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Transport-related measures to mitigate climate change in Basel, Switzerland: a health-effectiveness comparison study

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Abstract

Background
Local strategies to reduce green-house gases (GHG) imply changes of non-climatic exposure patterns.

Objective
To assess the health impacts of locally relevant transport-related climate change policies in Basel, Switzerland.

Methods
We modelled change in mortality and morbidity for the year 2020 based on several locally relevant transport scenarios including all decided transport policies up to 2020, additional realistic and hypothesized traffic reductions, as well as ambitious diffusion levels of electric cars. The scenarios were compared to the reference condition in 2010 assumed as status quo. The changes in non-climatic population exposure included ambient air pollution, physical activity, and noise. As secondary outcome, changes in Disability-Adjusted Life Years (DALYs) were put into perspective with predicted changes of CO₂ emissions and fuel consumption.

Results
Under the scenario that assumed a strict particle emissions standard in diesel cars and all planned transport measures, 3% of premature deaths could be prevented from projected PM₂.₅ exposure reduction. A traffic reduction scenario assuming more active trips provided only minor added health benefits for any of the changes in exposure considered. A hypothetical strong support to electric vehicles diffusion would have the largest health effectiveness given that the energy production in Basel comes from renewable sources.

Conclusion
The planned local transport related GHG emission reduction policies in Basel are sensible for mitigating climate change and improving public health. In this context, the most effective policy remains increasing zero-emission vehicles.

Keywords:
Health impact assessment, GHG emissions, climate change, policy, air pollution, physical activity, noise
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1. INTRODUCTION

Urban areas are responsible for up to 70% of the production of carbon dioxide (CO$_2$) and other greenhouse gas (GHG) emissions causing global warming (UN-Habitat 2011). A set of different policies have been and are being planned, developed and/or implemented in many cities to curb significantly GHG emissions in the future and meet reduction targets. Policies are aimed at different sectors of activities, such as transport, energy production or residential heating.

Many of these climate change policies - sometimes referred to “GHG policies” - imply changes of several non-climatic exposure patterns known to be related to health. Those secondary consequences of GHG policies may be of immediate or mid-term relevance to health whereas the reduction in GHG is a long-term target. Important secondary changes in exposure relate to ambient and indoor air pollutants, redistribution of urban green spaces or mode of transport. These exposures may have direct (positive or negative) effects on health and well-being of the population. The interrelationship between exposure changes, health impacts and climate change policy frameworks was evaluated in a series of papers in 2009 in large European and Asian cities in relation to hypothetical scenarios of policy changes in the household energy, transport, food and agriculture, and electricity generation sectors (Friel and others 2009; Haines and others 2009; Wilkinson and others 2009; Woodcock and others 2009). While these studies have been influential in raising awareness on the large health co-benefits of mitigating climate change, they have been more limited at helping evaluate or design future climate change policies for local policy-makers. Studies that integrated more realistic scenarios of local policy interest have been proven useful with several studies showing that the shift from private vehicle to active transport is a key intervention for improving public health (Hankey and others 2012; Rojas-Rueda and others 2011; Rojas-Rueda and others 2012).

An important gap of knowledge however to further contribute to climate discussions is to understand to what extent local actions set by intergovernmental agreements can really contribute to mitigation of climate change impacts given other local needs, priorities and realities. Here we present the framework, methodology and results of the health benefits and impacts of locally relevant transport-
related climate change policies in the Swiss city of Basel. Basel has been a case study in the 7th European Research Framework program funded project URGENCHE (Urban Reduction of Greenhouse gas Emissions in China and Europe). We focused our analysis on scenarios related to transport policies. In Basel, the national CO₂ emission reduction targets have been met for several years now and 100% of the electricity is produced by renewable energy (as of 2010). As such, the climate change debate in Basel could seem closed. However, traffic is and will remain a challenging problem due to hard to control internal and external traffic growth, a large contributor to GHG emissions in Basel as in most urban areas. The city of Basel is in an ongoing process to evaluate to what extent these measures can control traffic to fulfill the requirements of a citizen referendum that took place in 2010 and that requires that traffic in urban roads in the city of Basel be reduced by 10% by 2020 and avoid further increasing air pollution in living quarters in accordance with the air quality law. Given its unique context of a long history of environmental sustainability policies, Basel is also an interesting case study to understand to what extent future local transport development plans can contribute to mitigate climate change.
2. METHODS

We modelled differences in health impacts between current conditions (2010 year of reference), assumed as status quo until year 2020, and the year 2020 under different GHG transport-related policy scenarios of relevance for Basel. The target population of our analysis included only the residents of the canton of Basel-Stadt, the administrative unit where Basel city is located. Thus we only account for impacts of policies that may contribute to local changes. The methodological steps followed for the health impact assessment (HIA) include selection of relevant scenarios for the city, selection of outcomes and concentration-response functions (CFRs) available from current revision of the epidemiological literature and HIA practices, modelling changes in population exposure under the different selected scenarios and combining all the above for calculating the health impact resulting from predicted changes in exposures.

2.1 Choice of pathways of exposure and scenarios

Transport policies act on urban development and mobility aspects and imply changes in CO₂ emissions and exposure of the population to short-lived air pollutants such particles or nitrous oxide (NO₂), as well as primary pollutants near to transport sources, such as soot. These policies also imply changes in noise exposure or physical activity patterns and in general of time-activity that may be linked to accidents and further exposure to air pollution. Changes in mobility patterns are expected to influence fuel usage within the city limits with additional consequences for CO₂ emissions. For Basel, the pathway of exposure evaluated as a result of these changes include predicting changes in CO₂ emissions, regional pollution (represented by particulate matter up to 2.5 micrometer in diameter [PM₂.₅]), near-road traffic-related pollution (represented by elemental carbon [EC]), noise and physical activity patterns.

We retained four scenarios of transport changes compared to the reference scenario that assumes that all conditions in 2010 remain as they are until the target year 2020, except for population size:
(1) a scenario that includes all transport-related measures that are decided by the local government to be developed up to 2020. This scenario relies on the assumption that those policies are being currently implemented and likely to be maintained unless jeopardized by future political processes and decisions. We refer to this scenario as the “Decided Policies” (DP);

(2) the so-called “Z9 scenario” developed by the city that accounts for additional local transport measures beyond DP to further reduce traffic by 4% on inner roads. This local scenario complies with a successful citizen referendum requiring further traffic reduction. It includes a series of traffic measures targeted at channelling traffic along main avenues, reduce traffic and moderate speed in residential areas not contemplated in DP. This scenario also assumes a local shift of car trips to active transport (walking and cycling);

(3) A hypothetical scenario named “p10” assuming a 10% reduction of traffic on inner roads as compared to DP; in p10, all other measures of Z9 are also assumed to be implemented, thus the only difference between Z9 and p10 is the 10% instead of only 4% reduction in traffic; and

(4) the p50 scenario expanding p10 with the assumption that 50% of the private car fleet would be based on electric vehicles (p50).

While DP and Z9 were locally developed by the city authorities, p10 and p50 are default scenarios that the URGENCHE project team agreed upon for all cities included in the project. Supplemental Material Table 1 provides an overview of scenarios and assumptions.

2.2 Selection of outcomes and concentration-response functions

Table 1 summarizes exposure and outcomes retained in our analyses. We used PM$_{2.5}$ as the indicator of long-term exposure to air pollution. PM$_{2.5}$ has been associated with total, cardio-respiratory and lung cancer mortality and shortened life expectancy (WHO 2013a; WHO 2013b). Our core analysis includes the estimation of long-term exposure to PM$_{2.5}$ on all-cause natural mortality and cause-specific mortality (lung cancer and cardiovascular diseases) in sensitivity analyses (Hamra and others 2014; Hoek and others 2012). In recent years, epidemiological studies have shown that local traffic emissions may be independently related to the long-term health effects of regional air pollution (HEI 2009). While these local primary emissions contribute to only a small fraction of the total mass of
PM$_{2.5}$, their distribution depends on the distance to source. This is less the case of PM$_{2.5}$ that is more homogeneously distributed. Thus, studies using PM$_{2.5}$ may not fully capture the effects of near-road traffic-related particles. It has been suggested that indicators of near source combustion particles such as black carbon characterized by EC could be used in addition to PM$_{2.5}$ to evaluate the effects of local traffic sources (Keuken and others 2012a). In order to avoid double counting, the effects due to exposure to EC should not be added to the effects related to exposure to PM$_{2.5}$ (WHO 2013a). We conducted a sensitivity analysis using EC as pollutant indicator to compare results with PM$_{2.5}$ on mortality (Janssen and others 2011). There are also short-term effects of PM$_{2.5}$, such as increases in hospitalizations for cardiovascular and respiratory causes, and other minor ailments such as restricted activities days (RADs) evaluated in the sensitivity analysis. We used CRFs and baseline data as recently recommended in WHO reviews (Hurley F. and others 2005; WHO 2013a; WHO 2013b).

There is growing evidence of effect of noise on several health outcomes such as sleep disturbance, annoyance, hypertension, myocardial infarction, and tinnitus (EEA 2010). Of special relevance is that noise may have independent effects from air pollution on the cardiovascular system. We evaluated the health effects of noise on mortality by coronary heart diseases using a recent newly developed risk function (Babisch 2014). Annoyance and sleep disturbance have been traditionally recommended to be included in HIA from noise (EEA 2010). It is yet unclear how these outcomes relate to the more distal cardiovascular risk, as individuals more disturbed may also be more susceptible. We used these outcomes as a measure of independent impact on well-being (Miedema and Oudshoorn 2001; Miedema and others 2003).

The relative risk for an association between physical activity and health effects have been reported in recent reviews (Woodcock and others 2011). We retained for this analysis the outcome and risk function developed and implemented in the WHO’s Health economic assessment tool (HEAT) for cycling and walking that estimates changes in all-cause premature deaths given changes in walking and cycling (WHO 2014). Specifically we used a linear risk function for cycling that estimates a reduction in mortality of 10% for regular commuter cyclists compared to non-cycling commuters. A
regular commuter cyclist was defined as a commuter aged between 20 and 64 who cycles at least 100 minutes per week for 52 weeks per year. For walking, HEAT proposed a risk reduction of 11% for walkers compared to non-walkers. Walkers are defined as individuals aged between 20 and 74 years that walk at least 168 minutes per week for 52 weeks per year. While the CRFs used in this analysis were developed on a specific range of ages, for consistency our analysis is applied to ages above 30 years for all outcomes except RADs which was applied to the population 18-64 years and walking and cycling which was applied to those aged 15-74 years (Table 1).

2.3 Population exposure modelling

Annual PM$_{2.5}$ and EC concentration maps for 2010 and 2020 were developed for the different policy scenarios. We obtained annual regional and urban background concentrations and road traffic contributions by combining different models. The regional annual background concentrations of PM$_{2.5}$ and EC in 2010 and in 2020 were modelled by a regional scale model and urban concentrations were then modeled by adding 1 x 1 km urban traffic emissions to the regional background. The road traffic-related PM$_{2.5}$ and EC concentrations were further developed using a ‘street canyon’ model applied to urban streets, and a ‘line-source’ model to motorways. Detailed methods have been described elsewhere (Keuken and others 2014) and are summarized in Supplemental Materials. We used traffic models developed in by Basel city for DP and Z9 as input in the models. We developed additional traffic maps for p10 and p50 according to the assumed scenarios.

We used noise exposure levels for DP and Z9 developed by the city of Basel (see Supplemental Materials). Models of change in traffic noise given replacement of fleets with electric cars are poorly developed on the scale of cities like Basel, thus, the adoption of the above models for p10 and p50 come with major uncertainties. Thus, we adopted an alternative p50-scenario (p50*) for Basel that assumed a 2dB Lden reduction in the whole city if levels were above background compared to 2010. This scenario matched with local predictions developed previously in the city within the context of a pilot study on energy savings in Basel that assumed 80% of electric vehicles year 2030 (KBS 2011).
The health impact evaluation for the change in physical activity exposure was conducted only for Z9 for which an additional total 27,000 walking and cycling within-city trips per day has been estimated by the city (BKB 2008). No further modelling of the distribution of these new trips by transport mode was conducted at the city level. Thus, to estimate the percentage increase in trips per active transport mode for Z9 compared to the reference scenario, we assumed that the current share of cycling and walking trips as observed in the Swiss micro-census – a population-based survey - for the Canton of Basel-Stadt in 2010 would remain the same (SFOE 2010). Active trips at reference level were calculated using the ratio of total trips and active trips seen in the micro-census sample. Total active trips for each active transport mode for the Z9 scenario were afterwards estimated as the sum of the trips at the reference level and the 27,000 additional estimated active trips by the city.

For air pollution and noise, population-weighted concentrations were calculated for each scenario superimposing the spatially resolved maps with population data given at the building address level. To evaluate the variability of residential exposure to near-traffic sources, we further calculated population-weighted concentration by type of residential zone namely population living within 100 m of a motorway (Zone 1), people living 25 m from a street with more than 10,000 vehicles per day (street canyon) (Zone 2), and population living in zones other than zone 1 and 2, assumed as next to inner city roads (Zone 3). Population for 2010 was obtained from the Basel statistics department. (Statistisches Amt des Kantons Basel-Stadt). Figures of population growth for Basel provided by the Federal Office of Statistics (BfS) were used to calculate Basel population in 2020 at building entrance, by sex and 5-year age groups.

2.4 Calculation of health impacts

The primary impact metric of this analysis is the difference per year in number of premature deaths and morbidity cases due to each policy scenario compared to the reference level using standard population attribution fraction and life tables methodologies (Miller and Hurley 2006; Perez and Künzli 2009). We additionally developed a comparative risk assessment by using as a secondary
metric life-long changes in Disability Adjusted Life Years (DALY) expressed per 1,000 inhabitants. For each pathway of impact, DALYs were calculated as the sum of YLL gained (or lost) due to deaths prevented (or brought forward) and additional Years of Life lost due to Disability (YLD) from outcomes related to well-being aspects (RAD for air pollution exposure and annoyance and sleep disturbance for noise). For RAD, we estimated attributable cases using rates proposed in the WHO review given lack of local data (WHO 2013a). YLD were then estimated as the total number of attributable RADs due to change in exposure multiplied by a disability weight of 0.099 per year (Hänninen and Knol 2011). We used previous non-linear function to obtain the percentage change of people highly annoyed or with disturbed sleep given the average residential level of noise in the target population for each scenario and the reference level and calculated differences (Miedema and Oudshoorn 2001; Miedema and others 2003). YLD were then estimated using a disability weight of 0.02 per year for both outcomes as recommend in the WHO noise health impact guidelines (EEA 2010). There was no discounting in years or age.

Finally, the results of the comparative analysis were compared with changes in CO₂ emission reduction and fuel consumption. CO₂ emission factors for CO₂ and fuel consumption by vehicle type were combined with traffic intensities by vehicle and road type in Basel to obtain yearly CO₂ emissions and fuel consumption for each scenario.

3. RESULTS

3.1 Population and baseline mortality data

Table 2 presents a summary of the population and baseline health data used for the impact calculations. The population of Basel in 2010 accounts for 191,257 inhabitants (51% women). Over 68% of the total population is between the ages of 15 and 64 years. About 5% of the total population is
above 80 years old (7.9% for women). Most of the population lives away from highways and major
routes (90%). In 2020, an increase in population of about 2.5% is expected (to 196,066 inhabitants).

There were a total of 1884 natural deaths registered in 2010 in Basel above the age of 30 years, of
which 57% were women. Most of these deaths occurred in people above 80 years old (67% of all
deaths), although there was a marked difference between genders (55% of deaths due to natural cause
in men above 80 years versus 79% for women).

3.2 Change in traffic volumes and CO₂ emissions

Traffic data inputs and changes in traffic-related CO₂ emissions are presented in Supplemental
Materials Table 1 and Table 2. In Basel, it is modelled that despite the planned measures under way
road traffic volume will continue to grow until 2020 by about 4% compared to 2010 as will CO₂
emissions (from 186 kt/year today to 197 kt/year in 2020). While Z9 is able to compensate the traffic
growth and keep CO₂ emissions stabilized to current levels, scenario p50 only, can substantially
reduce CO₂ emissions (with 184 kt/year or ~20% compared to 2010).

3.3 Predicted exposure changes

Concentrations of PM₂.₅ and EC under the DP scenario was estimated to decrease by 38% and 66%
respectively as compared to the reference (Table 3). However, the models estimate the additional
reduction of PM₂.₅ and EC for the scenarios beyond DP to be very small. There was considerably less
change in average Lden and Lnight exposure for any of the scenarios considered (<2%) with DP and
Z9, resulting in a slight increase in the population-weighted mean exposure compared to reference.
The change in air pollution exposure did not depend on the residential zone while there was a larger
difference in changes for noise indicators for inhabitants of residential zone 1 (increase).

Within Basel, in 2010, 15% and 41% respectively of all trips are done by cycling and by walking
averaging 16 and 48 minutes per day, respectively. We estimated that the Z9 scenario could result in
about 7 percent point increase in the predicted number of cycling and walking trips compared to reference level 2020 or 7,222 (calculated as 108,049-100,827 trips) and 19,778 (calculated as 291,068-271,290) new daily cycling and walking trips, respectively (Table 2). This would represent an increase in the share of active trips compared to total trips of about only 1%. We found a slightly larger increase for women compared to men.

3.4 Health impacts

Postponed deaths and prevented RADs are reported in Table 4. We estimated that per year there could be a reduction in natural deaths by up to 3% (65 deaths) if PM$_{2.5}$ exposure levels were further reduced to DP-scenario levels. Given the minor additional reduction of exposure in the other scenarios, those contributed only moderately to a further reduction of impacts. Cause-specific analyses show that a large contribution of these attributable deaths are related to cardiovascular diseases (CVD) (50 of the 65 preventable deaths). Using EC as an indicator of near-road traffic pollution increases the preventable deaths to 6% (115 cases) per year for DP. We estimated that per year there are more than 2.3 million RADs in Basel and that 2.0% of those could be reduced if DP levels were achieved for PM$_{2.5}$.

In general, the benefits or impact of noise for mortality and annoyance and sleep disturbance were very limited given the small changes in the population weighted mean noise levels predicted by the scenarios. We found that 1% - corresponding to less than 7 CVD deaths - are expected to be postponed due to changes in noise exposure expected in the p50 scenario.

We estimated that about 0.03% premature deaths (<1 natural death in commuters) per year could be prevented if there was 1% more walking and cycling in Basel. The negative impact due to additional air pollution exposure while commuting was negligible (results not shown).
3.5 Comparative risk assessment

The comparative assessment to contribution of the reduction in DALYs due to changes in exposure and scenarios shows that near-road traffic reduction remains the largest benefit for DP (-3.8 DALYs per 1,000 population) with other scenarios bringing altogether only marginal benefits beyond DP (Table 5). The comparative analysis however shows that noise reduction from electro mobility contributes to reducing some of the well-being impacts. Figure 1 shows modelled CO₂ emissions under the different scenario and deaths averted per every ton of CO₂ emission reduced as compared to the reference scenario. Despite the p50 scenario contributing to the largest reduction of CO₂ emissions, a same reduction in CO₂, Z9 averts the most Years of Life Lost due to the additional reduction in mortality from more physical activity.

4. DISCUSSION

Our study evaluated the impacts on health of realistic local GHG reduction-related policy scenarios in an environmentally friendly and climate change sensitive middle-sized urban city in Europe. Many mid-size cities all around Europe and other regions in the world are governed by local authorities, thus the assessment may serve as a model applicable to other regions as well. Our study further puts into perspective potential health changes due to local realistic measures against changes from more ambitious hypothesized interventions such as large diffusion of electric cars that are less likely to be implemented in the near future although reflecting targets that are discussed in Basel and elsewhere.

Our results show that DP, including a range of already planned transport measures, will bring relatively large air pollution-related health benefits. This is principally due to the anticipated reduction of tail-pipe particle emissions from the new fleet of Euro 5/6 diesel engine vehicles expected to be in place by 2020 (Keuken and others 2012b; Kousoulidou and others 2008). Thus, we show for the first time that DP is also of major health relevance and authorities should remain very focused on its full implementation. If the adoption of DP gets delayed or diffused – e.g. through new political initiatives
against some of the DP measures - our beneficial DP results may be an overestimation of the true changes. Our study showed that further reductions in EC exposure are of substantial health relevance and clearly more sensitive to local policies than PM$_{2.5}$ because population exposure to EC (as an indicator for soot emissions) is strongly driven by local traffic-related emissions. Most air pollution impact assessments still rely solely on PM$_{2.5}$ as long-term indicator of health. Using PM$_{2.5}$ alone may be underestimating the benefits of local transport measures and, thus, underestimating the contribution of local policies to improvement in public health. Outdoor air pollution and diesel particles that mostly contribute to EC composition are now recognized as carcinogenic to humans (Hamra and others 2014; Raaschou-Nielsen and others 2013). For diesel particles, a level of 0.1 µg/m$^3$ of EC exposure over the lifetime is necessary to meet the acceptable risk of 1 in a million- of developing one additional cancer due to exposure (SoCAB 2008). Current levels and future scenarios resulted in exposure levels of EC well above this threshold, showing that there is still potential for large gains beyond reducing regional air pollutants such as PM$_{2.5}$, often the only target of most air pollution and GHG reduction policies.

Our results show in any case that zero emission vehicles will have very large benefits in many urban areas. Thus, the results support efforts to implement air quality standards that regulate the local traffic-related pollutants in addition to those capturing the background levels (such as PM$_{2.5}$). In spring 2014, The Swiss Federal Commission for Air Hygiene (FCAH) recommended to the government the inclusion of a binding 80% reduction of EC at all locations in within the next 10 years in its air quality law (CFHA 2014). Our study indicates that DP and the other scenarios will reduce EC exposure to 30-35% of current levels by 2020. Assuming continued and additional efforts to reduce traffic-related emissions after 2020, it appears rather plausible to curb the EC concentrations down to 20% of current levels by 2025. Assuming linear interpolation, compared to our reference point, the FCAH scenario would result in 59 prevented deaths, or some 17% higher benefits as compared to the best scenario considered in URGENCHE (p50). FCAH also proposed the adoption of the WHO guideline value for the PM$_{2.5}$ annual mean, namely to set 10 µg/m$^3$ PM$_{2.5}$ as a national air quality standard. According to our estimates, the DP scenario, if fully implemented and effective, is likely to achieve and go beyond this standard for the citizens of Basel by 2020.
Several studies have shown that the shift from private vehicle to active transport is a key intervention for improving public health, both physically and psychologically (Hankey and others 2012; Maizlish and others 2013; Rojas-Rueda and others 2011; Rojas-Rueda and others 2012; Woodcock and others 2013; Woodcock and others 2014). In Basel, the baseline level of active transport is already high so predicted growth in numbers of new active travellers under the Z9 scenario was rather small, with benefits of these measures remaining modest compared to past studies. For example, in Barcelona, it was estimated that 12 deaths per year could be postponed under a scenario assuming that 25,425 individuals replace car use with bicycle riding {Rojas-Rueda, 2012 #172}. In a study in England and Wales, a reduction of premature deaths between 3% and 9% was estimated assuming increased levels of walking and cycling could reach up to 37% (Woodcock and others 2013). In London a hypothetical increase in active travelling by up to 5 times the travel times observed in 2020, prevented 528 premature deaths projected for year 2030 (Woodcock and others 2009). From a public health, traffic management, and urban planning perspective, such strategies are very appealing not only for Basel but indeed on the global scale. This is particularly true for Chinese cities – like those participating in URGENCHE – where policy makers should take all efforts to keep the traditionally very common use of bikes very high on the urban planning agenda to not continue the unfortunate shift from bikes to cars.

As consequence of further increases in bicycle use, and in particular a substantial increase in the use of electric bicycles, there is in Switzerland and in Basel, an upward trend in accidents and injuries due to bicycle riding (BFPA 2014). Some studies have pointed to the potential increase in traffic injuries as a negative impact of these measures; in the San Francisco Bay, an increase in active commuting time was estimated to contribute an increase of 39% of the injury burden (Maizlish and others 2013). Given the uncertainty in Basel relating to our transport shift scenario we abstained from further analysis. Active transport policies should be accompanied by additional strategies for the safe use of bicycles. Though the city of Basel has adopted some of these measures, other regions such as the city of Copenhagen have promoted bicycle use with far more rigorous and coherent concepts (Fraser and Lock 2011).
Our results show that more ambitious hypothesized scenarios considering large penetration of electric cars in the city in the year 2020 did not contribute considerably to increased health benefits from noise reduction and that an increase in population exposure to noise and related negative health impacts is even predicted under the DP scenarios. It is estimated that at 50 km/h an electric car emits ~ 1 dB less than a combustion fuelled car and at 30 km/h this is ~ 2 dB (HEIMTSA 2011). Our evaluation suggests that the reduction of noise inner roads even if the fleet of private cars is mostly electric would not compensate for the increase in exposure to noise from more cars in high speed roads, expected to occur in most European cities. Thus, instead of accepting this increase as “a default”, policy makers need to be innovative to abate these trends. Moreover, our scenario assumed a conservative mix of electric and combustion-driven vehicles, i.e. every second car remains noisy. Policies that would restrict access to some densely populated areas of the city to electric cars only would lead to stronger noise reductions in those areas than considered in our scenario. Despite these moderate benefits compared to air pollution reduction, our study shows that this measure has the largest health effectiveness ratio when the energy production is principally from renewable energy like in Basel as confirmed in other settings (Buekers and others 2014). However one should be aware that the realistic level of diffusion of electric cars in the period study is rather small. In Europe, only 7% market share for electric vehicles is expected in 2020 (EC 2011).

Our study presents several limitations. Our results are represented only by a central estimate, i.e. uncertainties are not specifically quantified. Impact studies like ours remain projections based on a large number of assumptions behind each step of the calculation. We are not able to validate each assumption but only discuss potential impact for our conclusions. We took an approach to minimize double counting of benefits and impacts, but altogether the benefits may represent an underestimation. For example we did not account for all impacts of changes in air pollution or physical activity in health and we did not consider in depth well-being aspects beyond annoyance and sleep disturbance. Another limitation relates to the fact that we do not know how health in the population will be modified given other contextual changes that may occur at local level, thus, our scenarios assume that
all other health-relevant aspects remain stable. Given the short time frame of our analysis, we can only speculate that current conditions will apply to the future. We focused our analysis on transport-related policies given the interest of local policy-makers. Moreover, the benefits of the most effective scenario – DP - will only materialize if those measures do not become subject to new political initiatives to stall their implementation. Given the Basel context, we expect that any additional health benefits from a different sector of activity would only be marginal, unless far more substantial and possibly visionary scenarios were considered. Benefits and impacts of other exposure changes (i.e. heat, green spaces) over a longer time-frame were beyond the scope of this study. The distribution of exposure and impacts in relation to socio-economic status is also rather marked in Basel. Our analysis clearly showed differences by sex originating both due to difference in baseline health but also in exposures as is the case for physical activity and active commuting. We did not stratify further our results given the small population but these aspects should be better considered when developing future measures. Useful lessons in this regard could be drawn from joint analysis of the results obtained in other, larger cities involved in URGENCHE, such as Thessaloniki in Greece. Such a comparison will be the topic of future work on this theme.

5. CONCLUSIONS
The planned local transport-related GHG emission reduction policies in Basel are sensible for mitigating climate change and improving public health. In this context, the most effective policy remains increasing zero-emission vehicles. The benefits of such policies can be remarkable even in cities like Basel where environmental pollution is at only moderate levels due to long-term investments in policies to protect the environment and, thus, people’s health.
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