or even in Southern Europe), and the countries' robust institutions and economies give them a strong capacity to adapt. Still, the need for adaptation is real and substantial, and in most of the region, the work is only just beginning.

This white paper explores the potential for Nordic cooperation on adaptation – specifically, for the development of a regional adaptation strategy. It does not aim to develop a complete Nordic Adaptation Strategy, but identifies the key elements that would be needed for one, as well as integrated priorities that Nordic decision-makers may consider for action. It addresses two questions in particular:

1) What is the current state of adaptation in the Nordic countries?

2) What are the potential benefits and weaknesses of a Nordic strategy for adaptation?

The need for a more strategic Nordic approach to adaptation was already asserted in the 2006 Nordic Countries' Ministerial Declaration on Adapting to Climate Change, which called for improved collaboration across national borders and sectors, especially in the context of the Nordic Council of Ministers and other regional organisations (i.e., the Baltic Council and the Arctic Council). In addition, the Nordic Sustainable Development Strategy 2009-2012 included climate and renewable energy as one of its priorities, reflecting a desire to address climate change at a larger scale, regionally and not just on the national (or else Europe-wide) level.

The Nordic countries have also embraced a distinct approach to climate change that breaks down a long-standing distinction between mitigation and adaptation, which have typically been addressed in separate policy domains. There is a growing recognition in the region of the importance of ensuring that adaptation and mitigation actions complement each other, rather than working at cross-purposes. The term "adaptigation" has been coined to describe the Nordic countries' integrative approach to adaptation and mitigation (Langlais 2009).

To truly make an impact, mitigation and adaptation strategies also need to be integrated in countries' broader development strategies and plans. This, in turn, requires institutional transformation, as well as a sophisticated understanding of how climate issues intersect with policy challenges and goals across a wide range of sectors.

Over the past five years, considerable research on climate impacts and adaptation has been done in the Nordic region, laying the groundwork for more informed and effective policies. Several projects have explored the process of adaptation and policy development in specific Nordic countries (e.g., PLAN in Norway and Mistra SWECIA in Sweden, both described in a later section of this paper), while others have taken a more global approach – for example, looking at the underlying causes of vulnerability (Füssel and Klein 2006; Smit and Wandel 2006).

Nordic research institutes have done extensive work on institutions and decision-making (Storbjörk and Hedrén 2011; Juhola et al. 2011; Inderberg 2011; Glaas et al. 2010); social learning and social capital (Storbjörk 2007; Tàbara et al. 2010; Nilsson and Swartling 2009;

Pelling et al. 2008), and the links, synergies and potential conflicts between adaptation and mitigation (Klein et al. 2007). Analyses of adaptation and mitigation in sectors such as energy and transport have focused on roles for Nordic and European countries in a not-yet fully globalised world (Eskeland et al. 2010).

Yet despite all the progress in research and, to some extent, in high-level policy-making, a great deal of work remains to be done. Iceland, for example, has yet to develop a national adaptation policy, and many other countries' climate policies focus mostly on mitigation, or else fail to make connections between mitigation and adaptation. By harmonising their approaches to climate change and integrating adaptation and mitigation in cohesive climate policies, the Nordic countries will be better equipped to promote sustainable regional development and minimise vulnerability to climate impacts.

This white paper begins by defining the concept of adaptation and outlining some known barriers to adaptation. Then it briefly reviews current adaptation policy in Europe and the Nordic countries. Next, it discusses the benefits of collaboration amongst Nordic countries and potential barriers to such collaboration. Finally, it identifies key elements for a Nordic Adaptation Strategy and suggests priorities for Nordic decision-makers.

UNDERSTANDING ADAPTATION

For many decades, climate policy debates focused on how to curb greenhouse gas emissions. This remains an urgent priority, but it is also clear that some warming – at least 1.5°C above pre-industrial levels – is now inevitable due to historical emissions, and even more is likely given the slow pace of mitigation. Thus it is will be crucial to adapt to changing conditions.

The International Panel on Climate Change defined adaptation in its Third Assessment Report (IPCC 2001) as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". For the Nordic countries, this means trying to understand what climate change will bring, working to minimise negative impacts on our societies, economies and ecosystems, and taking advantage of any positive changes.

The IPCC (2001) notes that adaptation can be planned – the result of a deliberate policy decision – or autonomous – not a conscious response to climate change but rather to accompanying changes in natural or human systems. It can be anticipatory, before climate impacts are felt, or reactive. And it can be public – initiated by governments, and usually directed at collective needs – or private, initiated by individuals, households or businesses. There is also maladaptation, which exacerbates vulnerabilities instead of reducing them.

The policy review in this paper focuses on *public* and *planned* adaptation in the Nordic countries. It is important to note, however, that a great deal of adaptation in the region will, in fact, be autonomous and private; policy-makers must pay close attention to those processes and tailor public responses accordingly.

Limits and barriers to adaptation

Another key point to keep in mind as we review Nordic countries' approaches to adaptation is that not all climate impacts can be averted through adaptation; in fact, a recent review for the UK's AVOID programme (Warren et al. 2012) warned against counting on adaptation to offset the impacts of delayed or forgone mitigation. Adaptation will be most effective at relatively low levels of warming (perhaps up to 2.5°C), the authors noted, but it cannot undo

the impacts of more intense warming. And even when adaptation would be feasible and helpful, they stressed, the experience so far shows it will seldom occur to the optimal extent.

One useful way to look at the limits to adaptation is a chapter by Adger et al. (2007) in the IPCC *Fourth Assessment Report*, which identifies five types of limits and barriers to adaptation:

Physical and ecological limits: Socio-ecological systems' ability to adapt will depend on the rate and magnitude of climate change, and beyond "critical thresholds", they may radically alter their functional state and system integrity.

Technological limits: Even if technologies are available, they may not be economically feasible or culturally desirable, or uncertainty may inhibit decision-makers from adopting them.

Financial barriers: The projected costs of adaptation on a global scale far exceed the resources available, and even greater constraints exist at the local and individual levels.

Informational and cognitive barriers: Individual and social knowledge and perceptions of risk, personal vulnerability and adaptive capacity vary and can inhibit adaptation, and knowledge of climate change does not necessarily lead to adaptive action.

Social and cultural barriers: Risk tolerance and preferred adaptation options will differ based on individuals' and groups' world views, values and beliefs, and conflicting views may impede adaptive actions. Differences in power and influence will also affect adaptation.

In short, Adger et al. (2007) conclude, there are "substantial" limits and barriers to adaptation. Even high adaptive capacity "does not necessarily translate into actions that reduce vulnerability", as evidenced by continuing heat-stroke deaths in European cities despite the availability of fairly simple and low-cost ways to prevent them.

EUROPEAN ADAPTATION POLICY

Over the past five years, the European Union has actively promoted the development of adaptation strategies at the EU and national levels. An important first step was the publication of a "Green Paper" on adaptation (European Commission 2007), which launched a consultation on the future direction of EU adaptation policy. It also identified Europe's "most vulnerable" areas, including the Mediterranean Basin; the Alps; coastal zones facing sea-level rise and increasing storm risks; densely populated floodplains; Scandinavia, where increased rainfall is projected; and the Arctic region, "where temperature changes will be higher than in any other place on Earth".

In 2009, the EU followed with a white paper laying out a framework for adaptation policies and measures (European Commission 2009). The paper identifies the sectors likely to be most affected by climate change, including agriculture, fisheries, forestry, infrastructure, tourism, energy, water, human health and ecosystems. Climate change could affect crop yields, management of livestock and location of production, the paper notes, and more-frequent extreme weather events will increase the risk of crop failure. Infrastructure is cited as a particular concern for densely populated areas. Reduced snow cover in mountainous areas could affect tourism and ski resorts. Hydropower production could increase by 5% or more in Northern Europe, but decrease by 25% or more in Southern Europe. Water could become scarcer in some areas, affecting agriculture and food production.

The white paper notes that adaptation "is already taking place but in a piecemeal manner" and calls for a "more strategic approach" to ensure timely and effective adaptation as well as

coherence across sectors and levels of governance. It identifies building resilience as the key goal, and favours resource management, conservation, and working with natural systems, rather than relying on built infrastructure, as the preferred approaches.

The paper also warns against relying on autonomous adaptation by individuals and businesses, noting that due to uncertainty, imperfect information or financial constraints, autonomous adaptation is "unlikely to be optimal", and some maladaptation may occur – such as building flood protection that disturbs coastal or river dynamics. Most adaptation measures will still be taken at the national, regional or local level, the paper notes, but the EU policy will complement action by Member States and coordinate responses to climate impacts that transcend national boundaries. Coordinated EU action is also needed in sectors that are closely integrated at the EU level through the single market and common policies, such as agriculture, water, biodiversity, fisheries and energy networks.

The EU framework includes two phases: the first from 2009 to 2012, to "lay the ground work" for a comprehensive adaptation strategy, and then a second phase, starting in 2013, to implement it. For Phase 1, it identifies four "pillars of action", described in more detail below:

- Building a solid knowledge base on the impact and consequences of climate change for the EU;
- Integrating adaptation into EU key policy;
- Employing a combination of policy instruments (market-based instruments, guidelines, public-private partnership) to ensure effective delivery of adaptation;
- Stepping up international cooperation on adaptation

1. Building a solid knowledge base on the impact and consequences of climate change

This includes gathering reliable data on projected climate impacts, associated socio-economic aspects, and the costs and benefits of various adaptation options. Four actions are to be completed by 2011:

- Establish a Clearing House Mechanism for Member States to share information on climate impacts, vulnerability and best practices;
- Develop methods, models, data sets and prediction tools to help understand and predict impacts, identify vulnerabilities and develop adaptation measures;
- Develop indicators to better monitor the impact of climate change, including vulnerability impacts, and progress on adaptation;
  Assess the costs and benefits of adaptation options.

2. Integrating adaptation policy within the EU

This entails "mainstreaming" adaptation in all sectors on the basis of scientific and economic analysis. In each policy area, three questions are to be asked:

- What are the actual and potential impacts of climate change in the sector?
- What are the costs of action/inaction?
- How do proposed measures impact upon and interact with policies in other sectors?

Priority is to be given to "no-regrets" measures that can generate net social or economic gains even if climate impacts are uncertain; measures that support both mitigation and adaptation are also to be prioritised. The paper identifies several priority areas for this work, all sectors with "strong EU policy involvement", all with a view to increasing resilience: health and

social policies; agriculture and forests; biodiversity, ecosystems and water; coastal and marine areas, and production systems and physical infrastructure. Table 1 summarises the vision and recommended actions in each area.

Table 1: Integrating adaptation into EU policies

Policy area	Description	Actions
Health and social policies	The EU Health Strategy foresees adaptation action, though Member States will take the main policy actions. Focus is on disease surveillance, risks associated with extreme events, and control of communicable diseases. Impacts on animal health are also to be addressed. Recognition of socio-economic aspects of vulnerability demands policies that "distribute the burdens equitably" and consider job impacts and quality of life of low-income groups.	• Develop guidelines and surveillance mechanisms on the health impacts of climate change by 2011; • Step up existing animal disease surveillance and control systems; • Assess the impacts of climate change and adaptation policies on employment and on the well-being of vulnerable social groups.
Agriculture and forests	The Common Agricultural Policy (CAP) is expected to play a central role in adaptation, helping farmers adapt to climate change and promoting land management practices that support ecosystem services.	• Ensure that measures for adaptation and water management are embedded in rural development national strategies and programmes for 2007-2013; • Consider how adaptation can be integrated into the three strands of rural development and give adequate support for sustainable production, including how the CAP contributes to the efficient use of water in agriculture; • Examine the capacity of the Farm Advisory System to reinforce training, knowledge and adoption of new technologies that facilitate adaptation; • Update forestry strategy and launch debate on options for an EU approach on forest protection and forest information systems.
Biodiversity, ecosystems and water	Aims for a "comprehensive and integrated approach" to ensure healthy ecosystems and functions such as carbon sequestration, flood protection and protection against soil erosion. Key policies regarding water and adaptation are the Water Framework Directive, the River Basin Management Plans and the Floods Directive. Regarding habitats, climate concerns must be integrated into Natura 2000.	• Explore ways to address biodiversity loss and climate change in an integrated manner to fully exploit co-benefits and feedbacks that accelerate global warming; • Develop guidelines and tools by 2009 to climate-proof the River Basin Management Plans (RBMP); • Ensure climate is taken into account in the implementation of the Floods Directive; • Assess the need for further measures to enhance water efficiency in agriculture, households and buildings; • Explore potential policies and measures to boost ecosystem storage capacity for water in Europe; – Draft guidelines by 2010 on dealing with the impact of climate change on the management of Natura 2000 sites.
Coastal and marine areas	Key concerns include climate stresses on fisheries and the need for sound, climate-resilient coastal development.	• Ensure that adaptation in coastal and marine areas is taken into account in the framework of the Integrated Maritime Policy, in the implementation of the Marine Strategy Framework Directive and in the reform of the Common Fisheries Policy; • Develop European guidelines on adaptation in coastal and marine areas.
Production systems and physical infrastructure	Member States are primarily responsible for protecting infrastructure; the EU will promote best practices, set construction standards, and require climate-proofing of EU-funded projects. A coordinated approach is desired for improving the resilience of transport infrastructure and energy networks.	• Take account of climate change impacts in the Strategic Energy Review process; • Develop methodologies for climate-proofing infrastructure projects and consider how these could be incorporated into the TEN-T and TEN-E guidelines and guidance on investments under Cohesion policy in the current period; • Explore the possibility of making climate impact assessment a condition for public and private investment; • Assess the feasibility of incorporating climate impacts into construction standards, such as Eurocodes; • Develop guidelines by 2011 to ensure that climate impacts are taken into account in the Environmental Impact Assessment and Strategic Environmental Assessment Directives.

Source: Authors' summary of European Commission (2009 Section 3.2).

3. Policy instruments to ensure effective delivery of adaptation

Citing the *Stern Review* (2006), the white paper recognises finance as one of the main constraints to adaptation. It notes that the EU's 2007-2013 financial framework prioritises climate action, and the European Economic Recovery Plan (EERP) also includes climate-related measures.

In addition, the paper calls for optimising the use of insurance and other financial products, including exploring whether private actors providing critical services should be required to carry insurance, and whether EU-wide insurance schemes might be helpful. And the paper notes that specialised market-based instruments and public-private partnerships should be encouraged to help spread the investment, risk, reward and responsibilities.

Specific actions to be pursued include:

- Estimate adaptation costs for relevant policy areas so that they can be taken into account in future financial decisions;
- Further examine the potential use of innovative funding measures for adaptation;
- Explore the potential for insurance and other financial products to complement adaptation measures and to function as risk sharing instruments
- Encourage Member States to utilise the EU's ETS revenues for adaptation purposes.

The paper note that the European Commission intends to set up an Impact and Adaptation Steering Group (IASG) to help implement the framework, foster cooperation, and support Member States. The group is to be supported by technical groups specialising in key sectors (e.g., agriculture, biodiversity, energy, health). In addition, Member States are to be encouraged to keep developing their National and Regional Adaptation Strategies, with a view to considering mandatory adaptation strategies from 2012.

4. Stepping up international cooperation on adaptation

Looking beyond the EU, the paper recognises that climate change is already having significant impacts and calls for helping other countries to adapt, especially neighbours and the "most vulnerable" developing nations. Adaptation should be mainstreamed in all the EU's external policies, including trade policy – by fostering "green trade"; in bilateral and regional financial assistance programmes; in water management; in a wide range of sectoral policies; in social policy; in research, and in disaster risk reduction.

Moving forward

The 2009 EU white paper illustrates the broad scope of the task of mainstreaming adaptation in all relevant policies and ensuring that the necessary finance and institutional frameworks are in place. One key step for the EU was the establishment, in February 2010, of the Directorate-General for Climate Action (DG CLIMA), which leads the EU's international negotiations on climate, oversees mitigation efforts and the EU ETS, and is also responsible for adaptation and vulnerability reduction.

The European Commission has also proposed that at least 20% of the EU's 2014-2020 budget be spent on "climate-relevant" measures, including low-carbon technologies and adaptation.[1] In addition, a climate sub-programme within the LIFE fund, with a budget of €904.5 million, is to support capacity-building projects at local/regional levels and support private actors in implementing small-scale low-carbon and adaptation technologies. The EU is also preparing an adaptation strategy; a consultation on the strategy was conducted in May-August 2012.

[1] See http://ec.europa.eu/clima/policies/finance/budget/index_en.htm.

Also in 2012, the European Commission and the European Environment Agency launched the European Climate Adaptation Platform (CLIMATE-ADAPT[2]), a website where users can access and share information on expected climate impacts; current and future vulnerability of regions and sectors; EU, national and transnational adaptation strategies and actions; adaptation case studies and options; and tools to support adaptation planning.

The site is a useful resource in formulating adaptation policies and strategies, and it provides an overview of macro-regional approaches to adaptation. One of these macro-regions is the Baltic Sea Region, where an outline for a BSR-wide adaptation strategy was produced within the EU-financed project BaltAdapt.[3] The strategy aims at strengthening cooperation and information-sharing in the region, with a focus on the marine and coastal environment.

COMMON NORDIC POLICY

The Nordic Council of Ministers has published a number of studies and assessments of potential climate change impacts in different sectors in the region. NordForsk, which operates under the Council and funds research to inform policy-making in the Nordic countries, has supported significant climate-related work, most notably through the Top-level Research Initiative, which aims to cover "the entire solution chain", from understanding climate impacts, to renewable-energy technologies.[4] In addition, several regional meetings and conferences have been held, though to date, no official joint Nordic policy or action plan has been produced. In a comprehensive review of the "state of play" of Nordic cooperation on adaptation, Scherbenske and Diș (2011) note that the Nordic countries differ in projected climate change impacts, and their responses are also shaped by geography and different economic structures and relationships with the EU. However, the Nordic countries also have many commonalities, including similar legal frameworks, and they have been cooperating on climate-related issues for several years, in larger regional groups such as the Arctic Council and the Baltic Sea Region Programme, and in Nordic-specific groups under the Nordic Council of Ministers.

Based on a series of interviews with national officials and researchers, Scherbenske and Diș (2011) find significant interest in strategic cooperation on adaptation research as well as in exchanging experiences with implementation. They suggest that research programmes under the NCM, such as NordForsk, ongoing projects and the NCM Nordic Working Groups could serve as a starting point for broader cooperation. First, however, a common strategy is needed that recognises the different local circumstances and ensures a sense of ownership.

Nordic cooperation, Scherbenske and Diș (2011) find, could help overcome resource deficits that have hindered adaptation, strengthen expertise, and raise awareness of the seriousness of climate change among government officials and citizens, helping to "mainstream" adaptation. A common Nordic strategy could also help identify areas where a regional effort could achieve more than individual countries' actions, provide a useful mix of top-down (regional strategy) and bottom-up (local examples) guidance.

[2] See http://climate-adapt.eea.europa.eu.
[3] See http://www.baltadapt.eu.
[4] See http://www.nordforsk.org/en/programs/programmer/toppforskningsinitiativet.

ADAPTATION WITHIN NORDIC COUNTRIES

The Nordic countries have done considerable work at the national level to identify potential climate change impacts and begin adapting. Governments in all the countries have performed vulnerability assessments, and some have developed national strategies for climate adaptation (Finland in 2005, Denmark in 2008, and Norway in 2010. Iceland and Sweden have not developed an overarching national strategy, but they have developed sector-specific adaptation policies.

The sections that follow, which draw primarily on official documents and government websites, briefly describe national-level adaptation efforts to date.

Denmark

With 5.6 million inhabitants living on 43,000 km^2 as of late 2012,[5] Denmark is by far the most densely populated of the Nordic countries (130/km^2, vs. roughly 16/km^2 in Finland and Norway and 21/km^2 in Sweden). It was the second Nordic country to develop an adaptation strategy (The Danish Government 2008), after Finland. More recently, in November 2011, a Task Force on Climate Change Adaptation was established under the Ministry of the Environment to communicate the adaptation strategy and overall climate knowledge and contribute to research and planning. The Task Force runs the Danish Portal for Climate Change Adaptation,[6] from which much of the material in the next section was drawn.

Climate impacts

A particular concern for Denmark is sea-level rise. The waters around Denmark are expected to rise, on average, by 0.3m to 1m by 2100, according to the Danish Meteorological Institute.[7] After accounting for isostatic uplift and wind, the projected range of sea-level rise is 0.1m to 1.2m, depending on the location. The implications for Copenhagen, Denmark's low-lying capital, could be significant: roughly 2% of the population lives at less than 1m elevation, and around 24% of the industrial Total Insured Value (€ 1.7 billion) lies below 1m, and 18% below 0.5m (Hallegatte et al. 2011). Copenhagen is very well protected by dikes and other defence measures, but even 0.5m of sea-level rise could increase the economic impact of a 100-year storm from the current estimated € 3 billion to € 5 billion (ibid.).

Overall, Denmark's climate is expected to become warmer, wetter and cloudier, with more extreme weather events.[8] Under the IPCC's A1B scenario, by 2050, mean summer temperatures would rise by 0.4°C, with more heat waves, while mean winter temperatures would decrease by 1.0°C. Mean annual precipitation would increase by 11%, and the frequency of heavy precipitation events would increase by 6% – with summers including both droughts and downpours. More wind is expected, bringing more powerful storms. The growing season would extend by 21 days, while the frost would decrease by 17 days.

Adaptation research[9]

The Danish strategy for adaptation (The Danish Government 2008) established a coordination unit for adaptation research, charged with supplying validated climate and climate-impact data as well as other research relevant to adaptation. The unit also coordinates and maintains

[5] See http://www.dst.dk/en/Statistik/emner/befolkning-og-befolkningsfremskrivning.aspx.
[6] See http://en.klimatilpasning.dk.
[7] See http://en.klimatilpasning.dk/knowledge/climate/futuresealevels.aspx.
[8] See http://en.klimatilpasning.dk/knowledge/climate/denmarksfutureclimate.aspx.
[9] This section is drawn from http://en.klimatilpasning.dk/knowledge/research.aspx and its sub-sections.

an overview of existing research in climate adaptation in Denmark, guided by a technical advisory panel made up of Danish and international researchers.

A mapping of climate research in Denmark in 2009 found roughly 1.5% of public-sector researchers were focused on climate, while climate-related R&D accounted for 3% of total private R&D spending in Denmark. Internationally, Denmark ranks 19th in terms of climate research publishing, and fifth on a per capita basis. However, only a fraction of Danish climate researchers focused primarily on adaptation, the equivalent of 19 FTEs in the public sector (out of 160 total FTEs), concentrated at Aarhus University, the Technical University of Denmark and the University of Copenhagen. The main emphasis is on adaptation capacity and proactive adaptation, covering topics such as nature protection, buildings and construction, soil science and forestry.

Ongoing adaptation research projects in Denmark include a study of adaptation needs in architecture; a look at the influence of ecological dynamics and climate change on the marine environment in Danish waters; a risk assessment based on a statistical evaluation of extreme precipitation, storm surges and extreme wave heights; and participation in an international study of flood risks on motorways.

National adaptation policy

Danish climate change policy is overseen by the Ministry of Climate, Energy and Building, which was established in 2007 and is focused primarily on mitigation, leading an effort to make Denmark independent of fossil fuels by 2050 and to cut overall greenhouse gas emissions by 40% from 1990 levels by 2020. Adaptation efforts, meanwhile, span multiple sectors and relevant government agencies, with the Task Force on Climate Change Adaptation overseen by the Ministry of the Environment, as noted above.

The stated goal of the Danish adaptation strategy (The Danish Government 2008) is to ensure that climate change is "considered and integrated into planning and development in the most appropriate way". It does not aim to direct adaptation, but rather offers "sight-lines to enable authorities, businesses and citizens to react promptly and autonomously" to climate challenges. The strategy comprises three key measures:

- A targeted information campaign, including creation of a web portal operated by an information centre (initially the Information Centre for Climate Change Adaptation, within the Ministry of Climate and Energy; since November 2011, the Task Force for Climate Change Adaptation, under the Ministry of Environment);
- A research strategy, including establishment of a coordinating body to ensure that Danish climate research focuses on adaptation to a greater extent (see section on research); and
- An organisational framework, including establishing a horizontal coordination forum for adaptation that will ensure a coordinated effort among public authorities.

The strategy identifies several sectors in which climate impacts could be "significant", focusing on adaptation measures that are "attainable" within 10 years. The list is roughly consistent with the sectors that have been identified in other reports as requiring attention: coastal management, buildings and construction (including sewers and transportation infrastructure), water supply, energy supply, agriculture and forestry, fisheries, nature management, land-use planning, health, rescue preparedness, and insurance.

It should be noted that not all climate change impacts are expected to be negative; Danish agriculture, for example, is expected to benefit from the warmer temperatures and longer

growing season, with greater productivity and new crop options – though pests are also expected to increase.[10]

Adaptation in Danish municipalities

Given the local nature of many climate impacts and adaptation needs, Denmark has been encouraging local governments to draft adaptation plans. The Ministry of Environment has called for all municipalities to have adaptation action plans by the end of 2013, and a Climate Change Adaptation Squad was established in February 2012 to help them.[11] A mobile task force is also providing assistance, and is expected to have visited one-third of municipalities by the end of 2012.[12] The national government has made an agreement with municipal authorities that is expected to increase municipal investments in adaptation by up to DKK 2.5 billion by 2013, and several legislative changes have also been made, such as amending the Danish Planning Act to enable municipalities to cite adaptation as the basis for local plans.[13]

Copenhagen, the largest city in Denmark, with roughly 549,000 people[14], has set out to be a leader in sustainability – first with a plan to cut its CO_2 emissions by 20% from 2005 levels by 2015 (City of Copenhagen 2009), then with a plan to become the world's first carbon neutral capital city by 2025 (City of Copenhagen 2012). The 2009 plan also included adaptation measures, with five priorities: stormwater management, especially during heavy downpours; "green" solutions to reduce flood risks; increased use of passive cooling of buildings; protection against flooding from the sea; and preparation of a combined adaptation strategy.

The latter resulted in the Copenhagen Climate Adaptation Plan (City of Copenhagen 2011), which is geared to incorporating adaptation into all aspects of the city's development, with the idea that adaptation and the development of "an attractive and green major city" are "two sides of the same coin".[15] The plan adopts a development scenario in line with IPCC's A2 scenario – different from the national government's choice of A1B, but almost identical in terms of projected impacts on Copenhagen by 2050, the plan notes. Given the significant uncertainty around long-term climate change impacts, however, the plan also stresses that instead of making investments now to address long-term risks, the focus should be on taking account of the need for "climate-proofing" in municipal planning, so that urban development does not preclude future adaptation measures (p.5). Key goals include ensuring that "wrong" investments are not made, and that adaptation investments are recouped as a part of green growth; there is also a desire to ensure that adaptation measures contribute to the quality of life in the city, and that adaptation is based on analyses "at a high technical level".

The plan provides for a risk assessment to identify the most serious hazards, including their likelihood. Then it identifies three levels of adaptation measures: First, to reduce the likelihood of damages occurring, preferably to completely prevent them; this includes the establishment of dikes, building higher above sea level, local adaptation of sewer capacity, local management of stormwater, etc. Second, if prevention is not technically or economically feasible, measures will be taken to mitigate the damage; at this level are warning systems for rain, the establishment of watertight basements, sandbags, adaptation of public spaces so that

[10] The Danish adaptation portal builds on the strategy's sectoral analysis, with dedicated pages for each sector as well as case studies; see http://en.klimatilpasning.dk/sectors.aspx.
[11] See http://en.klimatilpasning.dk/recent/news/newsletter5.aspx.
[12] http://en.klimatilpasning.dk/recent/news/newsletter7.aspx.
[13] See http://en.klimatilpasning.dk/recent/news/newsletter6.aspx.
[14] See http://www.dst.dk/en/Statistik/emner/befolkning-og-befolkningsfremskrivning.aspx.
[15] See http://subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/LivingInCopenhagen/CopenhagenClimateAdaptionPlan.aspx.

they can store rainwater, etc. The third level is to reduce vulnerability by making it easier and cheaper to clean up after an event; this may include emergency preparedness with pumps, e.g.

Summary

Denmark is paying considerable attention to climate change adaptation, with a special focus on serious risks related to increased precipitation and more-frequent downpours, as well as to sea-level rise. It is also investing in research and has developed an adaptation information portal with valuable resources for multiple audiences. And it has recognised the importance of local-level adaptation and is supporting municipalities in developing action plans. The City of Copenhagen has been particularly ambitious and has linked adaptation with the higher-profile agenda of becoming carbon-neutral by 2050, seeing both efforts as complementary.

Finland

Finland, with the population of 5.4 million people as of November 2012,[16] is the northernmost country with significant agriculture, with 2.3 million hectares of utilised agricultural area in about 66,600 farms as of 2007, employing the equivalent of 67,400 full-time workers.[17] Climate change is expected to have significant effects there, and Finland was the first EU country to develop a national adaptation strategy (Marttila et al. 2005).

Climate impacts

The National Adaptation Strategy outlines the main expected impacts of climate change in Finland: Average temperatures will rise, by a projected 4-6°C by 2080, with the greatest changes in the winter; average precipitation could increase by 15-25%, and extreme weather events such as storms, heavy rains, floods, droughts and extreme frosts are likely to become more frequent. The damage could affect broad areas in Finland, not just isolated sectors. This will have major consequences for farming and water and energy supplies (Marttila et al. 2005).

Tree growth is expected to weaken, groundwater will have lower quality and frost will weaken berry yields. Extreme weather is also expected to cause damages to buildings and infrastructure. Tourism will be affected because of snow cover reduction and changes in ground frost. This will also affect wintering crops in southern Finland and compaction of clay soil. However, there could also be benefits in southern Finland, where this gives the opportunity to harvest wood over the winter period (Marttila et al. 2005).

The projected increases and greater extremes in precipitation could make it more challenging to anticipate hydropower availability; and increase the cost of maintaining transport infrastructure such as airports and railways. Precipitation changes will also affect harvests, while warming poses a risk to plants as diseases appear earlier and the overall risk of plants getting diseases increases. Population loss might be observed in fish stocks in southern Finland and fish farms might experience trouble in production. It is also possible that some advantages from climate change can be identified. These include longer growing season, longer pasture season, longer period for summer tourism, reduced heating energy needs, more growth in forest, and potential migration of warm-water fish species to Finnish waters (Marttila et al. 2005).

[16] See http://www.stat.fi/til/vamuu/2012/11/vamuu_2012_11_2012-12-20_tie_001_en.html.
[17] Per EuroStat; see http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Farm_structure_in_Finland.

Adaptation research

Finland's first major research project on adaptation was the FINADAPT consortium, which looked in-depth at the adaptive capacity of Finnish society and the environment in regards in the face of climate change (Finnish Environment Institute (SYKE) n.d.). FINADAPT was funded for 2004-2005 as part of the Finnish Environmental Cluster Research Programme under the Ministry of the Environment and comprised 14 work packages and 11 partner institutions. It produced numerous papers as well as a final summary for policy-makers (FINADAPT 2007) with included national-level climate scenarios for Finland, a review of key vulnerabilities, and options for adaptation.

Another major research effort was Finland's Climate Change Adaptation Research Programme (ISTO), which was launched as part of the implementation of the NAS in 2006.[18] It ran for four years, with the aim of producing information that would facilitate the planning of adaptation measures across administrative sectors. Within the programme, 30 research projects were carried out with funding from various sources, including the Ministry of Agriculture and Forestry, and the Finnish Environmental Cluster Research Programme of the Ministry of the Environment. Existing adaptation research projects that were funded at the time were also linked up to ISTO. A mid-term evaluation of the programme found that despite its limited resources, ISTO had increased awareness of climate change and provided knowledge necessary for implementation of adaptation measures. Given the constraints placed by limited funding, however, the programme did not fully achieve its desired goals.

Most recently, the Finnish Research Programme on Climate Change (FICCA) was launched by the Academy of Finland, to run from 2011 to 2014[19] to support multidisciplinary research to address the challenges of climate change. The programme includes 16 research projects that address adaptation challenges, ranging from resiliency in agri-food systems, to carbon capture and storage, protection of Arctic ecosystems, and economically optimal adaptation in forest ecosystems.

National adaptation policy

The National Adaptation Strategy (Marttila et al. 2005) outlined potential measures for planned adaptation and for strengthening adaptive capacity in to be taken by several specific sectors: those using natural resources (agriculture and food production, forestry, fisheries, reindeer husbandry, game management and water), biological diversity, industry, energy, transport and communications, land use, communities, buildings and construction, health, tourism and insurance. Along with those measures, which are meant to be implemented within the individual sectors between 2005 and 2015, the strategy also identifies priorities for adaptation to climate changes elsewhere that might affect Finland. Finally, it identifies several cross-sectoral issues: building administrative capacity; incorporating climate issues into the environmental and other management systems of various institutions; incorporating climate concerns into environmental impact assessments; and developing risk assessment methods applicable to climate change.

Five goals are set for the Finnish government:

- Climate change adaptation will be incorporated into the regular planning, implementation and development processes in various sectors
- Preparations will be made for extreme climatic events and the assessment of climate change impacts will be incorporated into the planning of long-term investments;

[18] See http://www.mmm.fi/en/index/frontpage/climate_change_energy/adaption/adaptation_research.html.
[19] See http://www.aka.fi/en-GB/A/Programmes-and-cooperation/Research-programmes/Ongoing/FICCA/.

- Existing observation and warning systems will be improved and new ones developed;
- The Climate Change Adaptation Research Program 2006–2010 will be implemented;
- Preparations will be made for changes in the international operational environment.[20]

The first evaluation of the NAS (Ministry of Agriculture and Forestry 2009) found that adaptation had been acknowledged as a concern in most administrative sectors, but not all sectors had made progress to a sufficient degree. Most advanced was the Environment Administration, in particular measures related to water management. The NAS is currently being revised, with a new version due to be released in 2013.

Adaptation in Finnish municipalities

Helsinki is Finland's largest city, with roughly 592,000 inhabitants as of January 2012 and nearly 1.4 million in its metropolitan area, which also includes the municipalities of Espoo, Vantaa and Kauniainen.[21] In 2009, the Helsinki Metropolitan Area cities and the Helsinki Region Environmental Services Authority (HSY) began developing an adaptation strategy, with HSY coordinating the process. The first output, a report on projected impacts (HSY 2010), noted the expected warming and warned especially about sea-level rise. While in Helsinki, the minimum recommended elevation for buildings was 2.6m, the report notes, with water levels expected to reach 2.3m once every 200 years, recent sea-level rise projections – especially on the high end – suggest much greater risks even within this century. The report also notes that there is great uncertainty about climate impacts on flood risks; fewer floods are expected on the Vantaa river, but more are expected on smaller tributaries of the Espoo river due to heavy rains and winter floods. Impacts on the urban and built environment are presumed to be negative, but more research is needed. Key challenges identified are extreme weather, stormwater management, moisture damage in buildings, securing energy distribution, and the maintenance of telecommunication networks.

The final output, the Helsinki Metropolitan Area Climate Change Adaptation Strategy (HSY 2012), which aims to "climate-proof" the city, lays out a series of recommended strategies to be implemented in 2012-2020. It focuses on land use; traffic and technical networks; buildings and infrastructure; water and waste management; water and waste management; rescue services and safety; health care and social services, and cooperation in the production and distribution of information.

Three Finnish municipalities – Espoo, Kokkola and Rahe – along with the Pirkanmaa region, were also involved in the ASTRA project in 2005-07.[22] The project aimed to assess climate impacts in the Baltic Sea Region, identify threats, and develop strategies and policies for adaptation. Espoo is Finland's second-largest city and has grown rapidly, from about 100,000 residents in 1970 to 235,000 at the time of the ASTRA project. The case study involving the city focused on climate impacts relevant to land-use planning. Projections include more frequent floods, winds, heavy rains and storms; increased rainfall; changes in soil humidity and groundwater levels; greater erosion and landslide risk; and changes in icing conditions. The vulnerability of energy, water and waste management systems and ecological systems were also considered. As part of the project, in the aftermath of the 2005 storm Gudrun, Espoo officials worked with ASTRA researchers to map areas vulnerable to flooding. Subsequently an operation model was created in case of future flooding in Espoo.

[20] See brochure from the Ministry of Agriculture and Forestry, Ministry of Environment and Finnish Environment Institute (2009), *Adapting to climate change in Finland*, http://www.mmm.fi/attachments/mmm/julkaisut/esitteet/5mM2RRBrs/Adapting_to_climate_change_in_Finland_FINAL_lowres.pdf.
[21] See http://www.hel.fi/hki/Helsinki/en/Information+on+Helsinki.
[22] See http://www.astra-project.org and individual case study descriptions on the site.

The Pirkanmaa case study focused on impact of climate change on nutrient flows in the catchment of the Kokemäenjoki river. Models developed through ASTRA found that there would be a considerable change in the seasonal dynamics of nutrient loading, with more nutrients overall regardless of the climate model or the emission scenario used, heavier nutrient loads in the winter, and lower and earlier spring peak loads.

Kokkola is a small city on the western coast of Finland, with about 36,000 residents (and roughly double this in the greater Central Ostrobothia region). The coastal land is rising there: uplift is about 8mm per year. The ASTRA case study in Kokkola focused on describing probable and worst-case scenarios for sea-level rise, storms, extreme weather, precipitation and river flows, among other factors; identifying key buildings and infrastructure of concern; and evaluating development options for Old Harbour Bay and surroundings as well as for the Ykspihlaja industry area in different scenarios up to the year 2100.

Summary

Finland is expecting significant climate change impacts, primarily several degrees of warming and a 15-25% precipitation increase, more unpredictable precipitation, and more frequent extreme weather events. The precipitation changes will make hydropower capacity less predictable and increase flood risks in many places. Sea-level rise is another major concern for Finland, especially around the Helsinki region.

In terms of public-policy responses and research, Finland has been ahead of some of its neighbours, with the region's first national adaptation strategy (Marttila et al. 2005) and almost a decade's worth of research activities. There have been concerted efforts to downscale climate models to the local and regional levels, to maximise their utility to planners and policy-makers; in addition, Finnish researchers have raised questions that have only recently begun to get significant international attention, such as cross-boundary climate impacts and adaptation needs, and limits to adaptation. Municipalities have also been involved in research projects and have incorporated new findings into their policies and plans. Insights from Finnish research could be of great value to other Nordic countries, and information-sharing would also benefit Finland itself, by raising awareness of risks and helping minimise spill-over effects.

Iceland

Iceland is the northernmost and most sparsely populated Nordic country, with just under 320,000 people living on its 103,000 km^2 territory as of January 2012 – about 200,000 of them in the Greater Reykjavik region.[23] It has very limited agriculture, with 2,592 farms as of 2010, but only 226 hectares devoted to growing vegetables, e.g., and 5,310 to cereals, vs. 154,045 of pasture. Iceland's fisheries, however, are relatively large, with 1.1 million tonnes caught in 2011, valued at about $1.2 billion USD (154 billion ISK); fish products are also the second-largest category of industrial products, accounting for 34.1% of the total value in 2011 (basic metals accounted for 35.1%). Iceland is rich with renewable energy, primarily geothermal, which supplied two-thirds of gross energy consumption in 2011; another 19% came from hydropower. The country has leveraged this to court the technology sector to set up large servers; it has also promoted tourism, which accounted for 5.9% of GDP in 2009.

[23] All data from Statistics Iceland, http://www.statice.is.

Climate impacts

Iceland has experienced considerable warming, an average of 0.35°C per decade from 1975 to 2008, according to the country's Fifth National Communication to the UNFCCC (Ministry for the Environment 2010). This is more rapid than the global trend of roughly 0.2°C per decade, and is believed to be due to a combination of local variability and global climate change. Based on the results of climate models used in the IPCC's *Fourth Assessment Report* (2007), warming is projected to continue at a rate of 0.16°C to 0.28°C per decade (with an intermediate-scenario rate of 0.23°C); by the end of the century, this would result in 1.4°C to 2.4°C of warming (the intermediate scenario shows 2.0°C). The number of frost days is expected to drop, and heat waves will increase. Based on 20th century records, the snow cover in the lowlands will be three to four weeks shorter for every degree of warming. Precipitation will increase; the average estimate is 5%, but the results are very variable.

The impacts of warming to date are quite visible, most notably in Iceland's glaciers, which cover about 11% of the country and are almost all retreating. Thinning glaciers are leading to uplift in parts of Iceland, potentially offsetting the impacts of sea-level rise; however, this is not the case in southwestern Iceland, where subsidence is occurring (in Reykjavik, sea level rose by 5.5mm per year in 1997-2007). Changes in glacier runoff are considered one of the most important climate change impacts in Iceland. Accelerated glacier melt has implications for hydropower infrastructure; it is also changing fluvial erosion patterns and changing the courses of glacier-fed rivers.

For Icelandic agriculture and forestry, on the other hand, warming is expected to be a boon. Long-term studies have shown that a 1°C rise in spring temperatures increases hay production by 11%; frost heaving, which frequently damaged hayfields in the 1960s-1980s, has now largely disappeared. Barley production is increasing due to both research and development, and warming: yields increase by an estimated 1 tonne per hectare for each 1°C of warming. New crops are also now being grown, such as winter wheat, and vegetables already grown outdoors in Iceland, such as potatoes, turnips and carrots, will be more plentiful. (As in other countries, however, there is concern about increases in pests and plant diseases.)

Animal husbandry is expected to benefit not only from increased production of fodder crops, but also from thriving wild grazing plants. The time available for grazing is expected to increase, reducing the need for sheltering livestock during winters. And annual growth rates and coverage of both natural and managed forests are expected to increase. However, warmer winters could harm some exotic tree species used in managed forests and as ornamental garden plants, especially if they start growing too early in late winter or early spring, becoming susceptible to frost damage. Forest pests are also a concern, especially for the natural woodlands of downy birch, which have already been repeatedly defoliated by both native and alien insects in the 2000s.

For fisheries, the projections are mixed. Warming waters are expected to increase the abundance of commercial stocks, but not as much as during the warming of the 1920s and 1930s, when fish stocks were better to begin with. A relatively new but significant concern is ocean acidification; the surface pH is falling about 50% faster in the Iceland Sea than has been observed in the sub-tropical Atlantic. The ecosystem impacts are being studied through the European Project on Ocean Acidification (EPOCA).

Iceland's Fifth Communication also briefly considers the societal impacts of climate change, which are described as uncertain. Impacts on fisheries would have some socio-economic effects, especially in fishing-dependent regions, but it is unclear whether fisheries will do better or worse, on balance; in any case, climate change is expected to cause instability or

fluctuations in harvesting possibilities. Impacts on human health, meanwhile, are not considered a major concern, except in the context of changes in the frequency or intensity of natural disasters or extreme weather events. Heat waves are not a worry here, and fewer colder days in the winter may have health benefits. More research is recommended on the indirect impacts of ecological changes on human health.

Adaptation research

Adaptation research in Iceland appears to have been very limited to date. The Fifth National Communication (Ministry for the Environment 2010) refers several times to a major government-sponsored study of climate change in Iceland published by an expert panel in 2008, but the text does not appear to be online, at least not in English.[24]

In 2012, the transnational project CoastAdapt published a report specifically on adaptation in Iceland (Jónsdóttir 2012), which built on the 2008 study and also explored adaptation options. The report notes that adaptation in Iceland is seen as "a relatively straightforward task", with science guiding policy, but the political, cultural and societal dimensions "are played down" (p.5). Adaptation has also been given low strategic importance, likely due to the fact that short-term impacts are mostly considered economically positive. Other findings include:

- Relevant information and tools, such as maps and databases, are needed to develop strategies and action plans – for example, to identify flood-prone areas.
- While adaptation often occurs at the local or national level, some challenges are multi-national; for example, Iceland is involved in an international dispute over its desire to increase its quota of Atlantic mackerel, which have been migrating north with ocean warming.
- While the effects of ocean acidification on marine organisms and ecosystems are not fully understood, their implications may be very serious.
- Roads must be prepared to withstand more frequent freeze-thaw cycles, and rising sea levels must also be taken into account in road design.
- As marine transport in the Arctic Ocean increases, there is a need to enhance marine safety, take actions to protect the environment, and build up marine infrastructure.
- The whole society needs to be more engaged in adaptation.
- Adaptation knowledge exists in Iceland but is dispersed; a better overview is needed of ongoing adaptation projects.

Adaptation policy

Iceland has yet to complete a national adaptation policy, although the country's national climate change strategy (Ministry for the Environment 2007) specifically identifies preparing the government for adaptation as one of its five principal objectives. The 2008 report cited in the previous section was a key aspect of pursuing that objective; the strategy also notes:

- The prospect of sea-level rise "shall be particularly considered" in connection with the design of coastal communities and structures; an assessment of the probability of flooding from the sea is to be carried out.
- Both opportunities and threats related to the likely increase in ship traffic and the transport of goods, oil, and gas in the Arctic region are to be evaluated.

[24] The reference provided in the Fifth National Communication is Björnsson H., Sveinbjörnsdóttir Á.E., Daníelsdóttir A.K., Snorrason, Á., Sigurðsson, G.D., Sveinbjörnsson, E., Viggósson, G., Sigurjónsson, J., Baldursson, S., Þorvaldsdóttir, S., and Jónsson, T. (2008) *Impacts of global climate change in Iceland*. Ministry for the Environment.

The Fifth National Communication (Ministry for the Environment 2010) includes only two short paragraphs on adaptation measures (even after multiple pages on projected impacts). It notes that impacts on infrastructure sectors are the subject of ongoing studies, and that plans for adaptation are, in most cases, not well developed yet, except for the National Power Company (Landsvirkjun). Finally, it is noted that although since a 1992 report on expected sea-level rise, adjustments have been made in the design of new harbours, "recent studies indicate that sea level rise may far exceed earlier expectations" (p.78).

Norway

Norway is by far the wealthiest Nordic country and one of the wealthiest nations in the world, with a 2011 gross national income (GNI) per capita of $61,460, compared with $42,200 for Sweden, $41,900 for Denmark, $37,670 for Finland and $31,020 for Iceland.[25] Norway's population was estimated at 5,038,100 as of October 2012, growing steadily. There is significant internal migration, with the greatest net gains in the southeastern counties Akershus and Østfold, while among the largest cities, Oslo, Bergen and Svandelag have seen small net losses (Trondheim remains stable).[26]

Norway has significant agriculture, though it is declining; in 2012, farms applying for agricultural subsidies covered 990,000 hectares, down from 1.02 billion in 2007. Forestry has declined even more, with both timber prices and employment halved in the last three decades (only 6,900 people worked in forestry in 2009). Fishing has historically been very important to Norway, but in 2011, fishing and fish farming accounted for only 0.7% of GDP and 5.7% of total export value (ranked third after oil and metals). Oil and gas production, meanwhile, accounted for 24.8% of GDP in 2008; Norway is one of the world's top exporters of crude oil. Norway's power consumption is about 10 times the world average, driven by power-intensive manufacturing and widespread use of electricity for heating; 98-99% of the country's electricity comes from hydropower.

Climate impacts

The Norwegian Green Paper on Climate Change Adaptation, prepared for the government by a committee of experts (Ministry of the Environment 2010), offers detailed projections of future climate change in Norway, based on three scenarios. It shows annual mean temperatures will increase by 2.3°C to 4.6°C by 2100, with the greatest increase during winter and the least during summer, and major regional differences – northern regions will warm the most, and western Norway the least. Annual precipitation could increase by 5% to 30%, with major seasonal and regional variations, and more frequent torrential rains and massive snow falls. Ocean temperatures and acidification are expected to increase, and sea level along the Norwegian coast is projected to rise by 50–100 cm along the southern and western coasts, 40–90 cm in northern Norway and 20–70 cm in the innermost areas of the Oslo and Trondheim fjords, with corresponding increases in storm surge heights.

Despite these fairly significant climate changes, the Green Paper finds that compared with most other countries, Norway is both less vulnerable and better equipped to address climate impacts. As in other Nordic countries, there are also some potential benefits from climate change, such as new opportunities within the primary sector and in the energy, petroleum,

[25] GNI given in international dollars, purchasing power parity (PPP) method. All data from the World Bank (2012), "Gross national income per capita 2011, Atlas method and PPP", *World dataBank*, 21 December. Available at http://databank.worldbank.org/databank/download/GNIPC.pdf.

[26] All population and economic statistics in this section taken from Statistics Norway, http://www.ssb.no/english/.

tourism and shipping sectors. However, the paper warns, exploiting some of these could be incompatible with Norway's environmental objectives, including emission-reduction targets.

Some of the bigger concerns identified in the paper relate to how warming will affect the natural environment in the Arctic and in the High North, as well as in higher altitudes; these are areas with "marginal" natural conditions, and they are also where the most warming is expected. Species and ecosystems will become more vulnerable, and adaptation may not be enough to prevent biodiversity loss. Infrastructure and buildings are also of some concern, especially given existing inadequacies in maintenance and repairs. And the committee notes that because new infrastructure may have many decades' lifespan, climate considerations should be taken into account in planning for infrastructure, buildings and facilities.

The power sector – which, as noted above, has a particularly high profile in Norway – is expected to see both positive and negative impacts. Increased precipitation is expected to result in higher hydropower generation potential, but how much is unclear; the Green Paper cites multiple estimates: 2.3-17.1% by 2071-2100 compared with 1961-1990; 5.5-18.2% by 2071-2100 compared with 1970-1999; 10% for 2021-2050 compared with 1961-90. At the same time, more frequent extreme weather, floods and landslides/avalanches could increase the risk of power disruptions and infrastructure damage. The analysis also indicates that climate change could increase agricultural productivity and forest growth and thus benefit bioenergy production. Energy demand, on the other hand, is expected to decline during the winter, as temperatures are milder, while summertime cooling requirements will increase.

Adaptation research

Norway has strong climate research capacity and a large body of adaptation- and resilience-focused work over the last decade, with major government initiatives as well as multiple projects led by the high-profile Center for International Climate and Environmental Research – Oslo (CICERO), universities and smaller institutes such as Vestlandsforsking, in Songdal. This work is also particularly well-mapped, thanks to an evaluation commissioned by the Research Council of Norway (2012), which has provided almost three-quarters of the external funding for climate research in the country over the last decade.

A "primary driver" of this research, according to the evaluation, has been the Council's 2004-2013 Programme on Climate Change and Impacts in Norway (NORKLIMA), with a total budget of 721.6 million NOK ($129 million USD). The stated goal of NORKLIMA is to generate new knowledge about the climate system; past, present and future climate trends; and direct and indirect impacts of climate change on the environment and society – all to help inform adaptation.[27] Target audiences include government, business, the research community and the public at large. Key outcomes have included the first Norwegian Earth System Model (NorESM); climate scenarios for Norway, scaled down to as little as 1x1 km; new knowledge on climate impacts on ecosystems and individual plant and animal species; new insights into climate impacts on fisheries, agriculture and forestry; assessments of landslide and avalanche impacts on infrastructure; and methodologies for local-level vulnerability assessment.

One large project funded by NORKLIMA is PLAN: Potentials of and Limits to Adaptation in Norway,[28] an interdisciplinary research collaboration between eight partners, based at the University of Oslo's Department of Sociology and Human Geography. The aim of the project is to investigate how individuals and communities in Norway adapt to climate change,

[27] See http://www.forskningsradet.no/prognett-norklima/Programme_description/1226993599916 and NORKLIMA brochure, http://www.forskningsradet.no/prognett-norklima/Key_documents/1226993599848.
[28] See http://www.sv.uio.no/iss/english/research/projects/plan/index.html.

focusing on three key questions: How do social processes influence the capacity to adapt to climate change? What are the limits to adaptation as a response to changing climate conditions? What are the implications of these limits for human security?

Another major initiative is NORADAPT, a four-year partnership (2007-2011) led by CICERO that focused on how projected changes in climate interact with changes in socioeconomic and institutional conditions, and how these interactions shape vulnerability and adaptation at the local level in Norway.[29] NORADAPT developed an indicator-based model for vulnerability assessments, using eight municipalities as test sites, ranging from large cities such as Bergen and Stavanger, to the Arctic communities of Hammerfest, Unjárgga and Nesseby. It sought to link science with policy-making, addressed questions of uncertainty, and examined the role of municipal government in adaptation.

Another CICERO-led project, Adapting to Extreme Weather in Norwegian Municipalities (Klima SIP),[30] was a seven-partner collaboration from 2006 to 2012 focused on how Norwegian municipalities can better deal with extreme weather events, including those related to climate change. The ethos of the project was to produce "usable science": generating new knowledge and translating that into advice that the municipalities can use. The main focus was on drinking water, cultural heritage, and flood risk reduction, and the project emphasised mapping out adaptation processes and identifying barriers. The project generated multiple publications, including a book, *Municipalities Addressing Climate Change: A Case Study of Norway* (Kelman 2011) as well as a website that provides advice and insights for municipalities, www.klimakommune.no.

The International Polar Year,[31] which ran from March 2007 to March 2009, organised by the International Council for Science (ICSU) and the World Meteorological Organization (WMO), also supported significant adaptation research in Norway, most notably through CAVIAR (Community Adaptation and Vulnerability in the Arctic Regions), a four-year consortium led by researchers at CICERO and the University of Guelph, Canada. CAVIAR aimed to fill knowledge gaps about the vulnerability of Arctic communities, developing a theoretical framework for community vulnerability assessment, procedures for case studies, a process to compare and integrate results, and a mechanism to ensure the application of research to policy. CAVIAR produced numerous publications, including a book, *Community Adaptation and Vulnerability in Arctic Regions* (Hovelsrud and Smit 2010).

A follow-up project, CAVIAR II (2013-14[32]), led by the Nordland Research Institute (Nordlandsforskning) with partners in Norway, Finland, Sweden and the USA, is exploring several additional questions: What are the consequences of changes in ecosystem services, and for their users? How and to what degree does policy address and implement adaptation across sectors? What are the consequences of climate change mitigation for industries and communities? How is adaptation gendered? How can we advance theoretical and conceptual frameworks for studying adaptive capacity of social-ecological systems?

Several more projects have also contributed to Norway's adaptation knowledge base. In 2010, for example, the Norwegian Institute for Agricultural and Environmental Research (Bioforsk) and partners published a report on how to adapt Norwegian agriculture to a changing climate.[33] The Norwegian State Housing Bank (Husbanken) funded a 2006-2008 project to

[29] See http://www.cicero.uio.no/projects/detail.aspx?id=30182&lang=EN.
[30] See http://www.cicero.uio.no/projects/detail.aspx?id=30129&lang=en.
[31] See http://www.ipy.org.
[32] See http://www.cicero.uio.no/projects/detail.aspx?id=30555&lang=EN.
[33] In Norwegian; see http://www.forskningsradet.no/servlet/Satellite?c=Nyhet&pagename=matprogrammet%2FHovedsidemal&cid=1253954888185&p=1222932060309.

build a web tool to help municipalities ensure more climate-robust housing.[34] Civil Protection and Climate Vulnerability (CIVILCLIM), a five-year project ending in 2011, examined the relationship between climate change and societal safety and security, with a focus on extreme weather.[35] And an on-going project, Spatial Planning and Preparedness for a Changing Climate (2012-14), is looking at how spatial planning could help mitigate the damage from more-frequent floods, mudslides, avalanches and storm surges in the decades to come.[36]

National adaptation policy[37]

The Norwegian government's climate adaptation efforts are coordinated by an inter-ministry working group established in 2007 and led by the Ministry of the Environment, supported by a secretariat at the Norwegian Directorate for Civil Protection and Emergency Planning. In 2008, the government published a five-year adaptation work programme (Directorate for Civil Protection and Emergency Planning 2008). The document begins by saying that the best adaptive measure that Norway can take is to reduce its greenhouse gas emissions, and stresses that climate change is a global issue that requires global cooperation. But it also identifies three pillars for domestic adaptation efforts: identifying vulnerabilities and integrating adaptation into key policy areas; developing a knowledge base, including a national vulnerability and adaptation assessment; and providing information and coordination.

The programme secretariat has set up an online adaptation portal for Norway, Klimatilpasning Norge,[38] which provides detailed information on climate impacts – nationally and locally, as well as by sector; descriptions of on-going projects and "best practices"; links to maps, publications and other research, and news updates.

The Norwegian government also sponsored a major expert assessment of climate impacts,, vulnerabilities and adaptation options, the Green Paper cited above (Ministry of the Environment 2010). The paper lays out three principles to guide adaptation in Norway: taking a comprehensive approach that also considers mitigation, pollution and other environmental concerns; taking an ecosystem-based approach to management of the natural environment; and integrating adaptation into regular planning processes. And it sets priorities:

- Climate change considerations must be given higher priority in the planning system.
- Increased uncertainty must be handled.
- The knowledge base must be strengthened through studies, monitoring and research.
- Capacity in the public administration must be enhanced.
- The adaptation back-log (existing deficits) must be rectified.
- Coordination of the adaptation efforts must be improved.
- The adaptation efforts must include an international responsibility.

The Green Paper also provides specific recommendations for ecosystems/environmental protection, public health, civil protection, transport, the power sector, water and sewage, the construction industry, insurance, tourism, agriculture, forestry, fisheries, the petroleum industry and other specific sectors and social groups, emphasizing the importance of close monitoring and data-gathering, research to fill knowledge gaps, and improved management, regulation and cross-sectoral coordination. Finally, the paper provides cost estimates for some of its key recommendations. For example, integrating climate considerations into municipal-

[34] See http://www.vestforsk.no/en/projects/climate-robust-housing-a-web-based-tool-for-municipalities.
[35] See http://www.vestforsk.no/en/projects/civil-protection-and-climate-vulnerability-civilclim.
[36] See http://www.vestforsk.no/en/projects/spatial-planning-and-emergency-provision-for-a-changing-climate.
[37] Along with individually cited sources, this section draws on a summary on the EU CLIMATE-ADAPT website, http://climate-adapt.eea.europa.eu/countries/norway.
[38] See http://www.klimatilpasning.no; materials available in Norwegian and English.

level planning could cost 250-300 million NOK per year, including the cost of personnel, mapping and other planning materials (p.244). The costs of other items range from a few million NOK to several billion (e.g., to correct road maintenance back-logs).

Adaptation in Norwegian municipalities

As should be clear from the research and policy sections above, municipalities in Norway are considered to play a key role in adaptation. Thus, there have been extensive national- and local-level initiatives to identify and address vulnerabilities, build adaptive capacity, and integrate adaptation into spatial planning, building codes, etc. Several research projects, including NORADAPT and Klima SIP (see section on research), have worked directly with municipalities and also provided resources that others can use as well. And the Klimatilpasning Norge web portal offers significant guidance.

Cities of the Future, a partnership between the national government and Norway's 13 largest cities to address various climate issues,[39] supports collaboration on adaptation as well as pilot projects. Work highlighted on the programme website includes a project in Bjølsen Student Village in Oslo, which added drainage channels and a drainage basin surrounded by greenery, as well as the "Midgard Snake" being built by the Oslo Water and Wastewater Department, an interruptive drainage system, estimated to cost 1 billion NOK, that will capture stormwater and protect the Oslo Fjord from pollution.

Oslo has also done considerable work on climate change and adaptation on its own. In conjunction with construction of the new urban area in Bjørvika, the capacity in the Hovin Stream is being increased to protect from flood risks to the railway tunnel and the underground tunnel of Norway's communication hub.[40] In recognition of the fact that most stormwater concerns are localised, rather than citywide, Oslo Water and Sewage Works (VAV) has also promoted the use of local stormwater handling systems as well as upgrades and capacity expansions, as needed.

Oslo assigned its Agency for Outdoor Recreation and Nature Management to coordinate climate efforts, which included surveying municipal agencies in 2009 to understand their needs, resources, expertise and plans for adaptation.[41] The review found only a few agencies had prepared climate risk and vulnerability analyses, but they were paying attention to adaptation in their internal planning. Extreme precipitation and flooding problems were identified as a priority, and cross-sectoral collaborations were recommended.

Oslo's Urban Ecology Programme 2011-2026, adopted by the City Council in 2011, focuses primarily on energy efficiency and reduction of greenhouse gas emissions and pollution, but it also includes a substantial adaptation agenda.[42] Specifically, it calls for Oslo to develop an adaptation strategy that includes:

- A strategy for dealing with stormwater, including opening up culverted rivers;
- The establishment of more green spaces and green roofs;
- Climate change assessments as part of planning for new infrastructure;
- Mapping of areas where there is a risk of landslides;
- Mapping of areas where there is a risk of flooding;

[39] See http://www.regjeringen.no/en/sub/framtidensbyer/cities-of-the-future.html?id=548028.

[40] See http://www.regjeringen.no/en/dep/md/kampanjer/engelsk-forside-for-klimatilpasning/library/cases/Oslo-is-getting-ready.html?id=544657.

[41] See http://www.regjeringen.no/en/dep/md/kampanjer/engelsk-forside-for-klimatilpasning/library/cases/oslo-identified-climate-adaptation-measu.html?id=611211.

[42] See http://www.miljo.oslo.kommune.no/english/environmental_policies/urban_ecology_programme, section 1.5.

- A strategy for the protection of large trees;
- Sectoral action plans for climate change adaptation.

Bergen, Norway's second-largest city and another participant in Cities of the Future, has examined its vulnerability to climate change in depth.[43] Bergen directly faces the North Sea and is very exposed to severe weather, including heavy rains, strong winds, floods, landslides and high waves. Bergen's *Climate and Energy Action Plan* (City of Bergen 2010) – though primarily focused on mitigation – notes that storm and extreme-weather risks are expected to intensify with climate change, and sea level and water temperatures off the coast of Hordaland (Bergen's home county) will also rise, making adaptation crucial. Overall, the plan says, Bergen anticipates "warmer, wetter and wilder weather"; more frequent intense bursts of precipitation; more violent storms; more frequent floods, avalanches and landslides; and more unpredictability – landslides and floods at different times and in different places than before. At the same time, population growth will require new housing and infrastructure, the plan says, so it is vital that these be developed in a way that is robust in the face of climate change.

As of the writing of Bergen's plan, the city had already undertaken a comprehensive project on risk and vulnerability assessment and reduction, including an assessment and mapping of avalanche/landslide risks; a survey of extreme wind conditions; isopleths (graphs) to map flood water levels; a thematic map for precipitation; an assessment of extreme values for water level and wave heights along the shoreline; linkage of the risk and vulnerability analysis to the land use part of the Municipal Plan; and a risk map combining these data. Several Cities of the Future projects were also under way to reinforce water treatment safety; identify critical points in the sewage system; improve sea-level rise projections, and address flood risks in several waterways, among other measures. Bergen was also part of NORADAPT, and through yet another project, BaltCICA (see footnote), the city worked to integrate all its multiple adaptation initiatives into an overarching strategy.

Many other Norwegian municipalities and counties are engaged in adaptation efforts as well. Fredrikstad is part of Cities of the Future and was part of NORADAPT, through which it worked with Vestlandsforsking to identify its vulnerabilities and lay the groundwork for a municipal adaptation plan. The analysis was completed in 2010.[44] The city of Stavanger is engaged in a six-year project with Vestlandsforsking to analyse its vulnerability to climate change and devise adaptation measures.[45] And as noted in the section above on research, multiple municipalities in northern Norway have worked extensively on these issues, looking at their overall vulnerability profiles, or focusing on specific sectors or concerns.

Summary

Norway a major oil exporter and heavy energy user, is very aware of climate change and is making significant efforts to reduce its greenhouse gas emissions. Impacts on Norway are expected to be a mix of good and bad: Projected warming is seen as mostly beneficial (in terms of agricultural productivity and reduced heating costs), and Norway also foresees possible new economic opportunities as a result of reduced Arctic ice cover. Increased precipitation, meanwhile, could boost hydropower generation potential, but may also exacerbate flood, landslide and avalanche risks, especially because more extreme and

[43] Where not directly citing the City of Bergen's *Climate and Energy Action Plan*, this section draws on background material in http://www.baltcica.org/casestudies/bergen.html.

[44] See http://www.regjeringen.no/en/dep/md/kampanjer/engelsk-forside-for-klimatilpasning/library/cases/climate-adaptation-in-fredrikstad.html?id=633495.

[45] See http://www.vestforsk.no/en/projects/vulnerability-and-adaptation-to-climate-change-in-stavanger.

unpredictable rainfall is expected. Impacts on fragile Arctic ecosystems are also of great concern.

Awareness of these threats has made adaptation a priority for both the national government and local governments. Very large investments have been made in adaptation and vulnerability research that has advanced scientific knowledge while also translating findings into useful information for planners and decision-makers. Some of those insights are already informing public-works projects and policy changes, especially at the city level. Nevertheless, it is clear that adaptation is far less of a priority than mitigation, nationally and locally.

Sweden

Sweden is the most populous of the Nordic Countries, with about 9.5 million residents in 2011 (Statistics Sweden 2012), concentrated in the south and along the coasts, while most of the interior and north of the country is sparsely populated. The largest cities are Stockholm (with about 864,000 residents in 2011, and another 1.4 million in the surrounding area), Gothenburg (520,000), Malmö (303,000) and Uppsala (200,000).

The vast majority of the land is undeveloped, however: as of 2005, 2.9% of Sweden's total area was built up, while 53.1% was covered with forests – 23.9 million hectares – and 7.9% was farmland. As in Norway, however, the share of arable land is shrinking slowly, to 2.6 million hectares in 2011. Hay and forage are the most widely grown crops, covering 45.6% of the arable land; cereals cover another 37.9%; other crops include oilseeds, legumes and potatoes. Forestry is a significant business, with about 2.9 billion m^3 of growing stock, and so is fishing, with saltwater fish landings valued at nearly 1 billion SEK (about $153 million USD) in 2011. However, these sectors are still much smaller than goods-producing industries, which had a total production value of 5.1 billion SEK in 2010. The single biggest electricity source is hydropower, accounting for 45% of power production in 2011, followed by 39.5% nuclear, 11.3% conventional thermal power, and 4.1% wind power.

Climate impacts

In 2005, the Swedish government appointed a Commission on Climate and Vulnerability to conduct an in-depth assessment of climate impacts and risks in Sweden. The report, which was published in 2007, found a need to begin adapting, with a particular need for strong action to reduce the risk of floods, landslides and erosion in many areas (Swedish Commission on Climate and Vulnerability 2007). Overall, the commission found, average temperatures will rise by 3°C to 5°C by the 2080s compared with 1960-1990, and winter temperatures may increase by 7°C in northern Sweden. Precipitation will increase in most of the country during the autumn, winter and spring, while summers will be warmer and drier, especially in southern Sweden. Sea levels are expected to rise by up to 0.2 metres. Trends in winds and storms were found to be uncertain, but appeared to be increasing.

The commission predicted that the number of days of heavy precipitation would increase in winter, spring and autumn in most of the country, and there would be "significant" increases in the heavy rain. Runoff will also increase in most of the country, and hydropower potential could increase by 15 to 20%, but there will be a need to invest in dam safety. There will also be a heightened risk of floods, which could affect building construction and infrastructure, especially roads and railways. Water and electricity supplies might also be disrupted. An increased interest in lakeside living has also put more homes in harm's way, the report notes. Sweden has already suffered severe landslides, and the commission anticipates even greater risks in the future, especially in areas where there is already a high risk today, such as around Lake Vänern, the valley of the Göta Älv river, eastern Svealand and most of the east coast.

The report estimates that more than 200,000 buildings are located close to water in areas where the risk of landslides will increase.

In northern Sweden, sea-level rise will be offset by land uplift, the report notes, but the south, Skåne, Blekinge, Halland and the West Coast will face new risks from sea-level rise and storm surges. With increased dominance of westerly winds, the maximum high-water levels in the Baltic Sea will rise substantially; for example, the maximum high-water level in Karlskrona is already one meter above the present-day mean water level, and by the century's end, it is projected to be two meters above the mean water level.

The commission also projected a sharp increase in the rate of forest growth, by 20 to 40% for pine, spruce and birch by the end of the century. However, there will also be more risk of storm-felling, and the warmer climate will make the forests more prone to fire, fungal and insect attack. The conditions for reindeer herding are expected to change significantly, with scrub increasingly covering the mountains, longer vegetation growth periods, and more insects, among other factors. Agricultural productivity, meanwhile, is expected to rise – harvests in Västerbotten could increase by 50% with the same crops grown today – but problems with pests, diseases and weeds will also increase.

The commission also expressed concern about "dramatic changes" in ecosystems in the Baltic Sea. Freshwater ecosystems will be affected as well, and maintaining good water quality will become more challenging.

Adaptation research

There is extensive adaptation research going on in Sweden, with both a domestic and international focus, including major projects funded by Mistra, the Swedish Foundation for Strategic Environmental Research.[46] The first major initiative was SWECLIM, in 1996-2003, an 88.5 million SEK programme, primarily funded by Mistra, that developed regional climate scenarios for Sweden, to be used by to planners and decision-makers within industry, public administration and political bodies.[47] A review of SWECLIM's accomplishments was published in *AMBIO* (Rummukainen et al. 2004).

Mistra-SWECIA (Swedish Research Programme on Climate, Impacts and Adaptation), which runs from 2008 to 2015, supported by 87 million SEK from Mistra, is a research programme on climate, impacts and adaptation that spans climate science, biology/ecology, economics, and social sciences.[48] The partners on the project are the Swedish Meteorological and Hydrological Institute (SMHI), Stockholm Environment Institute (SEI), Lund University and Stockholm University. The main target audiences are national and international policy-makers and regional-to-local decision-makers in the public and private sectors; the general public and fellow researchers worldwide are also seen as potential users of the research. The programme has generated a wealth of new knowledge and analysis, including studies on the governance of adaptation, participatory processes and social learning, as well as case studies in Swedish municipalities and in specific sectors, such as forestry.

Climatools, a 2007-2011 collaborative project between the Swedish Defence Research Agency (FOI), the Royal Institute of Technology, Umeå University and the National Institute of Economic Research, worked to develop eight tools to assist municipalities coping with climate change:

[46] See http://www.mistra.org.
[47] See http://mistra.org/en/mistra/research/completed-research/sweclim.html.
[48] See http://www.mistra-swecia.se/en/About-Mistra-SWECIA and http://mistra.org/en/mistra/research/ongoing-research/mistra-swecia.html.

- Local Climate Impacts Profile;
- Guide to adaptation to climate change with socioeconomic scenarios;
- Checklist for inventory of local adaptation to climate changes in healthcare and care services;
- Computational models for quantification of the effects of heat waves;
- Checklist for sustainability analysis;
- Guide for the integration of adaptation to climate change in local authority risk and vulnerability analyses;
- Guide for the assessment of drinking water risks;
- Guide for increased preparedness for heat waves – a tool for vulnerability charting.[49]

These tools were meant to assist authorities in calculating adaptation costs and the resulting benefits and in dealing with conflicting objectives and ethical issues.

It should be noted that the programmes described above are only highlights of a much broader body of adaptation research in Sweden. Several research institutes and universities, including those listed above, are leading adaptation-focused projects at all scales, often in partnership with one another. For an example of this diversity, see the adaptation and vulnerability project listings for the Centre for climate Science and Policy Research (CSPR) at Linköping University, which include Mistra-SWECIA, BaltAdapt and BalticClimate along with several other projects both within Sweden, and overseas.[50]

National adaptation policy

Since the 2007 vulnerability assessment (Swedish Commission on Climate and Vulnerability 2007), the Swedish government has implemented several concrete adaptation measures. It established an adaptation coordination post at all the 21 Swedish county boards to coordinate regional adaptation, for example, and it changed the Planning and Building Act (2010:900) to state that adaptation concerns are to be considered in municipalities' comprehensive and location-specific planning. The Swedish government also enlisted SMHI to coordinate the creation of the National Knowledge Centre for Climate Change Adaptation, with a web portal similar to the Danish adaptation portal.[51] Along with SMHI, 12 other government agencies are involved – among them, the Swedish National Board of Housing, Building and Planning, the Swedish Environmental Protection Agency, the Swedish Energy Agency, the Swedish Civil Contingencies Agency, the Swedish Board of Agriculture, and the County Administrative Boards. The portal provides up-to-date information about climate change and adaptation, as well as tools for starting up adaptation processes, including a 10-step guide for how to formulate an adaptation plan.

Adaptation in Swedish municipalities

Stockholm, with the population of 850,000 has the highest gross regional product among Scandinavian capitals and serves as the region's financial centre.[52] The city's Environmental Programme for 2012-2015, which envisions Stockholm as "an attractive and growing city, where the needs of people and nature complement each other in an environment characterized by functionality, quality and biological diversity", includes a mitigation goal: to reduce GHG emissions to less than 3 tonnes per resident.

[49] See http://www.foi.se/en/Customer--Partners/Projects/Climatools/.
[50] See http://www.cspr.se/forskning/sarbarhet-och-anpassning?l=en.
[51] See http://www.smhi.se/klimatanpassningsportalen; limited material is available in English.
[52] Unless otherwise noted, information in this section is taken from city's English-language website, http://international.stockholm.se, and the Statistics Stockholm website, http://www.statistikomstockholm.se/index.php/statistics-in-english.

In 2007, the City of Stockholm published a report examining its vulnerabilities, projected future climate impacts, and options for adaptation (Ekelund 2007). The report began by noting that "Stockholm is unable to manage the climate of today and will find it increasingly difficult to manage the climate of tomorrow", citing flood issues with Lake Malären as a prime example. Based on climate scenarios, the report predicted a mean temperature increase of 2.5°C to 4.5°C by 2100, fewer extremely cold winter days, earlier spring floods, and increased rainfall – 5-10% in 2011-2040, and 25% by 2071-2100, vs. 1961-1990. It also warned of rising sea levels, rising sea and lake temperatures, more common flooding along the coast, lakes and water courses, and more frequent severe weather. Rising water levels in Lake Mälaren could create serious flood risks, with damages estimated at 4 billion SEK if the water rises by 1.3 meters, and 7 billion if it rises by 2.3 meters (Ekelund 2007).

The report outlines risks by sector and identifies some on-going adaptation efforts as well as potential other measures. It calls for greater analysis and inventories as well as significant awareness-raising, and it stresses the need for a stormwater management strategy that takes climate change into account. With regard to ecosystems and biodiversity, the report calls for increased monitoring, greater efforts to protect habitats, and a continual review of the role of nature for recreation and health in Stockholm, among other measures.

The second-largest city in Sweden is Gothenburg, with a population of about 507,000. It has a history of flooding, and much to lose, as an industrial hub with dense settlements and a growing tourist and visitor sector (Hjerpe and Glaas 2012). While it does not have a formal adaptation plan, it has been a leader in Sweden in adapting to climate risks, having ordered, in 2004, that departments and agencies assess future impacts of extreme weather events in the light of climate change (ibid.). It has also been the focus of several studies. For example, the 2010-11 Mistra-funded pilot project "A City Structure Adapted to Climate Change: Scenarios for Future Frihamnen" [53] examined the implications of three different adaptation strategies – attack, retreat and defence – for the free-port area in Gothenburg. The project looked at the economic, social and ecological consequences of each approach. The goal was to help not only Gothenburg, but also other cities, plan for adaptation and identify and address conflicting objectives.

Sweden's third largest city, Malmö, launched a special climate initiative in 2009 ahead of COP15 in Copenhagen, which covered both adaptation and mitigation, as well as sustainability more broadly (City of Malmö 2009). Malmö is also a partner in two adaptation projects, GreenCLimeAdapt and GrAbs.[54] The aim of GreenCLimeAdapt ("Green Tools for Urban Climate Adaptation"), which runs from 2009 through 2013, is to demonstrate how cities can address and adapt to climate impacts, including increased rain and the urban "heat island" effect, via green tools such as open stormwater management, green facades and green roofs. In Malmö's Fosie neighbourhood, for example, the old stormwater pipes are being modified so water can be diverted and purified before it reaches Riseberg Stream, which floods frequently. Also as part of GreenCLimeAdapt, the Malmö Scandinavian Green Roof Institute is testing a new type of green roof, which is hoped to provide better shade and therefore cool the buildings more efficiently than before

The GRaBS project (Green and Blue Space Adaptation for Urban Areas and Eco Towns), is a network of pan-European organisations involved in integrating climate change adaptation into regional planning and development. Malmö is the only Scandinavian city involved in the

[53] See http://www.mistraurbanfutures.se/english/startpage/projects/pilotprojects20102011/acitystructureadaptedtoclimatechange.4.7df4c4e812d2da6a416800089449.html.

[54] See http://www.malmo.se/English/Sustainable-City-Development/Climate-change--Energy/Climate-adaptation.html.

project, and is focusing on integrating green and blue climate adaptation, at an early stage, in all city planning processes, and intensifying stakeholder and community involvement. On a regional level, GRaBS will enable the City Council to influence regional policy in Scania and beyond.[55]

Summary

Like its Nordic neighbours, Sweden anticipates significant warming due to climate change – 3°C to 5°C by the 2080s compared with 1960-1990, increased precipitation, increased flood and landslide risks, and rising sea levels – the latter primarily affecting the south. Since a major government-sponsored assessment in 2007, Sweden has been implementing policy changes to adapt to climate change, both at the national level and in individual municipalities, but much more remains to be done. A wealth of adaptation research in the country, through programmes such as Mistra-SWECIA as well as smaller-scale initiatives, is helping policy-makers, planners, businesses and the general public to better understand climate impacts, the need for adaptation, and the options available to them. There is also plenty of innovation on the ground, such as in Malmö, where multiple "green" technologies are being tested that could help reduce the impacts of increased precipitation and heat.

ASSESSING THE NEED FOR A NORDIC ADAPTATION STRATEGY

Introduction

This section builds on the above overview of national and sub-national adaptation practices to discuss the potential benefits and weaknesses of a Nordic adaptation strategy. It begins by presenting core rationales for implementing such a strategy, and presents a summary of challenges and opportunities, based on the national overviews and the results of a SWOT (strengths, weaknesses, opportunities and threats) analysis. Then it discusses possible objectives and priority areas for a Nordic strategy and presents an assessment of policy instruments which could be used to guide action. It concludes by summarising outcomes of the guiding research questions and outlines how the new NORD-STAR programme plans to address them.

Challenges of Nordic adaptation

As discussed earlier, there are limits and barriers to adaptation, which the IPCC's *AR4* (Adger et al. 2007) Classified under five categories: physical and ecological limits, technological limits, financial barriers, informational and cognitive barriers, and social and cultural barriers. To a greater or lesser extent, these five limits also apply to the Nordic region. Table 2 offers some examples.

[55] See http://www.grabs-eu.org/partnerdetail.php?id_ptn=7.

Table 2: Limits and barriers to adaptation in the Nordic countries

Limits and barriers	Description	Examples in Nordic countries
Physical and ecological limits	Dramatic climatic changes may lead to transformations of the physical environment that limit the possibilities for adaptation	Low-lying coastal cities may not be able to fully protect themselves from rising seas; plants may not be able to withstand hard frosts after warming periods
Technological limits	Technology may be too contextually specific and uncertainty can inhibit decision-making; technology can also be too expensive	Sewer systems can only take so much water at once during downpours, so floods may be unavoidable
Financial barriers	Some adaptation measures may be very costly and exceed the resources available to those seeking to implement them	Some municipalities may have more funds available for adaptation than others; lower-income people may find it more difficult to adapt their homes or livelihoods
Informational and cognitive barriers	Adaptive responses can be limited by lack of information and by people's perceptions	Community members may not fully understand climate risks or what to do about them; across the Nordic region, mitigation has gotten much more attention than adaptation
Social and cultural barriers	Differing risk perceptions and levels of prioritisation of climate change issues	People may resist adaptation measures they do not perceive as urgent, such as abandoning coastal properties

The Nordic countries have also found it challenging to translate their wealth of adaptation research into strong adaptation policies and practical measures. In a recent paper, Klein and Juhola (2013) identify five reasons for the limited uptake of adaptation research in policy and decision-making:

1. Theoretical concepts and constructs developed and applied in adaptation research do not relate to the decision "reality" of stakeholders;

2. Uncertainty surrounding the potential impacts of climate change makes stakeholders inclined to wait and see rather than act;

3. There is a mismatch between the local scale on which many stakeholders operate and the smaller-scale climate information provided by models;

4. There is a mismatch between stakeholders' primary concern to manage current climate variability and the medium- to long-term perspective of much adaptation research;

5. Adaptation research often ignores the fact that adaptation is not the only priority for many stakeholders.

In addition, there are informational and cognitive barriers that pose fundamental challenges to implementing adaptation to climate change, as they represent a gap between the scientific knowledge base and actual adaptive measures, particularly at the local level. This knowledge–action gap points to the need for expertise in effective climate communication as a means to facilitate decision-making. Recognising the significance and complexity of research on climate change means ensuring that the public and policy-makers at different levels comprehend uncertainties relevant to the decision that each faces, as understanding is a necessary condition for action (Pidgeon and Fischhoff 2011).

Thus, overcoming these barriers entails not only a robust knowledge base of climate change among citizens and policy-makers, but also a comprehension of the gravity of the problem and a perception that adaptive measures to climate change are relevant and applicable to them.

Rationale for a Nordic strategy

Our review of the Nordic countries' adaptation policies and strategies indicates that there is a fair amount of adaptation-related activity already occurring in the region, at both the national and local levels. Thus, in order to be useful, a Nordic strategy would have to add value to those efforts, and certainly not hinder them. Another key condition is that the countries have enough in common to be able to benefit from regional cooperation. In addition, the long-standing collaboration in other policy areas has already highlighted the benefits of Nordic co-operation.

Clearly, there are many shared climate risks: concerns about sea-level rise; about torrential rains, floods and landslides; about the potential impacts (positive and negative) of warming weather; about the fragile and rapidly changing Arctic region. This means the countries face many similar challenges, which they may want to solve in similar ways. A prime example is sewage management; there is much that Nordic municipalities can learn from one another. The opportunities for collaboration are particularly promising for cities that lie close to borders, such as Copenhagen and Malmö (Sweden).

Knowledge about policy effects could also be shared, since the political and cultural environment in these countries is quite similar. In addition, the Nordic countries share many resources, such as the Baltic Sea, and as neighbours, have interlinked economies. And they have many common elements in their economies: fisheries; extensive hydropower use in some countries; coastal tourism; agricultural sectors growing similar crops. In sectors such as agriculture and forestry, in which the countries face similar impacts, knowledge-sharing and joints efforts could be particularly beneficial.

Thus, there is a great deal to be gained from Nordic collaboration on adaptation: sharing knowledge and best practices, pooling resources for greater efficiency, and being able to take a broader, regional view of individual sectors. A regional strategy can also help the Nordic countries avoid adaptive measures that have negative knock-on effects – such as when fortifying a coastal area pushes water up or down the coast, increasing flood risks there. At the same time, it is crucial to remember that adaptation is most effective when tailored to the specific location, people and/or conditions; thus, a Nordic adaptation strategy must never take a "one-size-fits-all" approach, but rather facilitate national, sectoral and local-level action.

Table 3 shows the results of a SWOT analysis of handling climate adaptation at different levels, including through a regional Nordic strategy.

Table 3: SWOT analysis of addressing adaptation at different levels

	Strengths	Weaknesses	Opportunities	Threats
Local	Local knowledge of potential inputs and vulnerabilities	Weak local adaptive capacity or lack of resources to invest in or support adaptation	Merge adaptation concerns with other policy objectives for effective mainstreaming	Adaptation is marginalised or not considered important locally
Sub-regional	Pooling of resources can lead to higher adaptive capacity	Weak regional adaptive capacity, particularly in terms of institutional capacity	Tackle regional vulnerabilities, pursue larger projects, collaboration possibilities	Regional level can have limited political /economic significance
National	Greater political bargaining power; benefit from existing capacities/experience, existing political institutions	Capacity to implement may be limited by disconnect between national and local levels	Ability to better incorporate knowledge/centralise from other national Plans; develop common administrative structure	Conflict with other national priorities, lack of local ownership
Nordic	Potential to relate to other Nordic institutions, stronger Nordic capacity for responding to adaptation needs; increased bargaining power at an international level	Additional level of bureaucracy for adaptation policy, no direct political power	Synergetic effects can give better cost-effectiveness; collaboration and sharing of information can increase adaptive capacity	Political barriers to implementation, conflicting national objectives
EU	Resources and ability to address transboundary issues	Adaptation strategies are too broadly defined for implementation	Break gridlock in EU adaptation policies; tackling of cross-border vulnerabilities; sharing of information	Disrupt the functioning of EU adaptation policies, unbalancing the EU power structure

The analysis shows that adopting a Nordic strategy could yield multiple benefits. A Nordic strategy has the potential to relate to other Nordic institutions that can draw on the knowledge of the strategy. A common Nordic strategy can also further strengthen the Nordic capacity to adapt to climate change. Finally, a strategy can also improve the bargaining power of Nordic countries internationally as well as establish the position of Nordic countries in the forefront of dealing with climate change.

The weaknesses of a Nordic adaptation strategy include an additional level of bureaucracy that would be created. Institutional overcrowding is a real concern as adaptation policy emerges on several levels of social organisation. If a Nordic strategy is pursued, it is necessary to identify the exact contributions that can be made with such as a strategy, and avoid duplication of (or even worse, conflict with) strategic objectives and measures that are already in place nationally or might be included in the EU strategy that is to be published later in 2013.

The opportunities for a Nordic adaptation strategy mainly include different kinds of synergies. Given that Nordic countries are facing similar climate impacts across number of different sectors, there are possibilities for further sharing of knowledge and best practices. These can also improve the cost effectiveness of adaptation measures as there is no need to reinvent the wheel. Further collaboration on research on adaptation is another way of supporting Nordic efforts and information-sharing.

Finally, barriers to a Nordic strategy include different kinds of political barriers that can impede the adoption of a common strategy. It is unclear to what extent a Nordic strategy could steer adaptation in each country, or whether the emphasis would be on soft measures. Similarly, there can be conflicting national priorities that can hinder the preparation of a Nordic strategy.

To be effective, a Nordic adaptation strategy will need to build on commonalities among the countries and also examine trans-boundary climate risks and opportunities. It is also important to remember that the Nordic countries already collaborate in many realms, including climate change mitigation, and climate- and energy-related research and it is possible to build on this. As already mentioned, the Nordic countries have very similar cultures and political, economic and administrative systems, which can provide a good starting point for cooperation.

Assessing potential steering mechanisms and policy instruments

In order to make an impact, any Nordic adaptation strategy that is developed will need mechanisms to steer policy, practice and public opinion towards desirable goals and outcomes. One way to do this is to implement policy instruments that create incentives to take action at lower political levels and provide clear guidance on how to do so. This can be done through hard legal or economic policy instruments, or through information.

However, since adaptation policy is still in an early development phase, there are few tested policy instruments available. As Glaas and Juhola note, this is particularly true for trans-national adaptation policies, such as at the EU or Nordic levels (Glaas and Juhola 2013).

Glaas and Juhola analysed what type of steering mechanisms are planned for the central and macro-regional EU adaptation strategies, and what this might imply for the effectiveness of EU adaptation governance. They argue that due to the different ways in which Member States have institutionalised adaptation, it will not be possible for the trans-national policies to steer through top-down legal instruments. Instead, the policies might be more effective if they are directed towards coordinating adaptation by providing grants through a system of management by objectives (MBO).

Glaas and Juhola argue that an MBO system could provide clearer guidance of what to aim for in adaptation management, and make it possible to use an economic grant scheme to steer action. If a Nordic adaptation strategy also uses an MBO system, it might also be possible to take advantage of successful experiences with mitigation as well as adaptation in the Nordic countries.

The downside of a Nordic adaptation strategy built on MBO and grants is that it would require normative considerations of what constitutes successful adaptation. In contrast to mitigation or pollution management, the success of adaptation is harder to measure, since there is nothing concrete to measure against. One possible solution to this problem would be to develop a set of proxies for indicators that assess the effectiveness of adaptation measures.

Developing a common indicator system for adaptation in the Nordic countries would probably be feasible. Whatever approaches are chosen, it is clear that an effective Nordic adaptation strategy will require, at the outset, an agreement on how to set goals for adaptation and how to measure success.

KEY ELEMENTS NEEDED FOR A NORDIC ADAPTATION STRATEGY

Based on the analysis above, we propose a set of guiding principles for a comprehensive Nordic strategy for climate adaptation:

- Use the best available science in identifying climate change risks and adaptation measures.
- Recognise that the capacity to collect and process data is increasing, and that knowledge about climate change continues to evolve. An adaptation strategy

therefore needs to be able to incorporate new knowledge on climate change and adaptation.
- Involve relevant stakeholders in reviewing the adaptation strategy.
- Assess potential for positive synergies between the member countries' adaptation activities, to make the most efficient use of resources.
- Allow for new national initiatives, which are not covered under the joint strategy.
- Coordinate with other regional strategies which the member countries may be part of, such as the Baltic Adaptation Strategy (BaltAdapt) as well as the forthcoming EU strategy on adaptation.

The overarching goal of a Nordic Climate Adaptation Strategy should be to initiate and coordinate joint Nordic adaptation actions and to streamline Nordic adaptation and mitigation policies. Specific objectives might include:

- Assessment of climate change risks, including threats to human health, temperature changes, precipitation variations, seasonal shifts, sea-level rise, wind changes, ecosystem changes, etc.
- Assessment of potential benefits to Nordic countries arising from the changes in climate, for example in terms of changes in the length of growing seasons.
- Assessment of the effects of mitigation policies, including on the economy, infrastructure, ecosystems.
- Identification of sector-specific and cross-sectoral adaptation strategies.
- Identification of governance efforts (procedural adjustments, laws, etc.).
- Identification of incentives and resources needed to develop and implement adaptation strategies.
- Identification of additional cross-cutting supportive strategies such as decision-making, networking, monitoring, and review of stakeholders.

When thinking of a Nordic strategy, we propose that the Nordic countries examine whether they practice proactive strategic management, or rather, are more reactive. In line with the literature on strategic management, there are two opposite approaches to developing strategies: one focused on the internal strengths of an entity, the other on successfully navigating the external factors affecting the entities. An effective proactive Nordic adaptation strategy needs to combine the two. By internal strengths we refer to the aggregated capacity of Nordic countries in terms of political and economic environment, expertise, technology, know-how, economic resources. External factors include climate change effects, impacts from activities in other policy areas, and economic cycles.

CONCLUSION

A review of current state of adaptation in the Nordic countries shows that Nordic countries have been active on adaptation, both at the national level as well as at the municipal level. All the Nordic countries have taken a slightly different approach in preparing and implementing a national strategy but many of the adaptation concerns are similar. Local level adaptation is also emerging through different initiatives with various sources of knowledge and funding. Three Nordic countries – Denmark, Finland and Sweden – have launched web portals to support municipal-level adaptation, including sharing of experiences and information. Although the Nordic countries have been active in initiating adaptation policy, there are challenges in terms of implementing policy and ensuring that adaptation issues are considered in the wider policy realms. Much work remains to be done.

The potential benefits of a Nordic strategy emerge from the fact that the countries are facing similar challenges in terms of climate change impacts, such as increases in precipitation, sea-level rise, and heightened flood risks. Nordic countries have similar political and economic backgrounds and a long history of collaboration on other issues, which enhances the potential to address these challenges jointly.

A possible pitfall of a common Nordic strategy is that it could conflict with, or detract from, strategies that emerge at other scales. For example, an EU adaptation strategy will be published in 2013, and a Baltic Sea Region strategy is also under preparation. If a Nordic strategy is pursued, careful consideration must be placed to the areas in which a Nordic strategy can contribute the most. Finally, a common Nordic strategy is likely not to be legally binding, so its impact could be very limited if it is not strongly supported by national-level action.

Should the Nordic countries choose to formulate a collaborative strategy to address climate change adaptation, this white paper outlines a number of issues they should take into consideration. These include, amongst other things, reviews of European adaptation policy; of common Nordic policy in other realms; of benefits and barriers to adaptation in the Nordic countries; and of existing and proposed policies and adaptation measures in the individual countries.

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