5d. Urban Complexes

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5.1 Introduction / Background

In this chapter, studies of observed and potential future impacts of climate change on urban complexes are assessed. Urban complexes are understood as human dominated settlements with relatively higher population density in comparison to rural settlements. In this chapter, the term comprises cities and towns. Urban complexes are characterized by high concentrations of buildings and built-up areas with consequent soil sealing, high concentrations of people and infrastructure as well as specific economic and cultural roles and activities. These render them particularly vulnerable to climate change impacts (Hunt and Watkiss, 2011).

As every particular urban complex is characterized by a specific mix of social, ecological and economic interdependencies and its specific settlement and building structure, it is very difficult or almost not possible to generalize scientific findings on urban complexes. Moreover, in the assessed region of the Baltic Sea Basin, it seems that there is a notable overweight on some cities and towns which have been understudy with reference to climate change impacts while on others and on whole regions there is hardly anything published. And climate change impacts regard not only the specific structures of these urban complexes, but their extent depends also on the vulnerability of the urban society, its socio-economic and institutional structure as well as infrastructure and its capacity to cope with impacts (IPCC, 2007).

A key challenge in the urban context is to gain knowledge of and understand the key future climate risks in the relevant region as well as to distinguish key vulnerabilities, both physical and social (Hallegatte, Henriet and Corfee-Morlot, 2011) and to develop and implement adaptation measures. The IPCC defines adaptation as ‘adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities’ (IPCC, 2007). Thus, adaptation is a response strategy to climate change that involves the reduction of vulnerabilities and avoids potential damages, as well as to take advantage of opportunities that arise from climate change (Smit and Pilifosova, 2001). As this chapter focuses on climate change impacts, literatures on impacts are mainly assessed and adaption as topic was not primarily tackled.

Climate change is not the only phenomenon affecting the climate in urban areas of the Baltic Sea Region. Urban areas are influenced by their own climatic conditions by altering e.g. their radiation budget. Average temperatures rose due to urbanization in the 20th century in Uppsala (Bergström and Moberg, 2002), Stockholm (Moberg et al., 2002) and St. Petersburg (Jones and Lister, 2002). Furthermore, city growth, together with increasing heavy rainfall, can increase flood risks in urban areas like in Helsingborg (Semadeni-Davies et al., 2008a). Urban areas are usually characterized by higher temperatures than the surrounding countryside; this urban heat island effect was proved for various cities like Stockholm (Bolund and Hunhammar, 1999; Gustavsson et al., 2001; Moberg and Bergström, 1997; Moberg et al., 2002), Malmö (Bärring et al., 1985), Göteborg (Svensson, 2002) and Uppsala

(Moberg and Bergström, 1997). Urban cold islands appeared, too, for example in Göteborg (Svensson and Eliasson, 2002). These effects are not unique over the entire urban area and depend on the urban land use. In Göteborg there are differences of up to 6,8 °C between land use categories (Eliasson and Svensson, 2003).

Moreover, climate change is not the only driver for change in urban complexes as they are also influenced and impacted by demographic change, land-use changes, political and economic changes etc. which are interacting with climate change impacts. More detailed knowledge on this topic with a broader territorial reference can be found in chapter 6.4 of this book.

This subchapter reviews literature on climate change impacts on urban complexes, non-climatic drivers of change are not considered. The subchapter is subdivided in several sections. The subchapter 5.2 presents the outcomes of the literature assessed on past, current and future climate change impacts on urban complexes. (Subsection 5.2.1 assessed the impacts on natural resources and ecosystem services within urban complexes.) In subsection 5.2.2 are presented the reviewed literatures on urban services and technical infrastructure with an emphasis on wastewater management, drinking water supply systems and transport. Subsection 5.2.3 assesses the small volume of data on climate change impacts on building, housing and settlement structures. In subsection 5.2.4 the outcomes of the assessment on impacts on the socioeconomic structure are outlined with a subdivision in climate change impacts on different sectors of the urban economy and in social impacts. Finally, in this subsection a short outlook on adaptation is given, acknowledging that this is not the focus of the chapter but that it could point out to the next assessment. The final conclusions of the assessment outcomes are then drawn in section 5.3

5.2 Past, current and future impacts of climate change on urban complexes

5.2.1 Natural resources and ecosystem services

The final drafted text is not available yet (eventually this sub-chapter will be skipped totally and the topic as such will just be touched narrowly in the introduction or in the conclusions as to be optionally tackled in the next assessment process)

5.2.2 Urban services and technical infrastructure

Infrastructures are systems designed to meet human needs or, in other words, they perform a service for the urban population by for instance delivering drinking water, electricity or disposing waste water (IPCC, 2007). Their vulnerability to climate change depends on their state of development, their resilience and their adaptability (IPCC, 2007). The climate change impacts which are reported to affect technical infrastructure most (by physical damage) are sea level rise, extreme events like storm surges and the changing precipitation patterns, particularly flooding caused by expected increase in heavy precipitation events. Less research concerning for example heat and drought was carried out for cities of the Baltic Sea catchment, possibly due to the lack of risk for urban services and technical infrastructure in this region with moderate climate.

As the net-sea level rise is expected to be higher in the southern Baltic Sea, coastal cities like for example Gdansk will be more affected. Main infrastructures like dikes, port facilities, industrial areas, warehouses, transportation routes, drainage water systems, sewage plants, ground water recharge areas and energy infrastructure as heating pipes as well as power plants will be vulnerable (Schmidt-Thomé et al., 2006; Staudt et al., 2006; Virkki et al., 2006; Hilpert et al., 2007). Due to isostatic uplift of northern Baltic regions, lower net sea

level rise can be expected in the next decades with minor challenges for cities like Stockholm (Graham et al., 2006; Meier and Broman, 2003; Viehhauser et al., 2006), Helsinki (Lehtonen and Luoma, 2006), Pärnu (Klein and Staudt, 2006) and Loviisa (Virkki et al., 2006), regarding gradual sea level rise alone. The expected increase of heavy precipitation and rapid snow melting events could cause surface floods due to undersized urban drainage and sewage water systems such as in the cities Porvoo (Virkki et al., 2006), Loviisa (Virkki et al., 2006), Helsingborg (Semadeni-Davies et al., 2008b), Kalmar (Olsson et al., 2009), Lund (Niemczynowicz, 1989), Stockholm (Sverige, 2007) and Uppsala (Viehhauser et al., 2006). Less attention has been paid to the impacts of storms and heat on urban infrastructure and services. An overrepresentation of climate change impacts in the Baltic Sea region on coastal cities′ infrastructures can be found in the literature. This is probably due to expected worse consequences because of the expected cumulation of climatic impacts for coastal regions.
This chapter is subdivided into sectors of infrastructures concerning wastewater management, drinking water and transport.

Wastewater management

In Scandinavia, increases in maximum discharges from urban areas can be expected due to increases in maximum precipitation (Arnbjerg-Nielsen, 2011). Since an increase of mean temperature will result in changes in all components of the hydrological cycle, urban areas, which are characterized by fewer storage elements in comparison with rural basins, will respond with further decreases of storage capacity and enhanced runoff (Niemczynowicz 1989). The impacts of changing precipitation patterns on drainage and sewage systems were predominantly assessed by studies using different hydrological modeling systems with various assumptions about future precipitation amounts. As input for the modeling studies usually climate scenarios based on various global and regional climate model outcomes were used. Time scales of the modeling approaches ranged from single rainfall events to yearly precipitation amounts. In addition to climate change, other developments like population growth and continuing urbanization can influence the urban drainage systems due to increased imperviousness and removal of vegetation, among others (Semadeni-Davies et al., 2008a).
Inflow volumes to drainage and wastewater systems are expected to increase with a changing climate and will raise the occurrence of surface floods and of overflow of sewage systems and consequential environmental problems if current system conditions are assumed (Olsson et al., 2009; Nie et al., 2009; Semadeni-Davies et al., 2008a,b; Niemczynowicz, 1989; Plósz et al. 2009). In the case of Lund, although the stormwater system is designed for further development of the city, increases of rainfall intensity by 20 - 30% would bring significant flooding problems to the city's sewage network (Niemczynowicz, 1989). Then again, Semadeni-Davies et al. (2008b) showed specifically for Helsingborg that the impacts of urbanization and climate change could be more than met by implementing current trends in urban water management. For coastal cities high rainfalls in combination with sea level rise can cause further problems, for example seawater inflow into sewer and drainage water networks and to the wastewater treatment plants (Lehtonen and Luoma, 2006).

Drinking water supply systems

Generally, climate change may affect drinking water supply and lead to reductions in river flows, falling groundwater tables and, in coastal areas, to saline intrusion in surface- and groundwater and could damage the system itself, including erosion of pipelines by unusually heavy rainfall {IPCC 2007 #315}. Drinking water supply systems are endangered by climate change impacts in several urban areas of the Baltic Sea catchment. Research was carried out in large parts only for coastal cities. This is possibly related to the important threat of intrusion of saltwater into coastal aquifers serving as drinking water reservoirs through sea level rise. The risk of saltwater intrusion to drinking water reservoirs depends on geographical location and consequently on the rate of sea level rise and the distance of the drinking water aquifers from the coast. To assess these risks, different sea level rise scenarios were used. For instance there is not identified any risk of saltwater intrusion into groundwater deposits which are important for drinking water supply in Helsinki (Lehtonen 2006), whereas for Pärnu is seen the risk of contamination of drinking water wells (Klein 2006).

Water quality and availability can also be affected by flooding, changing precipitation patterns and higher temperatures. As a consequence of increasing precipitation amounts a higher groundwater recharge rate could be expected. Yet seasonal conditions can be very different. Fewer rainfalls combined with higher temperatures in the summer could have an effect on the quality of drinking water; another important issue is the possible impact on water quality after flooding (Ekelund, 2007; Meier et al., 2006). With an increase in heavy rainfall and rapid snow melting events the possible impact on water quality after flooding is an important risk in many Baltic cities through strong soil erosion and contamination with several chemical components (Klein 2006; Schmidt-Thomé 2006; Meier 2006).

Transport

Transport and its different subsectors of road, air and sea transportation are subjected to climatic changes such as precipitation, thunderstorms, temperature, winds, visibility and sea level rise. The impacts of climate change are likely to be felt through extreme events, given that the change is not so much about steady increase of temperature but fluctuation around the long term mean temperature (Love, Soares & Püempel 2010). Overall, research on the impacts of climate change on transportation has so far been overshadowed by the research on mitigation emissions emerging from this sector of the economy. Few examples specifically dealing with impacts of climate change on transport in the urban context exist for the Baltic Sea catchment; most of the insights derived here are from the SEAREG project. Consequently, the impacts of climate change on transportation considered are limited to sea level rise and flooding caused by heavy precipitation or storm surges. Possible impacts from higher temperatures like damage of rail and road surfaces are conceivable, but following IPCC (2007), among all possible impacts on transportation, the greatest in terms of cost is that of flooding. A continuous rising sea level can affect roads and railways situated near the coastline of the southern Baltic Sea where the topography is low and flat like in Gdansk (Schmidt-Thomé et al., 2006) or Malmö (City of Malmö, 2011), but also in Tallin and Pärnu (for 0,85-0,95 m sea level rise in Pärnu)(Kont et al., 2008), though Klein and Staudt (2006) stated that most roads and railways are safe in the "High Case" sea level rise scenario (+1,04 m) in Pärnu. Sea level rise in combination with higher storm surges can cause more serious damage in coastal cities than gradual sea level rise by itself (Schmidt-Thomé et al. 2006; Klein and Staudt 2006; Staudt et al., 2006). In more northern cities like Stockholm where sea level rise is not considered as a major problem, floods caused by heavy rain or rapid snow melting can inundate parts of the traffic infrastructure in most cities, independent of the rate of sea level rise (Graham et al. 2006; Viehhauser et al. 2006; Meier et al. 2006; Ekelund 2007). Even for Gdansk, where the rate of sea level rise is relatively high compared to more northern cities at the Baltic Sea coast, infrastructure is more vulnerable in case of river floods or flash floods as experienced during the 2001 flood where the central railway station and main streets were seriously affected (Staudt et al., 2006).

There are also possible benefits resulting from higher temperatures. Less salting and gritting will be required, and railway points will freeze less often (IPCC 2007).

5.2.3 Buildings, housing, settlement structure

To human settlements, extreme weather events associated with climate change pose particular challenges, as assets and populations are increasingly located in coastal areas, slopes, ravines and other risk-prone regions (IPCC 2007). When regarding the few studies dealing with building, housing and settlement structure in cities of

the Baltic Sea basin, sea level rise and changing precipitation patterns will be the most important impacts of climate change. In combination with eventually rising storm surges, there will be severe impacts to several cities. Partly, cities are already suffering damages during storms and floods nowadays (Virkki et al., 2006) like in 2005 when during storm “Gudrun” densely populated areas of Pärnu and Haapsalu were flooded for about twelve hours (Tonisson et al. 2005). Housing facilities and residential areas will be at risk in cities where buildings extend near the shore like Tallin (Hilpert et al., 2007), Malmö (City of Malmö 2011), Loviisa (Virkki et al., 2006) and Gdansk (Staudt et al. 2006). The settlements of other cities like Helsinki (Lehtonen and Luoma, 2006) and Pärnu (Klein and Staudt, 2006) will possibly not or only be slightly affected by sea level rise. Heavy rains and rapid snow melting are also expected to cause threats to settlements due to missing water infiltration capacity of the urban ground and consequential rapid surface runoff and/or overloaded drainage systems, as it is the case already today for some cities like Pärnu (Klein and Staudt, 2006) and Stockholm (Viehhauser et al., 2006). As an example, in the case of a projected 100-year flood, 21 percent of the area for single family houses and 9 percent of the apartment house area of Pärnu are in the flood prone area (Klein & Staudt, 2006).
Benefits of climate change in this sector could be decreasing expenses for heating of buildings, as for example in winter time in Finland by 10 percent by the period 2021 to 2050 (Venalainen et al., 2004) and 20 to 30 percent by the end of the century (Kirkinen et al., 2005). For urban areas, these values should become even higher due to the urban heat island.

5.2.4 Socioeconomic structure

This section is structured into three parts. The first part focuses on the impacts of climate change on the urban economy that is divided into three sectors, the primary, secondary and the tertiary sector. Secondly, this section examines the impacts of climate change on the urban population, particularly in terms of vulnerable groups and sectors of society as well as of human health and well-being. The final part of this section examines the ways in which cities have responded to the impacts of climate change and the measures that are taken to adapt to the impacts of climate change in the Baltic Sea region.

5.2.4.1 Impacts of climate change on different sectors of the urban economy

Estimating the impact of climate change on the urban economy is complex, and scientific studies on this subject are few. Hallegatte et al. (2011) distinguish between direct and indirect impacts, the former being related to the change in mean temperatures or increases in extreme weather events (Hallegatte, Henriet and Corfee-Morlot, 2011). The latter, on the other hand, consists of indirect impacts, where the disruption of the transport system, for example, has a knock-on effect to other economic sectors. These indirect effects of climate change are very difficult to assess, even when the impacts of climate change can be estimated with some level of confidence. Although a systemic approach to assessing the impacts of climate change in cities is advocated, it is recognized that very few examples of this exist (Mechler et al., 2010). See Box 1 for a case study of Copenhagen in terms of economic costs of climate change.
Box 1. Case study of Copenhagen.

> Systematic assessments of the costs of climate change impacts are rare. A study by Hallegatte et al. illustrate the methodology that can be used to assess the costs associated with climate change, sea level rise and storm surge in particular, in the urban context (Hallegatte et al. 2011). The researchers adopt a simplified catastrophe risk assessment to calculate the direct costs of storm surges, coupling this with an economic model.
>
> The analysis concludes that Copenhagen is not highly vulnerable to coastal flooding at the moment because of its high standards of defence, whilst in the absence of protection the losses would increase in the future. Thus with no protection, with the 25cm total mean sea level rise total losses caused by a 100 year event would be close to €4 billion. With 100cm mean sea level rise the costs would increase up to €8 billion.

The urban economy can be classified into three different sectors. The primary sector consists of mainly fishing in the urban context, and this continues to be important in the Baltic Sea Region. The secondary sector of the economy includes economic sectors that create a finished, usable product, such as production and construction. The tertiary sector, or the service sector, includes services that form the "soft" part of the economy, and are an important source of economic revenue in the Baltic Sea Region.

Primary sector

The primary sector of the economy that makes direct use of raw materials is relatively unimportant in the urban context, as little agriculture, mining and forestry takes places in the cities. *Fisheries* have naturally been an important source of economic revenue in the Baltic Sea, although its importance has been diminishing over the years. There are many uncertainties related to the impact of climate change on fisheries in the Baltic Sea that relate both to the physiological, ecological and social response (Mackenzie et al. 2007). More detailed knowledge on this topic is to be found in Chapter 5.3.4 *Agriculture* is not a significant source of economic revenue in the urban context but naturally is important around the Baltic Sea region. The knowledge relevant to this topic can be found above in Chapter 5.3.1 of this book.

Secondary sector

The secondary sector includes those industries that create a finished or a usable product, such as production or construction.

Industrial sector can also be impacted by climate change. A study of regional industries and the economic effects of climate change in the coastal and estuary zone of the German Northwest found that the industries were vulnerable to creeping, i.e. continuous climate change impulses (Elsner, 2005). These can have an impact on the regional GNP through primary and secondary impacts. Individual climate stimuli can also have an effect on the industrial sector. For example, sea level rise can pose risks to industrial sites located on the Baltic Sea. For example, the former uranium enrichment plant in Sillamäe in Estonia can pose a threat in a storm event (Kont, Jaagus and Aunap, 2003).

Energy sector is going to be impacted by climate change, both supply and demand side, though it is recognized that the impact of climate policy is likely to be greater than the changes in the mean temperature for example (Mideksa, Kallbekken 2010). The impacts on supply of the likely impacts are considered to be regionally very specific (Mideksa, Kallbekken 2010). The availability of renewable resources is of course also impacted by climate change, and the trend can be positive or negative. For example, the availability of forest biomass can be expected to increase (Lundahl, 1995). Changes in wind and solar energy are not easy to assess due to uncertainties in relation to wind variability and changes in cloud cover (Lundahl, 1995).

Tertiary sector

The tertiary sector consists of the service part of the economy, where knowledge and time improve productivity through intangible goods.

Tourism is an important sector impacted by climate change. Urban complexes contain either integrated or remote areas for recreational activities as an immanent part of their system. Citizens require space for recreation directly in cities or within a certain range around the city where urban citizens partly act as tourists or same-day visitors. At the same time urban complexes attract tourists from other regions and countries. Within the Baltic Sea Region the number of overnight stays is clearly linked to urban complexes (with the exception of Riga, which might be an effect of statistical scales). NUTS 2 regions containing larger urban complexes or having such complexes within a range of 200 km show a significant increase in the number of overnight stays. And the share of domestic versus international visitors indicates a strong relation between urban complexes and these recreational areas [Figure T1].

Climate change has direct impacts on the physical, environmental and social resources for tourism as well as on the comfort, perception and safety of participants (Patterson et al., 2006; Moreno and Amelung, 2009). This again has an impact on tourisms economic values. Already today tourism is of major importance for many coastal areas especially of the southern and south-western Baltic Sea. For Mecklenburg-Vorpommern, for instance, tourism is the most important economic sector (StatA-MV, 2010). As southern and south-western Baltic Sea regions are leading in this sector climate change impacts are best researched for these regions and their conditions (e.g. sandy beaches, nature and landscape, climate conditions). Scientific literature mentions following impacts with relation to the tourism sector:

- Beach wrack: Cleaning of macrophyte wrack on recreational beaches is common but expensive (e.g. Dugan et al., 2003; Davenport and Davenport, 2006; Fanini et al., 2005). Climate change might lead to increased beach wrack appearance (Björk et al., 2008) which has not been proven yet for the Baltic Sea.
- Demand: Comparatively attractive future climate conditions within parts of the Baltic Sea Region (Matzarakis and Amelung, 2008) might attract additional visitors to Baltic Sea resorts. Demographic change might counteract this development but might also lead to more elderly and more climate sensitive visitors (Coombes et al., 2009).
- Erosion: Relative sea level rise together with coastal abrasion and accumulation processes will lead to changes of Baltic Sea coastlines (Harff and Meier, 2011; The BACC author team, 2008). These differ from region to region (influenced e.g. by vertical crustal movement, sediments, coastal typology, exposure, protection status) and may lead decreased attractiveness and tourism capacity and/or increasing costs for coastal protection measures.

The relation of tourism and recreational activities to climate change shows a broad variety of direct (e.g. sunbathing) and indirect linkages (e.g. habitat changes in case of ecotourism). Threats and opportunities have only partly been research on regional levels so far (Moreno and Amelung, 2009) which is true also for the Baltic Sea. Therefore quantitative statements on the development of the tourism sector are still missing. But most publications assume a positive development of this sector. At the same time costs for being an attractive tourism destination might increase for southern and south-western coastal areas of the Baltic Sea.

Private tourism actors have short planning horizons of 1-5 years. Adaptation to long-term processes like a changing climate is therefore rarely discussed. At the same time tourism plays a major role for the territorial development of many Baltic Sea regions which have planning horizons of 10 to 30 years. According to Schumacher & Stybel (2009) tourism adaptation strategies exist on ministerial levels but there are only very rare examples for adaptation strategies in practice. The wide range of possible adaptation measures (Schumacher et al., 2010) necessitates co-operation with adjacent sectors like urban and regional planning, coastal protection, nature protection, health sector, water management, forestry and others more.

Transport and its different sectors of road, air and sea play an important role in all economic sectors, and are subjected to climate changes as shown above (subchapter 5.2.4). Even if several patterns of existing research can be observed, the generalised costs of climate change on the transport sector are uncertain and ambiguous (Koetse, Rietveld 2009). But due to climate change impacts, there can be expected shifts in passenger and freight transport, as well as damages on existing transport infrastructures with resulting congestion in urban complexes. For example, a heat wave can have costly impacts on the ground rail systems. The costs of the recent heat wave in London and surrounding areas in 2003 has been estimated to be around £750 000 (quoted in Love, Soares and Püempel, 2010).

Climate change naturally has an impact on maritime transport, also around the Baltic Sea. Coastal transportation infrastructure is vulnerable to several impacts of climate change, including global eustatic sea level rise and increases in local extreme water level events. Disruption in the flow of products can have a devastating impact on the regional economy. For example, it is estimated that Hurricane Katrina amounted to $1.7bn worth of damages and disrupted commerce in over 30 states in the US (quoted in Becker et al., 2011). A recent global review of sea ports in terms of impacts of climate change and adaptation found that according to the port authorities, sea level rise is likely to have negative impacts on their port, no systematic adaptation is taking place and that the more research is needed in this area (Becker et al., 2011).

The *insurance sector* is the part of the *financial sector* that is likely to become more important in terms of climate change as it can be a means to limit damages and spread risk. The insurance sector can enable the societies to reduce the costs of adaptation by risk sharing but climate change can also impact the insurance sector, causing the sector to take into account the heightened risks in setting premiums and risk management (Mills 2005). Thus, insurers must be able to set their premiums in a way that is financially viable by predicting the frequency and severity of insured losses based on expected, not historical risk (Gasper, Blohm and Ruth 2011).

Insurance practices naturally vary according to different countries. Within the Baltic Sea region, flood damage is privately insurable in Germany whilst there is no insurance for storm surges (Botzen, van den Bergh, 2008). Although private flood insurance is prevalent, most of the flood risk is carried by the government. For example in 2002 in Germany, the damages paid by the government amounted to €9.1 billion whilst the private sector compensation amounted to €1.8 billion (Botzen and van den Bergh, 2008).

Retail and commercial services are also likely to be impacted by climate change, by having an effect on the efficiency of the supply chain and distribution network as well as the health and comfort of the workforce (Gasper, Blohm & Ruth 2011). Case studies so far have focused on the effects on the transportation network with little research carried out on the retail or consumer sectors (Gasper, Blohm and Ruth, 2011).

5.2.4.2 Social impacts of climate change on urban population

The urban population is vulnerable to the impacts of climate change around the Baltic Sea. This section reviews the current literature on the topic, with a particular focus on human health and well-being of different groups of society. It is acknowledged that vulnerability differs between different groups of society, based on gender, age and race (Gasper, Blohm and Ruth, 2011). For example, the elderly or children can be more vulnerable to natural hazards as well as those living in informal settlements. Health is an important factor of social wellbeing and research shows that climate change can have both, immediate and lasting impacts on the urban population with the main stressors being severe weather events, extreme heat and disease transmission, as for example increasing incidence of tick-borne encephalitis in endemic regions (Lindgren, 1998(Gasper, Blohm and Ruth, 2011).

Thermal stress

Even if cold stress seems to be more important in countries like Sweden (Svensson et al., 2003), with a changing climate, heat stress and the demand for cooling in houses, health-care institutions, schools and work places is expected to increase during the summer (Svensson et al., 2003; Thorsson et al., 2011; Baccini et al., 2011; Rocklöv et al., 2009). In general, the rapidity of climate change expected in the coming decades under most scenarios of global warming makes future acclimatisation uncertain and populations from many cities around the world already experience a considerable burden from heat-related mortality and may become more vulnerable in future due to climate change, urbanisation and population ageing (Hajad and Kosatky, 2009).

Baccini et al. (2011) analyzed the impact of heat on mortality in 15 European cities including Helsinki and

Stockholm. They concluded that the current high summer ambient temperatures had an important impact on European population health and that this impact is expected to increase in the future, according to the projected increase of mean ambient temperatures and frequency, intensity and duration of heat waves (Baccini et al., 2011). Several studies in the Baltic Sea catchment showed the effects of heat on human health and well-being: for the impacts of moderate changes in ambient temperature on human health in Copenhagen, Denmark (Wichmann et al.; 2011); for the effect of heat on mortality for Stockholm and the Stockholm area, Sweden (Rocklöv et al., 2009; City of Malmö, 2011); for the intensification of thermal and humidity conditions with unfavorable bioclimatic effects including heat stroke on the urban population of Cracow , Poland (Piotrowicz, 2009). Differentiations between seasons were made for Cracow, Poland (Piotrowicz, 2009) and Gothenburg, Sweden (Thorsson et al., 2011) with increased problems of excessive temperatures in summer and different outcomes for the other seasons: while a more positive outlook on future decreasing temperature stress and an improved outdoor thermal comfort in winter, spring and autumn was made for Gothenburg (Thorsson et al., 2011), for Cracow the increasing frequency of mild winters was judged as a potential negative phenomenon which contributes to weak and moderate thermal stimuli for humans, that could render the human body oversensitive and thus lose the ability to adapt if stronger thermal stimuli were to occur (Piotrowicz, 2009).

The *costs of heat events* can be significant. For example, avoiding the loss of 18,000 lives lost during the 2003 European heat wave could have rendered benefits of up to $72 billion (Halsnæs, Kühl and Olesen, 2007). A heat wave is considered to be a prolonged period of hot weather and the recent incidences in Europe in 2003 and 2010 have shown the vulnerability of urban populations. This is despite the high levels of development in Europe (Lass et al., 2011).

Identifying the *social vulnerability* to heat waves is important. For example, urban populations in general are more vulnerable than rural populations. Within the urban population, particularly vulnerable groups include elderly people and those suffering from cardiovascular and respiratory diseases (Piotrowicz, 2009). A study on the effects of temperature on the elderly in Sweden confirmed the impact of heat on mortality (Rocklöv and Forsberg, 2010). The study also showed the effect of high relative humidity and high temperatures were largest in the most densely populated area, Stockholm (Rocklöv, Forsberg, 2010). In circumpolar regions, the populations that are at greatest risk for the adverse health effects of cold are children, elderly people or persons suffering from for example cardiovascular or respiratory diseases and factors like aging and urbanization may contribute to the rise in cold-induced health problems (Mäkinen, 2007). Svensson et al. (2003), referring to Gothenburg, argumented that climate in high latitudes presents a number of special bioclimatic problems, both physiological and psychological and cold stress is perhaps more important and interesting, since the people in Scandinavia seldom complain that conditions were too hot.

Changes in air quality

Another health-related effect of climate change in cities will be changes in air quality with cities having often higher concentrations of air pollutants than in surrounding rural areas (Eliasson and Holmer, 1990, Jacob and Winner, 2009). During 2005-2007 in Sczcecin, thermal stress and body overheating, together with high concentration of air pollutants, accounted for a high and direct threat to health for citizens, especially for people suffering from circulatory diseases and problems with blood pressure (Czarnecka et al., 2011).

Storms

Storms can also impact the urban population, claim lives, cause injury or leave parts of the population homeless (Gasper, Blohm and Ruth, 2011). Early studies suggest that wind damages in Europe for the next decades are likely to be caused by rare events rather and interannual variability (Schwierz et al. 2010). Insurance can act as a buffer to reduce the losses. Insured storm related losses depend on the frequency, nature, and dynamics of storms, the vulnerability of values at risk, the geographical distribution of these values and the particular conditions of the risk transfer (Schwierz et al. 2010).

Floods

Flood events also pose a threat to urban populations. A social vulnerability index of river floods in Germany demonstrates that irrespective of climate change, the vulnerable populations currently include the elderly, financially weak and urban populations (Fekete, 2009). A study of two cities in Denmark revealed that calculations show that increasing the urban drainage infrastructure is financially beneficial but larger adaptation measures were not considered to be financially viable just yet (Arnbjerg-Nielsen and Fleischer, 2009).

Food supply

Food systems, in addition to agriculture as primary production, are likely to be impacted by climate change and not only in relation to the primary production (Tirado et al., 2010). For example, impacts on food processing, transport and trading are largely unknown, as are issues related to food safety (Miraglia et al., 2009). Modelling of economic impacts on agriculture is an unexplored area, although early studies suggest that losses to the local economy are more serious when the impact is felt in neighbouring areas (Mechler et al., 2010).

5.2.4.3 Adaptation to climate change in the urban context

As climate change will have impacts on the socio-economic structures in the cities around the Baltic Sea, cities have taken steps to adapt to the impacts of these changes. Many cities have pursued strategies, which identify particular climate change impacts and are in the process of developing adaptation strategies. This section reviews the literature available on studies of urban adaptation strategies in the Baltic Sea basin.

Adaptation policy has emerged from the EU, national and regional level and these all affect urban areas around the Baltic Sea. The European Union White Paper on adaptation was published in 2008, the aim of which is to develop a knowledge base for adaptation (Commission of the European Communities 2009). The majority of the countries around the Baltic Sea have already published an adaptation strategy, except Lithuania, Poland and the Estonian still to be expected National Adaptation Strategy. The extent to which national strategies impact the urban areas depends on the legislation and planning systems of individual countries.

Regional or local level adaptation strategies are the most important tool for planning adaptation at the city level. The regional level is important because it is mainly the level that regulates issues related to built environment, building and maintenance of infrastructure in terms of drainage and piped water, and provision of services, such as fire protection, public transportation and disaster response (Gagnon-Lebrun, Agarwala 2006).

Many regions in the Baltic Sea region have developed strategies but these processes can be hindered by uncertainties of the uncertainties and timing of climate change impacts as well as lack knowledge and expertise (Ribeiro et al. 2009). Further barriers to the implementation of adaptation include social and cultural inertia on individual and collective actions and low priority of adaptation in relation to other policy agendas (Carter 2011). In addition, weak vertical interlinkages and lack of a coherent policy agenda can also slow down the adaptation process, c.f. in Finland (Juhola, Westerhoff 2011) and in Sweden (Storbjörk, Hedrén 2011).

Adaptive capacity plays an important part and is a prerequisite of a region's ability to adapt to climate change (Brooks, Adger & Kelly 2005). Adaptive capacity is defined as the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behavior and in resources and technologies (IPCC 2007). Knowledge facilitated by linkages to universities and research projects that are funded by the European Union play an important part in enabling adaptation to emerge at the sub-national level, for example in Germany (Frommer 2001) and Finland (Westerhoff, Juhola 2010). Although this has enabled some regions to pursue adaptation, the uncertainty of climate change impacts has slowed down the action (Carter 2011, Storbjörk 2007).

There are *examples of city level strategies* in the Baltic Sea that are summarized in Table 1. A review of adaptation strategies at the city level found that climate change is likely to interact with existing urban problems by exacerbating them and also creating new ones (Committee of the Regions 2011). The report makes several recommendations (Committee of the Regions 2011). Firstly, urban adaptation strategies must be developed and build on existing sectoral and cross-sectoral agendas. Secondly, urban adaptation requires new governance structures and innovative new solutions with the help of a wide range of stakeholders. Thirdly, no single type of measure is able to eliminate vulnerability to climate change but a portfolio approach is likely to be most effective. Finally, it is emphasized that that approach should be staggered and iterative in order to achieve progress in the short term.

Table 1. Examples of city adaptation strategies in the Baltic Sea region (Committee of the Regions 2011).

Cities	**Details**
Copenhagen	Main impacts are sea level rise, intense precipitation, drainage and flash flooding. The strategy is comprehensive and cross-sectoral. The key measures include expansion of the sewer grid and setting up a sustainable drainage system and reservoirs to store rain and wastewater and green roofing.
Hamburg	Main impacts are sea level rise, river floods, intense precipitation and heat waves. The strategy is comprehensive and cross-sectoral. The key measures are diversification of coastal protection, construction activities need to take into account rising levels of water and city development will have to leave room for thermal cooling.
Helsinki	The main impacts are sea level rise, intense precipitation, drainage and flash flooding and wind and storm damage. The strategy is comprehensive and focuses on cross sectoral impacts. Key measures have not been defined yet but the strategy is expected to be finalised by the end of 2011.
Riga	Main impacts include storm surges, coastal and river flooding and coastal erosion. The strategy covers water, waste, waste water treatment, energy, transport and social impacts. The key measures are the spatial plan for Riga for 2006-2010 and the dunes maintenance along the Riga Bay coastal line in Riga and Jurmala.
Stockholm	Main impacts are river floods, intense precipitation, drainage and flash floods, drought and water efficiency, heat wavers and wind and storm damages. The strategy will be comprehensive and cross-sectoral. No key measures are listed yet but the strategy is expected to be finished in the next two years.

There are many gaps in research in relation to adaptation in urban complexes. These include, for example, how to better understand the governance frameworks and stakeholder networks to implement appropriate adaptation measures as well as address the barriers to adaptation, whilst keeping mind the possibility of maladaptations (Carter 2011).

5.3 Synthesis / Conclusion: Impacts of climate change on urban complexes

To be done when all subsections are completed and when the final subchapter contents will be agreed upon *among the Lead Authors of BACC2 – especially the ones of chapter 5 and eventually also the ones of chapter 6.*

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