



Population Simulation Model for Air Pollution Hazards

Version 3.0 - U.S. and
International Versions

User Manual and Documentation

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prepared for:

Office of Policy Analysis and Review

Office of Air and Radiation

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue NW

Washington, DC 20460

prepared by:

Industrial Economics, Incorporated

2067 Massachusetts Avenue

Cambridge, MA 02140

617/354-0074

INTRODUCTION

The dynamic population simulation model described in this document is designed to track the effect of alternative assumptions about the mortality effects of fine particulate matter (PM_{2.5}) air pollution in populations over time. We have developed two versions of a benefits analysis tool based on this model: the PopSim model can be used for modeling dynamic changes in the U.S. population due to air pollution changes and PopSim-International can be used to model dynamic population changes in any of 182 countries globally. Both incorporate detailed life table data for historical years, by age, gender, and cause of death, obtained from the Census Bureau, the Centers for Disease Control (CDC), and the Global Burden of Disease study (GBD). They also incorporate Census mortality and population projections for future years, again by age and gender, using the projected death and birth rates that underlie the Census Bureau's published population projections.

These tools allow users to:

- Simulate population in by single year cohorts of age and gender for years between 1980 and 2050 for the U.S. and between 1990 and 2050 for other countries under alternative assumptions about the degree of hazard posed by air pollution relative to baseline historical and projected Census mortality rates;
- Estimate changes in life years relative to baseline Census and GBD mortality rates;
- Apply air pollution hazards differentially by cause of death in the U.S.; and
- Analyze the effect of alternative cessation lag structures on the timing of total mortality and on total life years in the U.S. population, based on differential application by cause of death or other specifications of cessation lag.

The dynamic life-table approach used in these models can theoretically provide improved estimates of the mortality impacts of air pollution in future years over the more common static approach because it explicitly accounts for the year-to-year cascade of impacts on mortality and population following an air pollution change. PopSim Version 3.0 improves on the earlier versions of the domestic model completed by Industrial Economics (IEc) in 2005, 2006, and 2012, using the latest data from the Census and CDC and includes additional data to allow the user to simulate population for 1980-1989. PopSim -International Version 1.0 adds 182 countries outside of the U.S., using the latest data from the Census International Database (IDB) and GBD to calculate dynamic life tables based on air pollution related changes in all-cause mortality rates.

The remainder of this document describes the models and how to use them. It consists of three sections: Model Overview and Structure; Using the Model; and Model Limitations and Caveats.

MODEL OVERVIEW AND STRUCTURE

The models are stored in Microsoft Access™ databases and accessed by the user through an Access form. The underlying calculations are written in Visual Basic code¹ and produce a series of results tables when the user runs the model.² After running the model, the user has the option to output the final results to a Microsoft Excel™ workbook for future reference and ease of manipulation. All calculations and results in the model are conducted at the national level, though future iterations of the model could be adapted to calculate impacts at the state or regional level. For the U.S., the model can be used to estimate changes in mortality risk for years between 1980 and 2050.³ The temporal range provides a "run-up" period using the more highly resolved by-cause mortality data available for historical years, and allows for testing of hypotheses on a retrospective and prospective basis.⁴ For non-U.S. countries in the International version, the model can be used to estimate changes in all-cause mortality risk for years between 1990 and 2050.

The models each consist of five linked components, as illustrated in Exhibit 1: Inputs, Hazard Estimation, Baseline Life Table, Regulatory Life Table, and Outputs. The five components are contained within an Access database. A table describing the contents of each Access table and query is presented as Appendix A to this document.

Inputs Form

The Inputs form allows users to specify parameters for each model run, such as the size of the changes in PM_{2.5}, the source of relative risk (RR) values, and the lag structure to be applied following each change. This form is discussed in greater detail in the Using the Model section below.

¹ Advanced users may wish to view the code, stored in a series of modules in the database. We have included ample comments throughout the code to help guide users.

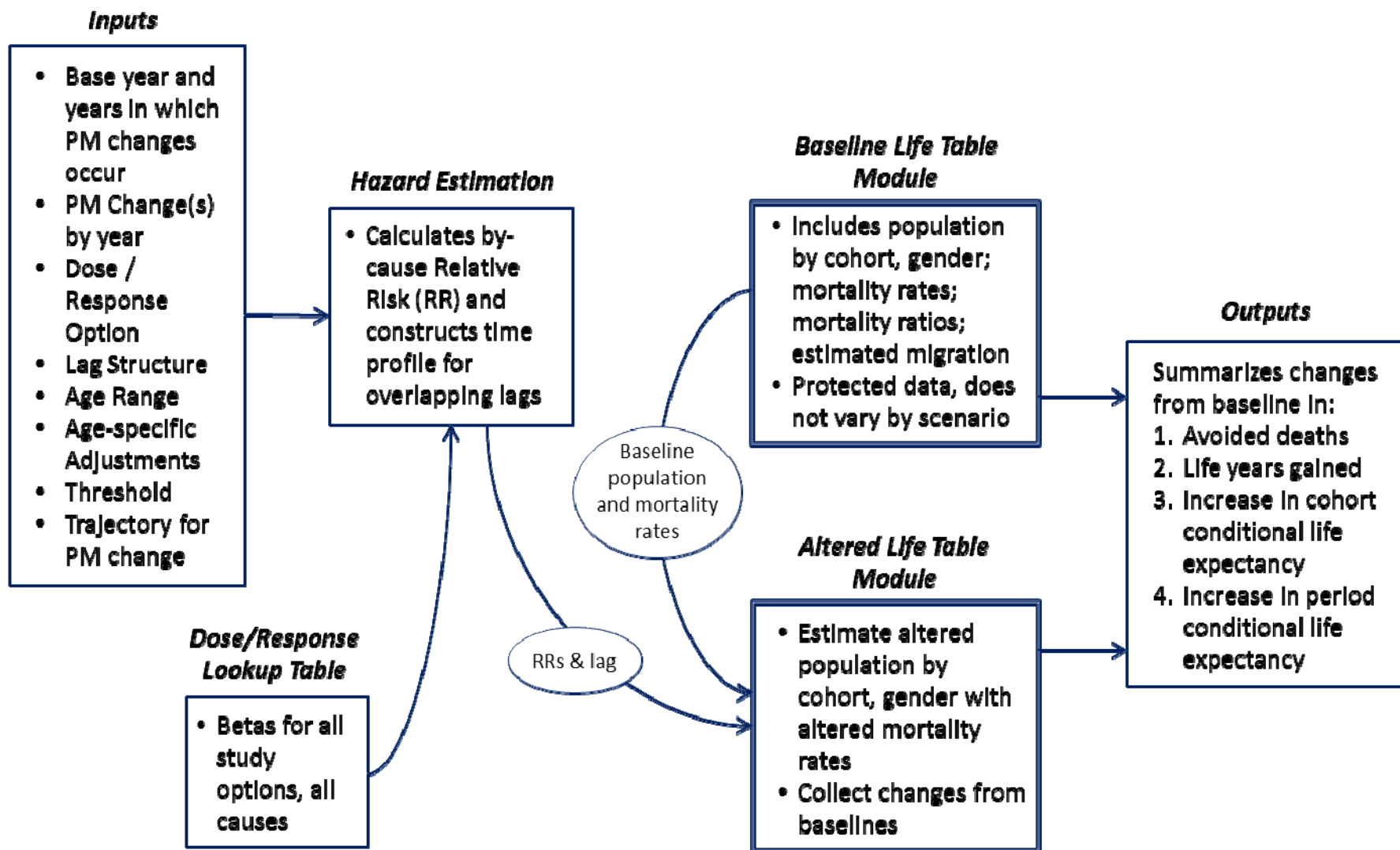
² A table describing the contents of each Access table is presented in Appendix A.

³ Note that 2050 is our end year for reporting the incremental air pollution hazard; however, the model does continue the population simulation out to 2150 to capture effects to the cohort born in 2050. For years beyond 2050, the model fixes mortality rates at their 2050 levels.

⁴ As outlined below in the data section of this memo, the most recent year for which detailed historical data are available is 2014; this year will represent the effective cut-off between retrospective and prospective analysis.

EXHIBIT 1

CONCEPTUAL FRAMEWORK FOR UPDATED POPULATION SIMULATION MODEL



Hazard Estimation Module

The hazard estimation module of the population simulation model takes the user-specified parameters from the inputs form and calculates a mortality hazard adjustment factor (MHAF) that is applied to the baseline mortality hazard. This portion of the model calculates values for each cause of death included in the epidemiology studies and also generates adjustment factors stratified by age cohort and year. In order to accommodate dynamic year-to-year variation in PM_{2.5} levels, the MHAF for each calendar year is calculated as a weighted average of adjustment factors for PM changes associated with that year and all previously modeled years using weights from the cessation lag structure specified by the user.⁵ The weighted average effect estimate of the change in mortality incorporates the effects of multiple, overlapping impacts for changes in annual average PM_{2.5} occurring up to 60 years prior to that year. The MHAF for each calendar year is calculated for each year of age in the cohort and is modified to reflect any age-specific adjustment factors specified by the user. The MHAF is calculated using the following formula:⁶

$$MHAF_{j,t} = 1 + \sum [(e^{\beta \times \Delta PM_i} - 1) \times LAF_{t-i+1} \times TAF_i] \times ASAF_j; i = \text{Base Year to } t$$

Where: MHAF_{j,t} = Mortality Hazard Adjustment Factor for age group j in year t;

β = the beta coefficient either from the selected epidemiologic study or user-specified (see Exhibit 2);

ΔPM_i = the change in PM_{2.5} concentration for year i ($\mu\text{g}/\text{m}^3$);

LAF_{t-i+1} = Lag Adjustment Factor in year t for total PM mortality impact from year i;

TAF_i = Threshold Adjustment Factor for year i; and

$ASAF_j$ = Age-Specific Adjustment Factor for age group j.

Beta Coefficient

The β coefficient used in the calculation of the MHAF is derived from risk models in epidemiologic studies. This value is not often published in the literature, but can be calculated from the published relative risks (RRs). Exhibit 2 contains the β s from the key epidemiologic studies that are included in the model.⁷ PopSim International includes only all-cause mortality as

⁵ The model calculates cumulative impacts from up to 60 years prior to a given calendar year.

⁶ The model assumes that the adjustment to the baseline mortality rate due to a change in PM is permanent and cumulative. Therefore, subsequent changes in PM will add to or detract from previous reductions or increases in the mortality rate, adjusted according to the specified cessation lag structure.

⁷ Note that when available, we used the beta coefficients from EPA's benefits analysis model (BenMAP, EPA, 2003). If there is no value in BenMAP for a specific study, we calculated a value, using the following formula:
 $\beta = [\ln(\text{Published RR})]/[\text{PM}_{2.5} \text{ increment for the Published RR}]$

the cause of death, while the U.S. version includes cause-specific mortality estimates. Users are also able to input a beta coefficient of their choosing from an epidemiologic study not included in the model or from other types of studies, such as a meta-analysis or expert elicitation.

Exhibit 2 EPIDEMIOLOGIC STUDIES USED TO CALCULATE CHANGE IN BASELINE MORTALITY			
Study	Cause of Death	Published RR¹	Beta (per 1 µg/m³ change in PM_{2.5})²
AGGREGATED			
Lepeule et al. (2012)	All-Cause	1.14	0.01310
Krewski et al. (2009)	All-Cause	1.06	0.00583
Pope et al. (1995)	All-Cause	1.17	0.00641
Pope et al. (2002)	All-Cause	1.06	0.00601
Dockery et al. (1993)	All-Cause	1.26	0.01243
Krewski et al. (ACS median) ³ (2000)	All-Cause	1.18	0.00676
Krewski et al. (ACS mean) ⁴ (2000)	All-Cause	1.12	0.00463
Krewski et al. (Six Cities) (2000)	All-Cause	1.28	0.01327
Laden et al. (Cross-Sectional) (2006)	All-Cause	1.16	0.01484
Laden et al. (Change) (2006)	All-Cause	0.73	0.03147
Jerrett et al. (44 Individual Covariates), 2005	All-Cause	1.17	0.01570
Jerrett et al. (44 Individual Covariates + Contextual), 2005	All-Cause	1.11	0.01044
DISAGGREGATED			
Pope et al. (1995)	Cardiopulmonary Diseases	1.31	0.01102
	Lung Cancer	1.03	0.00121
	All Other Causes	1.07	0.00276
Pope et al. (2002)	Cardiopulmonary Diseases	1.09	0.00889
	Lung Cancer	1.14	0.01266

Exhibit 2 EPIDEMIOLOGIC STUDIES USED TO CALCULATE CHANGE IN BASELINE MORTALITY			
Study	Cause of Death	Published RR¹	Beta (per 1 µg/m³ change in PM_{2.5})²
	All Other Causes	1.01	0.00099
Dockery et al. (1993)	Cardiopulmonary Diseases	1.37	0.01693
	Lung Cancer	1.37	0.01693
	All Other Causes	1.01	0.00053
Krewski et al. (ACS median) (2000)	Cardiopulmonary Diseases	1.32	0.00113
	Lung Cancer	1.02	0.00081
	All Other Causes	1.09	0.00352
Krewski et al. (Six Cities) (2000)	Cardiopulmonary Diseases	1.38	0.01732
	Lung Cancer	1.43	0.01923
	All Other Causes	1.01	0.00053
Pope et al. (2004) – 4 Cause	All Cardiovascular Diseases plus Diabetes	1.12	0.00113
	Diseases of the Respiratory System	0.92	-0.00834
	Lung Cancer ⁵	1.14	0.01310
	All Other Causes ⁵	1.01	0.00099
Pope et al. (2004) – 12 Cause	Ischemic Heart Disease	1.18	0.01655
	Dysrhythmias, Heart Failure, Cardiac Arrest	1.13	0.01222
	Hypertensive Disease	1.07	0.00677
	Other Atherosclerosis and Aortic Aneurysms	1.04	0.00392
	Cerebrovascular Disease	1.02	0.00198
	Diabetes	0.99	-0.00101
	All Other Cardiovascular Diseases	0.84	-0.01744
	COPD and Allied Conditions	0.84	-0.01744
	Pneumonia and Influenza	1.07	0.00677

Exhibit 2 EPIDEMIOLOGIC STUDIES USED TO CALCULATE CHANGE IN BASELINE MORTALITY			
Study	Cause of Death	Published RR¹	Beta (per 1 µg/m³ change in PM_{2.5})²
	All Other Respiratory Diseases	0.86	-0.01508
	Lung Cancer ⁵	1.14	0.01310
	All Other Causes ⁵	1.01	0.00099
¹ The PM _{2.5} increment for the published RRs is 10 µg/m ³ for Pope et al. (2002 & 2004), Jerrett et al. (2005), and Laden et al. (Cross-Sectional) (2006), -10 µg/m ³ for Laden et al. (Change) (2006), 18.6 µg/m ³ for Dockery et al. (1993) and Krewski et al. (Six Cities) (2000), and 24.5 µg/m ³ for Pope et al. (1995) and Krewski et al. (ACS) (2000). ² The beta coefficient value is taken from BenMap (EPA, 2003) for the All-Cause estimates (with the exception of Krewski et al. (ACS median) (2000)). The remaining beta coefficients are calculated with the following formula: $\beta = [\ln(\text{Published RR})]/[\text{PM}_{2.5} \text{ increment for Published RR}]$. ³ Krewski (ACS median) refers to data from Table 25c of the Krewski reanalysis of the Pope et al (1995) data that is based on an annual median value of PM _{2.5} . ⁴ Krewski (ACS mean) refers to data from Table 31 of the Krewski reanalysis of the Pope et al. (1995) data that is based on an annual mean value of PM _{2.5} . This data includes 13 additional cities that were not part of the original analysis. ⁵ These estimates are from Pope et al. (2002).			

Lag Adjustment Factor

The lag between changes in PM_{2.5} exposure levels and the full realization of the expected changes in mortality rates is modeled by applying a lag adjustment factor (LAF) to the relative risk calculated in each year. The LAF for a given year, t_n , represents the cumulative fraction of the total change in mortality associated with a PM_{2.5} change in year t_1 that is expected to be realized by year t_n . For example, if 30 percent of the mortality rate reduction associated with a decrease in PM_{2.5} is expected to be achieved in the first year following the decrease, and another 50 percent of the change is expected to be distributed evenly over the next four years, the series of LAFs for the years t_1 through t_5 would be 0.30, 0.425, 0.550, 0.675, 0.80.

The lag is applied both to decreases and increases in PM_{2.5} levels. In the case of increases in PM_{2.5}, we assume that the same default LAFs based on the Science Advisory Board's (SAB's) recommended "cessation lag" approach can be used to model the lag for increasing mortality risk. We recognize, however, that the lags for increases and decreases, in theory, may not be identical.

Threshold Adjustment Factor

The Threshold Adjustment Factor (TAF) accounts for the idea that only the percentage of the population experiencing PM_{2.5} concentration above a hypothesized threshold level would experience PM_{2.5} mortality effects. If a PM threshold is defined then we must adjust the dose-response curve above the threshold level to account for the fact that populations experiencing PM_{2.5} concentrations below the threshold are not experiencing PM_{2.5} mortality effects. To adjust the dose-response curve the user must specify a beta adjustment factor in the inputs form.

In order to determine the percentage of the population that are expected to experience all or part of the impact of a change in PM_{2.5} concentrations, the model uses a distribution of population-weighted PM_{2.5} annual average concentrations in the U.S. generated from BenMAP (EPA, 2003) for the year 2002. While this TAF is generated based on U.S.-specific values, they can also be used for the International version. The model then assumes that the PM change applies equally to all members of the population. Therefore, it is possible to break the population into three groups:

Group 1: those experiencing baseline and adjusted PM_{2.5} concentrations below the threshold, and therefore would not experience any mortality effects of PM_{2.5};

Group 2: those experiencing baseline and adjusted PM_{2.5} concentrations above the threshold, and therefore would experience mortality effects due to the full change in PM_{2.5}; and

Group 3: those experiencing baseline and adjusted PM_{2.5} concentrations that are on opposite sides of the threshold, and therefore would experience mortality effects due to a fraction of the change in PM_{2.5}.

Each of these three groups are assigned a specific impact value that represents the assumed fraction of the mortality effects experienced by that group, conditional on the user-specified PM threshold level and change in PM_{2.5}. For instance, Group 1 would be assigned a value of 0, since they do not experience any mortality effects. Group 2 would be assigned a value of 1 because they experience the full mortality effects, and Group 3 would be assigned a score of 0.5, assuming that on average, members of this group would experience roughly half of the total mortality effects. These impact values are then multiplied by the percentage of the population represented by each group, based on the population-weighted PM_{2.5} concentration distribution, to get the group-specific TAFs. These group-specific TAFs are then summed to calculate a total TAF across the whole U.S. population.

$$\text{TAF}_{\text{total}} = \text{TAF}_{\text{group 1}} + \text{TAF}_{\text{group 2}} + \text{TAF}_{\text{group 3}}$$

Where: $\text{TAF}_{\text{group } i} = \text{Percentage of the Population Associated with Group } i \times \text{Impact Value}_i$

Age-Specific Adjustment Factor

The Age-Specific Adjustment Factor (ASAF) allows users to reflect differences in susceptibility to PM_{2.5} across the population. The user can specify values for an ASAF between 0 and 2 for specific user-defined age groups, with a value of 1 meaning that age group experiences the full mortality impact of the change in PM_{2.5}. Values greater than 1 indicate that an age group is more susceptible to PM than the rest of the population and values less than 1 indicate that an age group is less susceptible to PM. The model default is for the ASAF to be set at 1 for all years of age included in the study population specified by the user and 0 for those outside the study age range.

Baseline Life Table Module⁸

For the U.S. version, the Baseline Life Table module is essentially a replication of the Census historical population data and projection for the 1980 to 2050 period (and beyond as necessary to capture long-term effects on life expectancy). It contains population data stratified by gender and year of age; mortality rates for each relevant cause, by age cohort; and natality (birth) rates by age. These data also include estimates of net migration that we developed by subtracting estimated deaths calculated using CDC mortality data from annual cohort population change reported in U.S. Census data. For the International version, the Baseline Life Table module is based on the Census IDB historical population data and projection for years 1990 through 2050 and beyond, as above. The International version contains population data stratified by gender and year of age; all-cause mortality rates by age cohort; and natality rates by age. These data also include estimates of net migration that we developed by subtracting estimated deaths calculated using historical GBD mortality rates and projected IDB mortality rates. We describe the source of the historic data and future projections for both the U.S. and International models in the section below.

Retrospective Population Data

U.S. Version

Estimates of the U.S. resident population for each year are available from the Census Bureau, by gender and single year of age, for 1980 through 2014.⁹ Resident population is defined

⁸ The model is currently set up to only calculate population and death values for the regulatory scenario when the user runs the model. The final tables are pre-loaded with baseline population and death values, which do not change based on user selections. There should be no need for the user to rerun the baseline calculations unless the preloaded tables accidentally get erased or deleted. If new baseline Census data becomes available, the user could load that data and rerun the baseline; however, data tables derived from the baseline and used in the regulatory scenario, such as migration rates, would also need to be updated prior to rerunning the baseline. If necessary, the way to rerun the baseline is to run Module "2_baseline". The run time is approximately 1-2 hours.

⁹ U.S. Census Bureau, Population Estimates, 1980s: State Tables, State Population Estimates and Demographic Components of Change: 1980 to 1990, by Single Year of Age and Sex, accessed by <https://www.census.gov/popest/data/historical/1980s/state.html>; U.S. Census Bureau, Population Estimates, National Intercensal Estimates (1990-2000), Intercensal Estimates of the United States Resident Population by Age and Sex, 1990-2000: Selected Months, accessed by <https://www.census.gov/popest/data/intercensal/national/index.html>; U.S. Census Bureau, Population Estimates, National Intercensal Estimates (2000-2010), Intercensal Estimates of Resident Population by Single Year of Age, Sex, Race, and Hispanic Origin for the United States: April 1, 2000 to July 1, 2010, accessed by <https://www.census.gov/popest/data/intercensal/national/nat2010.html>; U.S. Census Bureau, Population Estimates, Vintage 2014 National Population Datasets, Annual Estimates of the Resident Population by Single Year of Age and Sex for the United States: April 1, 2010 to July 1, 2014, accessed by <http://www.census.gov/popest/data/datasets.html>.

as all people (both civilians and members of the Armed Forces) living in the 50 states and the District of Columbia.

The Census Bureau does not publish data regarding the rates of change for each single-year age cohort that are implicit in their population estimates. Birth rates and mortality rates (including rates for common causes of death) are available from the CDC, but these rates are not published by single year of age. The CDC does release raw data on deaths in the United States; we have used this information to calculate birth and mortality rates by single year of age.

The *Nativity Data Public-Use Data Files* contain information on every birth in the country, including the mother's age at birth and the gender of the baby.¹⁰ These files are available for 1980 through 2013. In combination with the population estimates from the Census Bureau, we calculated age-specific birth rates for baby boys and baby girls. The model relies on natality projections for 2014 (see discussion below).

The *Multiple Cause-of-Death Public-Use Data Files* contain information on every death in the country, including each individual's age at death, the International Classification of Disease (ICD) code for the underlying cause of death, and the ICD codes for multiple conditions that may have contributed to death.¹¹ In combination with the population estimates from the Census Bureau, we used the CDC files to calculate age- and gender-specific mortality rates for the causes of interest.

These files are available for 1980 through 2013, although the data is coded using two different systems -- ICD-9 for 1980 through 1998 and ICD-10 for 1999 through 2013. Because the epidemiological articles from which we derived the adjustment factors use the ICD-9 system, we attempted to convert the ICD-10 data to ICD-9 codes, but the results did not appear reasonable for many cause-specific death rates. In addition, the World Health Organization cautions that it is not possible to translate between ICD-10 and ICD-9.¹² Due to this problem with the cause-specific data in the years after 1998, we calculated cause-specific death rates for 1999 through 2013 by adjusting the all-cause death rate for these years by the ratio of the cause-specific rates to the all-cause rate for 1998. We also rely on the projected all-cause rate for 2014 (see discussion below).

Age-specific net migration is calculated as the portion of a cohort's annual population change (from the Census data) that is not explained by deaths (from the CDC all-cause death rate). We assume that the all-cause mortality rates calculated from the CDC data provide a close

¹⁰ Centers for Disease Control and Prevention, National Center for Health Statistics, Vital Statistics Natality Birth Data, 1968-2013, accessed by <http://www.nber.org/data/vital-statistics-nativity-data.html>.

¹¹ Centers for Disease Control and Prevention, National Center for Health Statistics, Vital Statistics NCHS' Multiple Cause of Death Data, 1959-2012, accessed by <http://www.nber.org/data/vital-statistics-mortality-data-multiple-cause-of-death.html>.

¹² Specifically, WHO states that, "changes introduced at ICD-10 to the selection and modification rules for arriving at the underlying cause have a significant impact on the selection of certain conditions" (<http://www.who.int/classifications/help/icdfaq/en/>).

approximation of the rates implicit in the CDC's population estimates.¹³ This assumption allows us to conclude that the change in each age cohort that cannot be explained by the CDC-derived mortality rates is attributable to net migration. Using the residual to parameterize the effect of net migration on cohort change is necessary because neither the CDC nor the Census Bureau publish data on net migration by single year of age for all of the years of interest.¹⁴

International Version

Exhibit 3 lists the countries included in the International model; these are countries for which relevant data were available from both Census IDB and GBD databases. The International model includes countries which are recognized by the U.S. Department of State and have populations of 5,000 or more, excluding foreign military populations, tourists, and others visiting for short periods. IDB data capture the timing and impact of such events as wars, famine, and natural disasters. GBD 2013 was coordinated by the Institute for Health Metrics and Evaluation to estimate the mortality and morbidity burden of diseases, injuries, and risk factors globally.

Exhibit 3. International PopSim Countries					
Country Code	Country Name	Country Code (cont.)	Country Name	Country Code (cont.)	Country Name
AC	Antigua and Barbuda	GA	The Gambia	NO	Norway
AE	United Arab Emirates	GB	Gabon	NP	Nepal
AF	Afghanistan	GG	Georgia	NS	Suriname
AG	Algeria	GH	Ghana	NU	Nicaragua
AJ	Azerbaijan	GJ	Grenada	NZ	New Zealand
AL	Albania	GM	Germany	PA	Paraguay
AM	Armenia	GR	Greece	PE	Peru
AN	Andorra	GT	Guatemala	PK	Pakistan

¹³ There are two reasons why we believe that the CDC mortality rates are comparable to the mortality rates implied by the Census Bureau's population estimates. First, the CDC uses a similar definition of the population as the Census Bureau (CDC: "within the United States", Census: resident population). Second, the Census Bureau states that the "base data for estimates of births and deaths" used in generating estimates of population change "come from the National Center for Health Statistics" at the CDC, the same organization that releases the mortality and natality public-use files (www.census.gov/popest/births.html, accessed August 17, 2005).

¹⁴ The model does not apply a "net migration rate," and therefore there is not a means to adjust the net migration rate in response to changes in air pollution hazards. While it is plausible to hypothesize that net migration might be affected by air pollution at the local level, it seems to us that air pollution should have a negligible effect on the national-level net migration rate.

Exhibit 3. International PopSim Countries					
Country Code	Country Name	Country Code (cont.)	Country Name	Country Code (cont.)	Country Name
AO	Angola	GV	Guinea	PL	Poland
AR	Argentina	GY	Guyana	PM	Panama
AS	Australia	HA	Haiti	PO	Portugal
AU	Austria	HO	Honduras	PP	Papua New Guinea
BA	Bahrain	HR	Croatia	PU	Guinea-Bissau
BB	Barbados	HU	Hungary	QA	Qatar
BC	Botswana	IC	Iceland	RI	Serbia
BE	Belgium	ID	Indonesia	RM	Marshall Islands
BF	The Bahamas	IN	India	RO	Romania
BG	Bangladesh	IR	Iran	RP	Philippines
BH	Belize	IS	Israel	RS	Russia
BK	Bosnia and Herzegovina	IT	Italy	RW	Rwanda
BL	Bolivia	IV	Cote d'Ivoire	SA	Saudi Arabia
BN	Benin	IZ	Iraq	SE	Seychelles
BO	Belarus	JA	Japan	SF	South Africa
BP	Solomon Islands	JM	Jamaica	SG	Senegal
BR	Brazil	JO	Jordan	SI	Slovenia
BT	Bhutan	KE	Kenya	SL	Sierra Leone
BU	Bulgaria	KG	Kyrgyzstan	SN	Singapore
BX	Brunei	KN	North Korea	SO	Somalia
BY	Burundi	KR	Kiribati	SP	Spain
CA	Canada	KS	South Korea	ST	Saint Lucia
CB	Cambodia	KU	Kuwait	SW	Sweden
CD	Chad	KZ	Kazakhstan	SY	Syria

Exhibit 3. International PopSim Countries					
Country Code	Country Name	Country Code (cont.)	Country Name	Country Code (cont.)	Country Name
CE	Sri Lanka	LA	Laos	SZ	Switzerland
CF	Congo (Brazzaville)	LE	Lebanon	TD	Trinidad and Tobago
CG	Congo (Kinshasa)	LG	Latvia	TH	Thailand
CH	China	LH	Lithuania	TI	Tajikistan
CI	Chile	LI	Liberia	TN	Tonga
CM	Cameroon	LO	Slovakia	TO	Togo
CN	Comoros	LT	Lesotho	TP	Sao Tome and Principe
CO	Colombia	LU	Luxembourg	TS	Tunisia
CS	Costa Rica	LY	Libya	TT	Timor-Leste
CT	Central African Republic	MA	Madagascar	TU	Turkey
CU	Cuba	MD	Moldova	TW	Taiwan
CY	Cyprus	MG	Mongolia	TX	Turkmenistan
DA	Denmark	MI	Malawi	TZ	Tanzania
DJ	Djibouti	MJ	Montenegro	UG	Uganda
DO	Dominica	MK	Macedonia	UK	United Kingdom
DR	Dominican Republic	ML	Mali	UP	Ukraine
EC	Ecuador	MO	Morocco	UV	Burkina Faso
EG	Egypt	MP	Mauritius	UY	Uruguay
EI	Ireland	MR	Mauritania	UZ	Uzbekistan
EK	Equatorial Guinea	MT	Malta	VC	Saint Vincent and the Grenadines
EN	Estonia	MU	Oman	VE	Venezuela
ER	Eritrea	MV	Maldives	VM	Vietnam
ES	El Salvador	MX	Mexico	WA	Namibia

Exhibit 3. International PopSim Countries					
Country Code	Country Name	Country Code (cont.)	Country Name	Country Code (cont.)	Country Name
ET	Ethiopia	MY	Malaysia	WS	Samoa
EZ	Czech Republic	MZ	Mozambique	WZ	Swaziland
FI	Finland	NG	Niger	YM	Yemen
FJ	Fiji	NH	Vanuatu	ZA	Zambia
FM	Federated States of Micronesia	NI	Nigeria	ZI	Zimbabwe
FR	France	NL	Netherlands		

We obtained estimates of the population for each country and year from the Census Bureau IDB, by gender and single year of age, for 1990 through 2014.¹⁵

We obtained mortality rates by 5-year age group and gender beginning in 1990 through 2013 through the GBD Study 2013¹⁶. We applied age-group mortality rates to each age within that group, assuming consistent mortality rates across ages in each five-year age group.

We developed natality rates by five-year maternal age group by year based on IDB natality data for 1990-2014. To obtain age-specific natality rates, we assumed constant five-year age group natality rates for each age within that group. We then applied the sex ratio at birth to estimate the number of male and female births per year.

We calculate age-specific net migration as the portion of a cohort's annual population change (from IDB data) not explained by deaths (from GBD). Infant migration is calculated as the difference between the age 0 population per year (from IDB data) and the population calculated based on natality rates per year (from IDB).

Projections of Future Population (2015-2050)

U.S. Version

¹⁵ U.S. Census Bureau, IDB Data Files. IDBextCTYS: Country names, codes, and land area. IDBext001: Total Midyear Population. IDBext008: Crude Birth and Death, Net Migration, and Growth Rates. IDBext010: Infant Mortality Rate and Life Expectancy, Under-5 Mortality, and Mortality for ages 1-4, by Sex. IDBext028: Age-Specific Fertility Rates and Selected Derived Measures. IDBext094: Midyear Population, by 5-year Age Groups and Sex. IDBext194: Midyear Population, by Age and Sex. Accessed March 15, 2016 by <http://www.census.gov/population/international/data/idb/informationGateway.php>.

¹⁶ Data obtained from GBD 2013 Age-Sex Specific All-Cause and Cause-Specific Mortality 1990-2013. Seattle, United States: Institute for Health Metrics and Evaluation, 2014.

The Census Bureau publishes age- and gender-specific population projections for 2015 through 2060, derived from its 2013 population estimates (based on the 2010 Census).¹⁷ The Census Bureau also publishes the underlying natality and mortality projections.^{18,19} We used the natality rates published by the Census Bureau and calculated mortality rates using the Census' mortality data in combination with their population data.²⁰

It is important to note that the Census Bureau's mortality projections do not reflect explicit assumptions about pollution or cause-specific mortality. In order to forecast population through 2100, the Census Bureau makes three key assumptions:

1. Racial and ethnic differences in mortality rates will disappear by 2150.
2. Mortality rates for men and women will move closer to convergence by 2150.
3. Life expectancy by gender in 2150 can be estimated by using: a) life expectancy projections for 2065 from Lee and Tuljapurkar (1998); and b) expected changes in mortality in certain age groups relative to other age groups from Rosenberg and Luckner (1998), derived from a survey conducted at a conference of the Society of Actuaries.

With two fixed points (life expectancy in 1998 and in 2150) and the information about the age distribution of expected changes in mortality from the Society of Actuaries conference, the Census Bureau then estimates life expectancy and mortality rates for the intervening years. Although the demographers at the Census Bureau may have made implicit assumptions

¹⁷ U.S. Census Bureau, 2014 National Population Projections: Downloadable Files, Table 1. Projected Population by Single Year of Age, Sex, Race, and Hispanic Origin for the United States: 2014 to 2060, accessed by <http://www.census.gov/population/projections/data/national/2014/downloadablefiles.html>.

¹⁸ U.S. Census Bureau, 2014 National Population Projections: Methodology and Assumptions, Technical Appendix 1: Projected Fertility Rates, accessed by <http://www.census.gov/population/projections/data/national/2014/2014methodology.html>.

¹⁹ U.S. Census Bureau, 2014 National Population Projections: Downloadable Files, Table 3. Projected Deaths by Single Year of Age, Sex, Race, Hispanic Origin, and Nativity for the United States: 2014 to 2060, accessed by <http://www.census.gov/population/projections/data/national/2014/downloadablefiles.html>.

²⁰ The Census Bureau also published mortality rates; however, the rates are specific to race and Hispanic origin. Therefore, we had to calculate rates for the general population using mortality and population projections.

regarding future pollution, none of these three assumptions reflect an explicit pollution scenario.²¹

We therefore believe it is reasonable to assume that the Census Bureau's population projections reflect a constant level of pollution, consistent with that experienced in the late 1990s. In addition, given the absence of cause-specific mortality projections, we assume that the projected declines in all-cause mortality are also applicable to cause-specific mortality rates (derived from the CDC retrospective data). In practice, this means that cause-specific death rates from 2014 onward are calculated as the ratio of the specific-rate to the all-cause rate in 1998, multiplied by the all-cause rate for the future year.

International Version

The Census IDB publishes population projections by age and gender for 2015 through 2050. IDB also publishes five-year natality rates and crude death rates, which are used in conjunction with GBD gender-specific mortality rates to calculate age-specific mortality rate projections for 2014 through 2050.

The Census Bureau prepares national estimates and projections for all IDB countries using census and survey data, administrative statistics from those countries, vital statistics, and country-specific information from multinational organizations. Projecting and estimating populations requires data collection, evaluation, parameter estimation, and assumptions about future change for each country. Population projections are based on *de facto* population, or all who are present in the country at the reference date, whether or not they are legal or usual residents, excluding foreign military, tourists, and other visitors. To calculate projections, demographers consider socio-political circumstances, public health efforts, natural disasters, and civil conflicts. This information is input to the Census Bureau's Rural/Urban Projection (RUP) program²², which generates cohort component projections through 2050 for each country. The IDB's quality assurance process focuses on internal and temporal consistency of data, and statistical measures of uncertainty are included where available. Uncertainties exist in country-

²¹ Though there is no reference to environmental factors in Lee and Tuljapurkar (1998), their life expectancy projections are derived from historical mortality rates from 1900 to 1996, which presumably implicitly reflect declining levels of pollution. In the Society of Actuaries study, the only mention of environmental factors is as a possible driver of increasing mortality rates; however, this theory does not receive much support from respondents. The Actuaries study concludes that the main causes of declining mortality will be medical advances (such as genetic therapy) and lifestyle changes (such as improvements in diet and exercise and a reduction in smoking). (Ron Lee and S. Tuljapurkar, Population Forecasting for Fiscal Planning: Issues and Innovations, unpublished manuscript, September 1998; Marjorie Rosenberg and Warren Lucknert, "Summary of Results of Survey of Seminar Attendees," *North American Actuarial Journal*, vol. 2-4 (1998), pp. 64-82. For more on the Lee and Tuljapurkar (1998) projections, see Ronald D. Lee and Lawrence R. Carter, "Modeling and Forecasting U.S. Mortality," *Journal of the American Statistical Association*, vol. 87, no. 819 (September 1992), pp. 659-675).

²² For more information on the RUP program, see www.census.gov/population/international/software/rup.

specific IDB data due to potential deficiencies in source data and flawed assumptions about future scenarios, as some population dynamics are influenced by unpredictable events²³.

Regulatory Life Table Module

The Regulatory module begins with the same data underlying the Baseline module, and then applies adjustment factors (from the Hazards table) to the baseline mortality rates taken from the CDC data. As a result, the population simulation in the Regulatory module reflects the mortality rates implied by user's scenario specifications (entered in the Inputs form). If the user does not alter the Inputs form (i.e., all the variables are set to zero), then the Regulatory module and the Baseline module will generate identical results. The calculations in the Regulatory module and the Baseline module are equivalent, with the exception of the mortality rate, which is calculated as follows:

$$P_{\text{regulatory}}(\text{death}) = [P_{\text{baseline}}(\text{death})] * [\text{MHAF}]$$

In sum, the Regulatory module generates an alternative estimate of the mortality and population profile for the study period.

Output Tables

The results of the simulation are reported in a series of Access tables, which the user can output to a Microsoft Excel workbook for further analysis and future reference. This workbook is discussed in greater detail in the Using the Model section below.

USING THE MODEL

The model was created and tested using Access Version 2007-2010. Upon opening the database file (PopSim.accdb for the U.S. version; PopSim_International.accdb for the International version), users will see the main inputs form, with buttons to run the model and reset defaults. This section discusses how to use the model to estimate dynamic population changes over time due to one or more specific changes in PM_{2.5}.

Using the Inputs Form

U.S. Version

The Inputs form of the model allows users to specify both the details of the regulatory scenario being modeled and the way in which the baseline mortality hazard of the U.S. population is adjusted to account for changes in air pollution concentrations. It contains a series of drop-down menus and user-defined cells that allow the user to specify the following:

²³International Database Population Estimates and Projections Methodology can be found at <http://www.census.gov/population/international/data/idb/estandproj.pdf>

- The method of adjusting the mortality hazard, either an aggregated approach (i.e., apply a single adjustment across all causes of death) or a disaggregated approach (i.e., apply specific adjustments for individual cause of death categories);
- The specific epidemiologic study on which the adjustment is based or a user-specified concentration-response (beta) coefficient;
- The year(s) in which the PM_{2.5} change(s) occurs;
- The magnitude of the change(s) in concentration of PM_{2.5} as compared to a baseline scenario;
- The shape of the function describing how air pollution changes over time: either stepwise (all change occurs in the year specified) or linear (the change in PM is interpolated linearly across intervening years);
- The age cohorts to which the mortality hazard adjustment will be applied and optional age-specific adjustment factors to reflect differences in susceptibility across the population;
- A PM_{2.5} threshold concentration below which PM has no effect on mortality and an adjustment factor to be applied to the mortality beta coefficient above the threshold level (both optional); and
- The cessation lag structure describing the temporal pattern of the effects of the PM change on mortality.

Input fields have been constrained to accept only logically-valid inputs. If the user inputs a value outside of a field's set range, a message box appears to explain the specific constraints on the field and allows the user to revise the chosen value.

International Version

Using the International version of the model is very similar to the U.S. version, with minor changes to reflect differences in U.S. and International options. The differences are highlighted below:

- A drop-down menu to choose the country of analysis;
- The Dose-Response Technique radio button for choosing an aggregated approach or disaggregated approach for cause-specific mortalities has been removed, as the International version only allows for an aggregated approach using all-cause mortality (See Step 2, below);
- Studies which include only cause-specific mortalities are removed, as only all-cause mortality can be assessed;

- Cause-specific lag types are removed, to accommodate only the aggregated approach.

Step 1: Input begin and end years

Here the user inputs the chosen begin and end years for the analysis. The begin year should be between 1980 and 2030 for the U.S. version and 1990 and 2030 for the International version.²⁴ This is the starting point of the analysis in which the baseline and regulatory scenarios are assumed to have the same PM_{2.5} concentration.

Step 2: Choose dose-response technique and beta

In the U.S. version, the first choice that the user can make is whether the model employs an aggregated or disaggregated approach to hazard estimation. In the International version, only the aggregated approach can be used. Under the aggregated approach, the model applies a uniform hazard adjustment to mortality risk from all causes of death. Under the disaggregated approach, the model applies cause-specific mortality hazard adjustments based on epidemiologic results to each corresponding cause-specific mortality hazard.

After selecting the type of approach, the user then specifies whether the beta will be drawn from an epidemiologic study or input by the user to generate the mortality hazard adjustment. We have selected the two largest and most extensively reviewed cohorts examining the link between long-term exposure to fine particles (PM_{2.5}) and mortality, the American Cancer Society cohort (ACS) (Pope et al. (1995, 2002, & 2004); Krewski et al. (2000); Jerrett et al. (2005); Krewski et al. (2009)) and the Six Cities cohort (Dockery et al. (1993); Krewski et al. (2000); Laden et al. (2006); Lepeule et al. (2012)) on which to base the hazard adjustment calculations.

If the user selects an aggregated approach, they can choose among risk estimates for all-cause mortality derived from either the ACS cohort or the Six Cities cohort. The list includes risk estimates from the originally published cohort studies (Pope et al. (1995), Dockery et al. (1993)), as well as from the reanalysis of both cohort studies performed by the Heath Effects Institute (HEI) (Krewski et al. (2000)), the 2002 ACS follow-up (Pope et al. (2002)), the 2005 ACS Los Angeles analysis (Jerrett et al. (2005)), and the Six Cities follow-up (Laden et al. (2006)).²⁵ Users can also input a beta coefficient of their choice from another epidemiologic study, meta-analysis, expert elicitation study, or other relevant study type.

For the disaggregated approach available in the U.S. version only, the user chooses relative risk (RR) estimates for specific causes of death derived from the studies of the ACS or

²⁴ We have chosen the years 1990 to 2030 because the model calculates adjusted mortality risks from 1990 to 2050. The lag may be distributed across a maximum of 30 years, but the EPA default currently assumes a maximum lag of 20 years. Under the EPA default lag, by 2050, the entire population would experience the full mortality effects from the expected change in PM_{2.5} occurring in 2030. Note that if a change in PM is specified in 2030 or after with a lag greater than 20 years or, the full mortality hazard adjustment associated with this change will not be realized before the model “freezes” mortality in 2050.

²⁵ There are two choices for the ACS reanalysis, mean or median, which refers to whether the mean or the median of the ambient PM monitoring data was used in the risk model.

Six Cities cohorts. In addition, the user can designate how broadly the causes of death are defined. For instance, the user may select risk estimates from Pope et al. (2002), which includes separate adjustments for cardiopulmonary diseases, lung cancer, and all other causes. By choosing Pope et al. (2004), which includes several specific cardiovascular and respiratory causes of death, the user can explore the impact of changes in PM_{2.5} on more specific causes of death.²⁶ Note that the study drop-down menu lists two different options for Pope et al. (2004): "4 causes of death" or "12 causes of death." If the user selects "4 causes of death," mortality will be calculated for cardiovascular disease, respiratory disease, lung cancer, and all others. If the user selects "12 causes of death," mortality is calculated for specific cardiovascular and respiratory causes of death (e.g., ischemic heart disease, pneumonia).

Step 3: Input PM changes

For both the U.S. and International versions, the user can specify the magnitude of the changes in air pollution concentration from the baseline to the regulatory scenario.²⁷ The input page contains a series of fields to hold the values of the increases or decreases in annual average PM_{2.5} concentration (in $\mu\text{g}/\text{m}^3$) that the model will use to calculate the mortality effects associated with that specific scenario. The user can input up to five changes²⁸ in concentration with the corresponding years for those changes. The direction of each PM_{2.5} change is specified by the sign of the value entered by the user (i.e., a negative number indicates a decrease in PM and a positive number indicates an increase).

Here the user can also specify the shape of the curve describing how PM changes occur over time. If the option, "Step," is selected, each PM change will occur in the year specified and then a constant PM concentration is assumed until the next change.²⁹ The "Linear" option results in PM concentrations interpolated linearly over time from the base year until the first year specified and between the rest of the specified years. For instance, if the base year is 1990 and

²⁶ Note that Pope et al., 2004 analyzes respiratory and cardiovascular deaths, which comprise 53.3 percent of the deaths in the ACS cohort. This study is based on the same data and employs the same statistical model as Pope et al. (2002). Therefore we assume that the cardiovascular and respiratory deaths included in Pope et al. (2004) are an exact replacement for the cardiopulmonary category of Pope et al. (2002). To gain a complete representation of mortality effects, we plan on using the RRs for lung cancer and all other causes from Pope et al. (2002) to assess deaths from those other causes when using Pope et al. (2004).

²⁷ When running the model to evaluate the differences in mortality between a baseline and a regulatory scenario (e.g., from a regulatory impact analysis) we recommend simply entering PM changes as the difference between those two scenarios. This requires the user to run the model only once, and the outputs would reflect the impact of the differences in PM between these two scenarios. Alternatively, the user can run a baseline and regulatory scenario separately, first inputting the changes in PM over time for the baseline scenario, and then repeating this for the regulatory scenario. To calculate the impacts of the regulation, the user would calculate the difference in the outcomes from these two scenario runs.

²⁸ If fewer than five changes are desired, the user should simply leave the extra fields at their default values (i.e., 0).

²⁹ The "Step" option also assumes that the PM concentration remains constant from the base year until the first PM change.

the user inputs a change of $-2 \mu\text{g}/\text{m}^3$ in 2000, the PM concentration will decrease by $-0.2 \mu\text{g}/\text{m}^3$ each year from 1991 to 2000.

The user is also able to specify a threshold value to indicate the PM_{2.5} concentration below which changes in PM_{2.5} would have no impact on mortality rates.³⁰ In addition, users can enter an optional adjustment factor that is applied to the beta coefficient above the threshold, based on a “hockey stick” concentration-response model. This adjustment factor is limited to values between 0 and 1, because it represents a percent change increase that is applied to the beta coefficient.

Step 4: Specify age range affected

The user can specify the age cohorts to which the mortality hazard adjustment will be applied. The default value for the start of the affected age range is based on the age groups that were included in the cohorts used in the underlying epidemiology studies (ages 25 and above for the Six Cities cohort and ages 30 and above for the ACS cohort). The user may override these defaults and decide to apply the mortality hazard adjustment across all age cohorts or to other specific ranges of ages (e.g., those 65 and above).

Users can also determine the magnitude of the hazard adjustment that is applied to various subgroups within the age range selected in order to reflect perceived differences in susceptibility to PM across the population. Users can select up to five subpopulations to which specific adjustments will be applied. The age-specific adjustment factor (ASAF) must be between 0 and 2, where 0 indicates that no mortality hazard adjustment will be applied to those age groups, a 1 indicates that the full mortality adjustment will be applied, and a 2 indicates that twice the mortality hazard adjustment will be applied.³¹ If the user leaves the age-specific adjustment factor fields at their default values, then the full mortality hazard adjustment will be applied to all ages included in the age range selected.

Step 5: Specify lag type

The user is also able to specify a series of lag adjustment factors (LAFs) to account for the delay between changes in PM_{2.5} exposure levels and the full realization of the expected changes in mortality rates. This lag will be applied to each PM change specified by the user. In the U.S. version, the user first selects whether they would like to apply a single lag to all causes of disease or if they would like to specify cause-specific lags. If the user has selected the aggregated approach, they must choose the “Single or All Cause” option, since under this approach, mortality is not calculated for specific causes separately. Those using the disaggregated approach may also choose to apply a single lag to all of the specific causes of death by selecting the “Single or All Cause” option. However, users of the disaggregated, by-

³⁰ The threshold is applied across all age cohorts in the population.

³¹ A default ASAF of 1 will be applied to those age groups that are included in the overall age range, but that are not associated with a specific ASAF in the table. In addition, an ASAF of 0 will be applied to age groups included in the table that are outside the overall age range specified.

cause option may enter separate sets of LAFs for specific causes of death by selecting the "Cause-Specific" option. For example, a user may want to specify lower LAFs in earlier years for estimating the impact of PM_{2.5} changes on incidence of lung cancer deaths, due to the longer expected latency period (on the order of 20 years) associated with lung cancer. In the International version, cause-specific and disaggregated lag options are removed, as the user only has the option to use an aggregated approach and all-cause mortality associated with the lag function type options listed below.

Once the lag type is chosen, the user can specify the lag function type to determine how the lag will be calculated.³² The user has the following three options:

1. **HES Default** - This option reflects the cessation lag approach recommended by the EPA SAB Health Effects Subcommittee (HES) of the Advisory Council on Clean Air Act Compliance Analysis in their letter dated December 6, 2004. The approach recommended by SAB HES assumes 30 percent of the mortality effect occurs in the first year, another 50 percent occurs distributed evenly over years 2 through 5, and the remaining 20 percent is distributed evenly over years 6 through 20.
2. **Smooth** - This option generates the lag based an exponential decay model, similar to that used by Roosli et al. (2005), with the following equation:

$$LAF = 1 - e^{-k*t}$$

The user can input the value for the decay constant, "k," by inputting a positive value into the appropriate field.

3. **User-Defined** - This option allows users to specify a custom lag structure of values that represent cumulative percentages of the mortality effects that will be realized in that year. Therefore, any value that is input must be less than or equal to 1, and must be greater than or equal to the value of the lag in the previous year. If the user-defined option is selected, the user will be prompted with an input form to edit the lag values once the user runs the model. The default input values which will appear correspond to the HES Default values as described above. It is important that the user input values of 1 in the remaining cells of the grid when the lag is distributed across a period of less than the maximum of 30 years. For instance, if the lag is distributed over 20 years, the user should input a value of 1 for years 21-30, since it is assumed that for these years, the population will experience a fully realized mortality effect from the change in PM_{2.5}.

Step 6: Other options

³² All three of the lag options assume a cumulative function from year 1 (the year in which the change in PM occurs) to year 30. For instance, if 30 percent of the mortality effects occur in the first year, and another 20 percent occur in the second year, the first year of the lag distribution will show a value of 0.30 and the second year will show a value of 0.50.

Here the user must specify whether the number of births is to be calculated based on a dynamic or static view of maternal survival rates. If the user specifies “No,” then the number of births will be a static calculation of the number of births from the baseline model. If the user specifies “Yes,” then the number of births will be a dynamic calculation of the number of births expected from the current maternal population and the current age-specific birth rates.

Step 7: Input scenario name and run model

For both the U.S. and International versions, here the user must enter a scenario name to run the model. Once the model is done running, an option to export the scenario results to Excel will appear.³³ The user can specify the location of the file to be saved, and the file will be named according to the user-specified scenario name.³⁴ For convenience, once the model has completed a run and the results have been exported, there will also be an option to navigate to the folder where the Excel output file is saved. To reset the form to its default values, press the “Reset defaults” button at the bottom of the form. Note that any inputs entered in the inputs form will not be saved in the form after the model is closed.

Using the Output table

For both the U.S. and International versions, the output Excel workbook contains one worksheet that summarizes the chosen inputs and one worksheet that summarizes all the betas used for the various illness types employed by that model run, as well as additional worksheets that present avoided deaths, life years gained, the change in conditional life expectancy, and the change in period life expectancy. The definitions of these outputs are discussed in more detail below.

- ***Total avoided deaths.*** The Total Avoided Deaths worksheet provides the change in premature mortality attributed to a change in air pollution hazard. Positive values indicate a decrease in premature mortality; negative values indicate an increase in premature mortality.
- ***Life years gained.*** This worksheet reports aggregate changes in life years attributable to the incremental air pollution hazard over the 60-year domain. Positive values indicate an increase in life years; negative values indicate a decrease in life years.
- ***Changes in cohort conditional life expectancy.*** Cohort conditional life expectancy can be calculated from a life table; it is the sum of life years over all periods divided by the size of the starting population. Cohort life expectancy is constructed using age-specific mortality rates that reflect projected changes in mortality in future years. The output file includes two worksheets (one for males; one for females) with the change

³³ The model run time can take one or more hours. Despite the long run time, the model is stable and has not crashed during any test runs. At the end of the run, a message box will appear and display the start and end times. If the user wishes to exit the model mid-run, press the “Escape” key.

³⁴ If a file by that name already exists, the user will have the option to overwrite it or rename the file.

in cohort life expectancy by single year of age, from 1980 to 2050 under the Regulatory scenario.

- ***Changes in period conditional life expectancy.*** Period conditional life expectancy is constructed using age-specific mortality rates for a single year, with no allowance for projected changes in mortality. This is the methodology that is used to calculate the life expectancy statistics that are generally reported by the CDC.³⁵ The output file includes two worksheets (one for males; one for females) with the change in period life expectancy by single year of age, from 1980 to 2050.

MODEL LIMITATIONS AND CAVEATS

Please keep in mind the following model limitations and caveats when using the model and interpreting its results, for both the U.S. and International versions.

- The proposed model is designed to be flexible and allow users to test the impacts of alternative hypotheses on benefit estimates. The model does not represent an endorsement of any particular hypothesis concerning issues related to estimation of the mortality impacts of PM_{2.5} exposures. For example, data on the lag between exposure and PM-related death is very limited and any lag assumption is largely an educated guess based on the time course for the causes of death expected to be associated with PM exposure.
- All PM_{2.5} changes are measured from a baseline that reflects an assumed air quality trajectory embedded in Census projections of mortality rates in the U.S. and other countries. Based on our review of Census population projections in the U.S., we assume these projections reflect a flat trajectory of air pollution. However a flat trajectory is not consistent with the historical data from the U.S. (We have not evaluated baseline air pollution trajectories for the non-U.S. countries.) Plausible alternative trajectories in the baseline scenario for air pollution in the future could produce larger or smaller estimates for all countries, depending on whether air pollution is expected to increase or decrease over time.
- The model will not account for spatial variation in air quality changes in the population; all citizens are equally affected by the PM change, regardless of location. Conceptually, this restriction could be relaxed using fine scale concentration profiles available down to a more geographically-refined level (e.g., from BenMAP); however, in practice it would be necessary to address attendant computational challenges.
- The threshold adjustment factors are based on a single distribution of population-weighted PM_{2.5} concentrations in the U.S. from the year 2002. This distribution remains static through time, even though users may input changes in the annual average PM

³⁵ Centers for Disease Control and Prevention / National Center for Health Statistics, *Method for Constructing Complete Annual U.S. Life Tables*, Series 2, No. 129, December 1999.

occurring over time, which could shift this distribution. This could cause potential over- or underestimates in the percentage of the population experiencing PM concentrations above or below the threshold both in the U.S. and abroad and in turn could cause under- or over estimates in the MHAF applied in a given year.

- The means used to forecast mortality rates by cause does not account for trends in mortality or morbidity in the years prior to the cutoff between historical and forecast data. For example, in the U.S., increases in obesity and the incidence of diabetes would be expected to impact mortality rates in the future from diabetes and cardiovascular causes and could be expected to increase population susceptibility to air pollution.
- By-cause mortality results from the U.S. model should be interpreted with caution; for example, cause-specific RRs for PM mortality are typically more uncertain than all-cause RRs due to smaller sample sizes. Furthermore, there is only one source of estimates available for detailed cause-specific RRs at this time (Pope et al. (2004)). These results are also uncertain because causes of death are often more complex than is captured in death certificate data. This can lead to estimation bias. For example conditions such as COPD can make an individual more susceptible to death from pneumonia or cardiovascular disease, which could lead to an underestimate of the impact of PM on COPD related deaths (Pope et al. (2004)).
- Users should expect to see positive impacts for some age cohorts and negative impacts for other age cohorts, reflecting the fact that deaths may be advanced or delayed, but never completely avoided. Thus, in a pollution reduction scenario, reductions in mortality in earlier age groups of a cohort would result in increased mortality among later age groups, as those individuals whose lives have been prolonged eventually die. The changes in different age groups may not completely balance out, however, due to limitations in data for older age groups (e.g., the treatment of all individuals over 100 as a single 100+ group).
- We present estimates for changes in both period and cohort life expectancy (both terms are defined above). We believe the cohort life expectancy estimates to be a richer measure for air pollution-related changes in mortality, because it reflects a projection of long-term trends in mortality rates. However, these values, based on dynamic mortality estimates, may lead to some confusion because they tend to differ from the typical (period) life expectancy estimates calculated by CDC and reported in the media. Therefore we have also provided estimated changes in period life expectancy as an alternative measure.
- In the International version, we have removed results for age 100 or older due to greater uncertainty in these estimates in general and due to variation from country to country in the reporting and tracking of these data. For example, some countries collect age-specific information for those over 100, but other countries lack mortality data for these older age groups. Because the maximum age over 100 varies by country, we cannot apply the same cohort-specific simulation calculations that are used for those aged 0-99 in the

International version. Additionally, because the population numbers for those over age 100 are very small, they include large year-to-year fluctuation, and are therefore less certain than population counts of larger cohorts.

- For the U.S. version, we caution that our estimate of the change in avoided deaths for the 100+ cohort maybe less reliable than for the single year of age cohorts. The 100+ cohort contains individuals of multiple ages (100, 101, 102, etc) and our adjustment for the 100+ mortality rate is linear. This means that the model effectively assumes that it is just as likely that a 100 year old will be saved as a 110 year old. In reality, an individual who is 110 is probably frailer and therefore would show a different benefit from a reduction in air pollution than an individual who is 100.

REFERENCES

- Centers for Disease Control and Prevention / National Center for Health Statistics, *Method for Constructing Complete Annual U.S. Life Tables*, Series 2, No. 129, December 1999.
- Dockery, D. W., C. A. Pope, et al. (1993). "An association between air-pollution and mortality in Six United States cities." *New England Journal of Medicine* 329(24): 1753-9.
- Global Burden of Disease Study 2013. Global Burden of Diseases Study 2013 (GBD 2013) Age-Sex Specific All-Cause and Cause-Specific Mortality 1990-2013. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2014.
- Hollman, F.W., T.J. Mulder, and J.E. Kallan (January 13, 2000). "Methodology and Assumptions for the Population Projections of the United States: 1999-2100." *Population Division Working Paper No. 38*, U.S. Census Bureau, Department of Commerce (www.census.gov/population/www/documentation/twps0038.html, accessed 8/21/05).
- Jerrett, M., R.T. Burnett, et al. (2005). "Spatial analysis of air pollution and mortality in Los Angeles." *Epidemiology* 16(6): 1-10.
- Krewski D., M. Jerrett, R.T. Burnett, et al. (2009). "Extended Follow-Up and Spatial Analysis of the American Cancer Society Linking Particulate Air Pollution and Mortality." Health Effects Institute, Cambridge MA.
- Krewski, D., R. T. Burnett, et al. (2000). "Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality." Health Effects Institute, Cambridge MA.
- Laden, F., J. Schwartz, et al. (2006). "Reduction in fine particulate air pollution and mortality." *American Journal of Respiratory and Critical Care Medicine* 173: 667-672.
- Lee, R.D. and L.R. Carter (September 1992). "Modeling and Forecasting U.S. Mortality." *Journal of the American Statistical Association*, 87 (819): 659-675.
- Lee, R.D. and S. Tuljapurkar (September 1998). *Population Forecasting for Fiscal Planning: Issues and Innovations*, unpublished manuscript.
- Lepeule J., F. Laden, D. Dockery, J. Schwartz. (2012). "Chronic exposure to fine particles and mortality: an extended follow-up of the Harvard Six Cities study from 1974 to 2009." *Environmental Health Perspectives*, 120(7): 965-970
- Miller, B.G. and J.F. Hurley (2003). "Life table methods for quantitative impact assessments in chronic mortality," *Journal of Epidemiology and Community Health*, 57:200-206.

- National Center for Health Statistics. Data File Documentations, *Multiple Cause-of-Death, 1990-2002* (machine readable data file and documentation, CD-ROM Series No. 20), National Center for Health Statistics (the Centers for Disease Control), Hyattsville, Maryland.
- National Center for Health Statistics. Data File Documentations, *Natality, 1990-2002* (machine readable data file and documentation, CD-ROM Series No. 21), National Center for Health Statistics (the Centers for Disease Control), Hyattsville, Maryland.
- Pope, C. A., M. J. Thun, et al. (1995). "Particulate air-pollution as a predictor of mortality in a prospective-study of US adults." *American Journal of Respiratory and Critical Care Medicine*, 151(3): 669-74.
- Pope, C. A., R. T. Burnett, et al. (2002). "Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution." *Journal of the American Medical Association*, 287(9): 1132-41.
- Pope, C.A., R.T. Burnett, et al. (2004). "Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease." *Circulation*, 109(1): 5-7.
- Roosli, M., N. Kunzli, et al. (2005). "Years of life lost attributable to air pollution in Switzerland: dynamic exposure-response model." *International Journal of Epidemiology*, May 23 [epub ahead of print].
- Rosenberg, M. and W. Lucknert (1998). "Summary of Results of Survey of Seminar Attendees." *North American Actuarial Journal*, 2(4): 64-82.
- U.S. Environmental Protection Agency (2003). *Environmental Benefits Mapping and Analysis Program (BenMAP)*. Office of Air. (available at: <http://www.epa.gov/ttn/ecas/benmodels.html>).

APPENDIX A
DESCRIPTION OF ACCESS TABLES AND QUERIES

<p>Table A-1:</p> <p>ACCESS TABLES AND QUERIES IN U.S. VERSION</p>		
No.	Name	Description
Tables		
1	ASAF	Calculates age-specific adjustment factors (ASAF) that determine how the mortality hazard adjustment will be applied to specific age cohorts based on the user-specified age range.
2	Disease_Rates_Combined	Stores hazard-adjusted mortality rates relevant to the selected scenario.
3	Disease_Rates_RF	Baseline disease-specific mortality rates for females.
4	Disease_Rates_RM	Baseline disease-specific mortality rates for males.
5	Final_Table_Cohort_CLE	Cohort Conditional Life Expectancy = (Cohort Expected Life Years) / (Cohort Life Years). This table feeds into the tables produced for the final report.
6	Final_Table_Cohort_ELY	Cohort Expected Life Years = Sum of all future Cohort Life Years. This table feeds into the tables produced for the final report.
7	Final_Table_Cohort_LY	Cohort Life Years = Population, where the size of the cohort in one year equals its size in the previous year multiplied by the survival rate. Net migration does not affect cohort change, but does affect the size of the age 0 cohort. This table feeds into the tables produced for the final report.
8	Final_Table_Deaths	Stores final death data for both the baseline and the regulatory scenarios, divided out by male and female. This is the total number of deaths in each age cohort for every year, calculated as (Population Table)*(P(death)). (Example: Deaths in 1991, age 2 = (Population in 1991, age 2)*(P(death in 1991 if age 2))) This table feeds into the tables produced for the final report.
9	Final_Table_Period_CLE	Period Conditional Life Expectancy = (Period Expected Life Years) / (Period Life Years). This table feeds into the tables produced for the final report.
10	Final_Table_Period_ELY	Period Expected Life Years = Sum of all future Period Life Years. This table feeds into the tables produced for the final report.
11	Final_Table_Period_LY	Period Life Years = Population, where the size of any cohort equals the size of the cohort one year younger in

<p>Table A-1:</p> <p>ACCESS TABLES AND QUERIES IN U.S. VERSION</p>		
No.	Name	Description
		that same year, multiplied by the survival rate that is applicable for that year. Net migration only affects the size of the age 0 cohort. This table feeds into the tables produced for the final report.
12	Final_Table_Pop	Stores final population data for both the baseline and the regulatory scenarios, divided out by male and female. Population is calculated using baseline Census data, mortality rates, birth rates, and estimated net migration. This table feeds into the tables produced for the final report.
13	Hazards_Adj	Contains the disease-specific adjustment factor to be applied to each mortality rate.
14	Infant_Migration_Female	<p>This table contains a net migration calculation for the age 0 cohort that is calculated as the difference between actual population in the Census Bureau's data and the population calculated using the Census Bureau's population of women of child-bearing age and the CDC's natality rates.</p> <p><u>1980-2013</u>: Estimated Baby Girls Born = (Rate of Baby Girls) * (Number of Women in Population Table)</p> <p><u>2014-2050</u>: Estimated Babies Born = (Combined Birth) * (Number of Women in Population Table)</p> <p>The total estimated number of babies born is then divided into baby boys and baby girls using the ratio of boys to girls in the age 0 cohort from the Census Bureau's population projections.</p>
15	Infant_Migration_Male	<p>This table contains a net migration calculation for the age 0 cohort that is calculated as the difference between actual population in the Census Bureau's data and the population calculated using the Census Bureau's population of women of child-bearing age and the CDC's natality rates.</p> <p><u>1980-2013</u>: Estimated Baby Boys Born = (Rate of Baby Boys) * (Number of Women in Population Table)</p> <p><u>2014-2050</u>: Estimated Babies Born = (Combined Birth) * (Number of Women in Population Table)</p> <p>The total estimated number of babies born is then divided into baby boys and baby girls using the ratio of boys to girls in the age 0 cohort from the Census Bureau's population projections.</p>

<p>Table A-1:</p> <p>ACCESS TABLES AND QUERIES IN U.S. VERSION</p>		
No.	Name	Description
16	Lag	Contains lag values corresponding to user choices about the lag type: single vs. cause-specific, and the lag function type: HES Default, smooth, or user-defined, and values for k.
17	MHAF_Calcs	For each cause of death, calculates part of the average MHAF for each year weighted by the LAF. First calculates for each year: $[\text{Exp}(\beta \times \Delta \text{PM}_{2.5i}) - 1] \times \text{TAF}_i$
18	Net_Female_Migration	Net migration = (Change in Census Population) - (Census Population)*(P(death, unadjusted))
19	Net_Male_Migration	Net migration = (Change in Census Population) - (Census Population)*(P(death, unadjusted))
20	PM_Changes	Stores annual PM values given user inputs of PM changes and step/linear function type chosen by the user.
21	PM_Impact_Vectors	Reformats the values from MHAF_Calcs for use in the PM_Impact_Vectors_lag table.
22	PM_Impact_Vectors_lag	Uses the values in PM_Impact_Vectors and applies the LAF to calculate a weighted average for each year.
23	Population_F_Table_Census	This is the Census Bureau's data. It contains estimates of the female population for 1980-2014 and projections of the female population for 2015-2050.
24	Population_M_Table_Census	This is the Census Bureau's data. It contains estimates of the male population for 1980-2014 and projections of the male population for 2015-2050.
25	Probability_of_Death_BF	This table stores the baseline probability of death for females, by age and year.
26	Probability_of_Death_BM	This table stores the baseline probability of death for males, by age and year.
27	Probability_of_Death_RF	This is the all-cause death rate for females, as adjusted to reflect user specifications.
28	Probability_of_Death_RM	This is the all-cause death rate for males, as adjusted to reflect user specifications.
29	Rate_of_Babies_Combined_Post_2014	Combined Birth Rate =

<p>Table A-1:</p> <p>ACCESS TABLES AND QUERIES IN U.S. VERSION</p>		
No.	Name	Description
		<p>(Number of Babies Born, by Mother's Age, from the CDC) / (Number of Women that Age, from the Census)</p> <p>Available for 2014-2050.</p>
30	Rate_of_Baby_Boys	<p>Rate of Baby Boys =</p> <p>(Number of Boys Born, by Mother's Age, from CDC) / (Number of Women that Age, from Census)</p> <p>Available for 1980-2013.</p>
31	Rate_of_Baby_Girls	<p>Rate of Baby Girls =</p> <p>(Number of Girls Born, by Mother's Age, from CDC) / (Number of Women that Age, from Census)</p> <p>Available for 1980-2013.</p>
32	Report_Avoided_Deaths	<p>Total Avoided Deaths = (Female and Male Baseline Deaths) - (Female and Male Regulatory Deaths). This table feeds into the query exported in the final Excel output workbook for future reference and analysis.</p>
33	Report_Beta_Summary	<p>Contains a summary of all the illness types and corresponding beta values used in the model run. This table is exported in the final Excel output workbook for future reference and analysis.</p>
34	Report_Increase_Cohort_Conditional_Life_Expectancy	<p>Increase in cohort conditional life expectancy (f) = (cohort CLE regulatory, f) - (cohort CLE baseline, f). Increase in cohort conditional life expectancy (m) = (cohort CLE regulatory, m) - (cohort CLE baseline, m). This table feeds into the queries exported in the final Excel output workbook for future reference and analysis.</p>
35	Report_Increase_Period_Conditional_Life_Expectancy	<p>Increase in period conditional life expectancy (f) = (period CLE regulatory, f) - (period CLE baseline, f). Increase in period conditional life expectancy (m) = (period CLE regulatory, m) - (period CLE baseline, m). This table feeds into the queries exported in the final Excel output workbook for future reference and analysis.</p>
36	Report_Input_Summary	<p>Contains a summary of the drop-down menu options selected and the values input in user-defined cells. This table is exported in the final Excel output workbook for future reference and analysis.</p>

<p>Table A-1:</p> <p>ACCESS TABLES AND QUERIES IN U.S. VERSION</p>		
No.	Name	Description
37	Report_Life_Years_Gained	Life Years Gained = (Male and Female Regulatory Population) - (Male and Female Baseline Population). This table feeds into the query exported in the final Excel output workbook for future reference and analysis.
38	Sorted_PM_Conc	Contains data from the distribution of population-weighted PM _{2.5} concentrations from BenMAP in 2002.
39	Studies	Stores a list of studies and corresponding beta values.
40	Thresholds	<p>Returns the percentage of the population falling into Groups 1, 2, and 3 and calculates the TAF for each year in the analysis.</p> $TAF_{total} = TAF_{group\ 1} + TAF_{group\ 2} + TAF_{group\ 3}$ <p>Where: $TAF_{group\ i}$ = Percentage of the Population Associated with Group_i x Impact Value_i</p>
Queries		
41	Report_Avoided_Deaths_Xtab	A crosstab query of the Report_Avoided_Deaths table. This table is exported in the final Excel output workbook for future reference and analysis.
42	Report_Increase_CCLE_Female	A crosstab query of the Report_Increase_Cohort_Conditional_Life_Expectancy table, females only. This table is exported in the final Excel output workbook for future reference and analysis.
43	Report_Increase_CCLE_Male	A crosstab query of the Report_Increase_Cohort_Conditional_Life_Expectancy table, males only. This table is exported in the final Excel output workbook for future reference and analysis.
44	Report_Increase_PCLE_Female	A crosstab query of the Report_Increase_Period_Conditional_Life_Expectancy table, females only. This table is exported in the final Excel output workbook for future reference and analysis.
45	Report_Increase_PCLE_Male	A crosstab query of the Report_Increase_Period_Conditional_Life_Expectancy table, males only. This table is exported in the final Excel output workbook for future reference and analysis.
46	Report_Life_Years_Gained_Xtab	A crosstab query of the Report_Life_Years_Gained table. This table is exported in the final Excel output

Table A-1: ACCESS TABLES AND QUERIES IN U.S. VERSION		
No.	Name	Description
		workbook for future reference and analysis.

Table A-2: ACCESS TABLES AND QUERIES IN INTERNATIONAL VERSION		
No.	Name	Description
Tables		
1	ASAF	Calculates age-specific adjustment factors (ASAF) that determine how the mortality hazard adjustment will be applied to specific age cohorts based on the user-specified age range.
2	Country_List	Includes the list of countries by Country Name and Country Code available for simulation in the International version.
3	Disease_Rates_B	Baseline all-cause mortality rates, 1990-2150.
4	Disease_Rates_R	Baseline all-cause mortality rates, 1990-2050.
5	Final_Table_Cohort_CLE	Cohort Conditional Life Expectancy = (Cohort Expected Life Years) / (Cohort Life Years). This table feeds into the tables produced for the final report.
6	Final_Table_Cohort_ELY	Cohort Expected Life Years = Sum of all future Cohort Life Years. This table feeds into the tables produced for the final report.
7	Final_Table_Cohort_LY	Cohort Life Years = Population, where the size of the cohort in one year equals its size in the previous year multiplied by the survival rate. Net migration does not affect cohort change, but does affect the size of the age 0 cohort. This table feeds into the tables produced for the final report.
8	Final_Table_Deaths	Stores final death data for both the baseline and the regulatory scenarios, divided out by male and female. This is the total number of deaths in each age cohort for every year, calculated as (Population Table)*(P(death)).

<p>Table A-2:</p> <p>ACCESS TABLES AND QUERIES IN INTERNATIONAL VERSION</p>		
No.	Name	Description
		(Example: Deaths in 1991, age 2 = (Population in 1991, age 2)*(P(death in 1991 if age 2))) This table feeds into the tables produced for the final report.
9	Final_Table_Period_CLE	Period Conditional Life Expectancy = (Period Expected Life Years) / (Period Life Years). This table feeds into the tables produced for the final report.
10	Final_Table_Period_ELY	Period Expected Life Years = Sum of all future Period Life Years. This table feeds into the tables produced for the final report.
11	Final_Table_Period_LY	Period Life Years = Population, where the size of any cohort equals the size of the cohort one year younger in that same year, multiplied by the survival rate that is applicable for that year. Net migration only affects the size of the age 0 cohort. This table feeds into the tables produced for the final report.
12	Final_Table_Pop	Stores final population data for both the baseline and the regulatory scenarios, divided out by male and female. Population is calculated using baseline Census data, mortality rates, birth rates, and estimated net migration. This table feeds into the tables produced for the final report.
13	Hazards_Adj	Contains the disease-specific adjustment factor to be applied to each mortality rate.
14	Infant_Migration	<p>This table contains a net migration calculation for the age 0 cohort that is calculated as the difference between actual population in the IDB's data and the population calculated using the IDB's population of women of child-bearing age and the CDC's natality rates.</p> <p>1990-2013: Estimated Babies Born (by Gender) = (Birth Rate) *(Number of Women in Population Table)</p> <p>2014-2050: Estimated Babies Born (by Gender) = (Projected Birth Rate)*(Number of Women in Population Table)</p> <p>The total estimated number of babies born is then divided into baby boys and baby girls using the sex ratio at birth from IDB.</p>
15	Lag	Contains lag values corresponding to user choices about the lag type: single vs. cause-specific, and the lag

<p>Table A-2:</p> <p>ACCESS TABLES AND QUERIES IN INTERNATIONAL VERSION</p>		
No.	Name	Description
		function type: HES Default, smooth, or user-defined, and values for k.
16	MHAF_Calcs	For each cause of death, calculates part of the average MHAF for each year weighted by the LAF. First calculates for each year: $[\text{Exp}(\beta \times \Delta \text{PM}_{2.5i}) - 1] \times \text{TAF}_i$
17	Net_Migration	Net migration = (Change in IDB Population) – (Population)*(P(death, unadjusted))
18	PM_Changes	Stores annual PM values given user inputs of PM changes and step/linear function type chosen by the user.
19	PM_Impact_Vectors	Reformats the values from MHAF_Calcs for use in the PM_Impact_Vectors_lag table.
20	PM_Impact_Vectors_lag	Uses the values in PM_Impact_Vectors and applies the LAF to calculate a weighted average for each year.
21	Population_Table_Census	IDB data containing estimates of population by gender for 1990-2014 and projections of population by gender 2015-2050.
22	Probability of Death_R	Baseline mortality rate by gender, age, and year from GBD for 1990-2014 and projected by IDB for 2015-2050.
23	Rate_of_Babies	Birth Rate = (Number of Babies Born, by Mother's Age, from IDB) / (Number of Women that Age, from IDB), 1990-2050.
24	Report_Avoided_Deaths	Total Avoided Deaths = (Female and Male Baseline Deaths) - (Female and Male Regulatory Deaths). This table feeds into the query exported in the final Excel output workbook for future reference and analysis.
25	Report_Beta_Summary	Contains a summary of all the illness types and corresponding beta values used in the model run. This table is exported in the final Excel output workbook for future reference and analysis.
26	Report_Increase_Cohort_Conditional_Life_Expectancy	Increase in cohort conditional life expectancy (f) = (cohort CLE regulatory, f) - (cohort CLE baseline, f). Increase in cohort conditional life expectancy (m) = (cohort CLE regulatory, m) - (cohort CLE baseline, m). This table feeds into the queries exported in the final

<p>Table A-2:</p> <p>ACCESS TABLES AND QUERIES IN INTERNATIONAL VERSION</p>		
No.	Name	Description
		Excel output workbook for future reference and analysis.
27	Report_Increase_Period_Conditional_Life_Expectancy	<p>Increase in period conditional life expectancy (f) = (period CLE regulatory, f) - (period CLE baseline, f). Increase in period conditional life expectancy (m) = (period CLE regulatory, m) - (period CLE baseline, m). This table feeds into the queries exported in the final Excel output workbook for future reference and analysis.</p>
28	Report_Input_Summary	Contains a summary of the drop-down menu options selected and the values input in user-defined cells. This table is exported in the final Excel output workbook for future reference and analysis.
29	Report_Life_Years_Gained	<p>Life Years Gained = (Male and Female Regulatory Population) - (Male and Female Baseline Population). This table feeds into the query exported in the final Excel output workbook for future reference and analysis.</p>
30	Sorted_PM_Conc	Contains data from the distribution of population-weighted PM _{2.5} concentrations from BenMAP in 2002.
31	Studies	Stores a list of studies and corresponding beta values.
32	Thresholds	<p>Returns the percentage of the population falling into Groups 1, 2, and 3 and calculates the TAF for each year in the analysis.</p> $\text{TAF}_{\text{total}} = \text{TAF}_{\text{group 1}} + \text{TAF}_{\text{group 2}} + \text{TAF}_{\text{group 3}}$ <p>Where: $\text{TAF}_{\text{group i}} = \text{Percentage of the Population Associated with Group}_i \times \text{Impact Value}_i$</p>
Queries		
33	Report_Avoided_Deaths_Xtab	A crosstab query of the Report_Avoided_Deaths table. This table is exported in the final Excel output workbook for future reference and analysis.
34	Report_Increase_CCLE_Female	A crosstab query of the Report_Increase_Cohort_Conditional_Life_Expectancy table, females only. This table is exported in the final Excel output workbook for future reference and analysis.
35	Report_Increase_CCLE_Male	A crosstab query of the Report_Increase_Cohort_Conditional_Life_Expectancy table, males only. This table is exported in the final

<p style="text-align: center;">Table A-2:</p> <p style="text-align: center;">ACCESS TABLES AND QUERIES IN INTERNATIONAL VERSION</p>		
No.	Name	Description
		Excel output workbook for future reference and analysis.
36	Report_Increase_PCLE_Female	A crosstab query of the Report_Increase_Period_Conditional_Life_Expectancy table, females only. This table is exported in the final Excel output workbook for future reference and analysis.
37	Report_Increase_PCLE_Male	A crosstab query of the Report_Increase_Period_Conditional_Life_Expectancy table, males only. This table is exported in the final Excel output workbook for future reference and analysis.
38	Report_Life_Years_Gained_Xtab	A crosstab query of the Report_Life_Years_Gained table. This table is exported in the final Excel output workbook for future reference and analysis.