BenMAP

Environmental Benefits Mapping and Analysis Program

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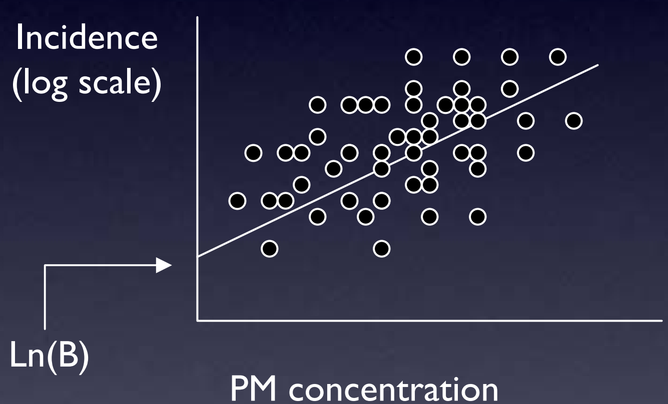
Air Benefits and Cost Group

Overview

- Principles of health benefits analysis
- Running BenMAP
- Interpreting BenMAP results
- Training opportunities

Scientific Foundation for BenMAP: Derivation of Health Impact Functions

$$Ln(y) = Ln(B) + \beta(PM)$$



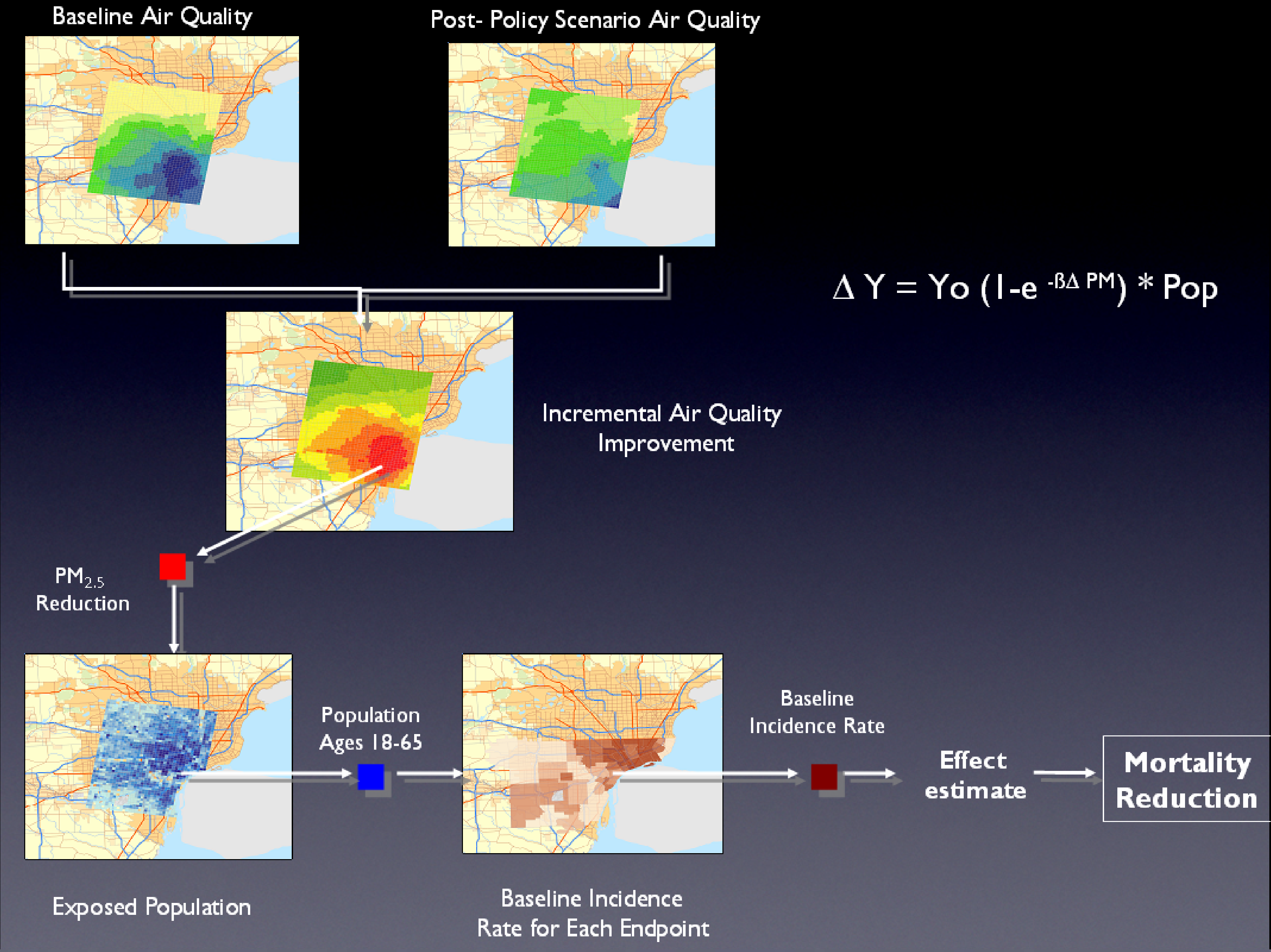
$$\Delta Y = Yo\,(1-e^{-\beta \Delta PM}) * Pop$$

Yo – Baseline Incidence

ß - Effect estimate

Pop – Exposed population

Epidemiology studies – derivation of concentration-response functions (beta values)


Baseline Air Quality
Post- Policy Scenario Air Quality
Δ Y = Yo (1-e -ßΔ PM) * Pop
Incremental Air Quality Improvement
PM2.5 Reduction
Population Ages 18-65
Baseline Incidence Rate
Effect estimate
Mortality Reduction
Exposed Population
Baseline Incidence Rate for Each Endpoint

What Health Effects Does EPA Quantify?

Health Endpoint	*Particulate Matter*	*Ozone*
Mortality	✓	✓
Chronic bronchitis	✓	
Nonfatal heart attacks	✓	
Hospital admissions	✓	✓
Asthma ER visits	✓	✓
Acute respiratory symptoms	✓	✓
Asthma attacks	✓	✓
Work loss days	✓	
Worker productivity		✓
School absence rates		✓

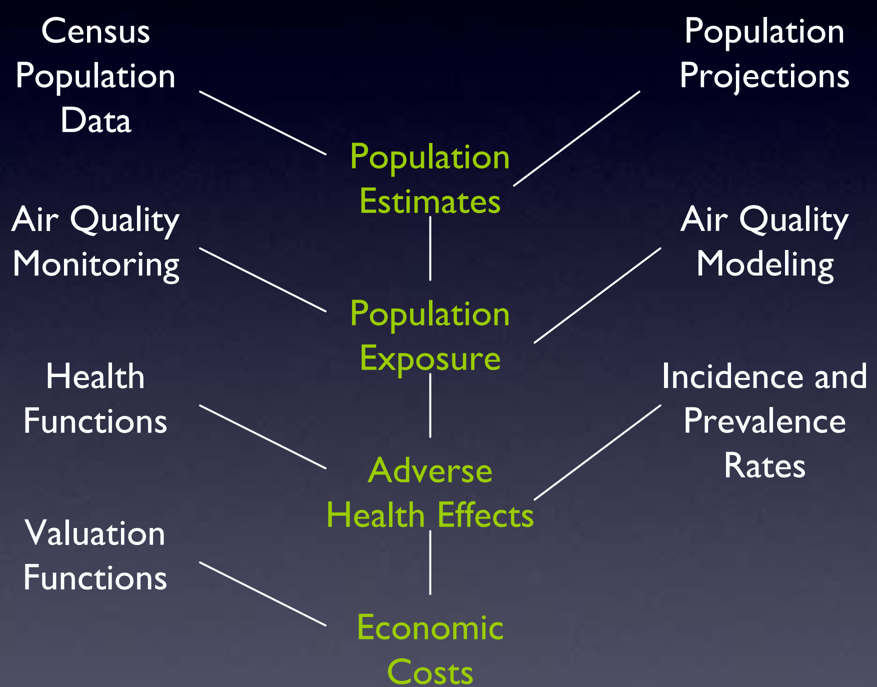
Scientific Foundation for BenMAP: Valuing Health Outcomes

- Cost of Illness (COI)
  - Medical expenses for treatment of illness
  - Captures the money savings to society of reducing a health effect
  - Ignores the value of reduced pain and suffering
- Willingness To Pay (WTP)
  - Lost wages, avoided pain and suffering, loss of satisfaction, loss of leisure time, etc.
  - Measures the complete value of avoiding a health outcome
- Quality adjusted life years (QALY) – measured in terms of “healthy” life year equivalents rather than dollars

Scientific Foundation for BenMAP: Valuing Health Outcomes

- Example: Value of a *statistical* life saved
  - 1 μg/m³ reduction in pollutant concentration produces decrease in mortality risk of 1/10,000
    - For every 10,000 individuals, one individual would be expected to die in the absence of the reduction in PM concentrations
  - WTP for this 1/10,000 decrease in mortality risk is $500
  - Value of a *statistical* life is 10,000 x $500 = $5 million
- Mortality benefits have accounted for about 90% of the total benefits of $PM_{2.5}$ air rules

The Data BenMAP Uses to Perform a Benefits Analysis

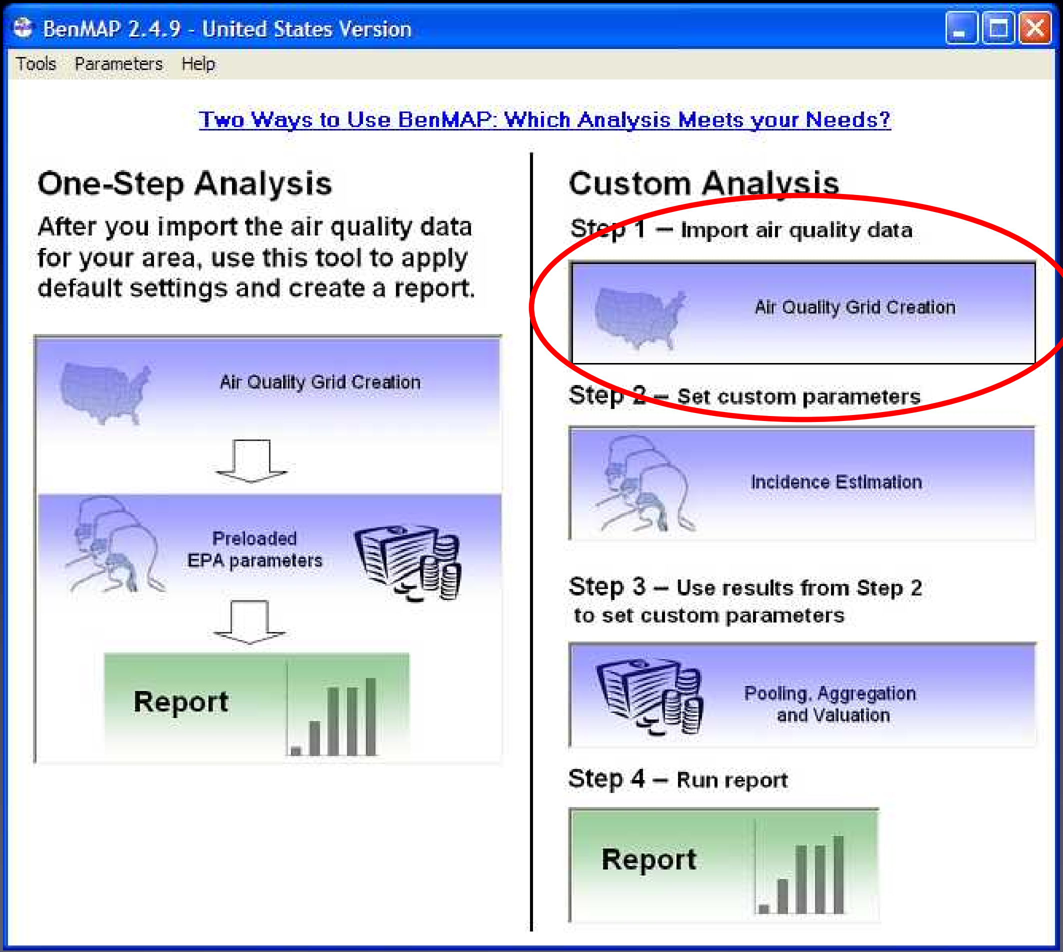


White text represents user specification or input
Green text represents result from inputs

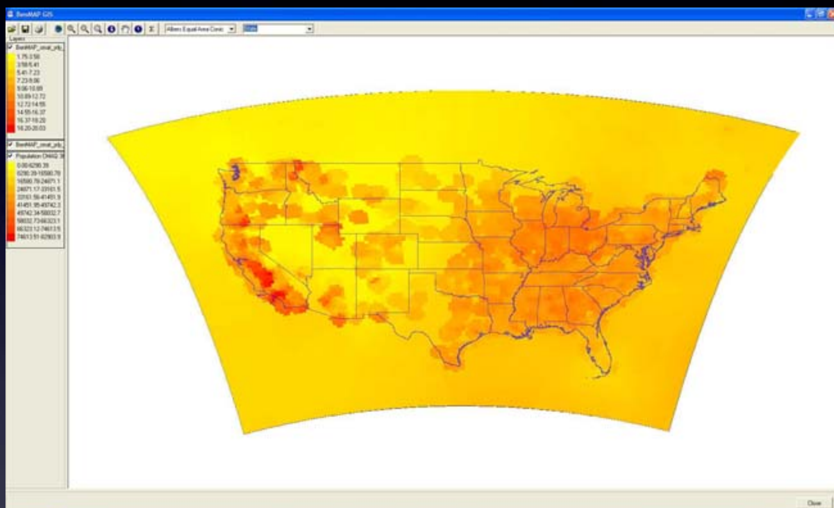
Step One: Specifying Air Quality Data and Calculating Changes in Exposure

- Goal: estimate population exposure to pollutant of interest
- Option 1: Apply user-generated modeled data
  - Easy to import CMAQ, CAMx data
  - Minor modifications required to accept other model data such as AERMOD
- Option 2: Apply built-in monitor data
  - AIRS data for ozone, PM_{10}, and $PM_{2.5}$ for a number of recent years (1996-2004)
  - In process of importing Pb, NOx, SOx and CO monitoring data

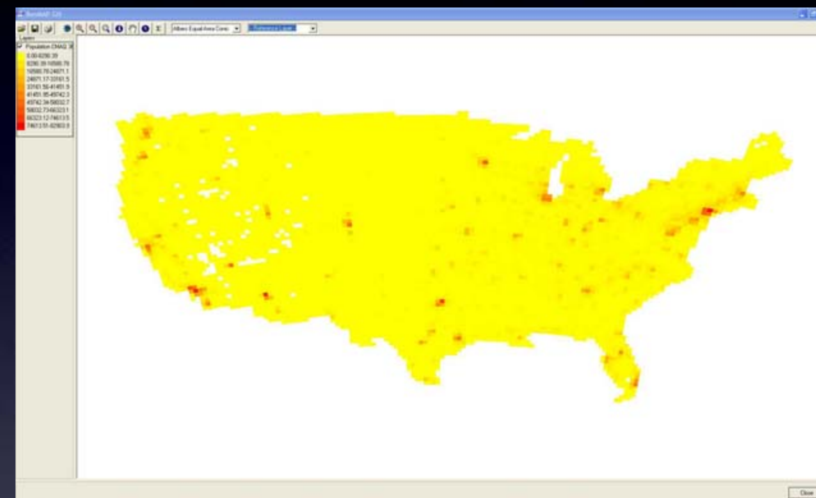
Step One: Specifying Air Quality Data and Calculating Changes in Exposure



Step One: Specifying Air Quality Data and Calculating Changes in Exposure



Air Quality Distribution

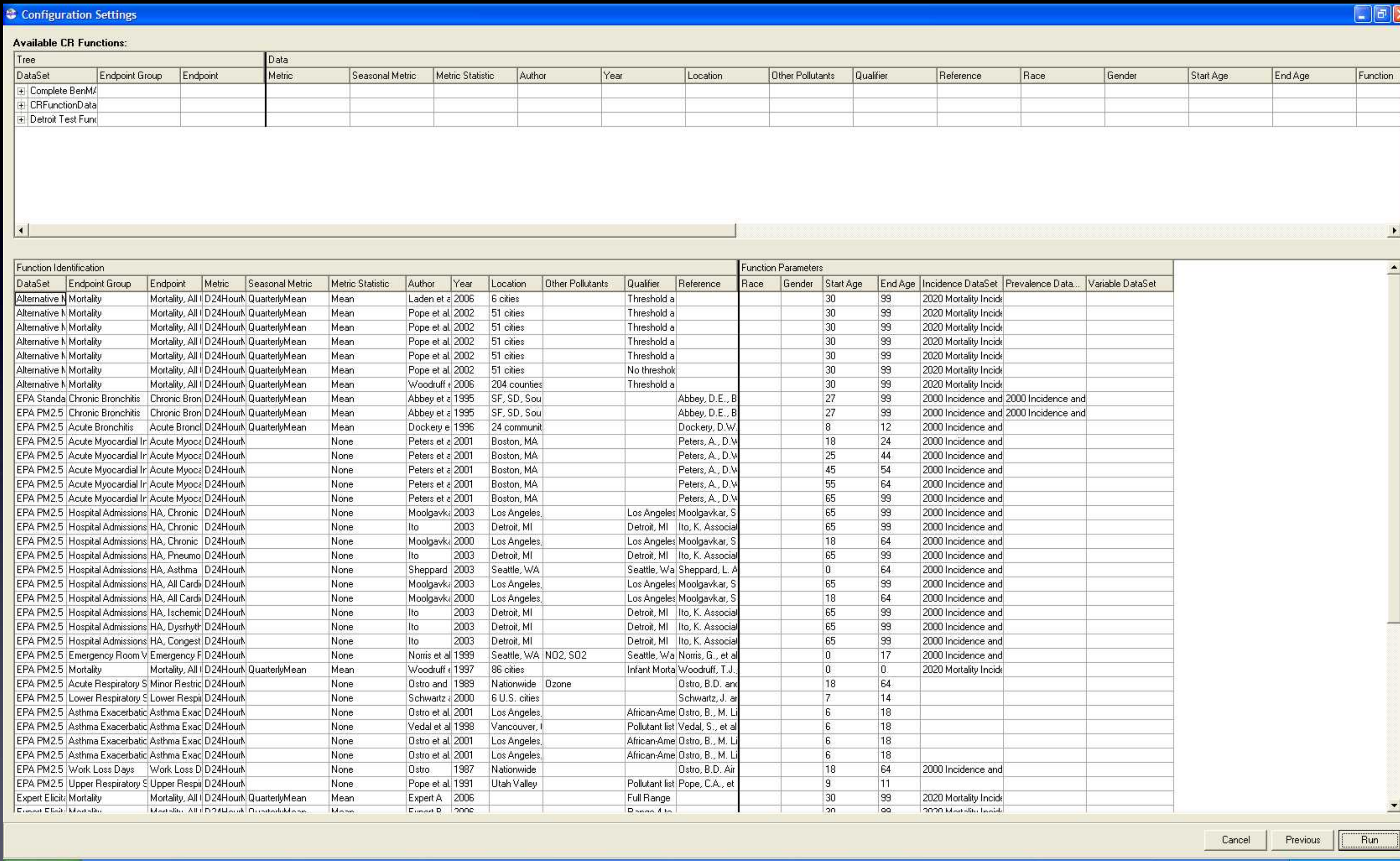


Population Distribution

Step Two: Specifying the Benefits Analysis Options

- Select health impact and valuation functions
  - BenMAP pre-loaded with hundreds of $PM_{2.5}$ and O_3 health impact functions
  - Users can add import additional functions through equation editor
- Model will "pool" functions and aggregate results
- BenMAP uses Monte Carlo methods to estimate distributions of incidence and valuation results

Step Two: Specifying the Benefits Analysis Options



Configuration Settings

Available CR Functions:

Tree			Data													
DataSet	Endpoint Group	Endpoint	Metric	Seasonal Metric	Metric Statistic	Author	Year	Location	Other Pollutants	Qualifier	Reference	Race	Gender	Start Age	End Age	Function
⊞ Complete BenMA																
⊞ CRFunctionData																
⊞ Detroit Test Func																

Function Identification												Function Parameters						
DataSet	Endpoint Group	Endpoint	Metric	Seasonal Metric	Metric Statistic	Author	Year	Location	Other Pollutants	Qualifier	Reference	Race	Gender	Start Age	End Age	Incidence DataSet	Prevalence Data...	Variable DataSet
Alternative M	Mortality	Mortality, All (	D24HourM	QuarterlyMean	Mean	Laden et a	2006	6 cities		Threshold a				30	99	2020 Mortality Incide		
Alternative M	Mortality	Mortality, All (	D24HourM	QuarterlyMean	Mean	Pope et al.	2002	51 cities		Threshold a				30	99	2020 Mortality Incide		
Alternative M	Mortality	Mortality, All (	D24HourM	QuarterlyMean	Mean	Pope et al.	2002	51 cities		Threshold a				30	99	2020 Mortality Incide		
Alternative M	Mortality	Mortality, All (	D24HourM	QuarterlyMean	Mean	Pope et al.	2002	51 cities		Threshold a				30	99	2020 Mortality Incide		
Alternative M	Mortality	Mortality, All (	D24HourM	QuarterlyMean	Mean	Pope et al.	2002	51 cities		Threshold a				30	99	2020 Mortality Incide		
Alternative M	Mortality	Mortality, All (	D24HourM	QuarterlyMean	Mean	Pope et al.	2002	51 cities		No threshold				30	99	2020 Mortality Incide		
Alternative M	Mortality	Mortality, All (	D24HourM	QuarterlyMean	Mean	Woodruff e	2006	204 counties		Threshold a				30	99	2020 Mortality Incide		
EPA Standa	Chronic Bronchitis	Chronic Bron	D24HourM	QuarterlyMean	Mean	Abbey et a	1995	SF, SD, Sou			Abbey, D.E., B			27	99	2000 Incidence and	2000 Incidence and	
EPA PM2.5	Chronic Bronchitis	Chronic Bron	D24HourM	QuarterlyMean	Mean	Abbey et a	1995	SF, SD, Sou			Abbey, D.E., B			27	99	2000 Incidence and	2000 Incidence and	
EPA PM2.5	Acute Bronchitis	Acute Broncl	D24HourM	QuarterlyMean	Mean	Dockery e	1996	24 communit			Dockery, D.W.			8	12	2000 Incidence and		
EPA PM2.5	Acute Myocardial Ir	Acute Myoca	D24HourM		None	Peters et a	2001	Boston, MA			Peters, A., D.W			18	24	2000 Incidence and		
EPA PM2.5	Acute Myocardial Ir	Acute Myoca	D24HourM		None	Peters et a	2001	Boston, MA			Peters, A., D.W			25	44	2000 Incidence and		
EPA PM2.5	Acute Myocardial Ir	Acute Myoca	D24HourM		None	Peters et a	2001	Boston, MA			Peters, A., D.W			45	54	2000 Incidence and		
EPA PM2.5	Acute Myocardial Ir	Acute Myoca	D24HourM		None	Peters et a	2001	Boston, MA			Peters, A., D.W			55	64	2000 Incidence and		
EPA PM2.5	Acute Myocardial Ir	Acute Myoca	D24HourM		None	Peters et a	2001	Boston, MA			Peters, A., D.W			65	99	2000 Incidence and		
EPA PM2.5	Hospital Admissions	HA, Chronic	D24HourM		None	Moolgavka	2003	Los Angeles,		Los Angeles	Moolgavkar, S			65	99	2000 Incidence and		
EPA PM2.5	Hospital Admissions	HA, Chronic	D24HourM		None	Ito	2003	Detroit, MI		Detroit, MI	Ito, K. Associat			65	99	2000 Incidence and		
EPA PM2.5	Hospital Admissions	HA, Chronic	D24HourM		None	Moolgavka	2000	Los Angeles,		Los Angeles	Moolgavkar, S			18	64	2000 Incidence and		
EPA PM2.5	Hospital Admissions	HA, Pneumo	D24HourM		None	Ito	2003	Detroit, MI		Detroit, MI	Ito, K. Associat			65	99	2000 Incidence and		
EPA PM2.5	Hospital Admissions	HA, Asthma	D24HourM		None	Sheppard	2003	Seattle, WA		Seattle, Wa	Sheppard, L. A			0	64	2000 Incidence and		
EPA PM2.5	Hospital Admissions	HA, All Cardi	D24HourM		None	Moolgavka	2003	Los Angeles,		Los Angeles	Moolgavkar, S			65	99	2000 Incidence and		
EPA PM2.5	Hospital Admissions	HA, All Cardi	D24HourM		None	Moolgavka	2000	Los Angeles,		Los Angeles	Moolgavkar, S			18	64	2000 Incidence and		
EPA PM2.5	Hospital Admissions	HA, Ischemic	D24HourM		None	Ito	2003	Detroit, MI		Detroit, MI	Ito, K. Associat			65	99	2000 Incidence and		
EPA PM2.5	Hospital Admissions	HA, Dysrhyth	D24HourM		None	Ito	2003	Detroit, MI		Detroit, MI	Ito, K. Associat			65	99	2000 Incidence and		
EPA PM2.5	Hospital Admissions	HA, Congest	D24HourM		None	Ito	2003	Detroit, MI		Detroit, MI	Ito, K. Associat			65	99	2000 Incidence and		
EPA PM2.5	Emergency Room V	Emergency R	D24HourM		None	Norris et al	1999	Seattle, WA	NO2, SO2	Seattle, Wa	Norris, G., et al			0	17	2000 Incidence and		
EPA PM2.5	Mortality	Mortality, All (	D24HourM	QuarterlyMean	Mean	Woodruff e	1997	86 cities		Infant Morta	Woodruff, T.J.			0	0	2020 Mortality Incide		
EPA PM2.5	Acute Respiratory S	Minor Restric	D24HourM		None	Ostro and	1989	Nationwide	Ozone		Ostro, B.D. and			18	64			
EPA PM2.5	Lower Respiratory S	Lower Respii	D24HourM		None	Schwartz a	2000	6 U.S. cities			Schwartz, J. ar			7	14			
EPA PM2.5	Asthma Exacerbatic	Asthma Exac	D24HourM		None	Ostro et al.	2001	Los Angeles,		African-Ame	Ostro, B., M. Li			6	18			
EPA PM2.5	Asthma Exacerbatic	Asthma Exac	D24HourM		None	Vedal et al	1998	Vancouver, I		Pollutant list	Vedal, S., et al			6	18			
EPA PM2.5	Asthma Exacerbatic	Asthma Exac	D24HourM		None	Ostro et al.	2001	Los Angeles,		African-Ame	Ostro, B., M. Li			6	18			
EPA PM2.5	Asthma Exacerbatic	Asthma Exac	D24HourM		None	Ostro et al.	2001	Los Angeles,		African-Ame	Ostro, B., M. Li			6	18			
EPA PM2.5	Work Loss Days	Work Loss D	D24HourM		None	Ostro	1987	Nationwide			Ostro, B.D. Air			18	64	2000 Incidence and		
EPA PM2.5	Upper Respiratory S	Upper Respii	D24HourM		None	Pope et al.	1991	Utah Valley		Pollutant list	Pope, C.A., et			9	11			
Expert Elicita	Mortality	Mortality, All (	D24HourM	QuarterlyMean	Mean	Expert A	2006			Full Range				30	99	2020 Mortality Incide		

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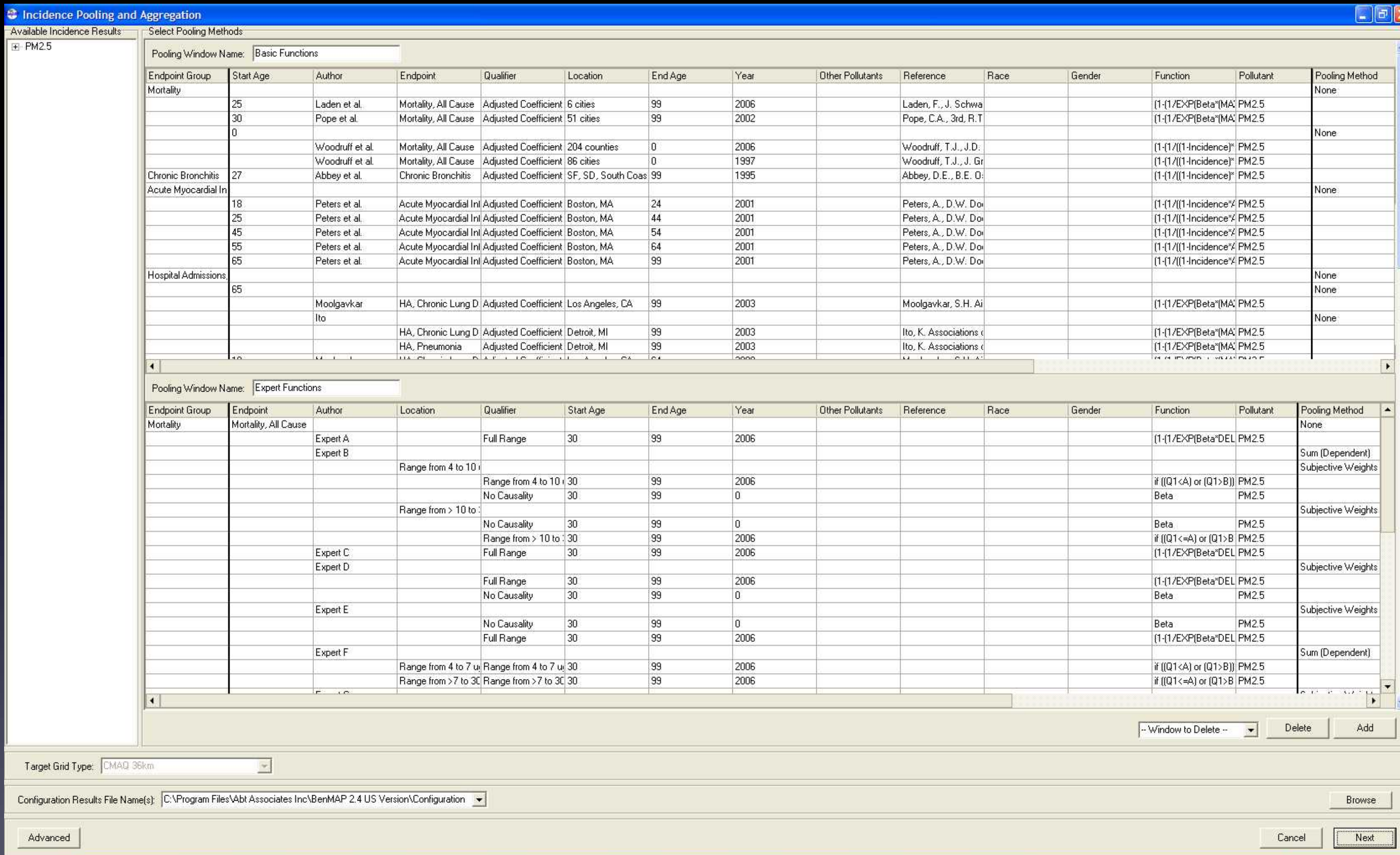
Step Two: Specifying the Benefits Analysis Options



Incidence Pooling and Aggregation

Available Incidence Results

PM2.5

Select Pooling Methods

Pooling Window Name: Basic Functions

Endpoint Group	Start Age	Author	Endpoint	Qualifier	Location	End Age	Year	Other Pollutants	Reference	Race	Gender	Function	Pollutant	Pooling Method
Mortality														None
	25	Laden et al.	Mortality, All Cause	Adjusted Coefficient	6 cities	99	2006		Laden, F., J. Schwa			(1-(1/EXP(Beta*(MA	PM2.5	
	30	Pope et al.	Mortality, All Cause	Adjusted Coefficient	51 cities	99	2002		Pope, C.A., 3rd, R.T			(1-(1/EXP(Beta*(MA	PM2.5	
	0													None
		Woodruff et al.	Mortality, All Cause	Adjusted Coefficient	204 counties	0	2006		Woodruff, T.J., J.D.			(1-(1/((1-Incidence)*	PM2.5	
		Woodruff et al.	Mortality, All Cause	Adjusted Coefficient	86 cities	0	1997		Woodruff, T.J., J. Gr			(1-(1/((1-Incidence)*	PM2.5	
Chronic Bronchitis	27	Abbey et al.	Chronic Bronchitis	Adjusted Coefficient	SF, SD, South Coas	99	1995		Abbey, D.E., B.E. O:			(1-(1/((1-Incidence)*	PM2.5	
Acute Myocardial In														None
	18	Peters et al.	Acute Myocardial Inf	Adjusted Coefficient	Boston, MA	24	2001		Peters, A., D.W. Do			(1-(1/((1-Incidence*A	PM2.5	
	25	Peters et al.	Acute Myocardial Inf	Adjusted Coefficient	Boston, MA	44	2001		Peters, A., D.W. Do			(1-(1/((1-Incidence*A	PM2.5	
	45	Peters et al.	Acute Myocardial Inf	Adjusted Coefficient	Boston, MA	54	2001		Peters, A., D.W. Do			(1-(1/((1-Incidence*A	PM2.5	
	55	Peters et al.	Acute Myocardial Inf	Adjusted Coefficient	Boston, MA	64	2001		Peters, A., D.W. Do			(1-(1/((1-Incidence*A	PM2.5	
	65	Peters et al.	Acute Myocardial Inf	Adjusted Coefficient	Boston, MA	99	2001		Peters, A., D.W. Do			(1-(1/((1-Incidence*A	PM2.5	
Hospital Admissions,														None
	65													None
		Moolgavkar	HA, Chronic Lung D	Adjusted Coefficient	Los Angeles, CA	99	2003		Moolgavkar, S.H. Ai			(1-(1/EXP(Beta*(MA	PM2.5	
		Ito												None
			HA, Chronic Lung D	Adjusted Coefficient	Detroit, MI	99	2003		Ito, K. Associations c			(1-(1/EXP(Beta*(MA	PM2.5	
			HA, Pneumonia	Adjusted Coefficient	Detroit, MI	99	2003		Ito, K. Associations c			(1-(1/EXP(Beta*(MA	PM2.5	

Pooling Window Name: Expert Functions

Endpoint Group	Endpoint	Author	Location	Qualifier	Start Age	End Age	Year	Other Pollutants	Reference	Race	Gender	Function	Pollutant	Pooling Method
Mortality	Mortality, All Cause													None
		Expert A		Full Range	30	99	2006					(1-(1/EXP(Beta*DEL	PM2.5	
		Expert B												Sum (Dependent)
			Range from 4 to 10											Subjective Weights
				Range from 4 to 10	30	99	2006					if ((Q1<A) or (Q1>B))	PM2.5	
				No Causality	30	99	0					Beta	PM2.5	
			Range from > 10 to											Subjective Weights
				No Causality	30	99	0					Beta	PM2.5	
				Range from > 10 to	30	99	2006					if ((Q1<=A) or (Q1>B	PM2.5	
		Expert C		Full Range	30	99	2006					(1-(1/EXP(Beta*DEL	PM2.5	
		Expert D												Subjective Weights
				Full Range	30	99	2006					(1-(1/EXP(Beta*DEL	PM2.5	
				No Causality	30	99	0					Beta	PM2.5	
		Expert E												Subjective Weights
				No Causality	30	99	0					Beta	PM2.5	
				Full Range	30	99	2006					(1-(1/EXP(Beta*DEL	PM2.5	
		Expert F												Sum (Dependent)
			Range from 4 to 7 u	Range from 4 to 7 u	30	99	2006					if ((Q1<A) or (Q1>B))	PM2.5	
			Range from >7 to 30	Range from >7 to 30	30	99	2006					if ((Q1<=A) or (Q1>B	PM2.5	

-- Window to Delete -- Delete Add

Target Grid Type: CMAQ 36km

Configuration Results File Name(s): C:\Program Files\Abt Associates Inc\BenMAP 2.4 US Version\Configuration

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Advanced

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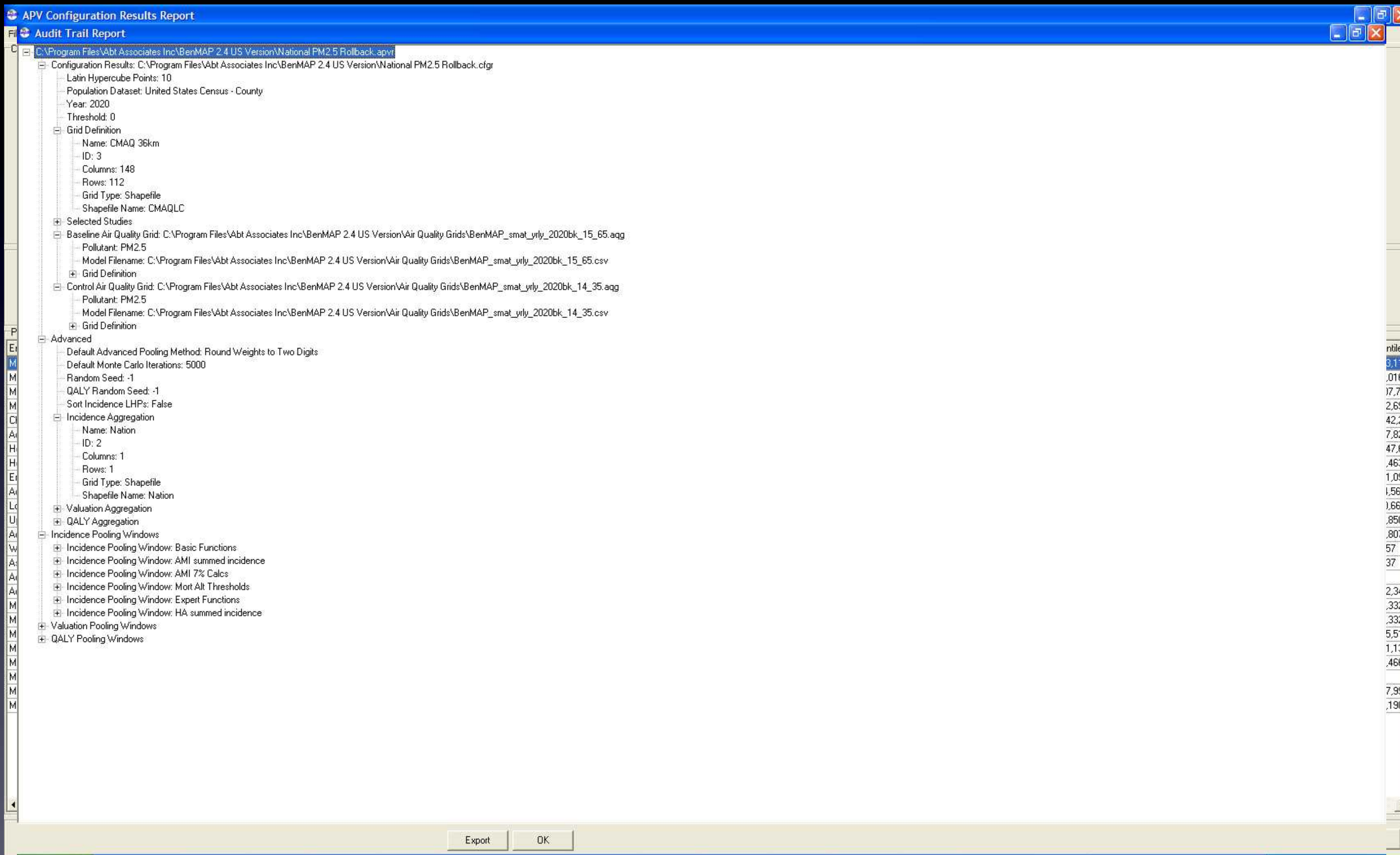
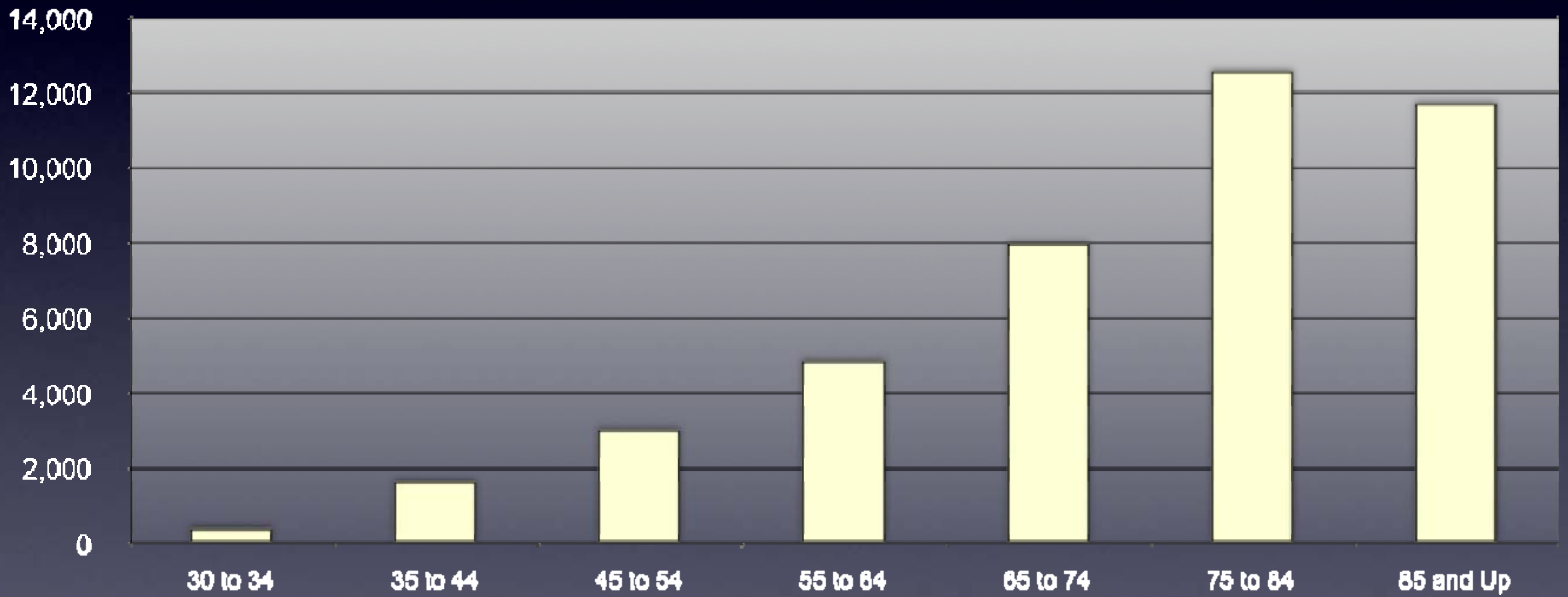
Step Three: Reporting the Results



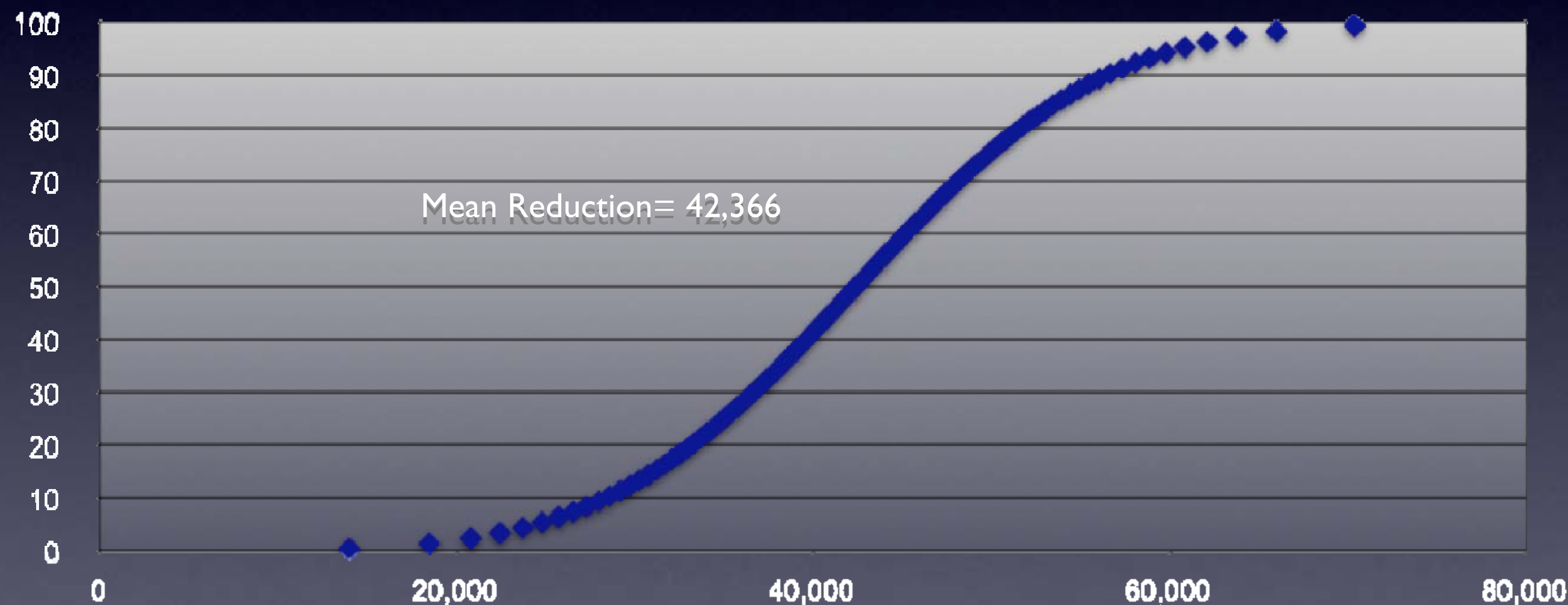
Step Three: Reporting the Results
(1) Age Group Impacts

Mortality Impacts by Age Group

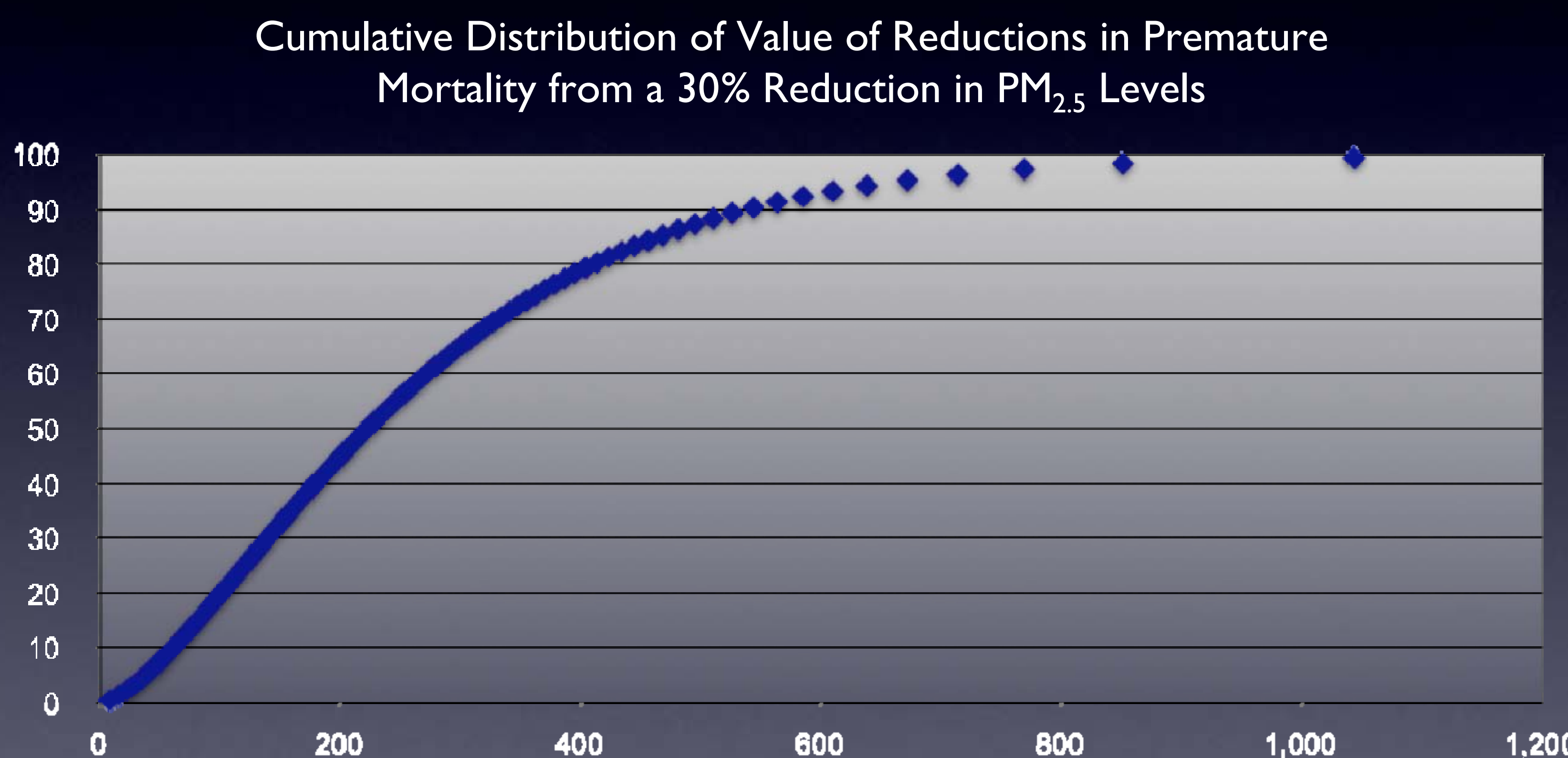


Step Three: Reporting the Results: (2) Distributions of Incidence

Cumulative Distribution of Total Change in Mortality from a 30% Reduction in $PM_{2.5}$ Levels



Step Three: Reporting the Results: (3) Distributions of Monetized Benefits



Use of BenMAP in EPA Analyses

- Past Projects:
  - Non-Road Diesel Rule
  - Clean Air Interstate Rule
  - $PM_{2.5}$ NAAQS
  - Small Spark Ignition Rule
  - Locomotive and Marine Diesel Rule
  - Ozone NAAQS
- Upcoming Projects:
  - SO_2 NAAQS
  - NOx NAAQS

Other BenMAP Projects

- FAA aircraft analysis
- Washington and Oregon woodstove analyses
- New York City Department of Health borough-level analysis
- Georgia Department of Natural Resources SIP planning

BenMAP International Projects

- China: Benefits analysis of EGU control strategy.
- South Korea: Health benefits of Seoul air quality management plan
- Latin America: Benefits of air quality improvements in Mexico City, Saõ Paulo, Santiago
- India: Benefits analysis in Mumbai

BenMAP Training

- Two providers of BenMAP Training:
  - Abt Associates Inc.
  - Community Modeling Analysis System