Published in final edited form as:
J Allergy Clin Immunol. 2014 November ; 134(5): 1028–1035. doi:10.1016/j.jaci.2014.09.029.

Cost of near-roadway and regional air pollution-attributable childhood asthma in Los Angeles County

Sylvia Brandt, PhD[1], **Laura Perez, PhD**[2,3], **Nino Künzli, PhD, MD, MPH**[2,3], **Fred Lurmann, MS**[4], **John Wilson, PhD**[5], **Manuel Pastor, PhD**[5], and **Rob McConnell, MD**[5]

[1]University of Massachusetts Amherst, Amherst, USA [2]Swiss Tropical and Public Health Institute and University of Basel, Basel, Switzerland [3]Swiss Tropical and Public Health Institute and University of Basel, Basel, Switzerland [4]Sonoma Technology, Inc., Petaluma, California [5]University of Southern California, Los Angeles, USA [6]University of Southern California, Los Angeles, USA [7]University of Southern California, Los Angeles, USA

Abstract

Background—Emerging evidence suggests that near-roadway air pollution (NRP) exposure causes childhood asthma. Associated costs are not well documented.

Objective—We estimated the cost of childhood asthma attributable to residential NRP exposure and regional ozone (O_3) and nitrogen dioxide (NO_2) in Los Angeles County. We developed a novel approach to apportion the costs between these exposures under different pollution scenarios.

Methods—We integrated results from a study of willingness to pay to reduce the burden of asthma with studies of health care utilization and charges to estimate the costs of an asthma case and exacerbation. We applied those costs to the number of asthma cases and exacerbations due to regional pollution in 2007 and to hypothetical scenarios of a 20% reduction in regional pollution in combination with a 20% reduction or increase in the proportion of the total population living within 75m of a major roadway.

Results—Cost of air pollution-related asthma in Los Angeles County in 2007 was $441 million for O_3 and $202 million for NO_2 in 2010 dollars. Cost of routine care (care in absence of exacerbation) accounted for 18% of the combined NRP and O_3 cost and 39% of the combined NRP and NO_2 cost—costs not recognized in previous analyses. NRP-attributable asthma accounted for 43% (O_3) to 51% (NO_2) of the total annual cost of exacerbations and routine care associated with pollution. Hypothetical scenarios showed that costs from increased NRP exposure may offset savings from reduced regional pollution.

Corresponding author, requests for reprints. Sylvia Brandt, Resource Economics and, Center for Public Policy and Administration, 205 Stockbridge Hall, University of Massachusetts Amherst, Telephone: 413-687-2166, Fax: 413-545-5853, sylvbrandt@gmail.com.

Conclusions—Our model disaggregates the costs of regional pollution and NRP exposure and illustrates how they might vary under alternative exposure scenarios. The cost of air pollution is a substantial burden on families and an economic loss for society.

Keywords

air pollution; asthma; cost of illness; urban growth; vehicle emissions; willingness to pay

Introduction

Approximately 36 million people in the U.S. live within 300 feet of a four-lane highway, railroad, or airport.[1] Emerging evidence suggests that near-roadway air pollution (NRP) exposure causes childhood asthma.[2,3,4,5] A causal relationship implies that any subsequent asthma exacerbation, regardless of its precipitating trigger, can be attributed to NRP exposure.[6] In urban areas in Southern California, NRP exposure may account for a substantial proportion of all air pollution-related exacerbations in children, which are commonly estimated on a population level only for regional pollutants.[7,8,9]

There has been little study of the costs of NRP-related health effects,[10,11] which may be substantial.[12] There are three categories of costs associated with these effects: direct costs are payments for healthcare; indirect costs reflect opportunity costs such as lost wages; and willingness to pay (WTP) to avoid the burden of asthma quantifies negative quality-of-life consequences.[13] Population estimates of asthma-related costs have generally not quantified the day-to-day experience of asthma, because no robust studies had appropriately measured it.[14,15,16]

We developed a model of annual cost of childhood asthma that integrated novel methods from economics and epidemiology including WTP to avoid asthma morbidity[17] and risk assessment incorporating asthma morbidity in children with NRP-attributable asthma.[7] We evaluated the cost of pollution-related childhood asthma in Los Angeles county (LAC) in 2007 and the hypothetical cost per year of pollution-related childhood asthma under alternative levels of regional pollution and exposure to NRP.

LAC has a high prevalence of childhood asthma,[18] dense traffic corridors, and high levels of regional air pollutants such as ozone (O_3), nitrogen dioxide (NO_2) and particulate matter. These regional levels are expected to continue to decline as a result of regulatory efforts.[19] While a reduction in regional pollution should decrease the cost of asthma, the net impact when that reduction is combined with a change in the proportion of the population living near a major roadway is not obvious. Based on results of a previously published evaluation of pollution- related asthma exacerbations in LAC,[7] we have now estimated (1) the childhood asthma-related costs attributable to regional and near-roadway pollution in 2007 and (2) the savings that might result from a 20% regional pollution reduction combined with a 20% increase or decrease in the proportion of families living in proximity to a major roadway relative to 2007 levels.[7]

Methods

Pollution-attributable asthma outcomes

The selection of pollutants, estimation of population exposure, concentration response functions (CRFs) and pollution-associated burden of asthma have been described previously.[7] Briefly, we examined the effects of O_3 and NO_2 because each has a well-established causal relationship with asthma exacerbations.[20,21] In Southern California, NO_2 may be used as a proxy for general regional pollution (exclusive of O_3) including particulate matter, elemental carbon, and nitric acid—all associated with respiratory health effects.[22,23] O_3 is relatively uncorrelated with other regional pollutants in the Los Angeles air basin.[23,24] We avoided double counting pollution-attributable exacerbations by evaluating each pollutant separately.

The baseline exposure for all scenarios was the 2007 population-weighted proportion of LAC children living near a major roadway and the 2007 levels of regional pollution.[7] A CRF for NRP was based on residence within 75m of a major roadway, a proxy for NRP exposure relevant for Southern California.[5,9] Major roadways included freeways, highways or major arterial roads (functional road classes FRC01, FRC03 and FRC04 from the TeleAtlas MultiNet roads network[7]). In the first scenario, we estimated total asthma-associated costs of having 17.8% of the population living near major roadways by constructing a hypothetical in which this population's NRP-exposure was reduced to background levels. We examined the costs imposed by the NO_2 and O_3 levels observed in LAC in 2007 as compared to their mean values in cleaner comparison cities in the Southern California Children's Health Study that year (Scenarios 1A and 1B, respectively). The 2007 baseline measures of 24-hr NO_2 across census tracts in LAC ranged from 6.2 to 31.4 ppb (population-weighted mean of 23.3 ppb). In Scenario 1A, we calculated the impact of a reduction in population-weighted NO_2 exposure to 4 ppb across all census tracts. The 2007 baseline measures of 8-hr daily maximums for O_3 across LAC ranged from 30.5 to 55.6 ppb (population-weighted mean of 39.3 ppb). In Scenario 1B, we reduced the population-weighted O_3 exposure to 36.3 ppb. This first scenario generates the full asthma burden of the combined effects of NRP and regional pollution in LAC as compared to cleaner communities.

To illustrate the change in costs with respect to the two components of pollution-attributable asthma, we constructed hypothetical scenarios in which a decline in each regional pollutant was combined with either a 20% decrease (second scenario) or a 20% increase (third scenario) in the population percentage exposed to NRP. Since 17.8% of LAC children live near a major roadway, a change of 20% constitutes 3.56 percentage points. The hypothetical reductions in NO_2 and O_3 concentrations are plausible and based projections in the current air quality plan for Southern California.[19] The health effects and their costs were estimated for a single year. When calculating outcomes in the hypothetical scenarios, we assumed that changes in the prevalence of asthma and resulting exacerbations were fully realized and instantaneous. These assumptions allowed us to compare costs across all of the scenarios and avoided the need for discounting.

For each scenario we used the near-roadway CRF to estimate the prevalence of asthma cases attributable to NRP in a given year.[9] We estimated three types of exacerbations among children in LAC for one year:[7] *regional pollution-triggered outcomes* among children with NRP-attributable asthma (Box 3, Figure 1), *outcomes triggered by other factors* among children with NRP-attributable asthma (Box 2, Figure 1), and *regional pollution-triggered outcomes* among children with asthma caused by factors other than NRP ("other-cause asthma") (Box 6, Figure 1). Asthma exacerbation-related outcomes included: bronchitis episodes, hospital admissions, emergency room (ER) visits, doctor visits, and school absences for respiratory illness (for O_3 only). Bronchitis, defined as a productive cough lasting three months or more, is a sensitive marker of NRP-attributable asthma exacerbations[25] and is distinct from viral or bacterial bronchitis. We estimated the annual frequency of each outcome attributable to these regional pollutants using published CRFs for Southern California children, when available, or other appropriate CRFs when not. Supplement Tables 1 and 3 provide details on the CRFs and the baseline rates.

Direct and indirect costs of an exacerbation

For each individual outcome we estimated the *direct cost* of goods and services and the *indirect cost* of caregivers' lost wages. For the direct costs of healthcare, we used the amount charged rather than the amount paid, because amounts charged are not confounded by insurance status. All costs were expressed in 2010 dollars[26] and sources are summarized in Supplement Table 2.

Direct costs of hospitalization and ER visits were calculated as the sum of facilities and physician charges.[27,28] The direct cost of an office visit was estimated using the national mean charge for a physician visit.[29] The direct cost of asthma inhalers (rescue and controller medications) was the average of the prices for each inhaler category weighted by the typical utilization of each category.[30] The average price for each category of drug was the weighted mean of the name brand and generic prices.[31,32]

The indirect costs for office visits, ER visits and hospitalizations were the value of the caregiver's time spent traveling,[33] waiting,[34] and receiving care[27,35,36] and were taken from secondary databases and peer-reviewed publications. We used one workday (eight hours) as the time for a school absence and valued time at the average wage rate.[37] While this is the standard approach to valuing indirect costs, it overlooks the fact that caregivers of children with asthma sometimes leave the labor force to provide care.[38] These caregivers face lower expected lifetime earnings even when they do return to the labor force.[39]

Direct and indirect costs of routine care

Children with asthma need more routine care than other children. These fixed costs of asthma (Box 1, Figure 1) include medication use and treatment for excess ear and sinus infections—an asthma-related comorbidity. The expected quantity for each outcome was estimated for children aged 0–17 in LAC using peer-reviewed literature and secondary databases (Supplement Table 2).[30,40,41] Costs were calculated using the same approach as for exacerbations.

Direct and indirect costs of a bronchitis episode

Each bronchitis episode includes five potential costs: school absences,[42] antibiotics prescriptions,[43,44,45,46] office visits,[47,48] ER visits,[47,48] and inpatient hospital stays.[47,48] We estimated the number of office visits, ER visits and hospital stays as the mean rate for children with asthma using the 2007 Medical Expenditure Panel Survey. These estimates are significantly lower than some reported rates.[49]

Willingness to pay

Bronchitis and asthma substantially impact quality of life.[13,49,50] The value of this impact is quantified as the WTP to avoid this burden, using contingent valuation. A contingent valuation study offers participants a hypothetical health-related product, quotes prices, and inquires about WTP. Surveys must be designed to elicit values specific to desired health outcomes and to ensure valid responses.[16] To meet these criteria we used the results of a contingent valuation study conducted in California among families with children with asthma.[17]

The WTP study[17] was designed to estimate a WTP *beyond* the household's current expenditures and included "debriefing" questions to ensure that the WTP was based on a desire to reduce the pain and suffering of asthma. Thus the estimate is specific to asthma and additive to the other costs. The quality-of-life burden of a single day of symptoms was calculated as the mean WTP divided by the mean number of symptom-days that would have been avoided using the hypothetical product.[17] The hypothetical product offered a 50% reduction in days with asthma symptoms, so we doubled that estimate to determine the WTP to avoid a case of asthma.[17]

Using the WTP results,[17] we calculated the quality-of-life value of symptom-days for bronchitis and ear and sinus infections. We multiplied the mean number of symptom-days in excess of those in children without asthma[41] by the WTP to avoid a day with symptoms.[17] The CRF was based on bronchitis lasting at least three months.[25] We used a more conservative value of 35 symptom-days per episode, based on other studies examining the cost of cough lasting more than four weeks.[50–52] The WTP estimate to assign costs to bronchitis episodes and ear and sinus infections[17] was used because it is specific to children, consistent with our outcome definitions, and meets guidelines for validity.[16] Our WTP estimates for these outcomes are more conservative than values extrapolated from existing literature by the Environmental Protection Agency.[53]

Results

We previously reported detailed estimates of the burden of pollution-attributable asthma in LAC that serve as the basis for our cost estimates.[7] Briefly, we estimated that 27,100 cases of childhood asthma (4,900 to 51,200; 95% CI) are attributable to current NRP exposure, equivalent to 8% of the total current asthma burden in LAC. If proximity to roadways were reduced as in Scenario 2, there would be 5,900 (1,000 to 11,800; 95% CI) fewer cases of childhood asthma; increasing proximity as in Scenario 3 would have the exact opposite effect. Table 1 shows the change in the numbers of exacerbations under each scenario relative to the 2007 baseline. Among children with asthma, substantial proportions of the 2007 burden of bronchitis (57%), hospitalizations (20%), ER visits (11%), doctor visits (12%), and school absences (31%) were attributable to the combined effect of NRP exposure and regional pollution (Scenarios 1A and 1B in Table 1). The magnitude of bronchitis episodes attributable to pollution reflects the susceptibility of the population of children with asthma and the prevalence of asthma consequent to NRP-exposure. A reduction in regional pollution and in NRP exposure (Scenario 2) decreases all asthma outcomes; a reduction in regional pollution accompanied by an increase in NRP exposure (Scenario 3) increases all outcomes among those children with asthma due to NRP. Despite the decrease in regional pollution, the increase in cases of asthma due to NRP exposure leads to a net increase in ER visits, doctor visits and school absences (Scenario 3 in Table 1).

Table 2 shows the mean annual cost for a typical asthma case and the cost for a single bronchitis episode, broken down into direct cost [column (2)], indirect cost [column (3)] and WTP [column (4)]. The total annual cost of routine care (not including acute exacerbations) plus the quality-of-life cost as measured by WTP is approximately $3,000 for a single asthma case. The cost for a single episode of bronchitis is $1,500.

The cost per year of asthma outcomes attributable to NRP and regional pollution for each scenario is the product of the quantity of each outcome due to pollution in that scenario (Table 1, column 4) and the cost of each outcome [Table 2, sum of columns (2)+(3)+(4)]. Table 3 shows the costs of the bronchitis episodes, hospital admissions, ER visits, doctor visits and school absences (O_3 only) due to regional air pollution for children with asthma due to NRP [Column (1)] and children with other-cause asthma [Column (2)]. Column (3) shows the cost of those outcomes due to triggers other than regional pollution among children with asthma due to NRP. The sum of the cost of these outcomes for NO_2 and exacerbation due to other triggers among those children with NRP-attributable asthma was $123 million [Table 3, Row (5), Column (5)]. A large portion ($108 million) is due to the reduction in bronchitis episodes brought on by pollution exposure. The cost of all outcomes among children with NRP-attributable asthma [the sum of the total row for NO_2 in Column (1) of Table 3, $9m, and the total row for NO_2 in Column (3), $15m], accounted for about 20% of the $123 million total.

The cost of outcomes due to O_3 and exacerbations due to other triggers among children with NRP-related asthma totaled $362 million (Table 3, Scenario 1B). The differences between Scenario 1B and Scenario 1A are largely due to school absences due to O_3. Across all O_3 outcomes, 30% of the potential savings were due to reducing exacerbations among children with NRP-attributable asthma.

Scenarios 2 and 3 in Table 3 illustrate the combined effects of the 20% change in NRP exposure and the 20% reduction in regional pollution. We reported the estimated costs for the regional pollutant most responsible for each outcome: NO_2 for all outcomes except school absences. Thus, if regional pollution were 20% lower than 2007 levels and the proportion of the population near roadways were reduced, there would be a decrease in the frequency of each outcome (from Table 1, Scenario 2), and a decrease in total costs (Table 3, Scenario 2) of approximately $66 million. If the decrease in regional pollution were accompanied by an increase in NRP exposure, then there would be an increase in each outcome that is triggered by regional air pollution or other factors among those with NRP-attributable asthma [from Table 1, Scenario 3, Columns (1) and (3) (in brackets to indicate an increase in disease burden)]. The total increase in costs would be $24 million [Table 3, Scenario 3, Columns (1)+(3)]. There would be a decrease in outcomes among those children with other-cause asthma [from Table 1, Scenario 3, Column (2)] and consequentially a decrease in costs of $43 million [Table 3, Scenario 3, Column (2)]. The net decrease in the total cost of all exacerbations in Scenario 3 would be $20 million. The exacerbations due to factors other than air pollution among children with NPR-attributable asthma [column (3)] account for most of the large difference between Scenarios 2 and 3 [a reduction of $23 million per year in Scenario 2 and an increase of almost that amount in Scenario 3].

Table 4 shows, for each scenario, the sum of the cost of exacerbations [column (1), which is the sum of columns (1)+(2)+(3) in Table 3] and of routine care for NRP-attributable asthma cases [column (2)]. Scenarios 1A and 1B in Table 4 reflect the total burden of NRP and regional pollution beyond that of cleaner comparison communities. A 100% reduction in major roadway proximity with a reduction in NO_2 levels to those in clean communities (Scenario 1A) would save approximately $203 million annually. Elimination of NRP proximity and reduction of O_3 to clean community levels (Scenario 1B) would save almost $441 million yearly. In Scenario 1A, 39% of the total cost of the current burden of NRP and regional NO_2 is due to the cost of routine care for NRP-attributable asthma cases (the analogous figure for O_3 is 18%). These NRP fixed costs have not been considered in previous regulatory risk assessments. The total cost savings achieved by reducing *both* regional pollution *and* proximity exposure (Scenario 2) are approximately $84 million; in comparison, *increasing* NRP exposure while reducing regional pollution provides a cost savings of only $2 million (Scenario 3). Thus, Scenario 3 suggests that the cost of the increased number of asthma cases due to NRP-attributable asthma eliminates almost all the savings of reducing regional pollution.

The asthma-related impact of NRP is the sum of the cost of all exacerbations among children with NRP-attributable asthma [columns (1) and (3) from Table 3] and the cost of routine care for NRP-attributable cases [column (2) from Table 4]. Thus, if NRP exposure were eliminated, $104 and $189 million could be saved, respectively, by also reducing NO_2 and O_3 to levels in clean communities.

Discussion

The cost of air pollution-attributable childhood asthma is large—between $203 (for NO_2) and $441 million (for O_3) in 2007. For perspective, that was 6% and 13%, respectively, of the health department's total expenditures on all health services for uninsured residents in LAC.[54] A 20% decrease in regional pollution accompanied by a 20% decrease in the proportion of children living near major roads would reduce the cost of asthma by approximately $81 million more than if that decrease in regional pollution were accompanied by a 20% increase in the proportion of the population living near major roads. If policies such as replacing automobiles with electric vehicles or creating buffers between major roadways and children's homes and schools are effective in eliminating cases of asthma attributable to traffic proximity exposure, the reduction in the total cost of the combined pollution-attributable burden would be 51% for NO_2 and 43% for O_3.

Expenditures to cover the direct costs of asthma represent a loss to society. In Los Angeles, 32% of children are covered by public insurance (Medi-Cal or Healthy Families);[55] therefore, public funds pay for 32% of the direct pollution-attributable costs of asthma ($34 million a year for NO_2). If this public expenditure were eliminated, that money could be used to extend Medi-Cal insurance to an additional 33,700 children each year (based on the cost of coverage and average healthcare expenditures[56]). Two doses of varicella vaccinations could be provided to an additional 135,218 children each year.[57] If we invested the recovered funds in education, then full-time pre-school could be provided for an additional 2,358 children, producing a societal benefit of $49 to $132 million a year (based on returns to investment in early education[58]).

Our methodology relied on two key assumptions. First, we assumed that without exposure to NRP, the child would not have developed asthma. Some of these children might have nonetheless developed asthma due to other risk factors, which would render our costs an overestimation. Second, we assumed that the CRF of proximity would be the same under alternative hypothetical scenarios, but the effects of traffic-proximity as a proxy for NRP are likely to decrease if average vehicle emissions decrease in the future.

There are additional uncertainties in estimating costs. Based on the previously estimated burden of disease,[7] we accounted for statistical uncertainty. Actual prices charged for healthcare vary over individuals; thus we used average estimates of charges. We also assumed that an NRP-attributable asthma case requires the same level of routine care and treatment for comorbidities as asthma due to other causes.

We assumed that outcomes associated with NO_2 and O_3 might affect the same individuals, and we did not sum the costs associated with each of these pollutants. In addition, some studies suggest that exposure to NO_2 may potentiate the effect of O_3,[59] or that prior O_3 exposure may exacerbate the effects of NRP in diesel exhaust.[60] Therefore, these estimates would underestimate costs if the effects were additive. Last, we may have underestimated the total costs of pollution-related asthma because we omitted the costs associated with adult asthma.

Conclusions

By properly accounting for the effects of both NRP and regional pollution on asthma exacerbations, we identified large and previously unappreciated costs. Disaggregating the effects of regional pollution and NRP exposure helps clarify the health co-benefits and cost savings that could be achieved by reducing exposure to both regional and near-roadway pollution. Although our results are specific to LAC, they are relevant to other large metropolitan areas because of the large numbers of children living near major roadways across the U.S.[1–2,61]

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding

This study was supported by the South Coast Air Quality Management District, a California state regulatory agency, with funds from a settlement with BP for violation of air quality regulations; NIEHS grants # R01 ES016535, P01ES011627, P30ES007048, P01ES009581, and 5R01ES014447; Environmental Protection Agency grants R826708, RD831861, R831845; and support from the Hastings Foundation.

References

1. U.S. Census Bureau. Current Housing Reports, Series H150/05. Washington, DC: U.S. Government Printing Office; 2006. American Housing Survey for the United States: 2005. Available at: www.census.gov/prod/2006pubs/h150-05.pdf. [Accessed December 23, 2012]
2. Health Effect Institute (HEI). Traffic-related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects. Boston, MA: Health Effects Institute; 2009.
3. Anderson H, Favarato G, Atkinson R. Long-term exposure to air pollution and the incidence of asthma: meta-analysis of cohort studies. Air Qual Atmos Health. 2013; 6:47–56.
4. Clark N, Demers P, Karr C, et al. Effect of early life exposure to air pollution on development of childhood asthma. Environ Health Perspect. 2010; 118:284–290. [PubMed: 20123607]
5. Salam MT, Islam T, Gilliland FD. Recent evidence for adverse effects of residential proximity to traffic sources on asthma. Curr Opin Pulm Med. 2008; 14:3–8. [PubMed: 18043269]
6. Kunzli N, Perez L, Lurmann F, Hricko A, Penfold B, McConnell R. An attributable risk model for exposures assumed to cause both chronic disease and its exacerbations. Epidemiology. 2008; 19:179–185. [PubMed: 18300713]
7. Perez L, Lurmann F, Wilson J, Pastor M, Brandt S, Künzli N, et al. Near-roadway pollution and childhood asthma: Implications for developing "Win-Win" compact urban development and clean vehicle strategies. Environ Health Perspect. 2012; 120:1619–1626. [PubMed: 23008270]
8. Perez L, Kunzli N, Avol E, Hricko AM, Lurmann F, Nicholas E, et al. Global goods movement and the local burden of childhood asthma in southern California. Am J Public Health. 2009; 99:S622–S628. [PubMed: 19890167]
9. McConnell R, Berhane K, Yao L, Jerrett M, Lurmann F, Gilliland F, et al. Traffic, susceptibility, and childhood asthma. Environ Health Perspect. 2006; 114:766–772. [PubMed: 16675435]
10. Landrigan P. The hidden costs of environmental contamination. ERJ. 2012; 40:286–288.
11. Levy J, Buonocore J, von Stackelber K. Evaluation of the public health impacts of traffic congestion: A health risk assessment. Environ Health. 2010; 9:65–76. [PubMed: 20979626]
12. Brandt S, Perez L, Künzli N, Lurmann F, McConnell R. Costs of childhood asthma due to traffic-related pollution in two California communities. ERJ. 2012; 40:363–370.
13. Sullivan PW, Smith KL, Ghushchyan VH, Globe DR, Lin SL, Globe G. Asthma in USA: its impact on health-related quality of life. J Asthma. 2013; 50:891–899. [PubMed: 23815682]
14. Organization for Economic Co-operation and Development (OECD). Economic Valuation of Environmental Health Risks to Children. Paris, France: OECD Publications; 2006.
15. Hubbell B, Fann N, Levy JI. Methodological considerations in developing local-scale health impact assessments: balancing national, regional, and local data. Air Qual Atmos Health. 2009; 2:99–110.
16. Arrow K, Solow R, Portney PR, et al. Report of the NOAA panel of contingent valuation. Fed Reg. 1994; 58:4601–4614.
17. Brandt S, Vásquez Lavín F, Hanemann M. Contingent valuation scenarios for chronic illnesses: The case of childhood asthma. Value Health. 2012; 15:1077–1083. [PubMed: 23244810]

18. Milet, M.; Tran, S.; Eatherton, M.; Flattery, J.; Kreutzer, R. The Burden of Asthma in California: A Surveillance Report. Richmond, CA: California Department of Health Services, Environmental Health Investigations Branch; 2007. Available at: http://www.californiabreathing.org. [Accessed June 19, 2013]
19. SCAQMD. Final 2012 Air Quality Management Plan. Diamond Bar CA: South Coast Air Quality Management District; 2013 Feb.
20. Jackson DJ, Sykes A, Mallia P, Johnston SL. Asthma exacerbations: Origin, effect, and prevention. J Allergy and Clin Immun. 2011; 128:1165–1174. [PubMed: 22133317]
21. Hall JV, Brajer V, Lurmann FW. Measuring the gains from improved air quality in the San Joaquin Valley. J Environ Manag. 2008; 88:1003–1015.
22. Ostro BD, Tran H, Levy JL. The health benefits of reduced tropospheric ozone in California. J Air Waste Manag Assoc. 2006; 56:1007–1021. [PubMed: 16878591]
23. Gauderman WJ, Avol E, Gilliland F, Vora H, Thomas D, Berhane K, et al. The effect of air pollution on lung development from 10 to 19 years of age. N Engl J Med. 2004; 351:1057–1067. [PubMed: 15356303]
24. Peters JM, Avol E, Gauderman WJ, Linn WS, Navidi W, London SJ, et al. A study of twelve southern California communities with differing levels and types of air pollution. Am J Respir Crit Care Med. 1999; 159:768–775. [PubMed: 10051249]
25. McConnell R, Berhane K, Gilliland F, Molitor J, Thomas D, Lurmann F, Avol E, Gauderman J, Peters J. Prospective study of air pollution and bronchitic symptoms in children with asthma. Am J Respir Crit Care Med. 2003; 168:790–797. [PubMed: 12893648]
26. Bureau of Labor Statistics (BLS). [Accessed December 15, 2013] CPI Inflation Calculator. Available at: http://www.bls.gov/data/inflation_calculator.htm.
27. Healthcare Cost and Utilization Project (HCUPnet). Rockville, MD: 2011. Agency for Healthcare Research and Quality. Available at: http://hcupnet.ahrq.gov. [Accessed Jan 15, 2011]
28. AAP Medicaid Reimbursement Survey 2007/2008. American Academy of Pediatricians (AAP). 2007/2008 Available at: http://www.aap.org/research/medreimpdf0708/49state_DC.pdf.
29. MEPS HC-089. [Accessed January 15, 2011] Full year consolidated data file. Agency for Healthcare Research and Quality. 2004. Available at: http://www.meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp.
30. Kattan M, Stearns S, Crain E, Stout J, Gergen P, Evans R, et al. Cost-effectiveness of a home-based environmental intervention for inner-city children with asthma. J Allergy Clin Immunol. 2005; 116:1058–1063. [PubMed: 16275376]
31. Epocrates. 2010 Available at: https://online.epocrates.com.
32. Steinman M, Gonzales R, Linder J, Landefeld S. Changing use of antibiotics in community-based outpatient practice, 1991–1999. Ann Intern Med. 2003; 138:525–533. [PubMed: 12667022]
33. National Household Travel Survey (NHTS). [Accessed June 30, 2010] U.S. Department of Transportation/Federal Highway Administration, Bureau of Transportation Statistics, and National Highway Traffic Safety Administration. 2009. Available at: http://nhts.ornl.gov/introduction.shtml.
34. Greek AA, Kieckhefer GM, Kim H, Joesch JM, Baydar N. Family perceptions of the usual source of care among children with asthma by race/ethnicity, language, and family income. J Asthma. 2006; 43:61–69. [PubMed: 16448968]
35. Cabana M, Slish K, Evans D, Mellins R, Brown X, Kaciroti N, Clark N. Impact of physician asthma care education on patient outcomes. Pediatrics. 2006; 117:2149–2157. [PubMed: 16740859]
36. Pitts, SR.; Niska, RW.; Xu, J.; Burt, CW. National health statistics reports. Hyattsville, MD: National Center for Health Statistics; 2008. National Hospital Ambulatory Medical Care Survey: 2006 Emergency Department Summary.
37. US Census Bureau. [Accessed December 15, 2012] State & County Quickfacts 2012. Available at: http://quickfacts.census.gov/qfd/states/06/06037.html.
38. Hanemann, M.; Brandt, S. Proceedings from Valuing Environmental Health Reductions to Children. Session V: Air Pollution and Asthma. Washington, D.C.: U.S. Environmental Protection

Agency; 2003. Valuing reduced asthma morbidity in children. Available at: http://www.epa.gov/ncer/publications/workshop/pdf/EE-0475-07.pdf. [Accessed June 5, 2013]

39. Anderson D, Binder M, Krause K. The motherhood wage penalty: Which mothers pay it and why? AEA Papers and Proceedings. 2002; 92:354–358.
40. California Health Interview Survey (CHIS). CHIS 2009 Adolescent and Child Public Use File. Los Angeles, CA: UCLA Center for Health Policy Research; 2009. Available at: http://www.chis.ucla.edu/get-data.html. [Accessed December 1, 2010]
41. Grupp-Phelan J, Lozano P, Fishman P. Health care utilization and cost in children with asthma and selected comorbidities. J Asthma. 2001; 38:363–373. [PubMed: 11456390]
42. Oeffinger KC, Snell LM, Foster BM, Panico KG, Archer RK. Diagnosis of acute bronchitis in adults: a national survey of family physicians. J Fam Pract. 1997; 45:402–409. [PubMed: 9374966]
43. Coco A, Mainou AG. Relation of time spent in an encounter with the use of antibiotics in pediatric office visits for viral respiratory infections. Arch Pediatr Adolesc Med. 2005; 159:1145–1149. [PubMed: 16330738]
44. Evertsen J, Baumgardner DJ, Regnery A, Banerjee I. Diagnosis and management of pneumonia and bronchitis in outpatient primary care practices. Prim Care Respir J. 2010; 19:237–241. [PubMed: 20490437]
45. Gonzales R, Sande M. Uncomplicated acute bronchitis. Ann Intern Med. 2000; 133:981–991. [PubMed: 11119400]
46. Nyquist AC, Gonzales R, Steiner JF, Sande MA. Antibiotic prescribing for children with colds, upper respiratory tract infections, and bronchitis. JAMA. 1998; 279:875–877. [PubMed: 9516004]
47. MEPS HC-112. [Accessed June 2010] Medical Condition Files. Agency for Healthcare Research and Quality. 2007. Available at: http://www.meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp
48. Machlin, S.; Yu, W.; Zodet, M. Computing Standard Errors for MEPS Estimates. Rockville, Md: Agency for Healthcare Research and Quality; 2005. Available at: http://www.meps.ahrq.gov/survey_comp/standard_errors.jsp. [Accessed May 5, 2011]
49. Bisgaard H, Szefler S. Prevalence of asthma-like symptoms in young children. Pediatric Pulmonolgy. 2007; 42:723–728.
50. Marchant JM, Newcombe PA, Juniper EF, Sheffield JK, Stathis SL. What is the burden of chronic cough for families? Chest. 2008; 134:303–309. [PubMed: 18641100]
51. Chang AB, Glomb WB. Guidelines for evaluating chronic cough in pediatrics: ACCP evidence-based clinical practice guidelines. Chest. 2006; 129:260s–283s. [PubMed: 16428719]
52. Chang AB, Robertson CF, van Asperen PP, Glasgow NJ, Masters IB, Mellis CM, Landau LI, Teoh L, Morris PS. Can a management pathway for chronic cough in children improve clinical outcomes: protocol for a multicentre evaluation. Trails. 2010; 11:103.
53. Abt Associates Inc. Bethesda, MD: Abt Associates Inc.; 2010. BenMAP: Environmental Benefits Mapping and Analysis Program, User's Manual. Available at: http://www.epa.gov/air/benmap/docs.html. [Accessed January 15, 2014]
54. Assessor. [Accessed September 2, 2014] The County of Los Angeles Annual Report 2007–2008. Public Affairs, Chief Executive Office. P 40. Available at: http://ceo.lacounty.gov/pdf/Annl%20Rpt%2007-08.pdf.
55. Lavarreda, SA.; Cabezas, L.; Jacobs, K.; Roby, DH.; Pourat, N.; Kominski, GF. The state of health insurance in California: Findings from the 2009 California Health Interview Survey. Los Angeles, CA: UCLA Center for Health Policy Research; 2012.
56. McCurdy, T.; Chan, R.; Chun, R.; Johnson, H.; O'Brien-Strain, M. Medi-Cal Expenditures: Historical Growth and Long Term Forecasts. San Francisco, California: Public Policy Institute of California; 2005. Available at: http://www.ppic.org/content/pubs/op/OP_605TMOP.pdf. [Accessed June 19, 2013]
57. Zhou F, Ortega-Sanchez I, Guris D, Shefer A, Lieu T, Seward J. An economic analysis of the universal varicella vaccination program in the United States. Journal of Infect Dis. 2008; 197:S156–S164. [PubMed: 18419391]

58. MacGillvary, J.; Lucia, L. Economic Impacts of Early Care and Education in California. California: UC Labor Center; 2011. Available at: http://laborcenter.berkeley.edu/research/child_care_report0811.pdf. [Accessed June 19, 2013]
59. Hazucha MJ, Folinsbee LJ, Seal E, Bromberg PA. Lung function response of healthy women after sequential exposures to NO_2 and O_3. Am J Respir Crit Care Med. 1994; 150(3):642–647. [PubMed: 8087332]
60. Bosson J, Pourazar J, Forsberg B, Ädelroth E, Sandström T, Blomberg A. Ozone enhances the airway inflammation initiated by diesel exhaust. Respir Med. 2007; 101(6):1140–1146. [PubMed: 17196810]
61. Health Effects Institute (HEI). Traffic-related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects. Boston, MA: Health Effects Institute; 2010.

Key messages

- The annual cost of asthma in Los Angeles County attributable to O_3 is approximately $441 million and to NO_2 approximately $202 million.
- Routine care for children with asthma attributable to near-roadway pollution was 18% of the combined NRP and O_3 cost and 39% of the combined NRP and NO_2 cost.
- NPR-attributable asthma accounted for 20% (NO_2) to 30% (O_3) of the cost of exacerbations due to pollution.
- The cost of near-roadway pollution (NRP) accounted for 51% of total asthma-related cost due to NRP and regional NO_2, and 43% of the total due to NRP and O_3.
- Cost of routine asthma care was almost $3,000 yearly for each child.
- The actual public expenditures in 2007 on the asthma-related burden of pollution could have provided public insurance to 33,000 children, or 135,000 varicella vaccinations, or full-time preschool for 2,000 children.

	NRP-caused asthma	**Other-cause asthma**
Routine care	Controller medication Comorbidities episodes Days with symptoms [Box 1]	NONE [Box 4]
Other-cause exacerbations	Bronchitis episodes Hospital admissions Emergency room visits Doctor visits School absences [Box 2]	NONE [Box 5]
Regional pollution-caused exacerbations	Bronchitis episodes Hospital admissions Emergency room visits Doctor visits School absences [Box 3]	Bronchitis episodes Hospital admissions Emergency room visits Doctor visits School absences [Box 6]

Figure 1.
Outcomes Associated with Exacerbations and Routine Care Attributable to Pollution

Table 1

Decrease [increase in brackets] in the number of asthma outcomes under different exposure scenarios relative to baseline NRP exposure and regional pollution

	Decrease [increase in brackets] in outcomes attributable to regional air pollution among those with asthma due to…			**Decrease [increase in brackets] in outcomes due to other causes among those with asthma due to NRP**	**Total decrease [increase in brackets] in outcomes (1)+(2)+(3)**
	Near roadway pollution (NRP) (1)	**Other factors (2)**	**Both NRP and other factors (1)+(2)**	**(3)**	**(4)**
Scenario 1A: Reduction in NRP-exposure and regional levels of NO_2 to background levels					
Bronchitis episodes	5600	59500	65100	5100	70200
95% CI	660–12100	20500–85700	22500–92800	900–11700	31000–95700
Hospital admissions	30	340	375	235	610
95% CI	5–65	265–420	295–450	50–450	410–840
Emergency room visits	35	370	405	1570	1970
95% CI	5–85	65–670	75–725	320–2970	690–3400
Doctor visits	870	9200	10100	19800	29900
95% CI	70–2140	1900–16500	2000–17900	4100–37700	12300–48900
Scenario 1B: Reduction in NRP-exposure and regional levels of O3 to background levels					
Bronchitis episodes	1610	17200	18800	9100	27800
95% CI	0–4050	530–32100	590–34900	1900–17600	9100–44300
Hospital admissions	1.9	20.7	22.6	270	290
95% CI	0.3–4.2	10–31.7	10.9–34.3	50–510	80–530
Emergency room visits	11	121	133	1590	1730
95% CI	2–23	75–167	84–181	330–3020	460–3160
Doctor visits	59	632	692	20600	21300
95% CI	6–144	160–1111	175–1207	4200–39100	4800–39800
School absences	27900	302000	329900	86200	416100
95% CI	449–70600	43800–562300	47700–612100	12000–168700	140200–681500
Scenario 2: Decrease in proportion of children living near major roadways and 20% reduction in regional pollution					
Bronchitis episodes (NO_2)	340	17600	17900	2000	19900
95% CI	30–820	4800–29300	4900–29900	400–4100	6900–31700

	Decrease [increase in brackets] in outcomes attributable to regional air pollution among those with asthma due to…			Decrease [increase in brackets] in outcomes due to other causes among those with asthma due to NRP	Total decrease [increase in brackets] in outcomes (1)+(2)+(3)
	Near roadway pollution (NRP) (1)	Other factors (2)	Both NRP and other factors (1)+(2)	(3)	(4)
Hospital admissions (NO_2)	1	75	80	60	135
95% CI	0–3	60–95	60–95	10–120	90–200
Emergency room visits (NO_2)	2	80	80	350	430
95% CI	0–4	15–145	15–150	70–700	140–790
Doctor visits (NO_2)	40	2020	2060	4500	6600
95% CI	0–100	400–3620	410–3700	860–9030	2530–11310
School absences (O_3)	350	18710	19050	24400	43400
95% CI	0–930	970–36510	980–37120	980–46800	14350–71760
Scenario 3: Increase in proportion of children living near major roadways and 20% reduction in regional pollution					
Bronchitis episodes (NO_2)	[339]	17929	17589	[2009]	15580
95% CI	[33]–[824]	4875–29879	4769–29273	[382]–[4042]	2288–27758
Hospital admissions (NO_2)	[1]	79	77	[58]	19
95% CI	[3]-0	62–96	60–94	[11]–[116]	[42]–70
Emergency room visits (NO_2)	[2]	81	80	[352]	[272]
95% CI	[4]-0	15–148	14–145	[67]–[703]	[630]-19
Doctor visits (NO_2)	[39]	2059	2020	[4519]	[2499]
95% CI	[3]–[100]	411–3697	403–3629	[859]–[9037]	[7305]-1552
School absences (O3)	[349]	19194	18846	[24367]	[5521]
95% CI	[930]-0	988–37354	968–36649	[968]–[46818]	[34370]-23222

Estimates are based on baseline outcomes, population and concentration-response functions reported in Perez et al. (2012). The baseline for each scenario is 2007 levels of NRP exposure and regional pollution. Scenario 1 is a 17.8 percentage point decrease in NRP exposure (to background levels of zero), decrease of 19.3 ppb of NO_2 (Scenario 1A) and decrease of 3.03 ppb of O_3 (Scenario 1B).

Scenario 2: Corresponds to a 3.56 percentage point decrease in NRP exposure, decrease of 3.9 ppb of NO_2 and decrease of 0.61 ppb of O_3 relative to the 2007 baseline.

Scenario 2: Corresponds to a 3.56 percentage point decrease in NRP exposure, decrease of 3.9 ppb of NO_2 and decrease of 0.61 ppb of O_3 relative to the 2007 baseline.

Values within brackets are an increase in the number of outcomes.

Table 2

Costs of routine asthma care for a single case of asthma and a single bronchitis episode (in 2010 US $)

Annual cost for routine asthma case	Mean annual occurrence (1)	Direct cost per occurrence (2)	Indirect costs per occurrence* (3)	WTP (4)	Annual cost per asthma case (1)*[(2)+(3)+(4)]
Quality of life	1	N/A	N/A	1549	1549
Medication					
Inhaled corticosteroid	2.19	125	N/ A		273
Cromolyn	1.07	95	N/A		102
Albuterol	6.81	55	N/A		374
Comorbidities*					
Doctor visits (non-urgent)	0.85	113	43		133
Mean cost of antibiotics	2.21	85	N/A		189
Urgent care visits	0.22	113	43		34
Hospital admissions	0.03	6,646	505		215
Days with symptoms	3.85			17	65
				Total cost per year	**2,934**

Cost for a typical bronchitis episode	Mean occurrence per bronchitis episode (1)	Direct cost per occurrence (2)	Indirect cost per occurrence* (3)	WTP per day (4)	Mean cost per bronchitis episode (1)*(2+3+4)
Doctor visits	1.15	113	43		179
Emergency room visits	0.06	844	107		57
Hospital admissions	0.01	16625	747		174
School absences	2.00	N/A	220		440
Antibiotics	1.16	85	N/A		99
Days with symptoms	35	N/A	N/A	17	595
			Total cost per episode		**1,544**

*The mean times were: 46.6 minutes for round-trip travel for medical purpose,[33] 23 minutes waiting for office visit,[34] 24 minutes for receiving care,[35] 3.16 hours for visiting the ER,[36] and 2.2 days for an asthma admission and 3.3 days for a bronchitis admission.[27]

Table 3

Decrease [increase in brackets] in annual costs of exacerbations of childhood asthma under scenarios (in 1000s of 2010 US $)

	Decrease [increase in brackets] in cost of exacerbations due to regional air pollution among children with asthma caused by…			Decrease [increase in brackets] in cost of exacerbations due to other causes among children with asthma due to NRP	Decrease [increase in brackets] in total cost of exacerbations
	NRP	**Other factors**	**All factors**		
	(1)	**(2)**	**(1) + (2)**	**(3)**	**(1) + (2) + (3)**
Scenario 1A: Reduction in NRP-exposure and regional levels of NO_2 to background levels					
Bronchitis episodes	8,646	91,868	100,514	7,874	108,389
95% CI	1,019–18,636	31,652–132,321	34,740–143,283	1,390–18.065	47,864–147,761
Hospital admissions	398	4,516	4,980	3,121	8,101
95% CI	66–863	3,519–55,778	3,918–5,976	664–5,976	5,445–11,156
Emergency room visits	33	352	385	1,493	1,873
95% CI	5–81	62–637	71–689	304–2,824	656–3,233
Doctor visits	136	1,434	1,574	3,086	4,660
95% CI	11–334	296–2,572	312–2,790	639–5,876	1,917–7,622
DECREASE IN COST IN SCENARIO 1A	**9,213**	**98,170**	**107,453**	**15,574**	**123,023**
95% CI	1,101–19,914	35,529–191,308	39,041–152,738	2,997–32,741	55,882–169,772
Scenario 1B: Reduction in NRP-exposure and regional levels of O_3 to background levels					
Bronchitis episodes	2,486	26,510	29,012	14,050	42,923
95% CI	0–6,258	823–49,522	908–53,898	2,934–27,174	14,050–68,399
Hospital admissions	25	275	300	3,586	3,851
95% CI	4–56	133–421	145–465	644–6,773	1,062–7,039
Emergency room visits	10	115	126	1,512	1,645
95% CI	2–22	71–159	80–172	314–2,872	437–3,005
Doctor visits	9	99	108	3,211	3,320
95% CI	1–22	25–173	27–188	655–6,094	748–6,203
School absences	20,785	224,981	245,766	64,216	309,982
95% CI	335–52,595	32,630–418,897	35,535–455,996	8,940–125,677	104,445–507,697
DECREASE IN COST IN SCENARIO 1B	**23,315**	**251,980**	**275,312**	**86,575**	**361,721**

	Decrease [increase in brackets] in cost of exacerbations due to regional air pollution among children with asthma caused by…			Decrease [increase in brackets] in cost of exacerbations due to other causes among children with asthma due to NRP	Decrease [increase in brackets] in total cost of exacerbations
	NRP	**Other factors**	**All factors**		
	(1)	**(2)**	**(1) + (2)**	**(3)**	**(1) + (2) + (3)**
95% CI	342–58,953	33,682–469,172	36,695–510,719	13,487–168,590	120,742–592,343
Scenario 2: Decrease in proportion of children living near major roadways and 20% reduction in regional pollution					
Bronchitis episodes (NO_2)	525	27,174	27,638	3,088	30,726
95% CI	46–1,266	7,411–45,239	7,566–46,166	618–6,330	10,654–48,945
Hospital admissions (NO_2)	13	996	1,062	797	1,793
95% CI	0–40	797–1,262	797–1,262	133–1,594	1,195–2,656
Emergency room visits (NO_2)	2	76	76	333	409
95% CI	0–4	14–138	14–143	67–666	133–751
Doctor visits (NO_2)	6	315	321	701	1,029
95% CI	0–16	62–564	64–577	134–1,407	394–1,763
School absences (O_3)	261	13,938	14,192	18,177	32,332
95% CI	0–693	723–27,199	730–27,653	730–34,865	10,690–53,459
DECREASE IN COST IN SCENARIO 2	**807**	**42,499**	**43,289**	**23,096**	**66,289**
95% CI	46–2,019	9,007–74,402	9,171–75,801	1,682–44,862	23,066–107,574
Scenario 3: Increase in proportion of children living near major roadways and 20% reduction in regional pollution					
Bronchitis episodes (NO_2)	[523]	27,682	27,157	[3,102]	24,056
95% CI	[51]–[1,272]	7,527–46,133	7,363–45,198	[590]–[6,241]	3,533–42,858
Hospital admissions (NO_2)	[13]	1,049	1,023	[770]	252
95% CI	[40]-0	823–1,275	797–1,248	[146]–[1,541]	[558]–930
Emergency room visits (NO_2)	[2]	77	76	[335]	[259]
95% CI	[4]-0	14–141	13–138	[64]–[668]	[18]–[599]
Doctor visits (NO_2)	[6]	321	315	[704]	[389]
95% CI	[16]-0	64–576	63–566	[134]–[1,409]	[242]–[1,139]
School absences (O_3)	[260]	14,299	14,040	[18,153]	[4,113]
95% CI	[693]-0	736–27,828	721–27,302	[721]–[34,878]	[17,300]–[25,065]

	Decrease [increase in brackets] in cost of exacerbations due to regional air pollution among children with asthma caused by…			Decrease [increase in brackets] in cost of exacerbations due to other causes among children with asthma due to NRP	Decrease [increase in brackets] in total cost of exacerbations
	NRP	**Other factors**	**All factors**		
	(1)	**(2)**	**(1) + (2)**	**(3)**	**(1) + (2) + (3)**
DECREASE [INCREASE IN BRACKETS] IN COST IN SCENARIO 3	**[804]**	**43,428**	**42,611**	**[23,064]**	**19,547**
95% CI	[51]–[2,025]	9,164–75,953	8,957–74,452	[1,655]–[44,737]	[24,368]–61,348

The baseline was 2007 exposure to NRP and levels of NO_2 and O_3. Scenario 1 was17.8 percentage point decrease in NRP exposure (to background levels of 0). Scenario 1A was a decrease of 19.3 ppb of NO_2, and Scenario 1B was a 3.03 ppb decrease of O_3. Values may not sum due to y not sum due to rounding.

Scenario 2 was a 3.56 percentage point decrease in NRP exposure with decreases of 3.9 ppb of NO_2 and 0.61 ppb of O_3. Scenario 3 was a 3.56 percentage point increase in NRP exposure with decreases of 3.9 ppb of NO_2 and 0.61 ppb of O_3. Values within brackets are increases in cost. Values may not sum due to rounding.

Table 4

Decrease [increase in brackets] in the annual total costs of pollution-attributable asthma relative to baseline (in millions of 2010 US $)

	Decrease in cost [increase in brackets] of pollution-attributable exacerbations (1)	Decrease in cost [increase in brackets] of routine care for asthma due to NRP (2)	Decrease in total cost [increase in brackets] (1) + (2)
Scenario 1A			
100% reduction in proportion of children living near major roadways AND reduction of NO_2 to the background level of clean communities	123	80	203
95% CI	56–170	14–150	70–320
Scenario 1B			
100% reduction in proportion of children living near major roadways AND reduction of O_3 to the background level of clean communities	362	80	441
95% CI	121–592	14–150	135–743
Scenario 2			
20% reduction in proportion of children living near major roadways AND 20% reduction in regional pollution	66	17	84
95% CI	23–108	3–35	26–142
Scenario 3			
20% increase in proportion of children living near major roadways AND 20% reduction in regional pollution	20	[17]	2
95% CI	[24]-61	[3]–[35]	[27]-27

Values within brackets are increases in costs. In scenarios 2 & 3, the pollution change is for NO_2 for all outcomes except for school absences, for which we used O_3. The cost of routine care is the cost for a case (Table 2) multiplied by the change in number of cases attributable to NRP exposure (decrease of 27,100 for Scenarios 1A and 1B, increase of 5,900 for Scenario 2, and decrease of 5,900 for Scenario 3). Values may not sum due to rounding.