Future air quality and related health effects in a Nordic perspective

The possible impacts of future changes in climate, anthropogenic emissions, demography and building structure

/Policy brief

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The possible impacts of future changes in climate, anthropogenic emissions, demography and building structure

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Key messages

Air Pollution?

Ground-level ozone (O_3) is a gas formed by a number of chemical reactions between other air pollutants e.g. the man-made nitrogen oxides emitted from traffic and volatile organic compounds (VOCs).

Particulate matter smaller than 2.5 µm ($PM_{2.5}$) is solid or liquid particles emitted directly to the atmosphere or secondary particles formed chemically within the atmosphere. The sources can be both natural (e.g. sea salt and dust particles) or anthropogenic (e.g. soot particles from combustion processes).

Both ozone and $PM_{2.5}$ are associated with negative health impacts for humans. Particulate matter is e.g. known to be responsible for increased mortality linked to cardiovascular and respiratory diseases.

- Ambient air pollution such as ground-level ozone (O_3) and particulate matter smaller than 2.5 µm ($PM_{2.5}$) are associated with negative health effects for humans, for example premature deaths.
- Today air pollution causes ca. 8000–11.000 deaths every year in Nordic countries due to $PM_{2.5}$ and almost 1000 deaths due to O_3.
- The external costs related to these health effects of air pollution amounts to 8–13 billion Euros per year.
- **Climate change** alone has a small impact on the concentration of important air quality components and hence on the related health effects in the Nordic region.
- Century wide trends suggest a substantial drop (50%–80%) in the number of premature deaths due to reductions in **man-made emissions** of air pollutants in Europe. The associated external costs in the Nordic countries could then be reduced to between 2 and 3 billion Euros pr. year.
- Energy policies and the related changes in the **building stock** in the Nordic region can contribute with an additional reduction in the negative health effects related to exposure to ambient particulate matter.
- The main threat is in the **ageing population**: The development toward an aging society in both Europe and the Nordic region might counteract assumed benefits of policies on air pollution, since elderly people are more vulnerable to the $PM_{2.5}$ exposure.

Recommendations

- The projected decline in the health-effects and the related external cost will only be possible if the anthropogenic emissions are cut significantly as projected in the applied emission scenario. Regulations and technology developments are key drivers for the necessary emission reductions and should be in focus at both the national and international political level.
- The expected positive impacts of emission regulation may be offset due to the more sensitive, aging population and due to the impact of climate change. These effects should be included in the evaluation of new policies.
- Optimal results can be reached by looking at co-benefits of energy efficiency and health.
- The exposure to in-door air pollution has not been included here. More research on the relative importance and interaction between out-door and in-door air pollution is needed.

Premature mortality?

The term premature mortality/death is often used as a measure to describe the effects of air pollution. It is referring to deaths that occur "premature" that is before the person would have died from other causes. Premature deaths can be due both to short-term exposures of high air pollution levels over short time or to long-term exposures over a year or more. A number of these deaths could be avoided if the exposure to air pollution was minimized.

External costs?

The term external costs is used to describe the costs for society due to e.g. hospital admissions, medicine, loss in production due to illness and the willingness to pay for minimizing the risk of premature deaths, etc. caused by air pollution.

Introduction

The overall purpose of the Future Air Nordic (FAN, funded by NMR) project has been to investigate how potential future changes in main drivers will impact the assessment of air quality-related human health effects. Many factors will change in the future, but we focus here on a few of the main drivers that can have an impact on air quality and health effects. These are changes in climate, anthropogenic emissions, building structure and the population distribution and age (also called demography).

An integrated assessment model has been used to estimate the premature mortality due to exposure to various air pollution components as well as the external cost associated with the negative health effects. The project is thereby an important step towards improved assessments under future conditions and a system like this can be used to evaluate how current and future policies and regulations will impact the health effects related to exposure to air pollution.

For more information: The main results of the FAN project has been published in the scientific paper "Future Premature Mortality due to O3 and Secondary Inorganic Aerosols in Europe – Sensitivity to Changes in Climate, Anthropogenic Emissions, Population and Building stock" in a special issue of the International Journal of Environmental Research and Public Health (Geels et al. 2015). The exposure-response functions and the valuations used are described in detail in Brandt et al. (2013).

In the last decade a number of studies have described how air quality components like ozone and particulate matter can be affected by projected changes in the climate (Langner et al. 2005; Langner et al. 2012; Hedegaard et al. 2008; Jacob and Winner 2009). These changes can be related to e.g. changed precipitation patterns or increased temperatures, but also to changes in the natural emissions of precursors. Changes in the climate can thereby lead to either an increase or a decrease in the concentration of a specific component – this is referred to as a climate penalty or a climate benefit. Based on current knowledge a climate penalty is expected for ozone (e.g. Langner et al. 2012), while for particulate matter it is more unclear if climate change will be a benefit or a penalty (Colette et al. 2013).

Background

The anthropogenic emissions of air pollutants will also change in the future. Recent studies have shown that the potential changes in emissions will have a larger impact on the air quality than the impacts from climate change alone (Simpson et al. 2014; Colette et al. 2013; Hedegaard et al. 2013). Due to complex processes in the atmosphere, the link between emissions and air quality is not necessarily linear and simulations for the future should include both emission and climate changes.

When investigating the exposure to air pollution and the related human health effects, the demography as well as the potential future change in the demography is also important. The European trend towards an "ageing society" (EEA 2009) will influence the overall health impacts as older people in general are more sensitive to air pollution. Likewise, urbanization will potentially impact the overall exposure to air pollution, as the population density then increases in the areas with e.g. highest traffic related air pollution. Only a few studies with focus on the future health impacts in US or at the global scales have so far included projections of the demography (Post et al. 2012).

The assessment model

Integrated assessment models are important tools for evaluation of current and future strategies for minimizing the negative effects of air pollution. An example is the GAINS model used by the European commission to design clean air policies at the European scale.

The current study uses the Danish Economic Valuation of Air Pollution (EVA) system (Brandt et al. 2013; Geels et al. 2015). The integrated EVA model system combines climate simulations with air-quality models and gridded demography data to get estimates of how much air pollution the population is exposed to. Population-level health impacts and external cost are then assessed by linking the exposure to information on health effects and economic valuations. Assessments have been made for the periods: 2000–2009, 2050–2059 and 2080–2089, based on projections in the development of climate and emissions. The future changes are valued relative to the simulation for the 2000s, see the next sections.

Figure 1 show how the health effect associated with exposure to air pollution is distributed across Europe. The largest number of premature deaths is seen in regions with many people and high levels of particulate matter e.g. in the Benelux region.

In the current study we estimate the total number of premature deaths in Europe (incl. 30 countries) to be between 296.000 and 421.000 per year on an average for the 2000s. This fits well with an earlier estimate made by the International Institute for Applied Systems Analysis (IIASA) for the European Commission. Using the GAINS model, they estimate that particulate matter is related to ca. 348.000 premature deaths pr. year as a total for EU25 (Amann et al. 2012; Watkiss et al. 2005).

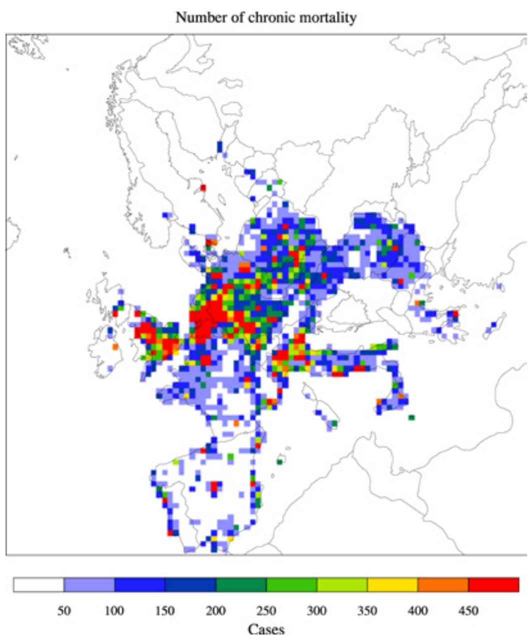
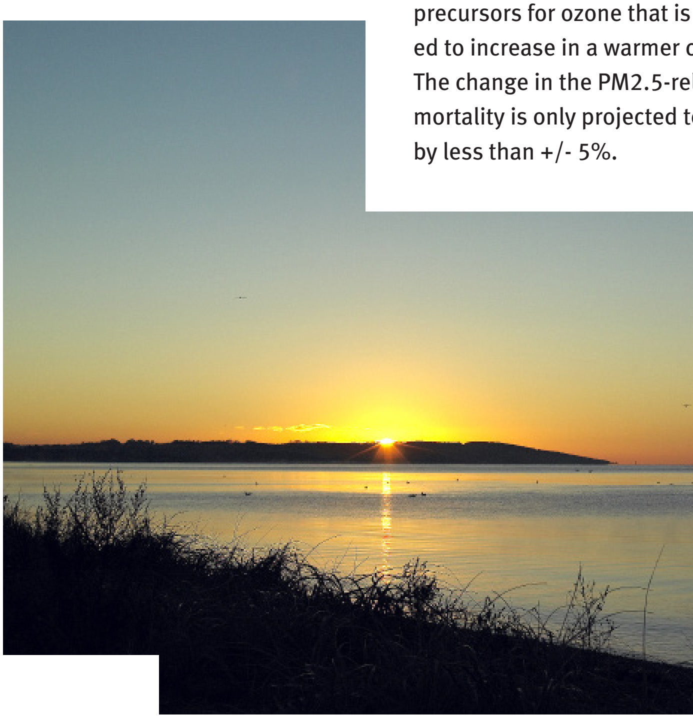


Fig 1.
An example of the spatial distribution of premature deaths due to exposure to particulate matter: given as number of cases per 2500 km². The highest numbers of premature deaths are seen in areas with both high population density and high air pollution levels.

Impact of climate change

Climate change alone can lead to a small increase (5–9% in the Nordic and ca. 15 % for Europe in total) in the number of premature deaths related to ozone-exposure in the two future periods. This increase is mainly caused by naturally emitted precursors for ozone that is projected to increase in a warmer climate. The change in the PM2.5-related mortality is only projected to change by less than +/- 5%.



Impact of emissions changes

The large decrease in anthropogenic emissions anticipated for the two future periods will have a huge impact on the air pollution levels and the associated premature mortality. Combined climate and emissions changes towards the 2050s can in the Nordic region lead to a 46% to 64% decrease in ozone-related mortality and a ca. 65% decrease in PM-related mortality. For the more distant future the assessment points towards a decrease between 53% and 85% for ozone-related mortality and a ca. 80% decrease in PM-related mortality in both the Nordic region and the total for Europe.

The health-related external costs will decrease with the same rate as the health effects. In the 2000s the total external costs are estimated to be between 8 and 13 billion Euros/year for Nordic region (depending on the model). With the applied climate and emission scenarios this cost is reduced to between 2 and 3 billion Euros in the 2080s.

[1] The Nordic region here refers to: Denmark, Sweden, Norway and Finland.

Impact of changes in building stock

Policies on energy savings will lead to changes in the building structure towards more energy efficient houses. For the Nordic region it has in this study been evaluated how this may impact the implementation of mechanical ventilation systems and the subsequent infiltration rate of outside air pollution into the houses. This has never been done in a long-term and regional scale assessment like this before. Nevertheless this first and simple attempt show that changes in the building stock has the potential to bring down the exposure significantly.

When accounting for the combined changes in climate, emissions and buildings the PM-related mortality could in the 2050s be decreased by ca. 80% relative to the 2000s. Climate and emission change alone reduced this mortality by 62–65% towards the 2050s.

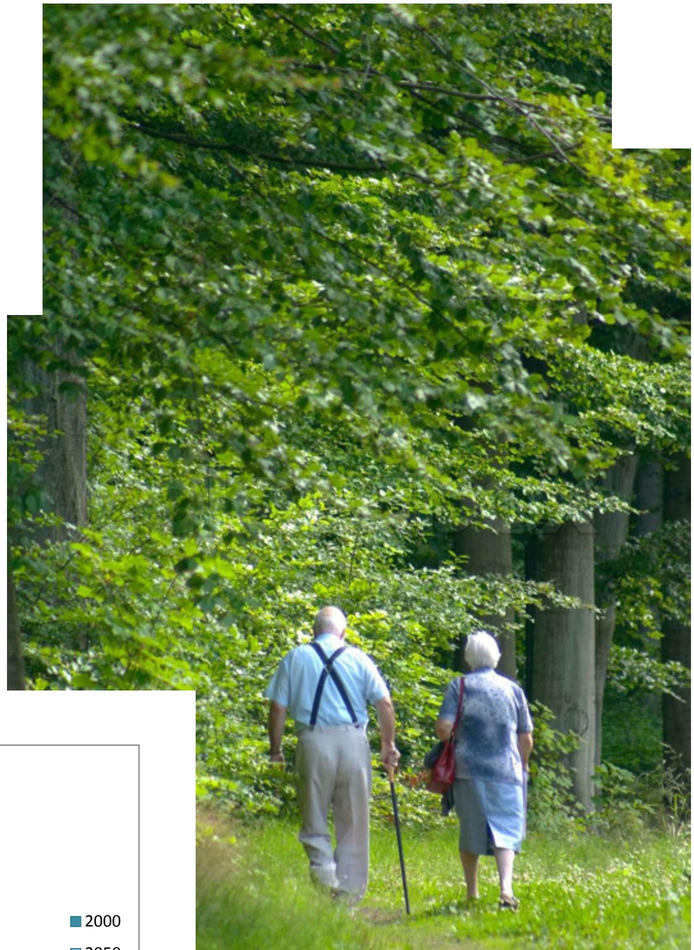
For the more distant future, the combination including changes in the building stock lead to a decrease of about 90%, compared to ca. 80% due to climate and emissions changes.

Impact of demography

The changes in demography (age, distribution and total number of the population) between the years 2000 and 2050 have been investigated here.

In the Nordic region the change in demography alone leads to a ca 20 % increase in the PM-related mortality. The total population is only increasing by ca 10%, but the fraction of people older than 65 years grow by almost 60% (see Fig. 2).

Studies of human health show that elderly people are more sensitive to air pollution. This is linked to the normal aging process in humans, which leads to generally weaker lungs and heart functions within the elderly population group.



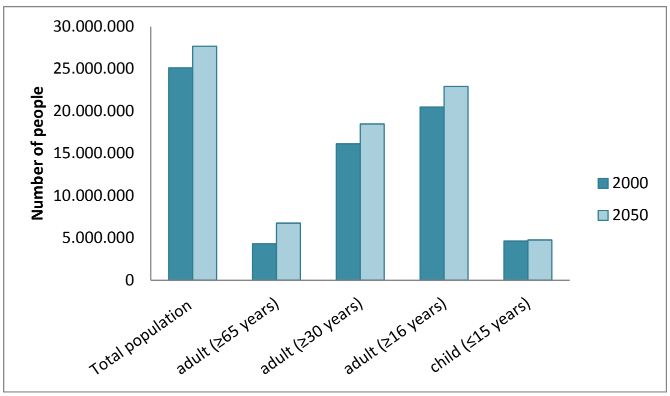
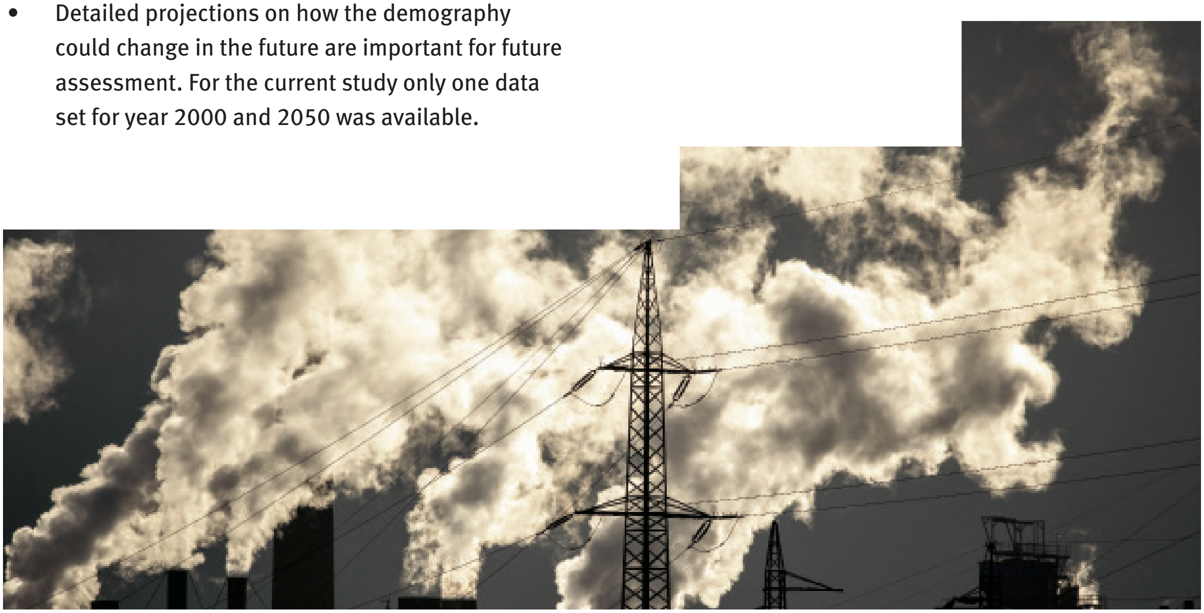


Figure 2. The projected development in the Nordic population from year 2000 to 2050. Based on data from the Integrated Environmental Health Impact Assessment System (IEHIAS 2011).

Unknowns and needs for improved assessments

- Assessments for the future are associated with large uncertainties. The underlying scenario for the development in climate and anthropogenic emissions represent one out of many possible future developments. "Medium" impact scenarios have been used in this study (based on the IPCC SRES A1B climate and IPCC RCP4.5 emission scenario).
- We have taken a conservative approach towards selecting the so called exposure-response functions linking a given air-pollutant to effects on the health. There is growing evidence for health effects related to additional pollutants not included in the current assessment, but additional analysis are needed in order to develop new exposure-response functions that can be recommended by WHO.
- Detailed projections on how the demography could change in the future are important for future assessment. For the current study only one data set for year 2000 and 2050 was available.
- The exposure to PM-pollution is in the current assessment underestimated as the components related to the secondary organic aerosols (SOA) is not included in the used setup. Further research is needed in order to be able to describe the complex nature of these components and especially how they may change in future due to changes in e.g. land use and environmental conditions.
- More research is needed on differentiating the human health impacts with respect to the chemical composition and sources of atmospheric particles as well and differentiating between health impacts from short-term and long-term exposure to air pollution in order to develop optimal policies for emission reductions



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Air pollution has been estimated to lead to ca 10,000 premature deaths every year in the Nordic countries. The external costs related to the health effects of air pollution amounts to EUR 8–13 billion per year. Main drivers, such as changes in climate, anthropogenic emissions, building structure and demography have a vast impact on air quality-related effects on human health.

The purpose of the FutureAirNordic project has been to investigate how potential future changes in main drivers will impact the assessment of air quality-related human health effects. Estimations of premature mortality due to exposure to air pollution as well as the external costs associated with the negative health effects have been analyzed. The results can contribute to improved assessments under future conditions and can be used to evaluate how policies and regulations impact the health effects of air pollution.

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