Estimated health benefits of exhaust free transport in the city of Malmö, Southern Sweden

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\textbf{ABSTRACT}

Air pollution is responsible for one in eight premature deaths worldwide, and thereby a major threat to human health. Health impact assessments of hypothetic changes in air pollution concentrations can be used as a mean of assessing the health impacts of policy, plans and projects, and support decision-makers in choices to prevent disease.

The aim of this study was to estimate health impacts attributable to a hypothetical decrease in air pollution concentrations in the city of Malmö in Southern Sweden corresponding to a policy on-road transportations without tail-pipe emissions in the municipality. We used air pollution data modelled for each of the 326,092 inhabitants in Malmö by a Gaussian dispersion model combined with an emission database with > 40,000 sources. The dispersion model calculates Nitrogen Oxides (NOx) (later transformed into Nitrogen Dioxide (NO\textsubscript{2})) and particulate matter with an aerodynamic diameter < 2.5\textsubscript{μ}g/m\textsuperscript{3} (PM\textsubscript{2.5}) with high spatial and temporal resolution (85 m and 1 h, respectively).

The average individual reduction was 5.1 (ranging from 0.6 to 11.8)\textsubscript{μ}g/m\textsuperscript{3} in NO\textsubscript{2}, which would prevent 55 (2\% of all deaths) to 93 (4\%) deaths annually, depending on dose-response function used. Furthermore, we estimate that the NO\textsubscript{2} reduction would result in 21 (6\%) fewer cases of incident asthma in children, 95 (10\%) fewer children with bronchitis every year, 30 (1\%) fewer hospital admissions for respiratory disease, 87(4\%) fewer dementia cases, and 11(11\%) fewer cases of preeclampsia every year. The average reduction in PM\textsubscript{2.5} of 0.6 (ranging from 0.1 till 1.7)\textsubscript{μ}g/m\textsuperscript{3} would mean that 2729 (0.3\%) work days would not be lost due to sick-days and that there would be 16,472 fewer restricted activity days (0.3\%) that year had all on-road transportations been without tail-pipe emissions.

Even though the estimates are sensitive to the dose-response functions used and to exposure misclassification errors, even the most conservative estimate of the number of prevented deaths is 7 times larger than the annual traffic fatalities in Malmö, indicating a substantial possibility to reduce the health burden attributed to tail-pipe emissions in the study area.

\section{Introduction}

During the last decades, epidemiological and toxicological studies have provided enough evidence for the conduction of health impact assessments (HIA) of air pollution (WHO, 2013a, 2013b). Whilst epidemiologists often study the risk of a disease in the presence of exposure relative to the risk of a disease in the absence of exposure, a risk assessor, on the other hand, often asks how many excess cases of disease will occur in a population of a certain size due to exposure at a certain dose level (Hertz-Picciotto, 1995)? HIA generally applies a health impact function combining a risk estimate from the epidemiology literature that relate hypothesized air quality changes to a population at risk (Fann et al., 2011). HIA are used for example in large projects such as the Global Burden of Disease by WHO where air pollution is now valued as one of the largest health threats of our time, responsible for one in eight premature deaths worldwide (Cohen et al., 2004; WHO, 2011, 2013a, 2013b).
2014). There were roughly equal contributions from household air pollution and ambient particulate matter pollution.

HIA can also be used as a systematic process to determine the potential health effect of i.e. air pollution from proposed policies, plans, programs or projects and can provide recommendations on monitoring and managing those effects (Chart-asa and Gibson, 2015). Results from HIA can thereby be a useful tool for policymakers and urban planners (Harris-Roxas and Harris, 2011; Shojaei et al., 2014). For example, Castro and colleagues estimated the health impacts attributable to a decrease in particulate matter with an aerodynamic diameter < 10 μg/m³ (PM_{10}) and Nitrogen Dioxide (NO_{2}) concentrations due to certain policy measures to be about 1% to 2% of total all-cause annual mortality in the population of the Agglomeration Lausanne-Morges in Switzerland (Castro et al., 2017).

In the city of Malmö, Southern Sweden, questions are raised, politically and within different parts of the municipality, if it is worth the effort to work on improving air quality. The city of Malmö has had problems complying with EU Air Quality Guidelines for NO_{2} in the past, and have had action plans since 2006 to reduce emissions, but the city now complies with EU Air Quality Guidelines for NO_{2}. Furthermore, the city of Malmö has agreed upon a policy to be fossil-free by the year 2020. The “Fossil-free initiative” is a transportation policy indicating no fossil fuels in on-road transportations used by the municipality. Decision-makers have raised the question of whether there are any health benefits from this policy. The Environmental Department of the city of Malmö therefore needs to quantify health effects of emissions from road traffic in Malmö, corresponding to a policy on on-road transportations without tail-pipe emissions, further referred to as exhaust-free transport, in the city of Malmö. More specifically, such a policy would imply a complete transition to electric vehicles, or replacing car transports with somatic energy transports such as cycling or walking. In line with that, our aim was to estimate health impacts of such a policy to assess the possible decreased health effects on citizens exposed to tail-pipe exhausts.

2. Materials and methods

2.1. Study area

The area of study is Malmö municipality. Malmö is Sweden’s third largest city with a population of approximately 330,000 (326092) inhabitants. On-road transports and non-road mobile machinery are the largest sources of NO_{2} emissions in Malmö, together they stand for 69% of the 2756 tons of NO_{2} that were emitted in 2016 (Spanne et al., 2017). Around 5000 annual deaths per year can be attributed to air pollution in Sweden. Malmö is one of the cities with the highest levels of air pollution in Sweden (Gustafsson et al., 2014). For many years, the city of Malmö has exceeded the Swedish Air Quality Standards for daily average concentrations of NO_{2} (not > 60 μg/m³ NO_{2} for 7 days/year). The city has made efforts to tackle these problems with a mandatory air quality action plan adopted in 2007 and revised 2011 (Spanne et al., 2017). Compliance with the Swedish air quality standard for daily averages was achieved for the first time in 2014 and in 2016 NO_{2} levels only exceeded 60 μg/m³ for 4 days (Spanne et al., 2017). It should be emphasized that the air quality in Malmö is generally well within the present-day annual WHO air quality guideline value of 40 μg/m³ (WHO, 2005) (Fig. 1). The annual mean NO_{2} concentration was 14 μg/m³ in urban background and at the City Hall (Rådhuset) monitoring station and 30 μg/m³ at the roadside location of Dalaplan in 2016 (Spanne et al., 2017). The NO_{2} levels at the regional background site were 3 μg/m³ in 2016. For particulate matter < 2.5 μm in aerodynamic diameter (PM_{2.5}) the concentration 2016 are also generally well within current air quality guidelines (annual mean 25 μg/m³) with a concentration of 9 μg/m³ at urban background site and of 12 μg/m³ at a roadside site (Spanne et al., 2017).

2.2. Modelling hypothetical changes in air pollution concentrations

To calculate the hypothetical changes in air pollution concentrations of exhaust-free transport in Malmö municipality, we used a Gaussian dispersion model (AERMOD) combined with an emission database (EDB) with > 40,000 sources. Emissions from surrounding areas such as shipping emissions in the Oresund and emissions from Sealand, Denmark, are included in the EDB. To account for background levels from sources that are more distant, we added the regional background mean levels of 3 μg/m³. Dispersion models are based on detailed knowledge of dynamical processes in the atmosphere by incorporating information on emissions and source characteristics, with meteorology to predict ground level concentrations (Holmes and Morawska, 2006). Gaussian dispersion models often rely on a Gaussian plume equation and uses data on emissions, meteorology and pollution concentrations to estimate spatial distribution of pollutant concentrations (Gilliland et al., 2005; de Hoogh et al., 2014). The Gaussian dispersion model was originally designed as an air quality management tool, but has been used widely for estimating long-term exposures (de Hoogh et al., 2014).

The advantage of a dispersion model in this context is that we can amend emissions from certain sources to account for policy or planning processes. Dispersion models were used to calculate concentrations of Nitrogen oxides (NO_{x}), PM_{2.5} with high spatial and temporal resolution (85 m and 1 h, respectively).

To convert NO_{x} to NO_{2} we used a formula based on empirical relationships between measured NO_{x} and NO_{2} levels in different environments and over different periods of time for South West Skåne, mainly in Malmö (Naturvårdsverket). In this report, a basic formula was formulated. Since 2005, the formula has been refined and the parameters in Malmö have changed in order to obtain a better model. This formula was used here:

\[
NO_{2} = NO_{x} \times 1.72 \times (0.28 \times \text{NO}_{2} + 1.42)
\]

The EDB used and dispersion programs are owned by the city of Malmö. We have previously used this model in many epidemiological studies (Oudin et al., 2009; Malmqvist et al., 2013; Malmqvist et al., 2017). Modelled levels have also been compared to measured levels at residential facades with good correlations for NO_{2} (N = 241, Spearman correlation of 0.8, p < 0.001) (Stroh et al., 2012). For PM_{2.5}, the R² for modelled vs measured level correlations was 0.86 (N = 96) in Malmö (Malmqvist et al., 2016). Individual air pollution concentrations were calculated with OPSIS EnviMan, which is a series of software modules for management of environmental information.

The dispersion model also enables modelling of specific pollutants by stratifying/excluding emissions from on-road traffic tail-pipe exhaust, wear and tear from tire and roads, marine shipping, wood smoke from residential heating, large-scale incinerators and long-range transported pollutants. Even if tail-pipe emissions were zero, vehicles produce particles from for example brake, wear and tear of tires and road surfaces. However, particles from wear and tear mainly do not affect the NO_{2} or the PM_{2.5} levels, but mostly the PM_{10} levels. Since we based our calculations on PM_{2.5} and NO_{2}, and not PM_{10} particles from brake, wear and tear of tires and road surfaces were thus not relevant for our calculations.

2.3. Health impact assessment

We linked modelled air pollution concentrations to our study populations by residential geocodes of each individual. We used the whole population residing in the city of Malmö in 2016 (326,092 persons) for the analysis. Data on individual residential geocodes, age and sex were retrieved from Region Skåne (a self-governing administrative region responsible for health care). As descriptive statistics, we calculated the average individual hypothetical air quality change.
Health impacts were calculated with the following formula:

\[ \sum \Delta Y_i = Y_{oi} (1 - e^{-\beta x_i}) \]

where \( \Delta Y_i \) is the change in disease rate for individual \( i \), \( Y_{oi} \) is the baseline disease rate for each individual, dependent on age and sex \( (\beta) \) is obtained from the exposure response function (ERF) from the epidemiology literature, and \( (x_i) \) is the hypothetical air quality change (on individual-level). The \( \Delta Y_i \)s are then summed over all individuals to obtain the estimated change in the number of health outcomes.

We thus calculated the hypothetical air quality change for each individual. We present outcomes and ERFs recommended by the WHO HRAPIE project (Héroux et al., 2015), Table 1a. The use of several different ERFs can also be used to illustrate uncertainty in estimates, as an alternative to using confidence intervals, as applied for example by Castro and colleagues (Castro et al., 2017). In order to illustrate uncertainty in the estimates, we instead used three different ERFs, similar to what Segersson and colleagues did (Segersson et al., 2017). The first additional ERF we used was obtained from a large Danish study, which has been considered more relevant in a Swedish context than the study used in WHO HRAPIE (Héroux et al., 2015; Hurkmans et al., 2017). We also used an additional ERF from a Swedish study (Stockfelt et al., 2015) which was rather similar to the widely spread European Study of Cohorts for Air Pollution Effects (ESCAPE) estimate (Beelen et al., 2014), Table 1b. These ERFs were chosen because the studies providing them have been conducted in study areas, which in many respects are similar to our study area, Malmö.

In WHO HRAPIE, outcomes related to pregnancy hypertensive disorders, dementia, and children’s asthma incidence were not taken into account. Since WHO HRAPIE was published, evidence have increased for air pollution effects also on cognitive function and dementia (Power et al., 2016) on pregnancy hypertensive disorders (Pedersen et al., 2014a, 2014b) and asthma incidence (Bowatte et al., 2015). Hence, we chose to include those outcomes as well, Table 1b.

To attribute relevant health effects to relevant population we used life tables stratified on age and sex for the outcomes where baseline rates depended on age or sex. Furthermore, for each outcome we chose to focus on either \( \text{NO}_x/\text{NO}_2 \) or \( \text{PM}_{2.5} \) in order to avoid double-counting, although this approach may result in too conservative estimates. For outcomes where ERFs were present for both \( \text{NO}_x/\text{NO}_2 \) and \( \text{PM}_{2.5} \) we chose to focus on \( \text{NO}_x/\text{NO}_2 \), since the local contribution to the concentrations of \( \text{NO}_x/\text{NO}_2 \) is relatively larger than the local contribution of \( \text{PM}_{2.5} \).

We obtained baseline health data from different sources. For mortality, age-specific natural-cause mortality for the county (Skåne) was obtained from official statistics provided by Swedish Board of Health and Welfare. For bronchitis, we used statistics from Wennergren that 9% (8–10%) of Swedish children between 5 and 14 suffer from asthma (Wennergren, 2015), and international statistics from WHO HRAPIE that 30% of all children with asthma have bronchitis (WHO, 2013a, 2013b). For hospital admissions for respiratory disease we used a baseline rate of 10.1/1000 person-years in Scania from the Swedish Board of Health and Welfare the employment rate of 65.9% in the population between 20 and 64 in Malmö, and that the average number of sick-leave days in Malmö is 7.5 days per year. For the calculations of restricted activity days (RAD), we used an international baseline rate from WHO HRAPIE, of 19 RAD per person years (WHO, 2013a, 2013b). For children’s asthma incidence, we used a baseline incidence of 0.01 per person year from a Swedish study (Rönmark et al., 2002).

Fig. 1. Modelled yearly average of \( \text{NO}_x \) concentration (\( \mu g/m^3 \)) in Malmö, based on emission data from 2015. Background levels (around 3 \( \mu g/m^3 \)) are excluded.
For pregnancy outcomes, we studied women 16–50 years (approx. 83,000), applied a county specific pregnancy rate of 3000/83,000) from the Swedish Medical Birth Registry and county specific prevalence of pregnancy hypertension was 4.7% and preeclampsia 3.4% in the Swedish Medical Birth Registry. The age-specific baseline incidence of dementia in people aged 65 or above was assumed according to an international study by Jorm and colleagues (Jorm et al., 1987). The health impact assessments were done with IBM SPSS version 24.

### 3. Results

The implementation of exhaust-free transport in Malmö would lead to a reduction in NO$_2$ of 5.1 μg/m$^3$ (average of individual-level reduction), ranging from 0.6 μg/m$^3$ to 11.8 μg/m$^3$, see also Fig. 2. This reduction would result in 55 to 93 prevented premature deaths in Malmö depending on what ERF was used, Table 2.

According to our calculations, implementing a policy on exhaust-free transport would furthermore mean that 30 cases of incident asthma could be prevented, 95 fewer asthmatic children would get bronchitis, and 30 fewer annual hospital admissions for respiratory disease by lowering NO$_2$ levels. The NO$_2$ reduction would further mean that 87 incident cases of dementia could be prevented and that 11 women in Malmö would avoid preeclampsia annually.

Exhaust-free transport in Malmö would further result in an average of individual reduction in PM$_{2.5}$ of 0.6 (ranging from 0.1 to 1.7 on individual level) μg/m$^3$. This would mean that 2729 less workdays would be lost annually and that there would be 16,472 fewer restricted activity days in the city of Malmö had all vehicles been exhaust-free. According to a report by Taavo and colleagues (Taavo, 2016) 0.025 per 1000 people in Malmö died in traffic accidents in the year 2015. This corresponds to around 8 people per year, meaning that a policy on exhaust free transport would save between 7 and 11 times more lives.

### Table 1

<table>
<thead>
<tr>
<th>Health outcome</th>
<th>Age group</th>
<th>RR (95% CI)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Mortality (all cause, natural)</td>
<td>≥ 30 years old</td>
<td>1.055 (1.031–1.080) per 10 μg/m$^3$ increase in NO$_2$</td>
<td>Hoek et al. (2013)</td>
</tr>
<tr>
<td>Bronchitis symptoms</td>
<td>5–14 years old</td>
<td>1.021 (0.99–1.056) per 1 μg/m$^3$ increase in NO$_2$</td>
<td>McConnell et al. (2003)</td>
</tr>
<tr>
<td>Hospital admissions respiratory disease</td>
<td>All ages</td>
<td>1.018 (1.012–1.025) per 10 μg/m$^3$ increase in NO$_2$</td>
<td>WHO (2013a, 2013b), Castro et al. (2017)</td>
</tr>
<tr>
<td>Work days lost</td>
<td>20–65 years old</td>
<td>1.046 (1.039–1.053) per 10 μg/m$^3$ increase in PM$_{2.5}$</td>
<td>Ostro (1967)</td>
</tr>
<tr>
<td>Restricted activity days</td>
<td>18–64</td>
<td>1.047 (1.042–1.053) per 10 μg/m$^3$ increase in PM$_{2.5}$</td>
<td>Ostro (1987)</td>
</tr>
<tr>
<td>b Mortality (all cause, natural)</td>
<td>≥ 30 years old</td>
<td>1.08 (1.01–1.14) per 10 μg/m$^3$ increase in NO$_2$</td>
<td>Raaschou-Nielsen et al. (2012)</td>
</tr>
<tr>
<td>Asthma incidence</td>
<td>≥ 30 years old</td>
<td>1.02 (1.01–1.04) per 10 μg/m$^3$ increase in NO$_2$</td>
<td>Stockfelt et al. (2015)</td>
</tr>
<tr>
<td>Preeclampsia and pregnancy-induced hypertension</td>
<td>Pregnant women</td>
<td>1.20 (1.00–1.44) per 10 μg/m$^3$ increase in NO$_2$</td>
<td>Khreis et al. (2017)</td>
</tr>
<tr>
<td>Preeclampsia</td>
<td>Pregnant women</td>
<td>1.13 (1.07–1.19) per 10 μg/m$^3$ increase in NO$_2$</td>
<td>Malmqvist et al. (2013)</td>
</tr>
<tr>
<td>Dementia</td>
<td>≥ 65 years old</td>
<td>1.05 (0.98–1.12) per 10 μg/m$^3$ increase in NO$_2$</td>
<td>Oudin et al. (2016)</td>
</tr>
</tbody>
</table>

According to our calculations, implementing a policy on exhaust-free transport would furthermore mean that 30 cases of incident asthma could be prevented, 95 fewer asthmatic children would get bronchitis, and 30 fewer annual hospital admissions for respiratory disease by lowering NO$_2$ levels. The NO$_2$ reduction would further mean that 87 incident cases of dementia could be prevented and that 11 women in Malmö would avoid preeclampsia annually.

Exhaust-free transport in Malmö would further result in an average of individual reduction in PM$_{2.5}$ of 0.6 (ranging from 0.1 to 1.7 on individual level) μg/m$^3$. This would mean that 2729 less workdays would be lost annually and that there would be 16,472 fewer restricted activity days in the city of Malmö had all vehicles been exhaust-free. According to a report by Taavo and colleagues (Taavo, 2016) 0.025 per 1000 people in Malmö died in traffic accidents in the year 2015. This corresponds to around 8 people per year, meaning that a policy on exhaust free transport would save between 7 and 11 times more lives.

### Fig. 2.

Showing the present day NO$_x$ levels (A) and the decline in NO$_x$-levels in μg/m$^2$ when implementing a policy on exhaust free transport (B) in the city of Malmö, Sweden. Background levels (of approximately 3 μg/m$^3$) are not included.
Table 2
Estimated impact of the policy of a policy on transportations without tail-pipe emissions in Malmö municipality on health.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Baseline N</th>
<th>Reduced number of events n (% of baseline N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure response functions from Table 1a (HRAPIE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td>2417</td>
<td>64 (2.6)</td>
</tr>
<tr>
<td>Bronchitis for asthmatic children</td>
<td>957</td>
<td>95 (10)</td>
</tr>
<tr>
<td>Hospital admissions for respiratory disease</td>
<td>3294</td>
<td>30 (0.9)</td>
</tr>
<tr>
<td>Work days lost</td>
<td>1,028,301</td>
<td>2729 (0.3)</td>
</tr>
<tr>
<td>Restricted activity days</td>
<td>6,195,748</td>
<td>16,472 (0.3)</td>
</tr>
<tr>
<td>Alternative exposure response functions from Table 1b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td>2417</td>
<td>93 (3.8)</td>
</tr>
<tr>
<td>Mortality</td>
<td>2417</td>
<td>55 (2.2)</td>
</tr>
<tr>
<td>Asthma</td>
<td>354</td>
<td>21 (6)</td>
</tr>
<tr>
<td>Pregnancy hypertension</td>
<td>141</td>
<td>14 (10)</td>
</tr>
<tr>
<td>Preeclampsia</td>
<td>102</td>
<td>3 (3)</td>
</tr>
<tr>
<td>Preeclampsia</td>
<td>102</td>
<td>11 (11)</td>
</tr>
<tr>
<td>Dementia</td>
<td>2280</td>
<td>87 (4)</td>
</tr>
</tbody>
</table>

1-5 Different exposure response functions result in different mortality estimates.

This study shows that 55 to 93 premature deaths could be prevented in Malmö each year attributed to a policy on exhaust-free transport in the city of Malmö. This is equivalent to about 2.2% to 3.8% of the total natural-cause annual mortality and at least 7 times larger than the annual number of traffic fatalities in Malmö. This study further estimates that 21 cases of incident asthma in children between five and fourteen years, 95 children with bronchitis, 30 hospital admissions for respiratory disease, 87 dementia cases, and 11 cases of preeclampsia every year would be prevented.

Our results are in line with another recent study, where the reduction in premature deaths due to air quality improvements corresponding to a 5.6 μg/m^3 reduction in NO2 exposure was estimated to be about 1% to 2% of the total all-cause annual mortality in the Agglomeration of Lausanne-Morges, Switzerland (Castro et al., 2017). The results of the present study were also in line with results from the London Low Emission Zone Baseline Study observing a 5–10% decline in patient consultation for respiratory illnesses or asthma prescriptions after implementing the low emission zone (Kelly et al., 2011). Also, Ballester et al. found that different reductions of PM2.5 led to reduced mortality, decreasing the air concentration to 15 μg/m^3 and to 10 μg/m^3 led to reduced mortality of 1.6% and 3%, respectively (Ballester et al., 2008). Recently co-benefits of climate policies on air pollution and health have been studied: Tobollik et al. studied Green House Gas Mitigation policy in Rotterdam and even though reductions in transportation emissions were only 10%, there were some health benefits (Tobollik et al., 2016). Perez et al. investigated different climate mitigation policies effects on reducing health costs and found most co-benefits from zero-emission vehicles (Perez et al., 2015). Furthermore, in Stockholm a similar estimation has been undertaken resulting in comparable estimates, published as a report in Swedish (Jennie Hurkmans, 2017).

Some calculative uncertainties should be mentioned. First, the source of baseline health data, definitions and study period can highly influence results in health impact assessments (Malmqvist et al., 2018). The importance of the latter has been highlighted in several reviews (Hubbell et al., 2009; Hunter et al., 2014). Generally, this is less of a problem in Europe where consistent data is available, but ICD codes change of the years and study years can influence results. Given the high quality of national register data in Sweden, we consider the quality of baseline health data to be a strength of the present study. However, for some outcomes, we had to use regional estimates, for the county of Skåne, which could differ somewhat from Malmö estimates, and cause some uncertainties. The largest uncertainty of the health impact assessment is most likely with respect to exposure misclassification and ERFs. Bias from exposure misclassification should be mentioned in all studies of health impact assessment of air pollution. We aimed to minimize exposure misclassification by using geocodes of each individual’s residential address, with a high spatial resolution (85 × 85 m). It should however be mentioned that people are mobile and do not stay in their homes all the time, which means that a high spatial resolution is not necessarily a better measure of actual exposure than a cruder exposure model. The spatial resolution is always a “give and take” between capturing residential exposure appropriately and taking into account the mobility of the population. The 85 m resolution is a compromise between these aspects. We modelled the air pollution concentrations outdoors, and an individual’s actual exposure correlates only moderately with modelled outdoor concentrations at residential addresses (Strohm et al., 2012). That study also showed however, that modelling exposure at the participants’ work places did not seem to improve the exposure assessment. Results from a study by Turner and colleagues furthermore suggest that “near-source” PM2.5 may have a much stronger association with all-cause mortality than regional PM2.5 (Turner et al., 2016). This may implicate that we have underestimated health effects of reducing local sources of air pollution, since the ERFs used stem from studies where the air pollution is a mix of local and regional sources. The results of Turner and colleagues further highlight the need of studying health effects of air pollution with high spatial resolution, and the need to further study measures to reduce local air pollution. Furthermore, in risk assessments, it is important to use a similar exposure assessment method as in the epidemiological studies used for the ERFs. Hence, we used residential addresses, which were generally used in the epidemiological studies where we derived ERFs.

The ERFs used for mortality had a substantial impact on the results, namely that either 55 (2.2%), 64 (2.6%) or 93 (3.8%) of all natural-cause mortality could be prevented with the hypothetical air pollution reduction. We consider the Danish relative risk from Raaschou and colleagues (Raaschou-Nielsen et al., 2012), which resulted in 93 prevented deaths, to be relevant for our study area, given that Denmark is similar to southern Sweden in geography as well as socio-demography, composition of air pollution, and welfare systems. The large European ESCAPE project included 22 cohorts (five Swedish cohorts) with a common Land Use Regression modelling method in its study of air pollution and total mortality (Beelen et al., 2014). Land Use Regression modelling are focused on local mainly traffic sources in The ESCAPE study, PM2.5 was in the meta-analysis found to be associated with an increased mortality of 14% per 10 μg/m^3. For NOx, the increased mortality was 2% per 10 μg/m^3. In an analysis with PM2.5 and NO2 simultaneously, the NO2 result was not changed. The ERF from an earlier study of Norwegian men was very similar to the Danish study, the adjusted mortality risk ratio was 1.08 (95% CI: 1.06–1.11) for a 10 μg/m^3 increase in average NO2 at the home address from 1974 through 1978 (Nafstad et al., 2004). In another Norwegian study, linear associations between NO2 concentrations and all causes of deaths were observed in the population older than 71 years of age (Næss et al., 2006). In a Swedish study of 7494 men however, the association was weaker; the total non-accidental mortality was associated with particulates’ NOx exposure in the last year (the year of outcome) with an HR of 1.03 (95% CI 1.01–1.05 per 10 μg/m^3) (Stockfelt et al., 2015). The effect estimate is quite similar to the estimate from ESCAPE (Beelen et al., 2014). We cannot be sure which ERF would be most appropriate to use in our study area, therefore we present estimates from both the most conservative estimate (Stockfelt et al., 2015), the “golden standard” from HRAPIE (Héroux et al., 2015) and the highest estimate (Raaschou-Nielsen et al., 2012).

We also included childhood asthma, dementia and preeclampsia...
into the health impact assessments. There is increasing evidence for air pollution to be associated with dementia-related outcomes (Oudin et al., 2009; Malmqvist et al., 2011; Oudin et al., 2012).

From REVIIHAAP and HRAPIE, it was reported that the scientific evidence has increased that NO2 in itself be based on the relationship between long-term exposure of NO2 and mortality (WHO, 2013a, 2013b). Previously, NOx and NO2 were primarily seen as indicators of exhaust gases, with exhaust particles being more likely to cause health effects. A literature review by Faustini et al. found that the largest effect on total mortality could be observed in Europe for both NO2 and PM2.5 (Faustini et al., 2014). In Europe, an increase of 7% per 10 μg m-3 of the total mortality of both NO2 and fine particles was observed, and that the effects in principle appear to be independent of each other. We chose to follow recent recommendations to use one or the other so as not to risk to “count twice” (double-count) (Yin et al., 2017), although this may have led to an underestimated of the health impacts. Furthermore, we only estimated effects of long-term exposure to air pollution (by using an annual mean of NO2 or PM2.5) and ignored short-term health effects. Results from a recent study suggests that the full extent of benefits from any public health or environmental policy involving chronic diseases should take into consideration both new onset and exacerbation of disease (Chanel et al., 2016). This might thus also have led to an underestimation of health effects in our study. It should also be noted that chemical and photochemical processes of secondary formation of particles and gases are usually included when simulating the fate of air pollution in the atmosphere. However, our model does not incorporate secondary formation. There is a previous study in a similar setting, where this has been investigated further. The authors found that the secondary formation was considered insignificant (Gidhagen et al., 2005). As our setting is very similar, concerning both emissions and temporal and spatial scale, secondary formation should therefore not influence our results.

We have not considered that policies that would lead to exhaust-free transport in Malmö would most likely also lead to other changes for the population, apart from a lowered air pollution exposure. Especially if the policies would target modes of transport such as a shift from cars to bicycles. Many policies to reduce air pollution could have other co-benefits. We chose to follow recent recommendations to use one or the other so as not to risk to “count twice” (double-count) (Yin et al., 2017), although this may have led to an underestimated of the health impacts. Furthermore, we only estimated effects of long-term exposure to air pollution (by using an annual mean of NO2 or PM2.5) and ignored short-term health effects. Results from a recent study suggests that the full extent of benefits from any public health or environmental policy involving chronic diseases should take into consideration both new onset and exacerbation of disease (Chanel et al., 2016). This might thus also have led to an underestimation of health effects in our study. It should also be noted that chemical and photochemical processes of secondary formation of particles and gases are usually included when simulating the fate of air pollution in the atmosphere. However, our model does not incorporate secondary formation. There is a previous study in a similar setting, where this has been investigated further. The authors found that the secondary formation was considered insignificant (Gidhagen et al., 2005). As our setting is very similar, concerning both emissions and temporal and spatial scale, secondary formation should therefore not influence our results.

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Wennergren, G., 2015. Astma är en av de vanligaste kroniska sjukdomarna hos barn (in English: asthma is one of the most common chronic diseases in children). Lakartidningen 46.


