IEc

MEMORANDUM | November 28, 2016

TO Elaine Shen, South Coast Air Quality Management District

FROM Henry Roman and Heather Marrison, Industrial Economics, Incorporated

Lisa A. Robinson, Independent Consultant

SUBJECT Review of Morbidity Valuation Estimates for Use in 2016 Socioeconomic Assessment

---

In its role as the air pollution control agency for the South Coast Air Basin, the South Coast Air Quality Management District (SCAQMD) develops air pollution control plans to help this portion of California achieve compliance with Federal and State air quality standards. As part of the development of the regional Air Quality Management Plan (AQMP), SCAQMD considers its socioeconomic impacts, including its expected benefits and costs. The resulting AQMP Socioeconomic Analysis includes a detailed assessment of the benefits of reducing air pollutant concentrations, which requires the use of several datasets covering a wide array of information including, but not limited to, data on health condition incidence, demographics, concentration-response relationships, and economic values.

A review of the SCAQMD's past socioeconomic assessment by Abt Associates (2014) identified the following ways in which the benefits analysis could be strengthened:

- Instituting a more transparent and systematic process for conducting literature reviews relevant to the Socioeconomic Assessment;
- Clarifying the application of benefit transfer approaches that may be used to adjust concentration-response functions or benefit valuation inputs; and,
- Providing greater information about uncertainty in the benefits analysis, both qualitative and quantitative.[1]

As it prepares for the 2016 AQMP Socioeconomic Analysis, SCAQMD needs to ensure that it is applying the most up-to-date, scientifically-defensible methods and inputs for calculating the benefits to society resulting from air pollution strategies, addressing the issues noted above. In a separate memorandum, we discuss the approach for valuing mortality risk reductions associated with implementation of the 2016 AQMP. In this memorandum, we provide our recommendations for valuing morbidity risk reductions.

---

[1] Available at http://www.aqmd.gov/home/library/clean-air-plans/air-quality-mgt-plan/socioeconomic-analysis.

Below, we define relevant concepts, describe our analytic approach (including the morbidity health endpoints to be valued), provide the results of our literature review, and summarize our conclusions.

CONCEPTUAL FRAMEWORK[2]

The approach for valuing morbidity risk reductions is grounded in the same standard welfare-economic concepts as the approach for valuing mortality risk reductions and other regulatory outcomes.[3] This framework assumes that each individual is the best judge of his or her own welfare ("consumer sovereignty"), which means that benefit values should be based on the preferences of those affected by a regulation. As a corollary, economists conventionally assume that if an individual chooses to buy a good or service, then he or she values the good or service more than the other goods or services he or she could have used that money to buy. Money is not of interest *per se*; rather it is used to measure the trade-offs that individuals are willing to make between different types of consumption.

More generally, economic theory recognizes that, because resources are limited, any decision to use them for one purpose means that they cannot be used for other purposes. Hence the value of a resource can be determined based on the value of its best alternative use; i.e., its opportunity cost. Given this framework, estimates of individual willingness to pay (WTP) provide the conceptually appropriate measure of value for benefits that represent an improvement from the status quo, such as the reductions in morbidity risks associated with SCAQMD's 2016 AQMP. However, WTP estimates are available for relatively few nonfatal health effects. As a result, alternative approaches are often used as proxies. The two most common are cost of illness (COI) and monetized quality-adjusted life year (QALY) estimates.

In previous SCAQMD analyses, as well as in analyses conducted by the U.S. Environmental Protection Agency (EPA), COI estimates are more commonly used. Estimating monetized QALYs requires addressing numerous difficult issues related to constructing the QALY measure and determining its monetary value (see Institute of Medicine 2006, Robinson and Hammitt 2013 for more discussion). Thus we first review the WTP literature to determine whether suitable estimates of reasonable quality are available for each endpoint. We then search for COI estimates to address those endpoints for which such WTP estimates are unavailable. We describe the WTP and COI concepts in more detail below.

WILLINGNESS TO PAY

WTP is the maximum amount of money an individual would voluntarily exchange to obtain an improvement, given his or her budget constraint. It indicates the point at which

---

[2] This discussion is derived from previous work conducted by Ms. Robinson in collaboration with Dr. James K. Hammitt of Harvard University, particularly Robinson and Hammitt, (2013), which can be freely download from: http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=9456622&fulltextType=RA&fileId=S2194588800000518.

[3] For ease of reference, we repeat some information here that is also provided in our memorandum on valuing mortality risk reductions.

the individual would be equally satisfied with having the good and less money, or with spending the money on other things. This framing mimics the actual trade-offs implicit in regulation. If we choose to spend more on regulations that reduce air pollution risks, we will have less to spend on other goods or services – including other risk-reducing measures.

For goods such as morbidity risk reductions, prices do not exist because they are not directly bought and sold in markets. Instead, economists typically use revealed or stated preference studies to estimate WTP. Revealed preference studies rely on observed market behavior to estimate the value of related nonmarket goods, and have the advantage of reflecting decisions with real consequences. However, few such studies are available that address the types of morbidity risk reductions associated with air pollution regulations. For example, wage-risk (or hedonic-wage) studies examine the compensation associated with jobs that involve differing risks of nonfatal injury, using statistical methods to separate the effects of these risks from the effects of other job and personal characteristics (see, for example, Viscusi and Aldy 2003, Gentry and Viscusi 2015). The nonfatal risk variable is usually defined as the overall injury rate, the rate for injuries severe enough to result in a lost workday, or the rate of lost workdays, which cannot be easily translated into values for the diverse types of respiratory and cardiovascular effects typically associated with air pollution regulations.

Other revealed preference studies consider averting behavior, including defensive measures or consumer products used to protect against perceived health risks. These may involve, for example, staying indoors when air quality is poor, or purchasing an air conditioner in part to filter pollutants. However, it is often difficult to separate out the value of a particular type of morbidity risk reduction from the value of other attributes, such as cooling in the case of air conditioners, and to determine the size of the risk reduction the individual believes he or she is achieving. In addition, such studies may require applying assumptions about the value of time or other influencing factors that are not necessarily well-supported by empirical research. Thus such studies are infrequently recommended for application in policy analysis.

In contrast, stated preference methods typically employ survey techniques to ask respondents about their WTP for the outcome of concern. They may directly elicit WTP for a particular scenario, or may present respondents with two or more scenarios involving different attributes and prices. In the latter case, estimates of WTP are derived from the way in which respondents choose, rank, or rate alternatives. Stated preference methods are attractive because researchers can tailor them to directly value the outcome(s) of concern; i.e., the survey can describe particular types of health risks that result from specific causes and also describe the characteristics of those affected. However, a key concern is that respondents may have little incentive to respond accurately, since the payment is hypothetical. Conducting a study that yields accurate and reliable results requires careful design and implementation.

COST OF ILLNESS

COI studies address the real resource costs of incurred cases of illness, injuries, and deaths, rather than the amount of money an individual is willing to exchange for a risk reduction. Thus they are a different measure, and value a different outcome, than the

WTP estimates discussed previously. The logic behind using costs to value benefits is that, if a policy allows society to avoid these costs, then the benefits are at least equal to the averted expenditures.[4]

COI studies often address both direct medical costs and indirect productivity losses. Medical costs may consist of those paid by patients, their families, and/or third parties such as insurance companies and employers. These costs may be associated with physician services, medication, hospital stays, and other treatment-related activities. Additional costs, such as those related to processing insurance claims, are at times included. The indirect costs associated with lost productivity may stem from absence from work or from decreased productivity while at work, and may include other costs such as those associated with idling assets or training replacement workers.

In COI studies, compensation is generally used to value productive time, under the assumption that workers are paid the value of their marginal product; this is referred to as the "human capital" approach. While the measure of compensation varies across studies, it often includes both pre-tax wages and fringe benefits. Some studies also consider unpaid work (such as volunteer and household services), in which case the value of lost productivity is often based on the compensation of employed workers with similar responsibilities (see, for example, Grosse, Krueger, and Mvundura 2009). This approach focuses on production and does not address the value of leisure time.

One question that arises is whether this approach to valuing changes in time use is appropriate for benefit-cost analysis. In such analyses, we are interested in opportunity costs, comparing time use without and with the policy, and in including the value of leisure time as well as paid and unpaid production. While both theory and empirical evidence suggest that the value of time varies depending on the characteristics of the affected individuals and activities, we generally lack estimates of WTP that are directly applicable to the types of time losses attributable to air pollution, as discussed in more detail in the "Results" section below.[5] Conventionally, analysts instead rely on compensation measures as a reasonable proxy.[6] For changes in paid work time, the rational for relying on compensation is the same as under the human capital approach introduced above. For unpaid work and leisure, analysts assume that, at the margin, the individual values an hour of unpaid work or leisure by at least the amount he or she could have earned in the labor market, which may differ from the costs of a replacement

[4] This need not be true in all cases. For example, when choosing a treatment, the individual may ignore those costs that are covered by insurance. As a result, adding costs paid by third parties to out-of-pocket costs may lead to a value that exceeds what the individual would have been willing to pay himself or herself for that treatment. However, costs paid by third parties can be added to WTP estimates to reflect the total impact of the health effect on both the individual and society at large, as long as the WTP estimates are based only on the individual's WTP for his or her own risk reductions (i.e., solely reflect out-of-pocket expenditures).

[5] Much of the work on these issues addresses the impacts of transportation options and recreational opportunities, rather than the types of time use of interest for the 2016 Socioeconomic Assessment. See, for example, U.S. Department of Transportation (2015) and Phaneaf and Smith (2005).

[6] See Russell (2009) for more discussion of these issues, including the need to measure opportunity costs in COI studies.

worker.[7] Both the human capital approach and this labor-leisure trade-off reflect simplifying assumptions and ignore labor market distortions (such as the requirement to work fixed hours and the effects of taxes), but have the advantage of relying on widely-available and easily-accessible compensation data. As a result, in benefit-cost analysis, analysts often use compensation data to estimate the opportunity costs associated with changes in both paid and unpaid time use.

Developing and applying COI estimates in these analyses requires first identifying the types of costs that may be averted then locating sources that estimate these costs. Many of the available data sources have significant limitations in this context. Air pollution and other policies often result in small changes in the overall incidence of a health effect, yet COI studies usually focus on average costs per case rather than on marginal costs per case averted. Such policies also may prevent an illness from occurring, averting related costs over many years. However, many COI studies are prevalence- rather than incidence-based, addressing costs within a particular year rather than over time. In addition, many of the available data sources were developed to support reimbursement decisions and are not necessarily appropriate for estimating costs in benefit-cost analysis.

Comparison across studies suggests that different approaches to cost estimation can lead to noticeably different results depending on the details of the approach (see, for example, Bloom et al. 2001, Akobundu et al. 2006, and Larg and Moss 2011), but there is no established set of recommended best practices applicable to benefit-cost analysis. Thus the use of these studies as a proxy for WTP for morbidity risk reductions requires application of substantial judgment as well as appropriate characterization of uncertainty. While COI estimates are believed to often understate WTP (e.g., because they ignore the value of averted pain and suffering), it can be difficult to demonstrate the extent to which this is the case. Comparing WTP and COI estimates for the same condition requires controlling for other factors that influence the values, including both how the health outcomes are defined in each case and the methodological choices made by the researchers. Thus the direction and magnitude of the resulting bias is difficult to quantify.

ANALYTIC APPROACH

In this section, we describe our approach to identifying values for the air pollution-related morbidity endpoints likely to be addressed in the SCAQMD 2016 Socioeconomic Assessment. We first list the endpoints recommended for evaluation and the values previously used. We then describe our search procedure and evaluation criteria, beginning with our review of the WTP literature then turning to the application of COI estimates where necessary.

Our approach follows the “benefit transfer” framework. Regulatory analysts generally must rely on existing valuation studies, given the substantial time and expense associated with conducting new primary research. As a result, they usually transfer values from

[7] For example, if a highly paid individual chooses to stay home to care for a child, his or her opportunity cost (i.e., foregone market wages) may well exceed the cost of hiring a child-care worker. Alternatively, some individuals engage in essential nonmarket work because the cost of hiring a replacement worker exceeds their market wage, and presumably value the nonmarket work time at minimum at their own market wage rate.

studies that address contexts that differ in some respects from the policy context. This approach requires careful review of the literature to identify high-quality studies that are suitable for use in the policy context. "Quality" can be evaluated by considering the likely accuracy and reliability of the data and methods used, referencing guidance on best practices. "Suitability" or "applicability" involves considering the similarity of the risks and the populations affected. The transfer itself may involve relying on a single study or combining the results from several studies, adjusting the results where feasible to better fit the policy context.

HEALTH ENDPOINTS AND PREVIOUS VALUATION APPROACHES

The starting point for monetary valuation is an estimate of the number of statistical cases averted by the policy for each health endpoint. The term "statistical" is used to emphasize that the policy leads to a reduction in risk across the affected population; in other words, the estimates of the cases averted represent the summing of probabilities across many individuals. The value of these statistical cases is then estimated using the methods introduced above.

Exhibit 2 lists the health endpoints which Industrial Economics, Incorporated (IEc) proposes that SCAQMD consider in the 2016 Socioeconomic Assessment, as discussed in our separate memoranda. The descriptions of each endpoint are taken from the epidemiological studies suggested for use in the 2016 analysis. In some cases, hospital admissions are assumed to reflect new incidence; in others, hospital admissions may reflect exacerbations of existing conditions as well as new incidence. In its 2012 analysis, SCAQMD relied on then-available values from the U.S. EPA's Benefits Analysis and Mapping Program (BenMAP).[8] In the exhibit, we provide updated values from that program, as reported in EPA's final 2015 regulatory impact analysis for the revised National Ambient Air Quality Standards for Ground-Level Ozone (EPA 2015b). That analysis provides unit (per case) values for health effects associated with particulate matter (PM) as well as ozone exposure.

Two issues are apparent from review of Exhibit 1. The first is that the values currently used by EPA are largely based on COI estimates, rather than on estimates of individual WTP for risk reductions. The second is that the WTP studies used are generally over 20 years old (derived from a review IEc conducted for EPA in 1994), and hence unlikely to reflect the preferences of the current population given changes in the medical treatments available and other factors. While SCAQMD could again rely on the BenMAP estimates in its 2016 Socioeconomic Assessment, as it did in 2012, these concerns suggest that an updated review of the literature is warranted.[9] Thus we first review the WTP literature to determine the extent to which newer research is available that addresses these health

---

[8] Available at: http://www2.epa.gov/benmap; see EPA (2015a) for more information.

[9] Before applying these values, SCAQMD would need to inflate them to the base year to be used in its analysis and adjust the WTP estimates for real income growth, and also discount future values at the same rate as used elsewhere in its analysis (see EPA 2015a, 2015b for more discussion). Thus the values to be applied would likely be somewhat larger than those reported in the exhibit.

endpoints. For the endpoints for which WTP studies are not available, we then review the COI literature and relevant databases to develop updated values.

EXHIBIT 1. PROPOSED NONFATAL HEALTH ENDPOINTS AND PREVIOUS ESTIMATES OF VALUE

NONFATAL ENDPOINT[a] (AGE RANGE)	POLLUTANT	EPA (2015) VALUES[b,c]	VALUATION METHOD
New incidence (chronic)			
Stroke, ischemic (>65 years)	PM	N/A	N/A
Nonfatal myocardial infarction (>18 years)	PM	$100,000 to $210,000 depending on age (Cropper and Krupnick 1990, Russell et al. 1998, Wittels et al. 1990)	COI (direct and indirect)
Asthma incidence (new cases) (<18 years)	NO_2	N/A	N/A
Hospitalization and emergency room visits only			
Hospital admissions, cardiovascular (>20 years)	PM	$42,000 to $44,000 depending on age and health condition (Agency for Healthcare Research and Quality 2007, U.S. Census 2007)[d]	COI (direct and indirect)
Hospital admissions, respiratory (>18 years)	PM, Ozone	$16,000 to $37,000 depending on age and health condition (Agency for Healthcare Research and Quality 2007, U.S. Census 2007)[d]	COI (direct and indirect)
Emergency department visits, respiratory, asthma; and hospital admissions, respiratory, asthma (<18 years)	PM, Ozone	$440 for emergency room visits (Smith et al. 1997, Stanford et al. 1999); $16,000 for hospitalization (Agency for Healthcare Research and Quality 2007, U.S. Census 2007)[d]	COI (direct and indirect)
Other respiratory ailments (not requiring hospitalization)			
Acute bronchitis (8-12 years)	PM	$460 (IEc 1994 literature review)	WTP
Lower respiratory symptoms[e] (7-14 years)	PM or NO_2/SO_2	$22 per symptom-day (IEc 1994 literature review)	WTP
Upper respiratory symptoms[f] (9-11 years)	PM	$35 per symptom-day (IEc 1994 literature review)	WTP
Asthma exacerbation[g] (4-18 years, >34 years)	PM or NO_2	$56 per symptom day (Rowe and Chestnut 1986)	WTP
Activity restrictions			
Work loss days (18-64 years)	PM	$150 (median) (U.S. 2000 Census as reported in Geolytics 2002)	COI (earnings only)
School loss days (5–17 years)	Ozone	$98 (U.S. Census 2001)	COI (parent's lost earnings only)
Acute respiratory symptoms/ Minor restricted-activity days[h] (18-65 years)	PM, Ozone	$64 (Tolley et al. 1986)	WTP

Notes:
N/A = not available; these endpoints were not included in the EPA (2015b) analysis.
PM = particulate matter; NO_2 = nitrogen dioxide; SO_2 = sulfur dioxide.
a. Endpoints are from IEc's separate memoranda; descriptions are from the recommended epidemiological studies and may differ in some respects from those used in EPA's analysis. Age ranges encompass all related studies; individual studies generally address a narrower range.
b. All values are per statistical case unless otherwise noted.
c. EPA (2015b) Chapter 6 and Table 6-10. Values are expressed in 2011 dollars, for 2000 income levels, using a 3 percent discount rate. EPA also reports values at 2024 income levels and using a 7 percent discount rate.
d. Medical cost data are taken from the Agency for Healthcare Research and Quality (AHRQ) Healthcare Utilization Project (HCUP) National Inpatient Sample (NIS) database. Lost earnings are estimated based on U.S. Census 2007 American Community Survey (ACS).
e. Includes two or more of the following: cough, chest pain, phlegm, wheeze.
f. Includes runny or stuffy nose, wet cough, burning, aching, or red eyes.
g. Includes cough, wheeze, shortness of breath, tightness of chest.
h. Minor restricted activity days not resulting in work loss or bed disability.

APPROACH FOR REVIEW OF THE WTP LITERATURE

The value of morbidity risk reductions has received less attention than the value of mortality risk reductions in the research literature. As a result, fewer studies have been completed and the available research is not likely to meet the stringent criteria IEc applied in its separate review of the mortality risk valuation literature. Instead, we apply the five criteria listed in Exhibit 2, understanding that the use of these less stringent criteria may affect our confidence in the estimates.[10]

EXHIBIT 2. EVALUATION CRITERIA FOR WTP STUDIES

GENERAL CRITERIA
1. Study is publicly available. 2. Study is written in English. 3. Study is conducted in the U.S.
CRITERIA FOR STATED-PREFERENCE STUDIES
4. Study elicits values for private risk reductions that accrue to the respondent. 5. Study estimates WTP, not willingness to accept compensation.

General Criteria: These criteria relate to the context in which the WTP estimates will be applied. Because SCAQMD's analyses are intended to inform decision-makers and the general public, those reviewing the analyses must be able to access and read the underlying data sources. We include studies published in peer-reviewed journals as well as those that have not yet appeared in journals but that are available as part of institutional working paper series or government reports.[11] We consider all U.S. studies, regardless of whether they address the national population or are limited to particular localities. We exclude studies based on convenience samples rather than on probabilistic samples, because the latter are more likely to provide estimates that are representative of the underlying population.

Criteria for stated-preference studies: We apply search criteria that include both stated and revealed preference studies, but focus on stated preference studies because of the concerns about the available revealed preference studies for nonfatal risks.[12] For example, as noted earlier, wage-risk studies generally provide values for nonfatal injuries that are not disaggregated to reflect their duration and severity, and averting behavior studies have several limitations that may affect their quality.[13] We select only studies that address WTP rather than willingness to accept compensation (WTA). WTP is conceptually the more appropriate measure because the policies to be assessed by SCAQMD generally involve expenditures for improvements from the status quo rather than compensation for damages. WTP is also more frequently studied and the estimates are generally considered

---

[10] Similar criteria were applied in the Robinson and Hammitt (2015) review of morbidity valuation studies.

[11] We exclude papers published as part of conference or workshop proceedings because such papers generally report preliminary results which are subject to change. If a peer-reviewed journal article is available on the same study, we exclude earlier working papers and reports.

[12] We did not identify any revealed preference studies that meet our general criteria and address the health effects of concern, as discussed in more detail below.

[13] Similar concerns apply to property value studies that use hedonic methods to estimate the contribution of health risks to these values.

more reliable; the large and variable differences between estimated WTP and WTA are poorly understood (see Robinson and Hammitt 2013 for more discussion).

For those endpoints that involve risks to adults, we focus on studies of individual WTP for one's own risk reductions, consistent with the concept of consumer sovereignty introduced above. For those endpoints that involve risks to children, it is necessary to diverge from this framing, because children lack the financial resources and the cognitive skills to respond to WTP questions (particularly if very young).[14] Therefore we instead focus on adult WTP to reduce children's risks.

Because very few studies are available, we select all that meet these criteria, without further screening for evidence of validity. However, we exclude studies published in 1994 or earlier for two reasons. First, earlier studies were identified in the review IEc completed in 1994, which is the basis for the WTP estimates currently used by EPA as presented in Exhibit 1. Our goal is to determine whether more recent studies are available that are more appropriate for valuing these endpoints. Second, in 1993 the National Oceanic and Atmospheric Administration issued an expert panel report that significantly influenced the conduct of stated-preference studies, presumably improving their reliability and validity.

We searched for WTP studies using the following search terms and databases:

Terms:

- Willingness to pay or WTP or willingness-to-pay, in combination with one or more of the terms in the next bullet.
- Respiratory, asthma, emergency room visits, hospital admissions, school loss days, acute bronchitis, myocardial infarction, cardiovascular, work loss days, stroke.
- Date: 1994-present

Databases:

- Scopus
- PubMed
- EBSCO EconLit, Business, and Environment databases
- Google Scholar[15]

We then compared each study to the criteria in Exhibit 2 and evaluated the similarities between the population and health effects studied and the endpoints listed in Exhibit 1. We also used the citations in each paper to identify additional studies.

As part of our search, we identified several reviews and meta-analyses that are not directly applicable to the SCAQMD analysis. Some are general methodological

[14] For more discussion of issues related to valuing children's health risks, see Dockins et al. (2002) and Gerking and Dickie (2013).

[15] We conducted all searches in November 2015.

discussions; others include studies that do not meet our evaluation criteria or that address health endpoints other than the types of cardiovascular and respiratory effects (and related activity restrictions) associated with air pollution exposures.[16] However, we reviewed the lists of studies they include to identify those that are relevant to the SCAQMD analysis. We provide our results in the subsequent section, after describing our approach to reviewing the COI literature.

APPROACH FOR REVIEW OF THE COI LITERATURE AND DATABASES

Our review of the COI literature included both databases and research studies, focusing on those endpoints for which WTP studies are unavailable or have significant shortcomings. For some endpoints, particularly hospitalization and earnings, we were able to retrieve up-to-date cost estimates from publicly accessible databases. Other endpoints, such as incident cases of stroke, myocardial infarction, and asthma, require additional analysis to track patients over time or to account for other expenses. For these latter endpoints, we review the COI literature to identify relevant studies.

In Exhibit 3, we list the criteria applied to COI studies. The general criteria are identical to the criteria used for the WTP studies; the specific criteria relate to the quality of the studies and their applicability to the health effects of concern. Note that although we include studies conducted anywhere in the U.S., we prefer estimates for California or the SCAQMD region where available.

EXHIBIT 3. EVALUATION CRITERIA FOR COI STUDIES

GENERAL CRITERIA
1. Study is publicly available. 2. Study is written in English. 3. Study is conducted in the U.S.
CRITERIA FOR COI STUDIES
4. Study includes clear description of the elements that make up the COI estimate. 5. Study includes clear description of health endpoint and estimates incidence-based or prevalence-based cost as appropriate for the health endpoint evaluated. 6. Prefer studies that estimate costs specific to affected groups (especially affected age groups).

For those endpoints where WTP studies that meet our criteria were unavailable, we searched the COI literature using the following search terms and databases:

<u>Terms</u>

- Adult stroke and cost of illness or COI or cost-of-illness;

[16] These reviews and meta-analyses include: Alberini et al. 2010, Cameron 2014, Diener et al. 1998, Gerking and Dickie 2013, Hunt and Ferguson 2010, Hunt 2011, Hunt et al. 2016, Johnson et al. 1997, Olsen and Smith 2001, Vassanadumrongdee et al. 2004, and Van Houtven et al. 2006.

- myocardial infarction or MI and cost of illness or COI or cost-of-illness and incidence;
- Child asthma cost of illness, child asthma COI, child asthma cost-of-illness, kid asthma cost of illness, kid asthma COI, kid asthma cost-of-illness, pediatric asthma cost of illness, pediatric asthma COI, pediatric asthma cost-of-illness
- Child asthma emergency cost of illness, child asthma emergency COI, child asthma emergency cost-of-illness, pediatric asthma emergency cost of illness, pediatric asthma emergency COI, pediatric asthma emergency cost-of-illness
- Dates: vary by endpoint; typically 2009 - present

Databases

- PubMed

We supplemented the results of this review with two COI-related studies prepared for the California Air Resources Board (CARB) and available on CARB's website (Thayer et al. 2003 and Hall et al. 2003). Thayer et al. (2003) was subsequently published as Chestnut et al. (2006); as discussed below, we supplement the COI-based hospital admissions values with WTP-based hospital admission values from that paper.

For hospital admissions, emergency room visits, and changes in time use, we identified relevant databases in addition to available studies, including the data sources referenced in the EPA (2015b) analysis cited in Exhibit 1 as well as in a comprehensive review of data sources (Lund et al. 2009) and in previous work conducted by team members. We describe the databases used for hospitalization and time use in more detail below. As discussed in the "Results" section, for emergency room visits we ultimately rely on COI studies that specifically address the outcomes of concern rather than drawing data from the available databases.

Cost of Hospital Admissions

Our estimates for hospitalizations include two components: the cost estimates discussed in this section and a WTP estimate discussed later in this memorandum. To develop the cost estimates, we reviewed free, publicly accessible databases within the Healthcare Cost and Utilization Project (HCUP) that are searchable through the HCUPNet website.[17] We rely on the State Inpatient Databases (HCUP-SID) which consist of hospital discharge records from the State data organizations. HCUP-SID is composed of annual, state-specific files with clinical and non-clinical information on all patients. We opted to use this source because it provides data specific to the counties of interest and the state of California. Within the databases, we searched for each endpoint based on the principal diagnoses grouped by Clinical Classifications Software (CCS) at the county level and by ICD-9-CM code at the state level. Our review of the ICD codes that comprise the CCS categories indicated that the categories for county-level data include some ICD codes not included in our endpoint definitions; thus, we chose to use the state-level data, which we were able to restrict to specific ICD codes.

[17] See http://hcupnet.ahrq.gov/HCUPnet.jsp.

Value of Changes in Time Use

As discussed in the "Conceptual Framework" section, we rely on compensation data to value the effects of air pollution-related morbidity on time use, including paid work and unpaid work and leisure. Our starting point is a per hour value, which can be multiplied by the number of hours affected to value lost work and school days as well as the indirect costs associated with hospitalizations and other health endpoints.

For this hourly value, we rely on data on employee compensation. One issue that arises in this context is the treatment of taxes and fringe benefits. For paid work, the cost to the employer clearly includes taxes and fringe benefits; for unpaid work and leisure, it is unclear whether individuals take taxes and fringe benefits into account in deciding how to allocate time between paid and unpaid activities. In addition, for air pollution-related hospitalizations and lost school days, we are uncertain about the extent to which individuals would otherwise spend time in paid work, especially since some health endpoints predominantly affect individuals who are likely to be out of the paid labor force, such as the elderly, young children, and some caregivers. Thus we use the same values for all types of time use, and include taxes and benefits. As with other values, SCAQMD may wish to test the sensitivity of the overall analytic results to these assumptions, if they appear likely to change the conclusions of the analysis.

To estimate this value, we obtain state-level data on pre-tax wages from the Occupational Employment Statistics (OES) program, a U.S. Bureau of Labor Statistics (BLS) database that is generated from a semiannual mail survey that covers a broad number of establishments across the United States.[18] We rely on the median hourly wage, and add the value of benefits from the Employer Costs for Employee Compensation (ECEC) survey.[19] The ECEC suggests that benefits average 45 percent of wages and salaries.[20] Based on these sources, we assume an hour of paid work time is worth $18.71 without benefits, or $27.12 including benefits, in 2013. We use the same per hour value for all types of time use for which separate estimation is necessary, including lost school days and lost work days as well as time losses associated with hospitalization.

---

[18] We rely on this source rather than on the National Compensation Survey (NCS) because the OES survey is larger, covering a greater range of occupations and geographic areas, and provides estimates of median as well as mean wages. See http://www.bls.gov/oes/ for the link to "OES Frequently Asked Questions" which provides a more detailed information on the OES as well as the NCS.

[19] Whether the median or mean (i.e., average) is the best central tendency estimate of compensation depends on the extent to which the distribution is highly skewed for workers in the occupations of concern. When considering the compensation of the overall population, the average is significantly greater than the median because of the small number of people who are very highly compensated. Thus, if only a fraction of the population is affected by a regulation, the best estimate of the wage or salary rate for this population may be the median (which is the center of the income distribution), rather than the mean (which is closer to the upper tail of the distribution).

[20] See http://www.bls.gov/news.release/archives/ecec_03122014.pdf - Table 1. Civilian workers, by major occupational and industry group (December 2013). Total benefits account for 31.0 percent of total compensation (wages and salaries plus benefits). We calculate benefits relative to wages and salaries as: 31.1/(100 – 31.0) = 44.9 percent.

RESULTS

In the following sections, we first discuss the results of our review of the WTP literature, and then discuss the results of our supplemental review of the COI literature and databases.

WILLINGNESS TO PAY ESTIMATES

In our literature search, we identified relatively few studies that meet our criteria and that address cardiovascular or respiratory effects similar to those proposed for consideration in SCAQMD's analysis. Below, we discuss the results for each category of endpoints listed in Exhibit 1.[21]

New Incidence (Chronic)

As summarized in Exhibit 1, the nonfatal endpoints recommended for inclusion in the SCAQMD analysis include three types of incident cases of chronic illness: strokes or heart disease (associated with a nonfatal myocardial infarction) diagnosed as a result of adult hospitalization, and childhood asthma.

We identified only one WTP study that meets the evaluation criteria and addresses incident cases for any of these effects: a stated preference study by Adamowicz et al. (2014) that addresses heart (coronary artery) disease risks.[22] It was designed to test models of household decision-making, considering differences between parents' willingness to pay for health risk reductions for themselves and their children. As a result, it relies on a sample of matched pairs of married parents living with children, rather than a sample of the general population.

The survey illustrates the timing of disease incidence using a graphic that shows the cumulative risk at each year of age. Respondents were told that chest pain, shortness of breath, activity limits, and the need for more medical treatment and medication would commonly follow diagnosis. Given this description, it is unclear whether respondents took into account the likelihood of myocardial infarction or of fatality associated with the disease. To value reductions in these risks, they were asked about their WTP for an annual vaccine that would reduce their risks by either 10 percent or 70 percent.

We do not recommend this study for use in the SCAQMD analysis because it focuses on a narrowly defined subset of the population whose preferences may not mirror that of the general adult population. In addition, the epidemiological research focuses on cases that are diagnosed as a result of hospitalization for myocardial infarction, whereas this study focuses on less severe effects.

For asthma, we identified three studies that meet our criteria and estimate WTP for treatment rather than new incidence. Blumenschein et al. (2001) and Blomquist et al. (2009) consider advisory services received by asthmatics from pharmacists, and Blomquist et al. (2011) consider alternative bronchodilator medications that differ in

---

[21] Because we do not expect the WTP studies to exactly match the age ranges considered in the epidemiological studies, we instead focus on whether these studies address the major age groups considered; i.e., children (generally under age 18), adults (generally 18 and older) or solely elderly adults (generally over age 65).

[22] More information on this study is provided in a report to EPA (Dickie and Gerking 2011).

safety and efficacy. These studies are not suitable for estimating reductions in new asthma cases, given that decreasing the severity of symptoms through participating in a treatment program is significantly different from reducing the risk of incurring the illness. However, the Blomquist et al. (2011) study provides useful information for comparison to the COI estimates reported in the next section. The researchers find that WTP for asthma control is about $4,055 for children at age 4, decreasing to $2,130 for children at age 17 (2007 dollars), or $4,556 to $2,393 in 2013 dollars, and varies from about $1,755 to $3,908 for adults of different ages (2007 dollars) or $1,972 to $4,391 in 2013 dollars. Presumably, WTP to reduce the risk of incurring the illness would exceed these estimates of WTP for treatment.

Given the results of this review, we recommend that all of the incident chronic effects (stroke, myocardial infarction, and asthma) be valued using the COI estimates discussed in the next section.

Hospital Admissions

As also summarized in Exhibit 1, the endpoints to be considered include hospitalization for cardiovascular and respiratory disease among adults and asthma-related emergency room visits and hospital admissions for children. Because it is unclear what percentage of these admissions represent new cases rather than existing cases, we focus solely on WTP for averting hospitalization or emergency department visits for these endpoints. We did not find any studies of hospitalization for childhood asthma, but found one study that addresses adult hospitalization for cardiovascular and respiratory disease and meets our evaluation criteria.

More specifically, Chestnut et al. (2006) developed a stated preference study that provides WTP estimates which can be combined with COI estimates for cardiovascular and respiratory hospitalization.[23] They survey Kaiser Permanente patients in Northern California who have been hospitalized for respiratory or cardiovascular illness. The WTP questions focus on preventing or shortening a hypothetical future hospitalization that would occur with certainty within the next year unless preventative health care, treatment, or reduction of environmental stressors is undertaken.

The survey was administered in 2002 to randomly selected patients, of whom 397 were included in the analysis. The researchers present the results for hospital stays of differing lengths, using models that vary in the extent to which they adjust for scenario rejection and control for other factors. In the abstract, the authors highlight the results for the model with the maximum adjustment for scenario rejection. Under this model, the mean estimates range from $1,886 for a one day stay to $2,463 for a 10 day stay (2002 dollars), or $2,442 to $3,189 if inflated to 2013 dollars. Although this survey focuses on a small, localized population and had a relatively low response rate (about 40 percent for adults 65

[23] Chestnut et al. (2006, p. 142) note “If the WTP estimates from this study are used to value prevention of hospitalizations, they should replace the value of lost household production, the value of lost recreation time, and the out-of-pocket expenses and lost earnings not covered by paid sick leave (about 75% in the sample). Thus, the WTP estimates should be added to all medical costs covered by insurance, lost earnings of the patient covered by paid sick leave (about 25% in our sample), and all lost earnings to family members and friends.” More information on this study is provided in a report to the California Air Resources Board (Chestnut et al. 2003).

and over and about 30 percent for adults under age 65), it is targeted on specific endpoints of concern for this project. Therefore, we recommend that the WTP estimates from this study be added to the COI estimates for hospitalization discussed in the next section, to provide a more complete estimate of the value of averting these effects.[24]

Other Respiratory Ailments

Other respiratory ailments include a variety of symptoms associated with acute bronchitis, asthma, and other conditions. As indicated in Exhibit 1, the specific symptoms include cough, phlegm, wheeze, hoarseness, sore throat, shortness of breath, chest pain or tightness of chest, runny or stuffy nose, and burning, aching, or red eyes. All of the endpoints address children except for those associated with asthma exacerbations, where adults are also included. The endpoints are described as symptom-days with the exception of acute bronchitis, which is described in terms of cases.

In our review, we identified a few studies that address asthma or other respiratory symptoms and meet our evaluation criteria. However, as noted earlier, most of the asthma studies estimate WTP for treatment, and cannot be easily converted to estimates for averting a symptom-day. Only one provides estimates per symptom-day. Brandt et al. (2012) conducted a stated preference study of 149 parents of asthmatic children ages 7 to 17 in California. The researchers elicited parental WTP for a hypothetical oxygen monitor, worn like a wristwatch, that provides immediate information about a child's asthma status and allows parents to take more timely corrective action. Depending on the model specification, WTP ranges from $14.90 to $17.11 per symptom-day (2006 dollars), or $17.22 to $19.77 in 2013 dollars.[25]

Another study, Dickie and Messman (2004), provides estimates per symptom day for a variety of acute effects. These researchers conducted a stated preference study in Hattiesburg, Mississippi in 2000, exploring parental values for both their own and their children's illnesses. Respondents included 284 parents of children ages 3 to 17. They were asked about their WTP for treatment of cough with phlegm, shortness of breath with wheezing, chest pain on deep inspiration, and/or fever with muscle pain, with durations of either 2 or 7 days. The researchers find that the median value to reduce symptom days by one (from two days to one) varies from $128 for mild symptoms to $217 for severe symptoms for children (in 2000 dollars), or $173 to $294 in 2013 dollars. The value for adults varies from $67 for mild symptoms to $114 for severe symptoms; or $91 to $154 in 2013 dollars. We summarize the estimates from these studies in Exhibit 4 below.

---

[24] Although the values are for adults, we recommend adding them to the values for children as well.

[25] The dollar year is not reported in the published article. However, a related working paper (Brandt et al. 2008) indicates that the survey was conducted in 2005 and 2006; we use 2006 as the base year for the values.

EXHIBIT 4. INDIVIDUAL STUDIES OF WILLINGNESS TO PAY PER SYMPTOM-DAY

STUDY	OUTCOME(S) VALUED[a] (age group)	RESPONDENTS AND LOCATION (year data collected)	WTP FOR ONE AVERTED SYMPTOM DAY	
			AS REPORTED (dollar year)[b]	INFLATED TO 2013 DOLLARS[b]
Brandt et al. (2012)	Asthma	149 parents of asthmatic children age 7-17 California (2005-2006)	Children: $14.90-$17.11 (2006 dollars)	Children: $17.22-$19.77
Dickie and Messman (2004)	Cough with phlegm, shortness of breath with wheezing, chest pain on deep inspiration, and/or fever with muscle pain	284 parents of children age 3-17 Hattiesburg, MS (2000)	Children: $128 (mild); $217 (severe) Adults: $67 (mild); $114 (severe) (2000 dollars)	Children: $173 (mild); $294 (severe) Adults: $91 (mild); $154 (severe)

Notes:
a. Estimates highlighted by authors in abstract or text.
b. Inflated using the Consumer Price Index (CPI). Prior to application in SCAQMD analyses, these estimates should also be adjusted for real income growth, as discussed below.

Given the limited number of studies available, we also reviewed three meta-analyses that consider acute nonfatal effects, but that do not meet our evaluation criteria, as summarized in Exhibit 5 and described below. The first provides U.S. values, but relies on older studies. The second and third include studies from outside the U.S. as well as older studies. These studies provide results for adults rather than children; the available research evidence (e.g., the Blomquist et al. 2011 study described above) suggests that values for children are likely to be larger. As indicated by Exhibit 5, these studies appear to support values within roughly the same range as the Brandt et al. and Dickie and Messman research summarized in Exhibit 4.

EXHIBIT 5. META-ANALYSES OF VALUES FOR ACUTE EFFECTS

STUDY	OUTCOMES VALUED[a]	STUDIES INCLUDED	WTP FOR ONE AVERTED SYMPTOM DAY	
			AS REPORTED (dollar year)[b]	INFLATED TO 2013 DOLLARS[c]
Johnson, Fries, and Banzhaf (1997)	Mild or severe cough or shortness of breath, eye irritation	5 contingent valuation studies from the U.S. (published 1979 to 1988)	$19 - $74 (1993 dollars)	$31 - $119
Vassanadumrongdee, Matsuoka, and Shirakawa (2004)	Mild or severe cough or shortness of breath, eye irritation, severe asthma attack, throat irritation	16 contingent valuation studies from 14 countries (published 1979 to 2001)	$21 - $58 (developed countries only) (1995 dollars)	$32 - $89
Van Houtven, Powers, Jessup, and Yang (2006)	Cough, wheezing, and shortness of breath	17 contingent valuation studies from 9 countries (published 1979 to 2002)	$125 - $158 (2000 dollars)	$169 - $258

Notes:
a. Includes only those endpoints that are also included in the descriptions in Exhibit 1.
b. Estimates highlighted by authors in abstract or text.
c. Inflated using the CPI. Prior to application in SCAQMD analyses, these estimates should also be adjusted for real income growth, as discussed below.

These three meta-analyses rely on similar data and methods. Johnson et al. (1997) combine available WTP estimates using the Quality of Well-Being (QWB) health status index to measure the severity of each condition (see Institute of Medicine 2006 for more discussion of such indices). The WTP estimates are derived from contingent valuation surveys that address adult WTP for their own health risks, generally in the air pollution context. As discussed by the authors, these studies have a number of limitations related to the clarity of the disease description, the format used to elicit WTP, the sample size and representativeness, and the controls for potentially confounding factors. Based on their preferred model, the researchers find values ranging from $19 to $74 for one day of symptom avoidance (1993 dollars). Inflated to 2013 dollars, the range for these symptoms becomes $31 to $119.

The second meta-analysis, Vassanadumrongdee et al. (2004), expands and refines the approach used by Johnson et al. (1997), focusing on the differences between developed and developing countries. The researchers add 11 studies to the five included previously, again using the QWB to indicate the severity of each condition. While the Johnson et al. study focused largely on the effects of severity and duration on the WTP estimates, Vassanadumrongdee et al. are able to also assess the effects of other characteristics because of the inclusion of a larger group of studies. They find that population characteristics (particularly education and income) and study design (particularly the format of the WTP questions and whether in-person interviews were used) affect the estimates. Based on their preferred model, the researchers find values ranging from $21 to $58 per day of symptom avoidance in developed countries (1995 dollars). This range increases to $32 to $89 when inflated to 2013 dollars.

The final study is Van Houtven et al. (2006). It focuses on developing a benefit transfer function that can be used to predict values for acute conditions not addressed in the primary research studies. It considers 17 contingent valuation studies from nine countries (the U.S., Canada, England, the Netherlands, Norway, Portugal, Spain, Sweden and Taiwan). After testing a number of different model specifications, the researchers select two to provide examples of their use in benefit transfer. They apply these models to four acute conditions, including one defined as "cough, wheezing, shortness of breath" combined. For this condition, the predicted values for a duration of one day are $125 to $158 depending on the model (2000 dollars), or $169 to $258 in 2013 dollars.

In sum, all of these studies have advantages and limitations, in terms of both their quality and the extent to which they address the same populations and health endpoints as likely to be considered in SCAQMD's analysis. Given the resulting uncertainty, we recommend that SCAQMD use a range of per symptom-day values in its analysis. The results above suggest that these values may range from $17 to $294 per day if we include the values for both adults and children. Because the risk estimates for acute bronchitis are based on incidence rather than symptom-days, these values will need to be multiplied by the expected duration of the illness in that case.

Activity Restrictions

The final group of endpoints in Exhibit 1 includes various types of activity restrictions, including lost work days, lost school days, and minor restricted-activity days. We found only two WTP studies that address these endpoints. The first, Dickie (2005) develops estimates of WTP for lost school days using a structural approach that combines theoretical assumptions from a health production model with data on medical costs and earnings. Hence it is unlike the other studies we consider, since it is not a stated or revealed preference study.[26] The data are taken from the 1997 Child Development Supplement of the Panel Study on income dynamics. The resulting estimates are about $100 to $150 per day (1997 dollars), or $145 to $218 in 2013 dollars. Given that this approach relies on relatively old data and strong assumptions, we do not recommend that these values be used in the SCAQMD analysis. We instead rely on the approach used in EPA (2015b) for lost school days as discussed previously.

A second study, Mansfield et al. (2006), is worth mentioning because it explicitly considers the effect of ozone on the time children spend outdoors using stated preference methods. However, applying this study would require data on the number of days of restricted outdoor activity for children, which is not included among the endpoints summarized in Exhibit 1.

Although we did not find any WTP studies that address minor restricted-activity days for adults, we expect that the health effects experienced during these days are likely to be similar to those discussed in the section on respiratory ailments. Thus the same range of values could be used for this endpoint as for the respiratory endpoints discussed above; i.e., $17 to $294 per day.

In sum, for restricted activity days and minor respiratory ailments, we find that suitable WTP estimates are available for valuation. We recommend that these values be adjusted for real income growth (as well as inflation) as discussed in the next subsection. For the remaining endpoints, we suggest that SCAQMD rely primarily on available COI studies and databases, as discussed later in this report.

Adjustment for Real Income Growth

As discussed in more detail in our memorandum on valuing mortality risk reductions, estimates of individual WTP should be adjusted to reflect increases in real income. (Such an income adjustment is not relevant for the COI estimates, because costs do not necessarily increase with income.) Adjusting WTP for changes in income involves two inputs: an estimate of the change in the values associated with a change in real income (the income elasticity), and an estimate of the change in real income.

Income elasticity measures the proportional change in WTP for an outcome (e.g., a 1 in 10,000 annual change in heart disease risk) associated with a small proportional change in income (e.g., 1.0 percent). It does not measure the extent to which a richer person may reduce his or her risk by more than a poorer person through investing in additional risk-reducing measures. In other words, it measures the change in the price an individual is willing to pay, not the change in the quantity of risk reduction he or she is willing to purchase. As discussed in more detail in Robinson and Hammitt (2015), we are not aware of a detailed theoretical investigation that specifically addresses the extent to which

[26] While at times studies that use structural models are described as revealed preference studies, this categorization is somewhat misleading. Structural models derive WTP estimates using theoretical expectations rather than by applying statistical methods to separate out the value of the risk reduction from other attributes of a product or observed behavior.

income elasticity may vary between fatal and non-fatal effects or across non-fatal effects of differing severities and durations. However, there is no reason to assume that the income elasticities are identical, given the differences in impacts. For example, different health effects have differing impacts on earnings, which may in turn affect the sensitivity of the WTP estimates to changes in income. Given the lack of well-developed theoretical expectations, we rely on empirical research to explore these elasticities, consistent with previous work.

The elasticities EPA currently uses in its BenMAP model and regulatory analyses for nonfatal health effects are summarized in Exhibit 6.

EXHIBIT 6. CURRENT U.S. EPA INCOME ELASTICITY ESTIMATES

HEALTH ENDPOINT	LOW ESTIMATE	CENTRAL ESTIMATE	HIGH ESTIMATE
Minor Health Effects[a]	0.04	0.15	0.30
Severe and Chronic Health Effects[b]	0.25	0.45	0.60

Source: EPA (2015a), Table 4-13, p. 4-60.
Notes:
a. Includes asthma exacerbation, acute bronchitis, acute respiratory symptoms (minor restricted activity days), lower respiratory symptoms, and upper respiratory symptoms.
b. Includes chronic bronchitis and chronic asthma.

These estimates are based on work that is over 15 years old (IEc 1999). In 2015, Robinson and Hammitt conducted a new literature review, using criteria very similar to those described for the WTP studies above (see Exhibit 2) but focusing on studies that estimate income elasticity. They identify four published studies (Dickie and Messman 2004, Chestnut et al. 2006, Hammitt and Haninger 2007, Blomquist et al. 2011), and one conference paper (Dickie and Hubbell 2004), that report these elasticities.[27] The estimates cover a wide range (from about 0.0 to 1.1).[28] Although all the studies address episodes of relatively short duration, the elasticities cover roughly the same range as the values for both minor and more severe effects in Exhibit 6, with some higher values.

Given this range, we suggest that SCAQMD rely on the mid-point estimate from these studies; i.e., an elasticity of 0.5. If it appears that the results of the AQMP analysis may be significantly affected by uncertainty in this elasticity estimate, SCAQMD may wish to conduct sensitivity analysis using the low and high end of the range; i.e., elasticities of 0.0 and 1.1.

[27] Hammitt and Haninger (2007) is not included in the preceding discussion on WTP for morbidity risk reductions, because it addresses foodborne illness rather than air pollution-related risks.

[28] The most recent of the meta-analyses discussed earlier (Van Houtven et al. 2006) reports elasticities of 0.7 or 0.9 depending on the model specification, which are within this range. However, it incorporates studies that do not meet our selection criteria.

Adjusting for changes in real income also requires an estimate of real income growth; the same data sources should be used to estimate income when valuing morbidity risk reductions as for mortality risk reductions. These data are needed for two periods: the time that has elapsed between when the data in the valuation studies were originally collected and the base year used in the SCAQMD analysis, and the time that will elapse between the analytic base year and each year for which impacts are estimated. For historical time periods, we suggest that SCAQMD consider using the same data source as used elsewhere in the analysis. We are not aware of projections that address only the State of California or the South Coast region; it may be necessary to rely instead on national estimates of the expected percentage change in earnings over time, as provided in the Congressional Budget Office's (CBO's) yearly *Long-Term Budget Outlook* reports.[29] For morbidity as well as mortality risk reductions, we expect that SCAQMD will rely on national rather than regional estimates.

COST OF ILLNESS ESTIMATES

As discussed above, WTP studies are lacking for many endpoints of interest to SCAQMD, including incident stroke, asthma, and nonfatal myocardial infarction, emergency room or emergency department visits, and work and school loss days. For these endpoints we use the COI estimates discussed in this section, either alone or combined with estimates of the value of time lost due to illness. For cardiovascular and respiratory hospital admissions, WTP estimates are available, but are designed to supplement estimates of medical costs and lost earnings. Thus for these endpoints we develop a hybrid valuation approach that combines COI and WTP estimates.

Ischemic Stroke (New Incidence)

We focused our review on five papers reporting COI values for ischemic stroke – two review articles (Luengo-Fernandez et al. 2009 and Demaerschalk et al. 2010) and three individual studies (Taylor et al. 1996, Simpson et al. 2013, and Lee et al. 2007). Of the two review articles, Demaerschalk et al. applied more stringent inclusion criteria than Luengo-Fernandez et al; however, they did not estimate a mean cost across the studies reviewed. Luengo-Fernandez et al. estimated a U.S. mean of approximately $28,000 (dollar year not specified) but acknowledged very wide variation in the estimates across the U.S. studies reviewed.

Of the three individual studies evaluated, Simpson et al. included some of the most recent cost data but restricted their analysis to a sample of South Carolina Medicare beneficiaries and only estimated one year's worth of costs. The Taylor et al. study uses a predictive computerized cost model based on data from the early 1990s; while this appears to be a thorough and well-conducted study, the study by Lee et al. appears to be a better match for the SCAQMD analysis. It provides a longitudinal four-year incidence-based COI value for ischemic stroke derived from a national random sample of Medicare beneficiaries aged 65 and older, based on Medicare Public Use Files cost and usage data from 1996 through 2001. Costs included medical procedures and services, hospital stays, skilled nursing facilities and use of ambulatory care. Outpatient costs of pharmaceuticals

[29] Available at www.cbo.gov.

are not included, because these were not covered by the Medicare program at the time of this study. The study also did not estimate indirect costs of stroke (e.g., lost productivity). Therefore, it is likely to significantly underestimate costs of incident stroke. Nonetheless, of the studies we evaluated it provides the best combination of specificity, transparency, and comprehensiveness from a incidence-based perspective. It reports a four-year cost per incident case of ischemic stroke of $39,396 in 2001 dollars. This increases to $61,384 if inflated to 2013 dollars.[30]

Non-Fatal Myocardial Infarction (New Incidence)

Our search for COI studies for incident cases of myocardial infarction uncovered two studies that provided U.S. estimates that met our criteria. However, neither provided estimates that were superior the values from the EPA (2015b) default studies in Exhibit 1. Zhao and Winget (2011) conducted a medical cost analysis for acute coronary syndromes including myocardial infarctions. The analysis included both direct medical costs and lost productivity costs from Thompson Reuters MarketScan Research Databases (Commercial Claims and Encounters and Health and Productivity Management). They report a range of 1-year costs depending on treatment method; unfortunately these costs are not easily compared to the 5-year costs in EPA's studies. While large ($34,000 to $87,000 in medical costs alone depending on treatment regimen), these first year costs could still fall within EPA's estimates if the smaller indirect costs associated with lost productivity become an increasing proportion of costs in later years. The second study, by Sullivan et al. (2011) describes the development of cost prediction models for health endpoints including myocardial infarction. The models were based on regression equations applied to a large database of claims data from case and control subjects aged 35 and older beginning in 2003. The COI is estimated based on the difference between the direct health care costs of myocardial infarction cases versus the costs of matched controls. The authors estimated a three-year cost of nonfatal myocardial infarction of $73,300 in 2007 dollars. This value appears to be within the range of the costs in EPA's recommended studies for myocardial infarction, when the shorter follow-up period and inflation adjustments are taken into account. In sum, we recommend continuing to use the pooled estimate applied by the U.S. EPA in Exhibit 1, although updated for inflation, resulting in a range of $106,293 to $223,214 in 2013 dollars.

Asthma (New Incidence)

Of the COI studies identified in our literature search, we found four published in the last ten years that met our evaluation criteria (Brandt et al. 2012, Jang et al. 2013, Wang et al. 2004, and Weiss et al. 2000). Of these, the latter two generated COI estimates based on health care cost data that is quite dated; Wang et al. used MEPS data from 1996, while the Weiss et al. estimate relies on data from 1985 and 1994. The Brandt and the Jang studies develop annual asthma cost estimates based on 2009 data, which are more likely to reflect current treatment practices. Both estimates from these latter two studies are

[30] SCAQMD should consider adding an estimate of lost productivity to this estimate. Doing so would require additional research on reasonable average estimates of lost time and disability associated with stroke cases, which is beyond the scope of this review. However, we believe it would significantly improve this value and reduce underestimation bias.

prevalence-based estimates of annual asthma costs, conducted using reputable methods; however, we prefer the estimate from Brandt et al. for three reasons: 1) it constructs a cost estimate for asthma that is presented very transparently; 2) it generates local estimates for children ages 0 – 17 years in Riverside and Long Beach, California; and 3) it includes more comprehensive estimates that include direct costs for asthma and co-morbidities (e.g., using HCUP data for direct medical costs and the Epocrates database for drug prices) and indirect costs (e.g., lost caregiver time associated with office and hospital visits based on the National Household Travel Survey and HCUP data). The Jang study also appears to be well conducted, but is a national-level estimate does not appear to include indirect costs in its estimates. Of note, the average Jang et al. estimate per child for 2009 is lower, but of similar magnitude to, the direct cost component of asthma related health costs in Brandt et al., excluding co-morbidities (approximately $1,100 per case per year versus about $1,600 per case per year in Riverside).

The overall annual cost estimate per asthma case reported by Brandt et al. for asthmatic children in Riverside, California is $4,008 in 2010 dollars. As noted above, this is a prevalence-based estimate, but because we found no incidence-based values, we propose to develop a per-case estimate based on the net present value of 13-years of the annual costs for a Riverside case. We chose 13 years because, according to NIH, most pediatric asthma cases are diagnosed by age 5. This is likely a conservative assumption, as a recent study by Radhakrishnan et al. (2014) found a decreasing trend in age of diagnosis from 4.7 years for children born in 1993 to 2.6 years for children born in 2000. It is also conservative because it does not factor in the potential for continued costs of asthma into adulthood. Based on the Brandt et al. estimate and assuming a 3 percent discount rate, we calculate a net present value cost per newly incident pediatric asthma case of $48,066 (2013 dollars).

Hospital Admissions

In Exhibit 7, we present unit values in 2013 dollars for different types of hospital admissions, based on the results of our HCUP search for mean length of stay and mean cost per stay, our estimates of the value of lost time, and the WTP increment from Chestnut et al. (2006).[31] Note that the Chestnut et al. estimates are intended to be added to the value of insured medical costs, lost earnings not covered by paid sick leave, and lost earnings experienced by family and friends (Chestnut et al. 2006, p. 142). However, we lack estimates that allow us to provide values at this level of disaggregation, and instead add the Chestnut et al. estimates to the available data on hospitalization and an estimate of the value of lost time.[32]

We conservatively assume that time losses are equivalent to the value of total compensation pre-tax wages and benefits) multiplied by 8 hours per day. This can be

[31] As noted earlier, we rely on state-level rather than county-level data on hospitalization costs, because the state data are reported using ICD codes that more closely correspond with the endpoints of interest; the county data are more aggregated and may include additional endpoints. However, the county-level costs tend to be within 10 percent of the state-level costs.

[32] Whether this approach under- or overestimates the value of hospitalizations is unclear, given the uncertainties associated with both the use of COI estimates as proxies for WTP and the application of the Chestnut et al. results.

interpreted as estimating the value of lost productivity of affected patients, family, and friends, assuming in combination they would otherwise be engaged in productive work for 8 hours per day, or as the value of lost leisure if they are unlikely to be engaged in paid or unpaid work. We add the Chestnut et al. WTP increment to these values. Chestnut et al. (in Table 9, column 4 of their paper) estimate the average amount that individuals are willing to pay to prevent hospitalization episodes for 1, 2, 5, and 10 hospital days as $2,442, $2,543, $3,079, and $3,189 respectively, if we inflate the values to 2013 dollars.[33] Because 5 hospital days are the closest to the average mean length of stay for these endpoints, we use $3,079 as the WTP increment.

EXHIBIT 7. CALIFORNIA HOSPITAL ADMISSIONS UNIT VALUES

ENDPOINT	MEAN LENGTH OF STAY (DAYS)	MEAN COST PER STAY[a]	LOST TIME PER STAY[b]	TOTAL COST PER STAY[c]	WTP INCREMENT[d]	TOTAL UNIT VALUE[e]
Asthma (<18 years)	2.2	$5,575	$477	$6,052	$3,079	$9,131
Cardiovascular Disease (>20 years)[f]	4.2	$19,479	$911	$20,390	$3,079	$23,469
Respiratory Disease (>18 years)	6.0	$17,128	$1,302	$18,430	$3,079	$21,509

Source: 2012 HCUP State Inpatient Database (HCUP-SID) for mean cost and length of stay, 2013 dollars.
Notes:
a. Mean cost per stay estimates were inflated from 2012 to 2013 dollars using the CPI.
b. Lost earnings per stay are estimated by multiplying lost earnings (including benefits) per hour (as described above using the OES and ECEC data) by 8 hours, multiplied by the mean length of stay, in days.
c. Total cost per stay = mean cost per stay + lost time per stay.
d. WTP increment from Chestnut et al. (2006) for 5 hospital days, which is closest to the average mean length of stay for these endpoints.
e. Total unit value = total cost per stay + WTP increment.
f. The HCUP values for cardiovascular disease reflect ages 18 and older.

Emergency Department Visits

We found relatively little publicly-available information on the cost of asthma-related emergency department visits for children under the age of 18. We reviewed the COI literature and found that Smith et al. (1997), Stanford et al. (1999), and Meng et al. (2010) provide the most relevant recent estimates (Exhibit 8). Smith et al. (1997) and Stanford et al. (1999) are both estimates used in EPA (2015b) as discussed earlier. We note that Hall et al. (2003) also estimated the value of avoiding an emergency room visit to be $540 for the South Coast Region, a value in the middle of the range of the studies in Exhibit 8.[34] Hall adapted estimates from Smith et al. (1997) and included a lost

[33] These values have been adjusted from 2002 to 2013 dollars using the CPI.

[34] Adjusted to 2013 dollars using the CPI-U for medical care. This is the average of Hall et al.'s (2003) mid estimates for the three counties (Los Angeles, Orange, and Riverside/San Bernardino). The average of the low and high estimates are $405 and $677 respectively (2013 dollars).

productivity effect to reflect the time lost from work by one of the caregiver parents or guardians. We recommend applying the mean of the three values in Exhibit 8.

EXHIBIT 8. ASTHMA-RELATED EMERGENCY ROOM VISITS (<18 YEARS)

STUDY	ESTIMATE (2013 DOLLARS)[a]
Smith et al. (1997)[b]	$510
Stanford et al. (1999)[c]	$425
Meng et al. (2010)[d]	$623
Average	**$519**

Notes:
a. Values adjusted to 2013 dollars using the CPI
b. Smith et al. (1997) reported approximately 1.2 million adult (>18 years) asthma-related emergency department visits in 1987 at a total cost of $186 million (1987 dollars). The average cost per visit was $155 (1987 dollars).
c. Stanford et al. (1999) reported a cost of an average adult asthma related emergency department visit based on 1996-1997 data at $235 (1997 dollars).
d. Meng et al. (2010) estimated the impact of a law requiring coverage of educational programs for asthmatic children on the costs of health care in California. They cite a cost to insurers per emergency room visit of $400 (2001 dollars), based on a review of MedStat 2001 claims data.

Lost Work and School Days

Exhibit 9 presents the results of our analysis of the value of time for lost days of work and school; the latter reflects the time losses associated with the adult caregiver, not the losses to the child himself or herself. Note that EPA (2015b) adjusts the value for lost school days downwards based on data on the percentage of women in the paid workforce. We do not make this adjustment, instead assuming that those involved in caring for a sick child would otherwise engage in more highly-valued activities, including paid or unpaid work and leisure. We assume such caretaking consists of an 8-hour day; however, in reality it may occur over varying time periods depending on factors such as the severity and duration of the symptoms and the age of the child affected.

EXHIBIT 9. VALUE OF TIME

DESCRIPTION	LOST WORK DAYS	LOST SCHOOL DAYS
Median hourly wage with benefits (BLS OES, and ECEC 2013)[a]	$27.12	$27.12
Hours of work/day	8 hours	8 hours
Value per day	**$217**	**$217**

Notes:
a. Based on the Employer Costs for Employee Compensation (ECEC) survey, we estimate that benefits average 45 percent of pre-tax wages and salaries.

SUMMARY AND CONCLUSIONS

Exhibit 10 summarizes our recommendations for economic values per statistical case associated each of our recommended health endpoints for the 2016 Socioeconomic Analysis. We recommend a range of WTP estimates for the six endpoints involving respiratory ailments and identify appropriate COI estimates where WTP values were not available. Using recent data and studies, we have updated most of these values to reflect improved methods and more current data. Nonetheless, uncertainties remain, particularly given that we rely on COI rather than WTP estimates for numerous endpoints and in some cases rely on relatively old data. It may be possible to update the available COI estimates for new incidence of chronic effects based on more recent data, given more time and resources, particularly the estimate for ischemic stroke, which currently excludes indirect costs.

Prior to applying these estimates, SCAQMD should inflate the values to the same base year as it uses elsewhere in the Socioeconomic Analysis, and should adjust the WTP to reflect the expected growth in population-average real income over time, as discussed earlier. In addition, for those effects that persist for more than one year, the same discount rates should be used in these calculations as in other parts of the analysis. We suggest that SCAQMD also discuss the uncertainties associated with these estimates, including those related to the gap between when the data were collected and the present, the limitations of applying COI estimates as proxies for WTP, and the differences between the populations and health effects studied and those addressed by the policies implemented under the 2016 AQMP.

EXHIBIT 10. SUMMARY OF RECOMMENDED VALUATION ESTIMATES (2013 DOLLARS)

NONFATAL ENDPOINT[A] (AGE RANGE)	POLLUTANT	VALUATION ESTIMATE[B]	VALUATION METHOD
New incidence (chronic)			
Stroke, ischemic (>65 years)	PM	$61,384 (Lee et al. 2007)	COI (medical costs for hospital admissions)
Nonfatal myocardial infarction (>18 years)	PM	$106,293 to $223,214 depending on age (Cropper and Krupnick 1990, Russell et al. 1998, Wittels et al. 1990)	COI (direct and indirect)
Asthma incidence (new cases) (<18 years)	NO_2	$48,066 (13-year NPV based on annual costs in Brandt et al. 2012, 3% discount rate)	COI (direct and indirect)
Hospitalization and emergency room visits only			
Hospital admissions, cardiovascular (>20 years)	PM	$23,469 (HCUP, Chestnut et al. 2006)	COI (direct and indirect) + WTP
Hospital admissions, respiratory disease (>18 years)	PM, Ozone	$21,509 (HCUP, Chestnut et al. 2006)	COI (direct and indirect) + WTP
Emergency Department visits, respiratory, asthma and hospital admissions, respiratory, asthma (<18 years)	PM, Ozone	$519 (range of $425 - $623) (emergency visits: Smith et al., 1997, Stanford et al., 1999, Meng et al, 2010) $9,131 (hospital admissions: HCUP, Chestnut et al, 2006)	COI (direct and indirect) + WTP for hospital admissions
Other respiratory ailments (not requiring hospitalization)			
Acute bronchitis (8-12 years)	PM, Ozone	$17 to $294 per day (Brandt et al. 2012, Dickie and Messman 2004)[C]	WTP
Lower respiratory symptoms[d] (7-14 years)	PM or NO_2/SO_2		WTP
Upper respiratory symptoms[e] (9-11 years)	PM		WTP
Asthma exacerbation[f] (4-18 years, >34 years)	PM or NO_2		WTP
Activity restrictions			
Work loss days (18-64 years)	PM	$217 per day (BLS 2012)	COI (compensation only)
School loss days (5–17 years)	Ozone	$217 per day (BLS 2012)	COI (parent's lost time only)
Acute respiratory symptoms/minor restricted-activity days[g] (18-65 years)	PM, Ozone	$17 to $294 per day (Brandt et al. 2012, Dickie and Messman 2004)[C]	WTP

Notes:
a. Endpoints are from IEc's separate memoranda. Age ranges encompass all related studies; individual studies generally address a narrower range.
b. All values are per statistical case unless otherwise noted.
c. As discussed earlier, three meta-analyses support values within this range, although each includes studies that are not consistent with our evaluation criteria (Johnson et al. 1997, Vassanadumrongdee et al. 2004, Van Houtven et al. 2006).
d. Includes two or more of the following: cough, chest pain, phlegm, wheeze.
e. Includes runny or stuffy nose, wet cough, burning, aching, or red eyes.
f. Includes cough, wheeze, shortness of breath, tightness of chest.
g. Minor restricted activity days not resulting in work loss or bed disability.

REFERENCES

Abt Associates, Inc. 2014. Review of the SCAQMD Socioeconomic Assessments. Prepared for South Coast Air Quality Management District. Available at http://www.aqmd.gov/home/library/clean-air-plans/air-quality-mgt-plan/socioeconomic-analysis.

Adamowicz, W. et al. 2014. "Household Decision Making and Valuation of Environmental Health Risks to Parents and Their Children." *Journal of the Association of Environmental and Resource Economists*. 1(4): 481-519.

Akobundu, E., J. Ju, L. Blatt, and C.D. Mullins. 2006. Cost-of-Illness Studies: A Review of Current Methods. *Pharmacoeconomics*. 24(9): 869-890.

Alberini, A., Bateman, I., Loomes, G., Ščasný, M. 2010. Valuation of Environment-related Health Risks for Children. OECD Publishing. Available at http://dx.doi.org/10.1787/9789264038042-en.

Agency for Healthcare Research and Quality. 2007. HCUPnet. Healthcare Cost and Utilization Project. Rockville, MD. Available at http://hcupnet.ahrq.gov.

Berger, M.C. et al. 1987. "Valuing Changes in Health Risks: A Comparison of Alternative Measures." *Southern Economic Journal*. 53(4): 967-984.

Bloom, B.S., D.J. Bruno, D.Y. Maman, and R. Jayadevappa. 2001. Usefulness of U.S. Cost of Illness Studies in Healthcare Decision Making. *Pharmacoeconomics.* 19(2): 207-213.

Blomquist, G. 2004. Self-Protection and Averting Behavior, Values of Statistical Lives, and Benefit Cost Analysis of Environmental Policy. *Review of the Economics of the Household*. 2: 89-110.

Blomquist, G., M. Dickie, and R.M. O'Conor. 2011. Willingness to Pay for Improving Fatality Risks and Asthma Symptoms: Values for Children and Adults of all Ages. *Resource and Energy Economics*. 33(2): 410-425.

Blumenschein, K. and M. Johannesson. 1998. "Relationship Between Quality of Life Instruments, Health State Utilities, and Willingness to Pay in Patients with Asthma." *Annals of Allergy, Asthma, and Immunology*. 80: 189-194.

Blumenschein, K., M. Johannesson, K.K. Yokoyama, and P.R. Freeman. 2001. "Hypothetical Versus Real Willingness to Pay in the Healthcare Sector: Results from a Field Experiment." *Journal of Health Economics*. 20(3): 441-457.

Brandt, S., F.V. Lavin, and M. Hanemann. 2012. "Contingent Valuation Scenarios for Chronic Illnesses: The Case of Childhood Asthma." *Value in Health.* 15(8): 1077-1083.

Brandt, S., L. Perez, N. Kunzli, F. Lurmann, and R. McConnell. 2012. "Costs of Childhood asthma Due to Traffic-Related Pollution in Two California Communities." *The European Respiratory Journal.* 40(2): 363-370.

Brandt, S., et al. 2008. Designing Contingent Valuation Scenarios for Environmental Health: The Case of Childhood Asthma. Paper presented in the Summer Workshop, Health and the Environment, Association of Environmental and Resource Economists, University of California, Berkeley.

Cameron, T.A. 2014. "Valuing Morbidity in Environmental Benefit-Cost Analysis." *Annual Review of Resource Economics*. 6:249–72

Centers for Disease Control and Prevention. 2008. National Center for Health Statistics. National Health Interview Survey. 1999-2008.

Chestnut, L.G., B.D. Ostro and N. Vichit-Vadakan. 1997. Transferability of Air Pollution Control Health Benefits Estimates from the United States to Developing Countires: Evidence from the Bangkok Study. *American Journal of Agricultural Economics*. 79 (5): 1630-1635.

Chestnut, L.G., J.K. Lazo, M.A. Thayer and S.K. Van Den Eeden. 2003 The Economic Value of Respiratory and Cardiovascular Hospitalizations. Report prepared under contract #99-329.

Chestnut, L.G., M.A. Thayer, J.K. Lazoand S.K. Van Den Eeden. 2006. "The Economic Value of Preventing Respiratory and Cardiovascular Hospitalizations." *Contemporary Economic Policy*. 24(1): 127-143.

Cropper, M.L. and A.J. Krupnick. 1990. The Social Costs of Chronic Heart and Lung Disease. Resources for the Future. Washington, D.C.

Demaerschalk, B.M., H. Hwang, H., and G. Leung. 2010. US Cost Burden of Ischemic Stroke: A Systematic Literature Review. *American Journal of Managed Care*. 16(7):525-533.

Dickie M. 2005. "Parental Behavior and the Value of Children's Health: A Health Production Approach." *Southern Economic Journal*. 71:855-72.

Dickie, M. and B. Hubbell. 2004. Family Resource Allocation and the Distribution of Health Benefits of Air Pollution Control. Paper presented at the Association of Environmental and Resource Economists Workshop, *Distributional Effects of Environmental Policy*.

Dickie, M. and V. L. Messman. 2004. Parental Altruism and the Value of Avoiding Acute Illness: Are Kids Worth More Than Parents? *Journal of Environmental Economics and Management*. 48, pp. 1146-1174.

Diener, A., B. O'Brien, and A. Gafni. 1998. Health Care Contingent Valuation Studies: A Review and Classification of the Literature. *Health Economics*. 7(4): 313-326.

Dockins, C. et al. 2002. "Valuation of Childhood Risk Reduction: The Importance of Age, Risk Preferences, and Perspective." *Risk Analysis.* 22(2):335-346.

Evans, M.F., C. Poulos, and V.K. Smith. 2011. Who Counts in Evaluating the Effects of Air Pollution Policies on Households? Non-market Valuation in the Presence of Dependencies. *Journal of Environmental Economics and Management*. 62(1): 65-79.

Finkelstein, E.A., P.S. Corso, T.R. Miller, et al. 2006. The Incidence and Economic Burden of Injuries in the United States. Oxford and New York: Oxford University Press.

Freeman, A.M. III, J.A. Herriges, and C.L. Kling. 2014. The Measurement of Environmental and Resource Values: Theory and Methods (Third Edition). New York, N.Y.: RFF Press.

French, M.T. and J.A. Mauskopf. 1992. "A Quality-of-Life Method for Estimating the Value of Avoided Morbidity." *American Journal of Public Health.* 82(11): 1553-1555.

Gerking. S. and M. Dickie. 2013. "Valuing Reductions in Environmental Risks to Children's Health." *Annual Review of Resource Economics*. 5:245–60

Gentry, E.P. and W.K. Viscusi. 2015. "The Fatality and Morbidity Components of the Value of Statistical Life." Vanderbilt University Law School Law and Economics Working Paper Number 15-4.

Grosse, S.D., K.V. Krueger, and M. Mvundura. 2009. Economic Productivity by Age and Sex: 2007 Estimates for the United States. *Medical Care*. 47(7): S94-S103.

Hall, J.V., V. Brajer, F.W. Lurmann, and J. Wu. 2003. Economic Valuation of Ozone-Related School Absences in the South Coast Air Basin. Final Report. State of California Air Resources Board.

Hammitt, J.K. 2007. "Valuing Changes in Mortality Risk: Lives Saved Versus Years Saved." *Review of Environmental Economics and Policy*. 1(2):228-240.

Hammitt, J.K. and K. Haninger. 2007. Willingness to Pay for Food Safety: Sensitivity to Duration and Severity of Illness. *American Journal of Agricultural Economics.* 89(5):1170-1175.

Hunt, A. and J. Ferguson. 2010. A Review of Recent Policy-Relevant Findings from the Environmental Health Literature. Prepared for the Organisation for Economic Co-Operation and Development. ENV/EPOC/WPNEP(2009)9/FINAL.

Hunt, A. (2011). Policy Interventions to Address Health Impacts Associated with Air Pollution, Unsafe Water Supply and Sanitation, and Hazardous Chemicals. OECD Environment Working Papers, No. 35. Paris: OECD Publishing. http://dx.doi.org/10.1787/5kg9qx8dsx43-en

Hunt, A. et al. 2016. Social Costs of Morbidity Impacts of Air Pollution. OECD Environment Working Papers, No. 99. Paris: OECD Publishing.http://www.oecd-ilibrary.org/environment/social-costs-of-morbidity-impacts-of-air-pollution_5jm55j7cq0lv-en

Industrial Economics Incorporated. 1994. "Linkage between Health Effects Estimation and Morbidity Valuation in the Section 812 Analysis—Draft Valuation Document." Memorandum to J. DeMocker, U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Policy Analysis and Review, from J.E. Neumann, M.T. Dickie, and R.E. Unsworth. http://www.epa.gov/ttn/ecas/regdata/Benefits/background/neumannn1994.pdf.

Industrial Economics, Incorporated. 1999. Recommended Approach to Adjusting WTP Estimates to Reflect Changes in Real Income. Memorandum to J. Democker, Office of Policy Analysis and Review, Office of Air and Radiation, U.S. Environmental Protection Agency, prepared by N. Kleckner and J. Neumann. http://www3.epa.gov/ttnecas1/regdata/Benefits/background/klecknerandneumann1999.pdf

Industrial Economics, Incorporated. 2004. Responding to SAB Council Comments on the May 2003 Draft Analytical Plan for the Section 812 Second Prospective – Options for Adjusting WTP Estimates to Reflect Changes in Real Income. Memorandum to N. Smoke, Office of Policy Analysis and Review, Office of Air and Radiation, U.S. Environmental Protection Agency, prepared by J. Neumann and S. Brennan.

Institute of Medicine. 2006. Valuing Health for Regulatory Cost-Effectiveness Analysis. (W. Miller, L.A. Robinson, and R.S. Lawrence, eds.). Washington, D.C.: The National Academies Press.

Jang, J., K.C. G. Chan, H. Huang, and S.D. Sullivan. 2013. "Trends in Cost and Outcomes Among Adult and Pediatric Patients with Asthma: 2000-2009." *Annals of Allergy, Asthma, and Immunology.* 111(6): 516-522.

Johnson, F. R., M.R. Banzhaf and W. H. Desvousges. 2000. Willingness to Pay for Improved Respiratory and Cardiovascular Health: A Multiple-Format, Stated-Preference Approach. *Health Economics.* 9:295-317.

Johnson, F. R. et al. 2000. Willingness to Pay for Improved Respiratory and Cardiovascular Health: A Multiple-Format Stated-Preference Approach. *Health Economics*. 9:295–317.

Johnson F.R., E.E. Fries, and H.S. Banzhaf. 1997. Valuing Morbidity: An Integration of the Willingness-to-Pay and Health-Status Index Literatures. *Journal of Health Economics*. 16:641-665.

Larg, A. and J.R. Moss. 2011. Cost-of-Illness Studies: A Guide to Critical Evaluation. *Pharmacoeconomics*. 29(8):653-671.

Lee, W.C., D.C. Christensen, A.V. Joshi, and C.L. Pashos. 2007. Long-term Cost of Stroke Subtypes among Medicare Beneficiaries *Cerebrovascular Diseases.* 23:57-65.

Lund, J.L., K.R. Yabroff, Y. Ibuka, L.B. Russell, P.G. Barnett, J. Lipscomb, W.F. Lawrence, and M.L. Brown. 2009. "Inventory of Data Sources for Estimating Health Care Costs in the United States." *Medical Care*. 47(7):S127-S142.

Luengo-Fernandez, R., A.M. Gray, and P.M. Rothwell. 2009. Costs of Stroke Using Patient-Level Data: A Critical Review of the Literature. *Stroke* 40:e18-e23.

Mansfield, C., R.F. Johnson, F., and G. van Houtven. 2006. "The Missing Piece: Valuing Averting Behaviour for Children's Ozone Exposures." *Resource and Energy Economics*. 28:15-228.

Meng, Y.Y., D. Pourat, R. Cosway, and G.F. Kominski. 2010. "Estimated Cost Impacts of Law to Expand Coverage for Self-Management Education to Children with Asthma in California." *Journal of Asthma.* 47:581-586.

National Institutes of Health: National Heart, Lung, and Blood Institute. 2014. How is Asthma Diagnosed? Accessed November 30, 2015. Available at: http://www.nhlbi.nih.gov/health/health-topics/topics/asthma/diagnosis

National Oceanic and Atmospheric Administration. 1993. Report of the NOAA Panel on Contingent Valuation. (Arrow, K., R. Solow; P.R. Portney, E.E. Leamer, R. Radner, and H. Shuman.) *Federal Register.* 58:4601-4614.

O'Conor, R.M. and G.C. Blomquist. 1997. "Measurement of Consumer Patient Preferences using a Hybrid Contingent Valuation Method." *Journal of Health Economics.* 16(6):667-683.

Olsen, J. A., and R.D. Smith. 2001. Theory versus Practice: a Review of 'Willingness-to-Pay'in Health and Health Care. *Health Economics*. 10(1):39-52.

Phaneuf, D.J. and K.V. Smith. 2005. Recreational Demand Models. *Handbook of Environmental Economics, Vol. 2* (K.-G. Maler and J.R. Vincent, eds.). The Netherlands: Elsevier.

Radhakrishnan, D.K., S.D. Dell, A. Guttmann, S.Z. Shariff, K Liu, and T. To. 2014. "Trends in the Age of Diagnosis of Childhood Asthma." *Journal of Allergy and Clinical Immunology.* 134(5):1057-1062.

Robinson, L.A. and J.K. Hammitt. 2013. Skills of the Trade: Valuing Health Risk Reductions in Benefit-Cost Analysis. *Journal of Benefit-Cost Analysis*. 4(1): 107-130. http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=9456622&fulltextType=RA&fileId=S2194588800000518.

Robinson, L.A. and J.K. Hammitt. 2015. The Effect of Income on the Value of Mortality and Morbidity Risk Reductions. Prepared for the U.S. Environmental Protection Agency under subcontract to Industrial Economics, Incorporated. http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/0CA9E925C9A702F285257F380050C842/$File/IEc_Income+elasticity+Report+_final.pdf

Rowe, R.D. and L.G. Chestnut. 1986. Oxidants and Asthmatics in Los Angeles: A Benefits Analysis. Report to the Office of Policy Analysis, U.S. Environmental Protection Agency. Energy and Resource Consultants, Inc., Boulder, CO.

Russell, L.B. 2009. Completing Costs: Patients' Time. *Medical Care*. 47(7):S89-S93.

Russell, M.W., D.M. Huse, S. Drowns, E.C. Hamel, and S.C. Hartz. 1998. "Direct Medical Costs of Coronary Artery Disease in the United States." *American Journal of Cardiology*. 81(9):1110-1115.

Simpson, A.N., H.S. Bonilha, A.S. Kazley, J.S. Zoller, and C. Ellis. 2013. Marginal Costing Methods Highlight the Contributing Cost of Comorbid Conditions in Medicare Patients: a Quasi-experimental Case-control Study of Ischemic Stroke Costs. *Cost Effectiveness and Resource Allocation.* 11(1):29.

Smith, D.H., D.C. Malone, K.A. Lawson, L.J. Okamoto, C. Battista, and W.B. Saunders. 1997. A National Estimate of the Economic Costs of Asthma. *American Journal of Respiratory and Critical Care Medicine*. 156(3 Pt 1):787-793.

South Coast Air Quality Management District. 2012. Socioeconomic Report 2012: Air Quality Management Plan.

Stanford, R., T. McLaughlin and L. J. Okamoto. 1999. The Cost of Asthma in the Emergency Department and Hospital. *American Journal of Respiratory and Critical Care Medicine.* 160(1):211-5.

Sullivan, A.K., J. Rubin, J. Nyambose, Kuznik, D.J. Cohen, and D. Thompson. 2011. Cost Estimation of Cardiovascular Disease Events in the U.S. *PharmacoEconomics.* 29(8):693-704.

Taylor, T. N., P. H. Davis, T.C. Torner, J. Holmes, J.W. Meyer, and M.F. Jacobson. 1996. Lifetime Cost of Stroke in the United States. *Stroke*. 27:1459-1466.

Thayer, M.A., L.G. Chestnut, J.K. Lazo, and S.K. Van Den Eeden. 2003. The Economic Value of Respiratory and Cardiovascular Hospitalizations. Final Report. Prepared for California Air Resources Board and California Environmental Protection Agency.

Tolley, G.S. et al. 1986. Valuation of Reductions in Human Health Symptoms and Risks. University of Chicago. Final Report for the U.S. Environmental Protection Agency, Office of Policy Analysis. http://yosemite.epa.gov/ee/epa/eerm.nsf/a7a2ee5c6158cedd852563970080ee30/eaa2842b3d2bc2798525644d0053bf48!OpenDocument#_Section6.

U.S. Bureau of Labor Statistics. 2014. Economic News Release, Table 1. Civilian Workers, by Major Occupational and Industry Group. June 2014. http://www.bls.gov/news.release/ecec.t01.htm

U.S. Bureau of Labor Statistics. Occupational Employment Statistics. http://www.bls.gov/oes/home.htm

U.S. Department of Transportation. 2015. Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis. Memorandum to Secretarial Officers and Modal Administrators from C. Monje, Assistant Secretary for Transportation Policy; prepared by R. Endorf, Economist.

https://www.transportation.gov/administrations/office-policy/2015-value-travel-time-guidance

U.S. Environmental Protection Agency. 2010. Guidelines for Preparing Economic Analysis. EPA 240-R-10-001. (With 2014 update) http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf

U.S. Environmental Protection Agency. 2011. The Benefits and Costs of the Clean Air Act from 1990 to 2020. Final Report- Rev. A. U.S. Environmental Protection Agency, Office of Air and Radiation.

U.S. Environmental Protection Agency. 2015a. *BenMAP: Environmental Benefits Mapping and Analysis Program – Community Edition User's Manual.* Prepared for the Office of Air Quality Planning and Standards by RTI International. (http://www2.epa.gov/sites/production/files/2015-04/documents/benmap-ce_user_manual_march_2015.pdf)

U.S. Environmental Protection Agency. 2015b. Regulatory Impact Analysis of the Final Revisions to the National Ambient Air Quality Standards for Ground-Level Ozone. U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Air Quality Planning and Standards. EPA-452/R-15-007 http://www3.epa.gov/ozonepollution/pdfs/20151001ria.pdf

Van Houtven, G., J. Powers, A. Jessup, and J-C Yang. 2006. Valuing Avoided Morbidity Using Meta-Regression Analysis: What Can Health Status Measures and QALYs Tell Us About WTP? *Health Economics*. 15:775-795.

Vassanadumrongdee, S., Matsuoka, S., Shirakawa, H. 2004. "Meta-Analysis of Contingent Valuation Studies on Air Pollution-Related Morbidity Risks." *Environmental Economics and Policy Studies*. 6:11-47.

Viscusi, W.K. and J.E. Aldy. 2003. The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World. *Journal of Risk and Uncertainty*. 27(1): 5-76.

Wang, L.Y., Y. Zhong, and L. Wheeler. 2004. "Direct and Indirect Costs of Asthma in School-Age Children." *Preventing Chronic Disease.* 2(1):A11.

Weiss, K.B., S.D. Sullivan, and C.S. Lyttle. 2000. "Trends in the Cost of Illness for Asthma in the United States, 1985-1994." *The Journal of Allergy and Clinical Immunology.* 106(3):493-499.

Wittels, E.H., J.W. Hay, and A.M. Gotto, Jr. 1990. Medical Costs of Coronary Artery Disease in the United States. *American Journal of Cardiology.* 65(7):432-440.

Yabroff, K.R. et al. (eds.). 2009. Health Care Costing: Data, Methods, Future Directions. *Medical Care*. 47(7): Supplement 1.

Zhao, Z. and M. Winget. 2011. Economic Burden of Illness of Acute Coronary Syndromes: Medical and Productivity Costs. *BMC Health Services Research.* 11-35.

Zillich, A.J., K. Bumenschein, M. Johannesson, and P. Freeman. 2002. "Assessment of the Relationship Between Measures of Disease Severity, Quality of Life, and Willingness to Pay in Asthma." *PharmacoEconomics*. 20(4): 257-265.