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Vulnerability and adaptive capacity in Hammerfest, Norway

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ABSTRACT

This article focuses on vulnerability assessment and climate change adaptation strategies in the city of Hammerfest (Northern Norway). The analysis is based on the CoastAdapt framework and will be looking at both current and future climate. Vulnerability is split into "natural vulnerability", "socio-economic vulnerability" and "institutional vulnerability". Historically, Hammerfest has been vulnerable to avalanches and landslides, and has over time built up considerable climate adaptive experience. Hammerfest is now undergoing deep transformation. The petroleum industry descended on Hammerfest in 2002; ten years later it provides employment for more than 1 000 people in a town with a total population of approximately 10 000. Over this period, new property taxes and other sources of income have made Hammerfest an affluent community. The result is considerable investment in urban development and new infrastructure (schools, a culture center, new sewers and a streets renovation scheme, etc.). In terms of climate adaptation the impact of the oil industry may be seen as a double edge sword. On the one hand, greenhouse gas emissions have rocketed. One the other hand, the economic development has boosted the municipality's revenue and population, thus enabling Hammerfest to consider, and spends money on, local climate adaptive projects that are far beyond the realm of possibility for neighbouring municipalities. The article will look at the instruments employed by Hammerfest in this process.

1. Introduction

The contention that climate change (CC) is man-made is winning increasing acceptance, as thoroughly documented in the Intergovernmental Panel on Climate Change Report (IPCC, 2007). The short and long term impacts of CC on individuals and communities will vary depending upon location and socio-economic conditions. How vulnerable are the communities, and to what sort of vulnerability are they exposed? What is a community's ability to adapt to (increased) vulnerability, and how can the drawbacks be prevented and their consequences reduced? We will employ the vulnerability assessment standard developed by the CoastAdapt project[2] to examine these issues, discussing current and future vulnerabilities and adaptive capacities in the process.

Our discussion is based on data collected in Hammerfest, a coastal town in Northern Norway. The town has, over the past decade, experienced a societal transformation brought about by the arrival of the petroleum industry as the Barents Sea was opened up to petroleum activity (the gas field Snøhvit and the oil field Goliat). This activity has resulted in a significant increase in the local authority's revenues, thereby putting it in a very different economic situation to that of other municipalities. This has resulted in large-scale urban development with new and upgraded infrastructure. In addition, the petroleum activity causes substantial global greenhouse gas emissions for which the responsible oil operating companies are granted waste disposal permits by national authorities. As such, a major source of emissions contributes to ensure that the municipality will have the capacity and financial resources to implement CC mitigation measures.[3] While looking at the transformation that Hammerfest is experiencing, it is particularly interesting to study local efforts made to implement climate adaptation measures and undertake vulnerability assessments. As this article illustrates, the Hammerfest municipality has adopted a

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[2] The CoastAdapt project (Full name: The Sea as our Neighbour: Adaptation to CC on Coastal Communities and Habitats on Europe's Northern Periphery) is a partnership of research institutes and administrative bodies in Scotland, Ireland, Iceland and Norway. Led from Scotland, the Norwegian partners are Hammerfest municipal council, Norut Alta and the Norwegian University of Life Sciences (UMB). A total of five pilot studies are underway, focussing on small coastal communities in Scotland (Outer Hebrides), Ireland (Tralee Bay) and Iceland (Árborg and Vík í Mýrdal) as well as Hammerfest.

[3] This is a large and important subject sparsely discussed here, but it will be the subject of a separate article.

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number of measures designed to reduce vulnerabilities of the natural, socio-economic and institutional kind. Our discussion will be referring to the close association between measures designed to reduce vulnerability and adaptation measures, and how today's initiatives can affect future vulnerability.

In this paper, we will first briefly explain the concepts of vulnerability and adaptive capacity and then present the model developed under the CoastAdapt project for showing a community's current and future vulnerability to CC as well as its adaptive capacity. After presenting the method, the key aspects of Hammerfest, the Norwegian CoastAdapt study site, will be described. Thereafter, the current situation and future vulnerabilities will be discussed, divided into the themes natural, socio-economic and institutional vulnerability, in each case focussing on Hammerfest municipality's approach. Finally, we will make the link between vulnerability and adaptation and draw our final conclusions.

2. Vulnerability and adaptive capacity

2.1. Vulnerability

The concept of vulnerability is used extensively in the literature about CC and is influenced by research within a wide range of disciplines (Soares et al., 2012). The most wide-ranging definition is put forward by Smit et al. (2000) who see vulnerability as the degree to which a system is susceptible to injury, damage or harm. Blaikie et al. (1994) describe vulnerability as "[...] the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard". This explicitly identifies social systems and their characteristics as the subject of analyses whilst recognising natural hazards as the source of harm to the system. The IPCC's definition is broadly scoped with respect to the subject of analysis, but very specific regarding the hazard affecting the system (which is climate changes) is the IPCC's definition. The IPCC conceives vulnerability as the degree to which a system is susceptible to and unable to cope with adverse effects of CC, including climate variability and extremes (Parry et al., 2007; in Soares et al., 2012).

O'Brien et al. (2003) emphasise that it is important to focus on reducing vulnerability to current climatic extremes, rather than to wait for consensus in the debate about whether or not CC is man-made. Vulnerability is used in the international climate change literature to describe the possibility of being negatively affected by climate change, although CC may have positive consequences. Vulnerability can hence be seen as a function of the degree of exposure to CC, one's sensitivity to these changes and one's adaptability (op. cit).

Aall (eds.) (2011a and 2011b and 2009) breaks up the vulnerability concept into three types of vulnerability: i) N*atural vulnerability,* which is a combination of climate parameters such as precipitation, temperature, wind, and effect parameters such as drainage, sea levels and storm surges and indicates the climate's effect on nature; *ii) Socio-economic vulnerability* indicates society's exposure to CC, for example, the extent and loss of cultivated and fertile land, the quality and level of operation and maintenance of physical infrastructure, and positioning of buildings and infrastructure; and iii) *Institutional vulnerability*, which says something about an organisation's institutional capacity to develop and implement a strategy for adaptation to CC (Aall et al., 2009) and may involve access to expertise, administrative capacity, financial resources, knowledge, tools and the instruments to implement adaptation. Such a classification of vulnerability will reveal that society's climate vulnerability is the combined effects of change in both climate and society. Examples of changes in society are housing developments in the coastal zone that will increase future climate vulnerability to sea level rise and tide. Aall (2011a and b) has again used a variety of indicators to assess each of these types of vulnerability. One challenge is to ensure access to sufficient data to operationalise the possible development trends; this applies to socio-economic vulnerability, and, to an even greater extent, to institutional vulnerability. Moreover, Aall (2011a) emphasises that both the assessment of risk and the evaluation of uncertainty are fundamental to how vulnerability should be presented and, in turn, how adaptation processes to this vulnerability should be considered.

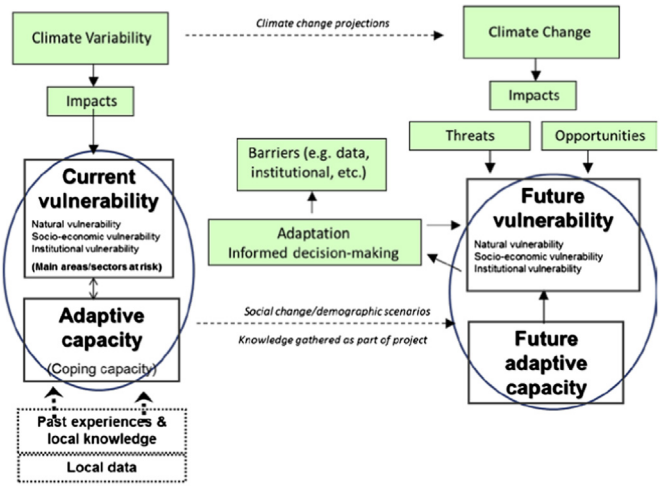

Fig. 1. Vulnerability analysis model developed by the Coast Adapt project.

A government-appointed committee that has studied CC in Norway (NOU, 2010:10) assumes an understanding of climate vulnerability as a result of society's exposure to CC (character, magnitude and rate of change) and its adaptive capacity. This is in keeping with the underlying understanding of the CoastAdapt project and Soares et al. (2012).

2.2. Adaptive capacity

Adaptive capacity can be defined as the ability or potential of a system or a territory to respond successfully to climate variability and change (Brooks and Adger, 2005). Adaptive capacity is influenced by a range of different factors, available resources and knowledge being some of the obvious ones. In an international context, Norway should be in a good position to work on adaptation, with access to both knowledge about CC and the necessary economic resources (O'Brian et al., 2004). Nevertheless, there may be barriers to the adaptation effort. In order to identify such barriers, adaptation must be understood as a social process (Adger et al., 2009). Actual adaptation does not necessarily follow from successful learning about CC and its impacts, as adaptation requires both the capacity to learn and the capacity to act. The capacity to learn depends on acknowledging that CC is a problem. Furthermore, in an organisational perspective, such knowledge and learning has to be integrated into everyday routine-based activities and through interaction. In general, action can be understood as decision-making and resource allocation (Inderberg and Eikeland, 2009), and is dependent upon a will to search for possible solutions and to convey the selected set of solutions into new routines (Winsvold et al., 2009). For a municipality, this could be to integrate CC considerations into their planning process, as planning can be described as the link between knowledge and action (Friedman, 1987). However, there could be a set of barriers to actual adaptation, such as conflicting goals and interests. For

instance, there is an intrinsic conflict between measures to reduce the level of greenhouse gas emissions on the one hand and adaptive measures on the other. Another barrier is the uncertainty of future CC scenarios.

2.3. Model for current and future vulnerability and adaptation

The model below (Fig. 1) shows vulnerability and adaptive capacity in the current climate (left hand side) and similarly for future climates (right hand side). It is a shared tool that underpins the thinking in all five CoastAdapt project partners (see footnote 1), Hammerfest being the Norwegian study site. In this article, the model is primarily used as a basis for discussing vulnerability and to some extent adaptation, to both current and future climates. Hence, this is not a discussion of the model itself, but the thinking behind the model will inform our discussions. The vulnerability concept is divided into three constituent parts: natural vulnerability, socio-economic vulnerability and institutional vulnerability (Aall, 2011a, 2011b and 2009), as explained in Section 2.1. The current climate vulnerability and adaptive capacity (left) affect the right hand side of the model that focuses on future climates, in particular future vulnerability and adaptive capacity. Adaptation to future climates and vulnerabilities are new challenges for Hammerfest, as it is for other (Norwegian) municipalities. Our work to safeguard against future climate challenges has yet to be tested. Hammerfest has in recent years been involved in several research programmes (NORADAPT,[4] CoastAdapt, PLAN[5]) that have concerned themselves with these topics and in the process, the municipality has gained interesting experience that may be useful to others.

3. Methods

Data have been collected from multiple sources. The *interview* form has been applied. In connection with the PLAN Project, eight people were interviewed. There were municipal officers (three), staff at the Housing Bank's regional office in Hammerfest (three) and private developers (two). Follow-up telephone interviews with key informants in the municipal administration (Klausen et al., 2012) were also conducted. The interviews were semi-structured, using an interview guide. The informants were asked, among other things, about their attitudes towards CC, their assessment of vulnerability and what is being done to meet the challenges, especially related to urban and residential development, and what they saw as key barriers to, and conditions for, adaptation. In addition, three *workshops* were organised by the CoastAdapt project, involving people from different parts of the municipal administration, the Housing Bank's regional office in Hammerfest and the research community. One of the workshops was attended by researchers and representatives from the local government of the five CoastAdapt project partners (Angell and Stokke, 2012). Furthermore, *register-based data* has been used, e.g. demographic data and population projections, as well as employment data obtained from public databases (Statistics Norway). A number of existing research reports and other available *secondary data* have also been used to inform our analyses and discussions.

[4] NORADAPT is a research programme funded by the Norwegian Research Council's Norklima programme, led by CICERO. Hammerfest is one of ten municipalities involved in the project whose main purpose is to develop models for local climate vulnerability and test them in the municipalities. The project was completed in 2011 (Oort et al., 2012).

[5] The project Potentials and Limits to Adaptation in Norway was funded by the Norwegian Research Council. One of the project sub-tasks focused on adaptation in urban planning and development, Hammerfest being one of five case-cities.

4. About Hammerfest

4.1. A town in transition

The town of Hammerfest is located in the north of Norway, in the county of Finnmark, on the Barents Sea coast. Historically, Hammerfest has been an industrial and service town. The fishing and fileting industry emerged in the 1950s; the hospital for Western Finnmark is located in the town; in addition, trade is important. In 2002, the Norwegian Government made an important decision for the town when the Barents Sea was opened to petroleum activity. The first major gas development was the Snøhvit gas field. Gas is piped ashore to a location close to Hammerfest (Melkøya) to a plant where it is processed into liquid form (liquefied natural gas, LNG) (see Fig. 2). From there, it is transported by custom-made ships to the global markets. The main operator is the oil company Statoil. Production commenced in 2007. There are further plans to start oil production from the Barents Sea (the Goliat field) in 2014. This is an offshore rather than an onshore installation like the LNG-factory, but the operating company (Italian-based Eni) has set up its operating organisation and base in Hammerfest, hence it provides important economic activity in the town. Over the last decade, the town has become a very important petroleum town in Northern Norway. With new oil and gas discoveries (Havis and Skrugaard), increased petroleum activity is expected in the years ahead, despite the fact that the most optimistic projections have proved incorrect so far and despite the fact that several exploration wells have been found to be empty.

In 2012, Hammerfest's population was round 10 000. It is the second largest town in Finnmark. In the 1990s, Hammerfest experienced stagnation and a falling population, until 2002 (with 9 000 inhabitants) (see Fig. 4). There was, in particular, a dramatic reduction in the younger age groups (20–30 years), which in turn provided gloomy prospects for the town's future population

Fig. 2. The LNG plant is located on a small island (Melkøya), close to Hammerfest.

Fig. 3. Example of avalanche protection measure in Hammerfest.

growth. Once the petroleum activity began, emigration from even the younger age groups slowed down, and actually turned to growth, especially among the 20-49 year-olds (Karlstad (eds.) 2011). The economically active population increased by 23% from 2002 to 2009. Since the petroleum development began, the job market has changed significantly with a sharp increase in sectors that traditionally provide a high proportion of male employees. The petroleum industry is the key driver for change (Eikeland et al., 2009). In 2012, there were over 1 000 petroleum jobs in Hammerfest (Nilssen et al., 2012). Local and central government is still the largest employer, accounting for 39% of all employment (in 2009).

4.2. Local government finances and investments

The economic position of the municipality provides an indication of its development potentials, particularly with respect to schemes which are not introduced by statutory requirement. In the 1990s, the municipality's economy was poor and the administration of its finances was placed under state control. Hammerfest had many dilapidated public buildings and a run-down infrastructures. In 2000, municipal investment was in the region of NOK 30 million. Since 2003, the economy of Hammerfest has been characterised by major investment in new buildings and maintenance projects, funded by substantial loans. In the period 2003 to 2010, the Hammerfest municipality spent approximately NOK 1.6 billion on capital projects (Karlstad (eds) 2011 and Eikeland et al., 2009). First, the primary schools were modernised and then a great new culture centre was built. This high level of investment has continued in recent years, funded by a sharp increase in revenues form property taxes which rose from a modest NOK 6 million in 2002, to NOK 163 million in 2010. Most of this increase is associated with the petroleum plant. Should further petroleum developments materialise, the revenue is expected to further increase. By comparison, Hammerfest municipality received NOK 144 million in ordinary government grants in 2010. Since 2006, the municipality's property tax revenues have been higher than the amount received in government grants (Angell and Stokke, 2012). This shows how essential this new source of revenue is to Hammerfest municipality. Revenues from income tax have also increased as many have well-paid jobs.

4.3. Dramatic increase in greenhouse gas emissions

Once the LNG plant began operations, Hammerfest became one of the Norwegian municipalities with the highest greenhouse gas emissions to air, along with big cities and other municipalities with a large petroleum industry or other processing industry. In 2005, before the LNG production began, Hammerfest's CO_2-equivalent greenhouse gas emissions to air was 23 000 tonnes[6] (which was consistent with emissions in preceding years). There was a dramatic increase in emissions after the LNG plant began operations, and in 2008 the emissions were 1 413 000 tonnes CO_2 equivalents, which was reduced to 848 000 tonnes of CO_2 equivalents in 2009. In 2008, 2009, respectively, Hammerfest was ranked third and fifth on the list of Norwegian municipalities with the highest total emissions to air. The emission of greenhouse gases is the primary source of pollution, but there are additional local pollutants, such as soot. Road traffic constitutes the municipality's main source of greenhouse gas emissions (Hammerfest municipality 2011).

5. Vulnerability and adaptation – the current situation

Hammerfest's geographic location has always forced residents to adapt to the harsh Arctic environment and climatic conditions. Storms have historically affected the municipality in varying ways depending on the strength and direction of the wind. Several locations are exposed to floods, avalanches and landslides.[7] The Hammerfest community has long experience of living in and adapting to a harsh climate. In this section, *the current* situation is discussed in view of the three-way division of natural, socio-economic and institutional vulnerabilities, while looking at the actions that Hammerfest has implemented, cf. left side of Fig. 1.

5.1. Natural vulnerability

Hammerfest has carried out a **Risk And Vulnerability (RAV) analysis** (Hammerfest, 2010a) to assess important risk and vulnerability factors and consider appropriate actions, strategies and plans for the municipality to draw up and implement in order to be prepared for unforeseen events. The planning authority (e.g. the municipality) has a duty to carry out such a risk and vulnerability analysis under s. 4(3) of the Norwegian Planning and Building Act (PBA)[8].

5.1.1. Floods, avalanches, extreme weather and storm surges

The Hammerfest RAV analysis highlights a number of safety issues that require attention and action. Six risk factors were assessed: i) epidemic - pandemic, ii) water utilities, iii) flooding - avalanches, iv) telecommunications - data, v) extreme weather - power outage and vi) the situation in Hammerfest harbour. The risks were assessed for probability[9] and for severity of impact[10]. Three of these risk factors are considered to be particularly climate related: iii) flooding and avalanches, v) extreme weather and vi) the Hammerfest harbour, especially quay-side storm damage and storm surges. Floods, avalanches, extreme weather and storm surges can be seen as the *natural vulnerabilities*, ports, infrastructure and buildings that suffer damage because they are located in high-risk areas (e.g. particularly prone to flooding and avalanches), are economically vulnerable, which we will return to later. Responsibility for measures proposed in the RAV assessment has been

[6] Source: www.ssb.no/statistikkbanken (downloaded 5th Nov. 2012).

[7] There are 14 registered historic avalanches damages with a loss of 24 lives in Hammerfest from 1723 to 1963, and February and April have dominated as the time of avalanche release (Leivestad et al., 2008).

[8] A county RAV for the county of Finnmark has also been made. This assesses, among other things: Adverse events related to petroleum activity, more precisely to i) acute pollution and ii) the major accident at petroleum installation.

[9] On the scale: highly likely – very likely – likely – unlikely – extremely unlikely.

[10] On the scale: harmless – less harmful – harmful – critical – catastrophic.

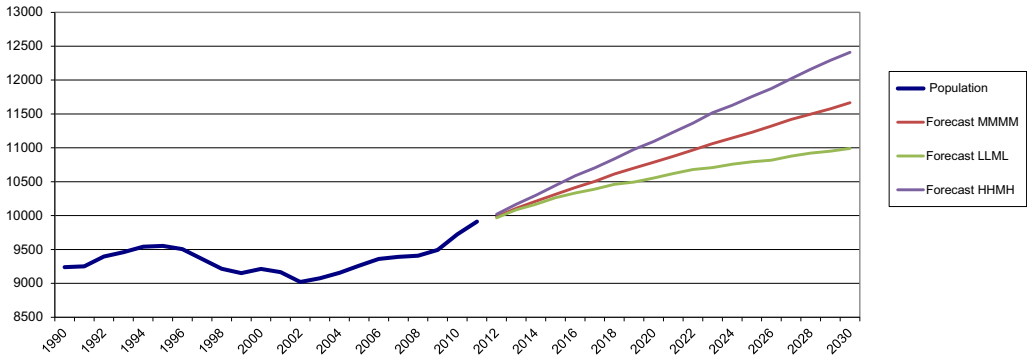

Fig. 4. Actual population growth in Hammerfest from 1990 to 2011 and forecasts to 2030.

allocated to a specific authority and deadlines have been set for their implementation.

Certain locations in Hammerfest are exposed to *floods, avalanches and landslides.* New "hazard maps" have been issued by national agencies and constitute important tools for municipal planning authorities as they assess the vulnerability of their areas. However, it is important to keep in mind that the national mapping of landslide, avalanche and flooding hazards does not take into account the expected future climate changes; the work is solely based upon historical data (Aall, 2011a). The RAV analysis considers rockslides, avalanches and mudslides to be particularly "critical", and rates these hazards as "likely" to occur. Storm surges are considered "less harmful", but are also considered "likely" to occur.

5.1.2. Increased greenhouse gas emissions contribute to increased natural vulnerability

The increased emissions of greenhouse gases, such as from the LNG plant, contributes to increased natural vulnerability for the entire globe, and Hammerfest is thus not more adversely affected than the rest of the world (see also Section 5.3.2). However, there are also local emissions, such as soot, affecting neighbouring areas.

5.2. Socio-economic vulnerability

5.2.1. Damage from flooding, avalanches s and extreme weather

The critical factors emphasised by the RAV analysis also affect the socio-economic vulnerability. In relation to *flooding and avalanches*, important parts of the town's building mass are located within defined avalanche zones, and this must be understood as a socio-economic vulnerability. Hammerfest municipality has taken several steps to prevent and protect against avalanches and the damage they cause. Following a fatal avalanche in 1950, a plan for securing the affected settlement was developed, and subsequently a number of avalanche protection measures have been erected to safeguard vulnerable settlements (Fig. 3). Additional safety measures were implemented after the avalanches in 1989 and 1994, including the introduction of building exclusion areas and further surveying of areas prone to avalanches (Leivestad et al., 2008). Further measures were implemented at a later stage, and today Hammerfest has a comprehensive system for measuring snowfall and assessing snow conditions throughout the winter season. A safety plan has also been introduced, to be updated annually. This shows that through the years, Hammerfest has gained experience and knowledge about how the handling of the avalanche hazard. The town council's RAV analysis also proposes to update the avalanche hazard report and to strengthen the existing safety plan with respect to avalanches and rock falls in built-up areas.

Power outages caused by *extreme weather* is here interpreted as an economic vulnerability when affecting a number of public institutions, but may also be considered an institutional vulnerability depending on the extent to which the institutions are set out of action. The RAV analysis lists several adaptive measures, such as purchasing generators to reduce the vulnerability of extreme weather. *Storms damage to the pier* is considered to be "harmless" but "likely" to occur. The analysis proposes new preventive measures such as minimum mooring requirements and other mandatory safety measures whenever extreme weather is forecast. Parts of the existing building mass and infrastructure are considered vulnerable to storm surges. There are considerable local variations with respect to the hazard represented by storm surge as the impact will depend on the positioning of buildings and infrastructure vis-à-vis the sea.[11]

5.2.2. Plans for climate-adapted housing

Hammerfest municipality and the Housing Bank have worked together on a climate-adapted housing scheme. A neighbourhood has been designed that take account of local climatic conditions such as snowfall and snow drift. We believe that these measures are reducing both social and institutional vulnerabilities. Experience tells us that it is not sufficient to concentrate on individual houses. To achieve the best results, we need to focus on larger residential area, because the positioning of houses relative to one another is of great importance. Based on this experience, the municipality has developed its own *climate-adapted zoning plan* for a residential area. The plan takes the prevailing wind direction into account when deciding the location of doorways, garages and roads. Roof pitch, roof height and the direction of the hip are also regulated. The housing sites are currently being prepared and construction will begin in the summer of 2013. New climate-adapted residential areas are in the pipeline.

5.2.3. Increased maintenance and modernisation can reduce vulnerability

Significant maintenance, renovation and modernisation work has been carried out on municipal buildings and infrastructure after the upturn in Hammerfest's economy. For example, the town's high street has been completely redeveloped and has a new water supply and sewer system. This work has taken account of the need

[11] The indemnity statistics from the Norwegian Natural Perils Pool show that storm surge so far represent only a small problem in Hammerfest and that storms gave rise to higher payouts in damages than any other type of natural disaster in the period 1980–2006. Avalanches come second on the list. If we look at the payout per claim, however, avalanches are the most serious type of natural peril (Leivestad et al., 2008).

for more surface water runoffs. There is awareness in the community that all such redevelopments should allow for future climate changes. Thus, the economic vulnerability to CC will be reduced. The fact that there is good awareness today, at a time when major modernisation projects are being implemented, will be a significant factor for reducing future vulnerability.

5.2.4. Transforming the Hammerfest community

Above, the major transformations that have occurred in Hammerfest since 2002 have been described. Demographically, there is a more favourable composition of the population as the age 20–49 year group has increased. Hammerfest municipality has become more robust in demographic terms, but increased population pressures also generate a need for more housing, etc. How these houses are designed and where they are located will affect the community's socio-economic vulnerability, which may, for example, generate pressures in avalanche-exposed and seaside areas. The economically active population has increased by 23% (from 2002 to 2009), and there has been a change in the industrial structure. Although the public sector is still by far the largest employer and has experienced growth, there has also been an increase in petroleum-related activities. A range of other sectors, such as shipping and engineering, construction, hospitality, security and cleaning have also been boosted. On the other hand, the fishing industry has seen a decline, as has fish processing, publishing and graphic printing, as well as post and telecommunications. More than 1 000 people worked in petroleum-related industries in 2012. Socio-economic climate vulnerability is affecting different industries in different ways; the data provide no basis for drawing strong conclusions about the overall effect of industrial transformation.

5.3. Institutional vulnerability

5.3.1. Unclear division of responsibilities

The division of responsibility for CC between local and central government authorities has not been sufficiently clarified. There is also confusion regarding the division of responsibilities between different governmental levels and sectors. The municipalities use the lack of instruction from central government as a justification for inaction, while the Government, for its part, believes that CC is the municipalities' responsibility. Furthermore, the fact that there is no legal framework for introducing adaptation measures can be viewed as a barrier to local action. Thus, "hierarchical apathy" rules, where everyone is waiting for someone else and no-one is doing anything (Klausen et al., 2012). Aall et al. (2009) also point out that the lack of government policies and regulations is a clear obstacle to local adaptation. This lack of regulatory assertiveness may be considered an institutional vulnerability that affects the local handling of climate issues.

5.3.2. The municipal plans

The way in which a municipality works with its *municipal plans* reveals important aspects of its institutional vulnerability. Municipalities that are forward-looking and work actively with their plans are generally less institutionally vulnerable than municipalities that take a more passive approach.

The *Municipal Master Plan* is the main plan. A new local bye-law in Hammerfest (Hammerfest kommune 2010b) regulates construction work in seaside locations. New structures erected less than 3 m above normal sea level (contour line + 3) must have measures implemented to prevent water intrusion (see Stokke, 2013. In addition, house-building is not allowed within a 25-m zone of any lake or stream. These vulnerable areas are marked in the municipal mapping system, GIS, which makes them an integral part of the municipality's ordinary case work procedures and work schedules. These are planning tools which allow the municipality to reduce its vulnerability to CC in relation to sea level rise, storm surges and flooding. Hence, both institutional and socio-economic vulnerabilities are reduced. The principal recommendation forthcoming from the public committee set up to explore adaptation issues were that CC must be integrated into mainstream community planning (NOU, 2010:10 p 16). These two provisions that Hammerfest has included in its *Municipal Master Plan* will serve as good examples of such practice.

Hammerfest municipality has, as described above (see chapter 5.1), prepared a *RAV analysis*. Through such a plan, vulnerabilities are identified and measures are considered. This planning tool can be seen as a method to reduce the institutional vulnerability.

In 2009 Hammerfest municipality decided that a dedicated climate analysis would have to be submitted whenever a zoning plan is drawn up for a major development project. This has been followed up, and one informant representing a private developer, said the climate requirement imposed by the municipality has neither led to problems nor been particularly costly, as it is flagged up at the very start of the planning process, and the dialogue with the community on these issues has been clear and good (Klausen et al., 2012). It appears that this requirement is incorporated as a regular part of the process and followed up in the daily work.

The Government instructed all municipalities to draw up a Climate and Energy Plan by July 2010 and provided some of the resources required do this work. The Climate and Energy Plan could form part of the Municipal Master Plan, or it takes the form of a zoning plan. At the end of 2012 almost all Norwegian municipalities had such a plan. Hammerfest has commissioned a *Climate and Energy Plan* which has been under preparation for a number of years. Among other things, this plan will be looking at CC – both short term and long term. The fact that Hammerfest still finds itself without such a plan is in itself an indication of a lack of capacity and/or priority. We have been led to believe that it is primarily due to the lack of administrative capacity, but of course, it is also a political responsibility to chase up the work once it has commenced. One informant in the municipal administration told us that the plan would be completed in 2013; a named officer has been asked to prioritise work on the plan, as it requires "a new beginning". The plan will include a factual section, and an action section covering energy saving efficiency, CO_2 emissions and CC.[12] An informant from the administration said that the emissions from Melkøya will be discussed, but it is yet not clear how this will be presented, as the municipality does not have the authority to demand reductions in CO_2 emissions. Such plans should be seen as a tool, and if they provide a strict timetable, this will reduce the community's institutional vulnerability.

5.3.3. Increased capacity and expertise

Hammerfest's improved economic situation, thanks to the sharp increase in property tax and the general rise in income tax revenues, has strengthened the municipality's institutional adaptive capacity. This has contributed to increased human resources and increased expertise in the municipal administration, but has also increased the municipality's workload. This applies, for example, to the pressure on the planning authorities to release land for residential and commercial purposes. Hence, there will be a discussion

[12] In an early draft of the Climate and Energy Plan (Hammerfest municipality 2011), it was decided that the LNG plant should be excluded from the measurements presented in the plan. Instead, the focus was on other sources of emissions (traffic, etc.) and measures were assessed. It remains to be seen whether this still will be the case when the planning process resumes.

on how this strengthened institutional capacity affects climate vulnerability. Since the 1990s, Hammerfest municipality has had a dedicated council officer employed as environmental advisor. The expertise that has been built remains in the organisation, and this acts as a "driving force", so that more people are motivated to work on the environment in general and climate in particular. Several people in the administration have environmental expertise and these individuals are important supporters. In general, studies show that a lack of administrative capacity is the main obstacle to putting CC on the agenda (Aall et al., 2009, 2008a and 2008b). The municipality's administrative staff have participated in various professional networks, even where CC has been the topic. For example, in recent years Hammerfest has taken part in a number of research projects concerned with CC and adaptation (e.g. NORADAPT and CoastAdapt). They have also participated in several national and international professional, with participants from management as well as the research sector. The increased capacity is likely to contribute to putting the community in a better position to prioritise participation in various networks where the staff can find inspiration, knowledge and ideas. However, it seems that the municipality's politicians have been little involved in the networks and the work that has been accomplished so far on the climate and energy plan. There are indications that CC has received relatively little attention from the policymakers. In recent years, there has been a strong demand for development in Hammerfest in relation to petroleum activities. A number of new developers have wanted to establish themselves with increased activity, and local politicians have generally been preoccupied with jobs and growing employment. It also appears that private property developers, other business sectors and civil society organization rarely participate in networking and planning processes where climate vulnerability and adaptation are discussed. Increased competence and capacity in the administration would reduce the community's institutional vulnerability, but because decision-makers, the general public and the business sector seem to be less involved in the building of knowledge about CC and its possible effects, increased vulnerability may well be the case.

6. Future vulnerability and adaptation

This section is about the future and includes scenarios and projections related to climate and social conditions, and refers to the right hand side of Fig. 1. Adaptation to future climate is a new challenge for Hammerfest, as it is for all municipalities.

6.1. Future natural vulnerabilities

Under the research project NORADAPT, we have seen the downscaling of several global climate scenarios affecting Hammerfest have been implemented (Engen-Skaugen et al., 2010; Oort et al., 2012) for the period through to 2030. There is considerable uncertainty as to the use of global scenario models for regional and local conditions (a top-down approach). Yet this is an important tool which enables us to say something about the effects of global CC on local communities. These climate scenarios have reviewed expected changes in temperature, precipitation, sea level (and storm surge), as well as wind conditions. *Temperatures* are expected to increase by 1.7° annually until 2025 and 2.9° on an annual basis until 2060, compared to the 1961–1990 reference point (Leivestad et al., 2008). Temperatures are expected to rise more in winter (1.5–2°) and less in summer (up to 1°). Future projections show that in general, temperatures will rise more in Northern Norway than in Southern Norway. Furthermore, the sea temperature is expected to increase, which will affect the range of fish species and their migration patterns as well as conditions for aquaculture.

More rain is also expected, with a greater increase in precipitation levels anticipated for the winter, up to 30 per cent in some areas through to 2050. The precipitation is expected to become more intense and most of it will fall as rain or sleet in winter, thus reducing snow levels. In addition, over the summer and autumn, precipitation levels are expected to increase. This means a clear decrease in the number of days with snowfall, and the seasons of autumn and spring will be extended. During summer, fewer days of rain are expected, without an alteration in total rainfall. This means that precipitation will fall with greater force. Estimates - uncertain of course - of future *sea level rises* in Norwegian coastal communities have been worked out for the years 2050 and 2 100. These include estimates of storm surges. By 2050, the sea level in Hammerfest is expected to have risen by approximately 19 cm (maximum 33 cm), with a storm surge rise of 236 cm (max 250 cm) (Oort et al., 2012). How Hammerfest relates to the anticipated sea level rise is discussed in Stokke (2013). Estimates of future wind conditions are unreliable. It is expected that the number of polar lows will be moderate.

Assessing the impact of all this is riddled with uncertainty. Changing climate conditions will lead to greater natural vulnerability. For example, more intense rainfall will result in more frequent floods, avalanches and landslides. At the same time, climate scenarios show that the overall snow level is expected to fall. However, it is the wind that brings the type of snow conditions that increase the risk of avalanches in Northern Norway. On the one hand, shorter winters will mean that the number of critical avalanche periods will go down, but on the other hand, the higher temperatures will increase the likelihood of wet snow and rain on snow, leading to frequent slush avalanches (Leivestad et al., 2008). These factors show the expected changes and increased natural vulnerability, which will affect the socio-economic and institutional vulnerabilities.

6.2. Future socio-economic vulnerability

6.2.1. Future transformation of Hammerfest

The future projection of the population from 2011 to 2030 shows three different growth options, where MMMM[13] is the middle option based upon medium growth rate, while LLML and HHMH are the extreme alternatives showing, respectively, the lowest and highest national growth (Fig. 4). Today Hammerfest's population is in the region of 10 000. The middle projection shows a population of 11 700 in 2030. As described earlier (cf. Section 4.1), there has been a very favourable population growth since 2002, especially as the emigration of young adults has been reversed. This makes the population structure more favourable for future population growth. Still, higher growth in petroleum activity suggests a more optimistic population projection. The alternative with the highest growth shows a population of 12 400 inhabitants in 2030. A larger population will give rise to further demands on the housing market, and the shortage of land may lead to renewed pressures on seaside areas and areas vulnerable to landslides and avalanches. This will in turn influence the socio-economic vulnerabilities negatively, although it demographically becomes a more robust population structure.

[13] The MMMM option shows the average level of fertility, mortality, internal migration and net migration. LLML: Displays the alternative with low fertility, low life expectancy, average domestic mobility and low net immigration, and the HHMH alternative: Displays high fertility, high life expectancy, average domestic mobility and high net immigration. However, it is unlikely that the actual development in the long term will follow these extreme alternatives for all components simultaneously. Source: http://statbank.ssb.no/statistikkbanken/ and http://www.ssb.no/folkfram/(downloaded 18th May 2011).

6.2.2. Expected growth in petroleum-related industries

The petroleum operations in Hammerfest are expected to grow. Production on the first oil field in the Barents Sea (the Goliat field) is set to commence in 2014, and all helicopter and supply base operations, as well as the oil field's operating organisation, are based in Hammerfest. New commercial discoveries (Skrugaard and Havis) mean base activities, and possibly other activities serving a number of oil and gas fields, will be run from Hammerfest. Nonetheless, there have been fewer discoveries than envisaged by the most optimistic projections. An expansion of the LNG plant is currently on hold. Hammerfest may also become an attractive location for companies involved in oil exploration in the Russian sector of the Barents Sea. There are therefore great expectations of growth in Hammerfest's petroleum-related activities, even if the most optimistic estimates so far have been proved wrong. Increased petroleum activity will result in increased greenhouse gas emissions and the local economy will be more firmly tied to petroleum. This may increase the future economic vulnerability to climate change, although at least initially it will strengthen the local economy.

6.2.3. The need for new infrastructure and modernisation

Even based upon today's activity, there is a need for new infrastructure, and with expectations of future growth, this need increases. The municipality is, for example, working to secure a new airport with an extended runway at a new location which will ensure better regularity, a new route alignment for the main road into Hammerfest, and to have new power lines installed. These major investments require major environmental interventions. Hammerfest is a growing town with plans for a number of new urban developments, such as an upgrade of the town square and moving the multi-storey car park from the town centre to a custom-built mountain caves location. The municipality's requirement for new development sites to be made subject to climate analysis (see Section 5.3.2) is an important measure in the work to reduce the future socio-economic climate vulnerabilities of new developments. It is essential that such measures are made integral to standard procedures.

The extent to which climate and vulnerability concerns are embedded in current large-scale modernisation and construction projects, will have a decisive impact on future vulnerabilities (see 5.2.3). Many of these projects concern an upgrade of essential infrastructure that is expected to last a lifetime. By taking a conscious approach today to the planning and management of sites and designs for commercial buildings, residential housing and infrastructure, the future level of economic vulnerability can be reduced.

The expected population growth, increased activity levels in petroleum-related industry and further major investments in infrastructure, will necessarily affect the socio-economic vulnerability to CC. By taking deliberate strategic steps today, Hammerfest will put themselves in a position to implement adaptation measures to reduce the vulnerability in the future. Hammerfest has in place some tools for implementing climate adaptation measures that could reduce the community's future vulnerability.

6.3. Future institutional vulnerability

6.3.1. Capacity and competence

More knowledgeable people and greater climate expertise in Hammerfest's municipal administration provide a better basis for the town to meet future challenges, even if they seem to be increasing. There are many examples of capacity being the crucial resource with respect to the extent to which the climate is taken into account. When more administrative staff acquire environment and climate expertise, it becomes easier to integrate climate consideration into projects and to make these consideration a regular part of daily procedures. Hence they prevent climate adaptation from becoming a "costly extra" that is introduced only when a development or modernisation project is well into the planning stage. At the same time, they must have the required resources (e.g. time) allocated to them to enable them to work on CC adaptation. Climate adaptation has to compete for attention with a number of other matters, and it is by no means certain that climate change will be victorious, even if Hammerfest in recent years, perhaps more than many other Norwegian municipalities, has focused on CC adaptation (Klausen et al., 2012). Hammerfest has lately been enjoying a very high demand for development, and it is expected that this boom will continue. Many would probably agree that economic activity and jobs, especially associated with petroleum activities, should have first priority. It is important for the future that systems are introduced as part of municipal plans and development regulations to ensure that vulnerability and adaptation to CC are given due consideration.

6.3.2. Municipal plans

Hammerfest has integrated a number of climate adaptation measures into the municipality's current plans, for example in the land use section of the *Municipal Master Plan* 2010–2022 (Hammerfest kommune 2010b), and in the provision that a climate analysis must be carried out whenever a zoning plan is prepared. These are relatively new local regulations, so it is essential that they be followed. This gives Hammerfest a set of easily accessible tools designed to ensure that the level of future institutional vulnerability can be reduced.

Hammerfest has drawn up a municipal Planning Strategy for 2012–2015, which is a new Norwegian planning tool. The Strategy dictates what municipal plans should be prepared over a four-year period, and the Climate and Energy Plan will be implemented under this overall Planning Strategy.

7. Discussion and conclusion

7.1. Links between vulnerability and adaptation

When discussing current socio-economic and institutional vulnerabilities (cf. 5.2 and 5.3), it has been important to us to emphasise examples of local initiatives that have been implemented in Hammerfest to reduce the level of vulnerability. This review makes it clear that there is a close relationship between measures to reduce socio-economic and institutional vulnerabilities on the one hand and adaptation measures on the other. Measures to reduce and prevent vulnerability are climate adaptation strategies. It could be argued that the relationship works both ways, and that adaptation measures that are implemented similarly will reduce vulnerability. Adaptation measures implemented today can reduce future vulnerability. Hence, there is a close relationship between vulnerability and adaptation. Before measures are implemented, it will therefore be important to determine which vulnerability is the greatest and to prioritise preventive measures in these areas. We have also touched upon adaptive capacity, a concept that carries clear similarities with institutional vulnerability, as both are focused on the institutions' ability to adapt society to CC.

We have described Hammerfest's extensive experience of taking preventive action against damage from avalanches, which has gradually increased since the 1950s. These measures have been implemented in the aftermath of accidents caused by various types of landslides and avalanches, some fatal. Thus, this is a form of reactive adaptation to the existing climate and an already perceived risk (associated with the left hand side of Fig. 1). The driver of

adaptation has been external events (cf. Oort et al., 2012). Avalanche and landslide prevention measures have changed with increased knowledge and better technical equipment. When expected changes in future climates may affect the avalanche danger, current climate adaptation measures can affect future vulnerabilities associated with avalanches. Norwegian municipalities working to introduce adaptive measures for CC are primarily preoccupied with measures designed to prevent flooding, avalanches and landslides (Berglund and Nergaard, 2008). Another important point is that experience gained and lessons learnt in one area can be transferred to other vulnerable areas.

Climate-adapted housing has also been boosted by the experience and lessons learnt from the construction of climate-adapted homes. A need to look at larger residential areas in a wider context has been identified. Climate-adaptation of residential areas will reduce their socio-economic vulnerability.

To reduce the level of vulnerability to future CC, we need a type of proactive adaptation which is completely different from the measures designed for adaptation to current climates and perceived risk. Adaptation to future climates, based upon climate scenarios, is a new and radical challenge which asks people to act and make decisions based upon the uncertainty that is inherent in the scenarios. Thus, there is considerable uncertainty as to what needs to be adapted. We have shown the importance of a proactive approach through integrating climate concerns, both current and future, in the municipal plans. This is particularly important for areas undergoing a transformation as deep-seated as that in Hammerfest.

The extent to which current vulnerabilities are assessed and evaluated while the Hammerfest community is in transformation will be crucial for its future vulnerability and adaptation to CC. This is a town in rapid growth with land in high demand and an increasing population; the level of economic activity is rising and there is a need for existing infrastructure to be renewed (water supply and sewer system, roads, airports). Today's development projects will therefore be important in the long run. They take account of the expected sea level rise in that the municipality has introduced planning restrictions for waterfront building projects in order to reduce the community's vulnerability. These restrictions are plotted into the municipal mapping system, GIS, and are easy to access whenever new issues need to be considered and addressed, thereby forming an integral part of day-to-day procedures. Similarly, a climate analysis requirement has been introduced for all major new developments as part of the municipality's standard regulations, and climate considerations are thus built into the organisation's procedures. There are several examples of how these measures have been implemented as part of the process of considering and deciding on new development projects, and they now seem to have become routine within the municipal organisation. This shows the adaptive capacity of the organisation, and demonstrates that once the organisation's adaptation measures have become routine, its institutional vulnerability is reduced. They become part of the organisation's regular work, no longer dependent on the CC "idealists" who always keep their cause in mind. By implementing such adaptation measures today, both current and future vulnerabilities could be reduced.

7.2. Types of vulnerability and willingness to adapt to climate change

Let us return to the questions posed in the introduction: how vulnerable are communities, and what type of vulnerability are they exposed to? Our discussion has shown that Hammerfest is vulnerable to CC and that natural, socio-economic and institutional vulnerabilities are all present. This applies both in the current climate and in relation to expected future climates.

When it comes to the question of how a community is able to adapt to (increased) vulnerability and how the drawbacks can be avoided and consequences eased, we have shown how Hammerfest over time has developed strategies and measures to reduce vulnerability to the current climate. Avalanches and storms are seasonal, and measures are implemented to protect against avalanches safety and to adapt housing to the climate. In recent years, considerations for the future climate have been put on the agenda. Global climate models have been downscaled to reflect local conditions by putting temperatures, precipitation and sea level rise into context, thus adding new knowledge. Based upon this knowledge, the municipality decided to take into account of future sea level scenarios in the current Municipal Master Plan (see also Stokke, 2013) Hammerfest has come a long way in thinking about adapting to future CC. The municipality has worked on close cooperation with partners such the Housing Bank's regional office in Hammerfest and various research communities on these issues. The municipality's participation in various research projects such as NORADAPT and CoastAdapt has also helped to increase the level of knowledge and to put future CC on the municipal agenda.

7.3. The petroleum industry, despite its global greenhouse gas emissions, strengthens the climate adaptive capacity

While Hammerfest is well ahead of other Norwegian communities in adapting to CC (Klausen et al., 2012), the development of the petroleum industry led to a sharp increase in CO_2 emissions. It has placed Hammerfest at the top of the list of Norwegian municipalities with the highest greenhouse gas emissions. This contributes to the increased global natural vulnerability, and thus will affect Hammerfest with the same as the rest of the globe. The revenues that the municipality receives from the petroleum industry have, on the one hand, contributed to increased administrative capacity and expertise in the community. For instance, it has meant that the required climate studies for major planned developments in Hammerfest are in fact carried out. The petroleum activity has been the driving force behind a number of positive changes in the community: the population trend shows growth in the important youth groups; employment has increased; the number of jobs for people with higher education has increased. The change in industry development is positive, with a growth in industries that often are described as modern and progressive. Hammerfest municipality now has a better economic base with considerable growth in tax revenues, particularly through increased property taxes, which now account for more than the amount received by the municipality in ordinary government grants. The town is being modernised through local government investment in schools, a culture centre, high street renewal projects, etc. In addition, the private sector has experienced modernisation. Consequently, the municipality enjoys increased adaptive capacity. Modernisation and renewal of infrastructure has made the Hammerfest municipality better equipped to meet future challenges. In relation to the discussion on climate adaptation, it is a paradox that the development of petroleum activities and the construction of the LNG plant on Melkøya, one of the most significant sources of greenhouse gas emissions, is the single factor that has contributed to the positive local development and boosted the climate adaptive capacity. Similarly, this paradox is also part of the important administrative challenge relating to different levels of government. The climate issue is a global challenge, so a decision at national level (the Norwegian Parliament) to allow petroleum activity in the Barents Sea with the landing of gas pipes in Hammerfest, resulted in dramatic growth in the local economy and population.

A barrier to local adaptation is that local politicians need to prioritise between many considerations, and the fact that Hammerfest's Climate and Energy Plan has yet to be completed suggests that the climate and climate adaptation is not particularly high on the political agenda. Another barrier is that not all politicians, businesses and other members of the Hammerfest community are equally convinced of the veracity of man-made CC, which influences the institutional vulnerability and its capacity to handle future CC.

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