Characterizing the Uncertainty in Estimated Benefits of Reduced PM-Mortality Using Expert Elicitation

Presentation to Clean Air Compliance Council

Lisa Conner, Bryan Hubbell, Harvey Richmond
Office of Air Quality Planning and Standards

May 8, 2008

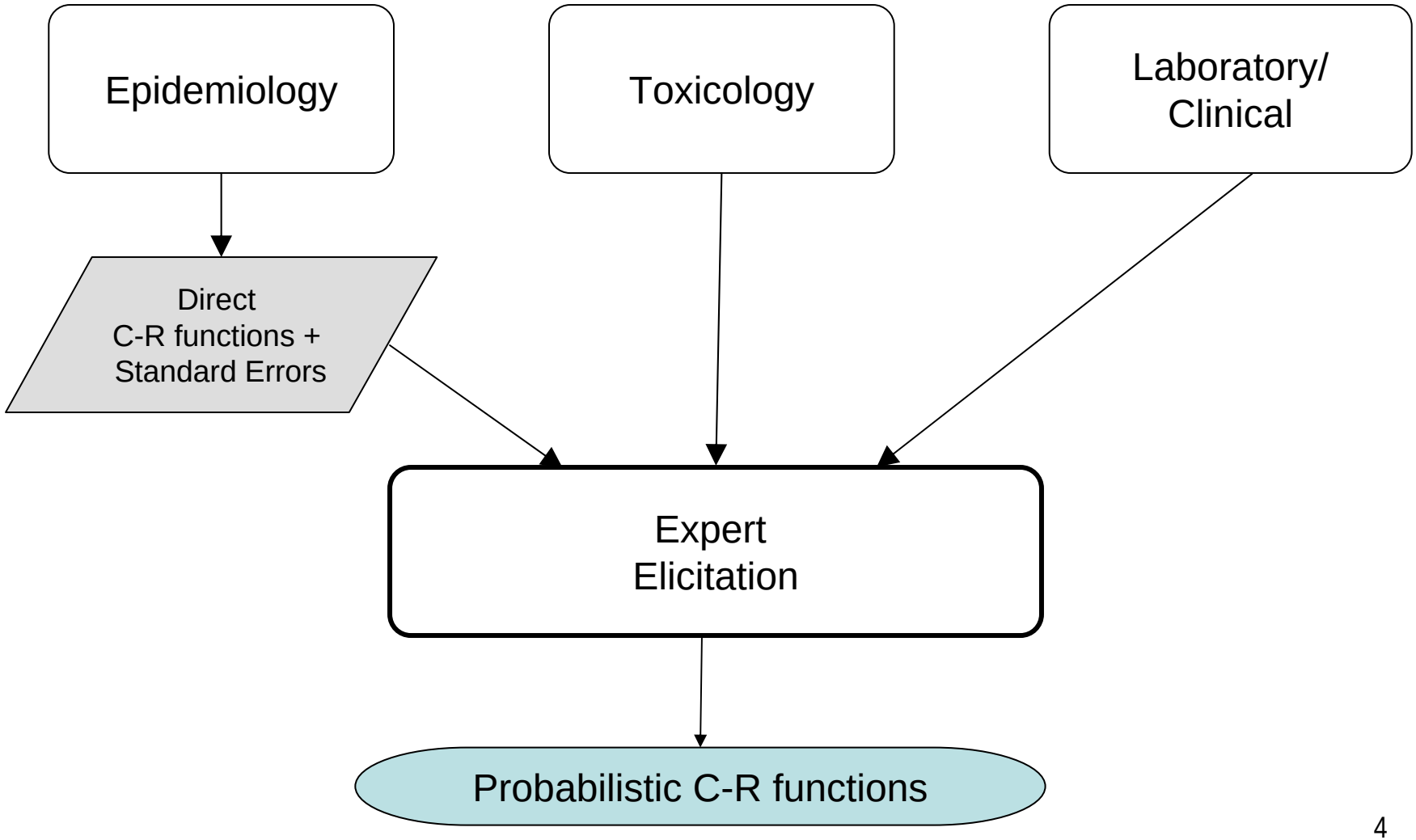
Topic Discussions

- Motivations for Conducting the PM-Mortality Elicitation
- Background on Expert Elicitation at the EPA
- Overview & Findings of the PM-Mortality Expert Elicitation
- Translating the Elicitation Results into a Benefits Analysis for the PM NAAQS RIA
- Presentation of Results in the PM NAAQS RIA
- Should the Results of the Elicitation be Combined?

Motivation for Conducting $PM_{2.5}$-Mortality Expert Elicitation

- National Academies of Science (NAS) reviewed how EPA estimates the benefits of air pollution regulations (Report to Congress, 2002)
  - Commended EPA on the approach to estimating PM benefits
  - Recommended improvements in the characterization of uncertainty and suggested the use of expert elicitation as one of several tools
    - Probability distributions should be obtained from experts where limits in data or understanding preclude the use of conventional statistical techniques
    - EPA should build on the past experience of OAQPS in the area of encoding expert judgments
    - When expert judgment is used, it should be clearly identified and rationale and empirical bases for judgments should be made available
- PM mortality constitutes >90% of total benefits of most air pollution regulations
- Key uncertainties which cannot be addressed directly by the existing epidemiological literature related to PM2.5 mortality
- Expert elicitation allows for synthesis of information from different disciplines (see figure) to inform characterization of uncertainties such as causality and existence of threshold

Sources of Scientific Data



What is Expert Elicitation?

- Eliciting the judgments of experts on a topic using a formal instrument
  - A protocol provides the script for questions to ask of the experts
    - Well-thought out; passes clairvoyance test; avoids biases or leading questions
  - Experts use empirical data from a variety of sources, past experience, and judgment in providing their quantitative and qualitative responses
- Judgment expressed as probabilities - degree of belief
- Probabilistic judgments are a quantitative expression of what an expert knows and doesn't know about a subject
- Also elicit reasoning/rationale that is the underlying basis for their judgment – evidence, theory

Background on Expert Elicitation

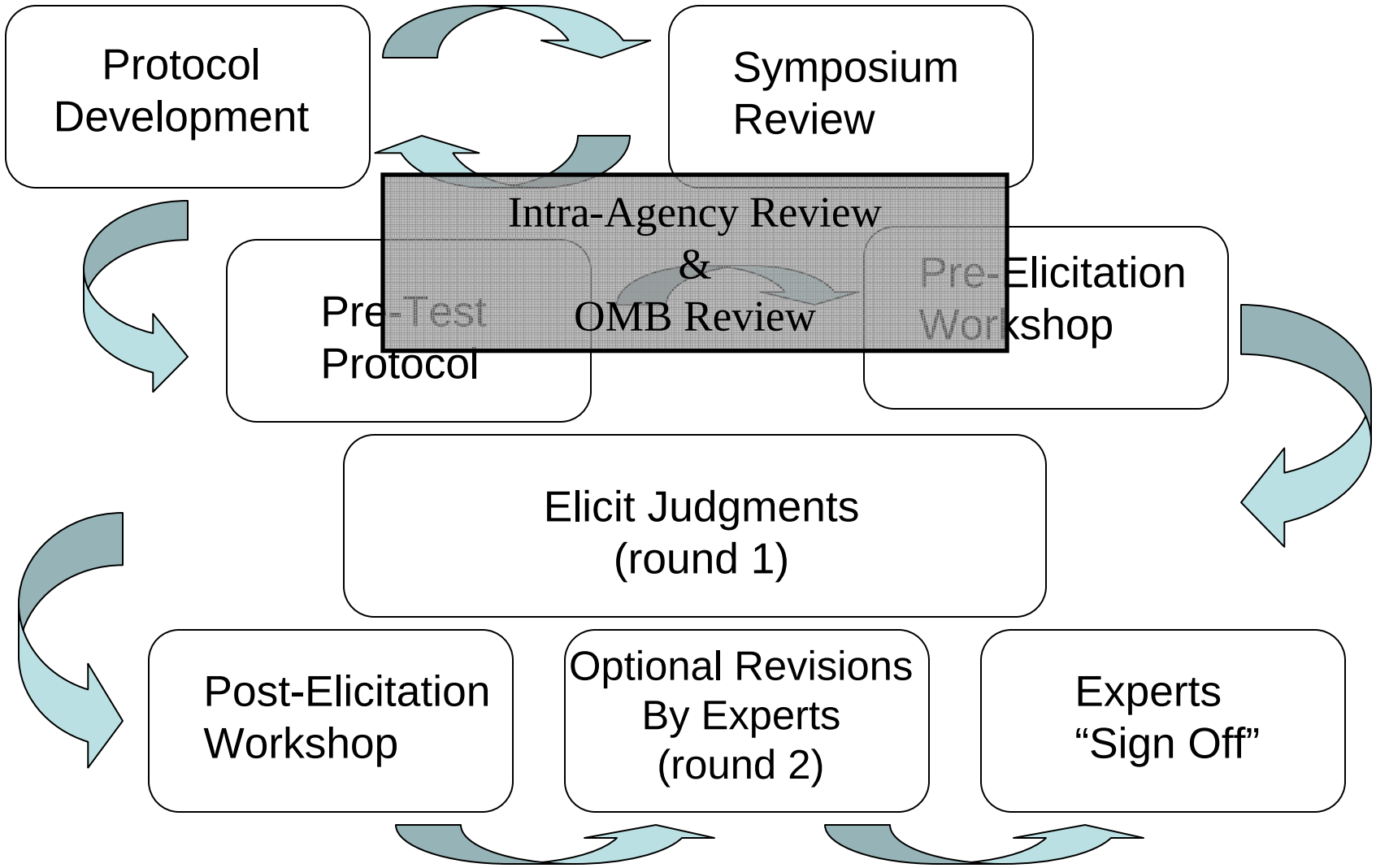
- Experience in EPA's Air Program
  - 1977 ozone health risk assessment (Feagans and Biller, 1981)
  - 1986 lead (Pb) NAAQS health risk assessment – (Whitfield and Wallsten, 1989).
  - 1990 ozone chronic lung injury health risk assessment (Winkler et al. 1995)
  - 2003 $PM_{2.5}$ mortality concentration-response for health benefits analyses – pilot project
  - 2006 $PM_{2.5}$ mortality concentration-response for health benefits analyses
- Outside of EPA – Health/Exposure
  - Sulfates health risk assessment – (Morgan et al. 1984)
  - Dose-response for formaldehyde (Evans et al. 1994a)
  - Dose-response for chloroform in drinking water (Evans et al. 1994b)
  - NHEXAS/exposure (Walker et al. 2001, 2003)
- EPA Task Force on Expert Elicitation
  - Anticipate SAB review of White Paper on Expert Elicitation – late summer 2008

Design Elements of an Elicitation

- Problem Definition -- Decision on Scope and Focus
- Protocol Development
  - Introduction: purpose and goal of elicitation
  - Background: scenario description, trends in air quality
  - Factors to consider relating to the estimation of PM-related mortality
  - Elicitation questions – quantitative probabilistic distributions
- Expert Selection
- Briefing Book
- Pilot Test of Protocol
- Pre-Elicitation Workshop
- Elicit Judgments
- Post-Elicitation Workshop
- Analysis of Results
- Peer Review

Overview & Findings of the PM-Mortality Expert Elicitation

The Encoding Process for the PM Elicitation



How We Selected Experts

- Peer Nomination process
    - Database of literature/authors ("Science Citation Index")
    - Select peer nominators based on their number of publications
  - Nominators provided us with recommendations of experts in four Categories for Nominations
    - Epidemiology
    - Toxicology
    - Up-and-Coming new scientists
    - PM policy experts
  - Nine experts selected (8 epidemiologists, 1 toxicologist)
- Peer Nomination for toxicologists
  - HEI nominated a list of 10 individuals from which we randomly selected 3 experts
- OVERALL: We selected 8 epidemiologists, 3 toxicologists/health scientists, and 1 clinician

Participating Experts

NAME	AFFILIATION
Dockery, Doug W.	Harvard School of Public Health
Ito, Kazuhiko	New York University School of Medicine
Krewski, Daniel	University of Ottawa
Kuenzli, Nino*	University of Southern California Keck School of Medicine (currently at Institut Municipal d'Investigació Mèdica - Center for Research in Environmental Epidemiology, Barcelona , SPAIN)
Lippmann, Morton	New York University School of Medicine
Mauderly, Joe	Lovelace Respiratory Research Institute
Ostro, Bart D.	California Office of Environmental Health Hazard Assessment
Pope, C. Arden III	Brigham Young University
Schlesinger, Richard	Pace University
Schwartz, Joel	Harvard School of Public Health
Thurston, George D.	New York University School of Medicine
Utell, Mark	University of Rochester School of Medicine and Dentistry

* Dr. Kuenzli was based in the U.S. at the time of expert selection, and subsequently began a sabbatical in Barcelona midway through the project.

What We Asked Experts to Provide – The Elicitation Question

- "What is your estimate of the true percent change in annual, all-cause mortality in the adult U.S. population resulting from a permanent 1 µg/m3 reduction in annual average ambient PM2.5 across the U.S.?"
  - "In formulating your answer, please consider mortality effects of both reductions in long-term and short-term exposures."
  - "To characterize your uncertainty in the concentration-response relationship, please provide the 5th, 25th, 50th, 75th, and 95th percentiles of your estimate."

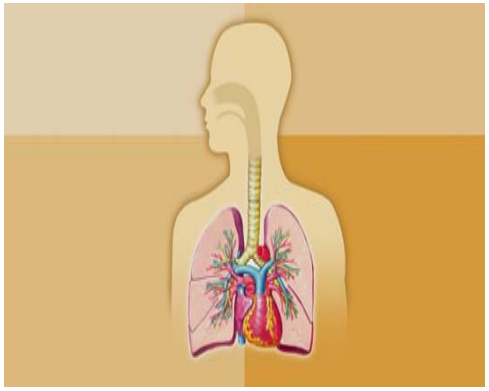
Factors Considered in the Characterization of Uncertainty

- Factors discussed with each of the 12 experts
  - Causes of death and underlying mechanisms
  - Level of overlap in effects from short-term and long-term exposures
  - Key studies used in quantification
  - Confounding
  - Effect modification
  - Exposure Issues
  - Likelihood of a causal relationship
  - Thresholds & Shape of the function

- Details on each expert's response to these factors is provided in: "*Expanded Expert Judgment Assessment of the Concentration-Response Relationship Between PM2.5 Exposure and Mortality*" (IEc, 2006) – *www.epa.gov/ttn/ecas/benefits.html*

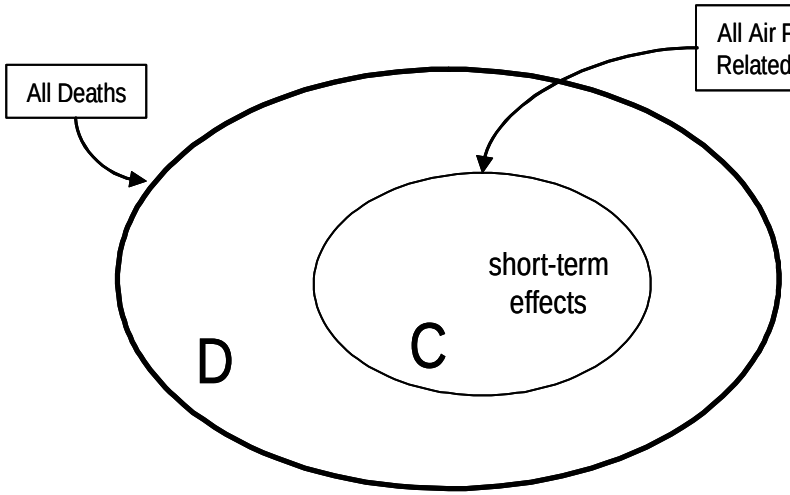
What the Experts told us – Causes of Death

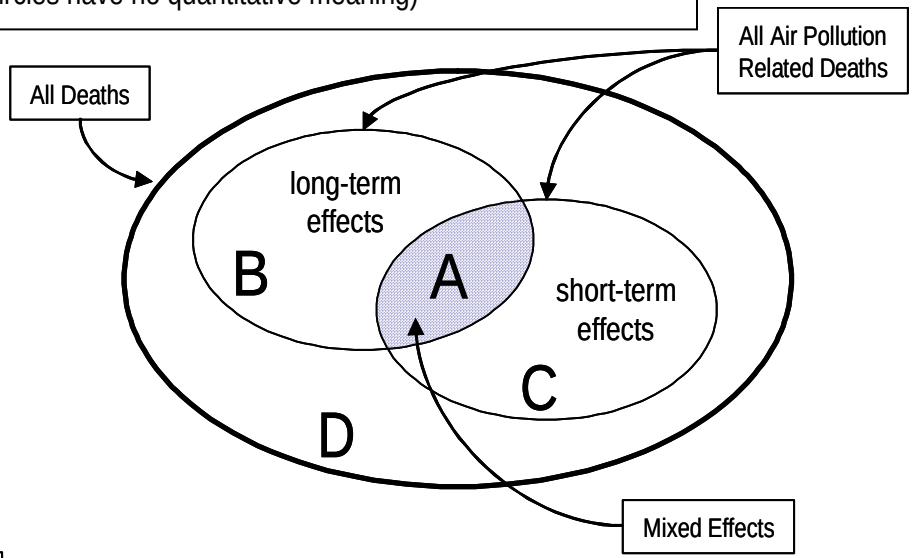
- Short-Term Causes of Death
  - Cardiovascular Disease
    - Heart attacks, stroke
  - Respiratory Disease
    - Lung inflammation leading to exacerbation of existing disease
    - Respiratory infection (e.g., influenza, bronchitis, pneumonia) in those with decreased defenses, such as elderly or infirm
- Long-Term Causes of Death
  - Cardiovascular Disease
  - Respiratory Disease
    - Chronic lung inflammation leading to decreased lung function; COPD
  - Lung Cancer

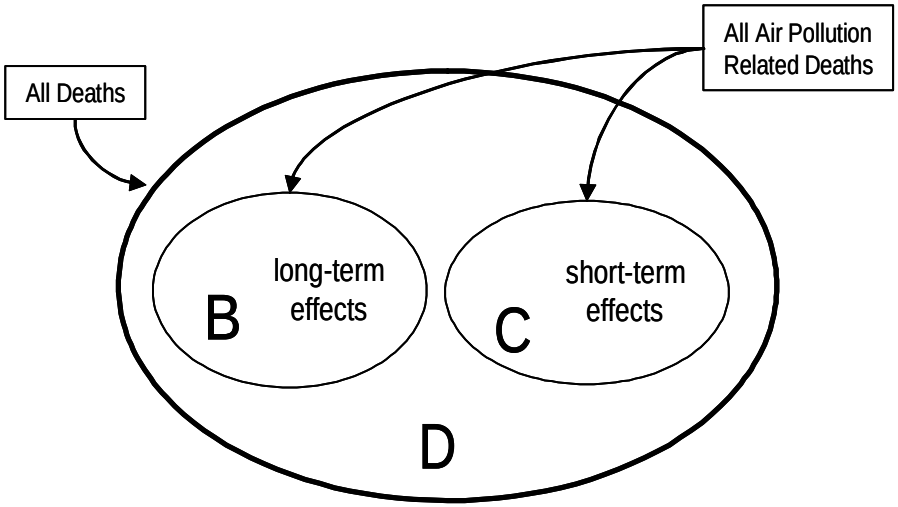


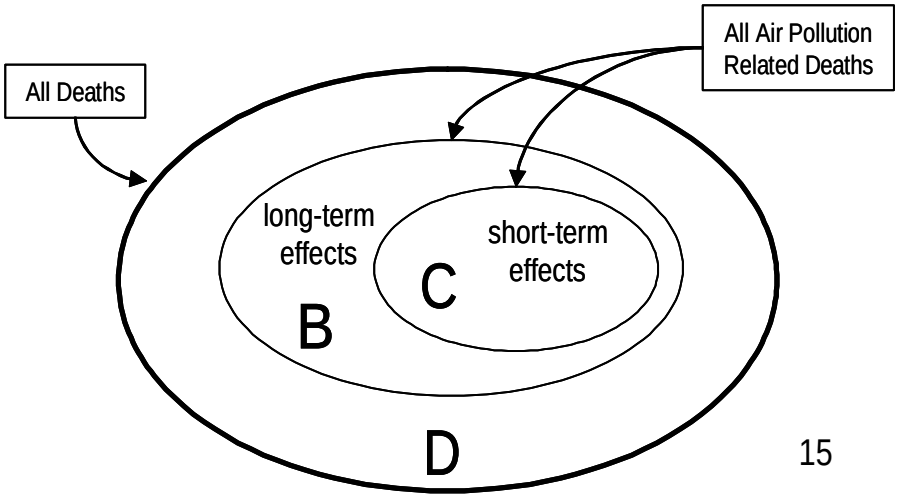
Is there Overlap Between Short-Term & Long-Term Effects?

(Adapted from Kunzli et al. (2001) Note that sizes of circles have no quantitative meaning)









Experts Views: Overlap between Effects of Long-Term Versus Short-Term Exposures

- Most experts stated that long-term effects dominate, captured in cohort studies
  - Time series results serve as lower bounds
- Several experts indicated that the recently published intervention studies show significant intermediate impacts not fully captured in time-series or cohorts

Experts Views on Factors that Contribute to Uncertainty

- Studies used to estimate the concentration-response function
  - Applicability nationwide
  - Representativeness of the cohort population and exposures to the general population
- Educational Attainment
  - Indicator of other factors of uncertainty (SES, health, occupational exposures, exercise, access to health care)
  - Several experts adjusted their C/R functions upwards for educational attainment
- Is there a causal relationship between PM and mortality
  - We measured the experts views of the probability (likelihood) of a causal link between PM and mortality

Percent Probability of a Causal Relationship

100

99

99

99

98

95

95

95

95

90

- - - - - - - - - - -

70

35

Experts Views on Factors that Contribute to Uncertainty

- Confounding
  - Whether other factors are the cause of the effect or a catalyst to the occurrence of the effect instead of the PM exposure alone
    - Examples of confounders considered = exposures from other pollutants, smoking, occupational exposures
  - Most did not consider confounding likely to significantly affect mortality estimates

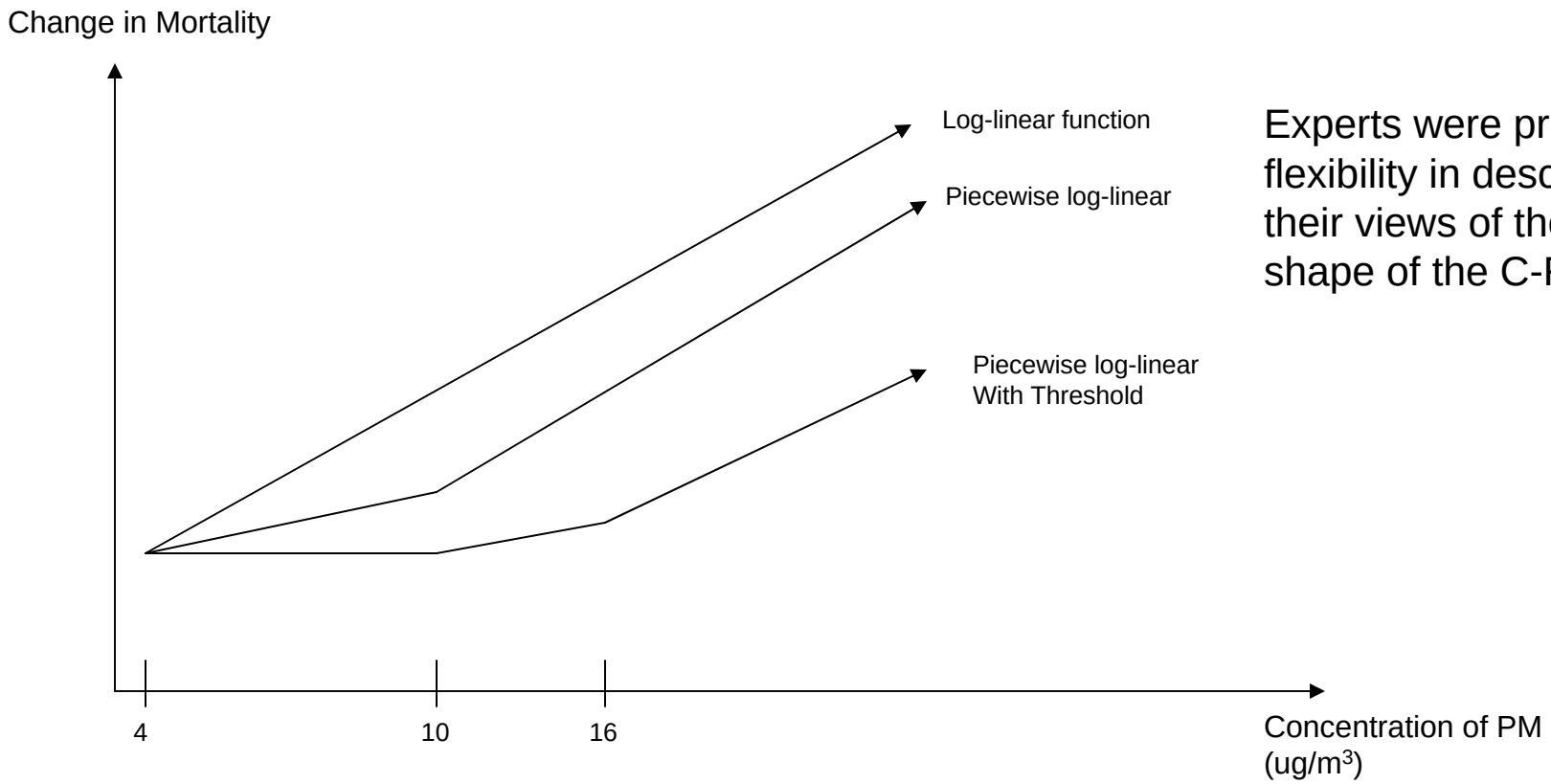
- Factors cited by experts as having minimal effect on uncertainty estimate
  - Race, air conditioning, susceptibility, and weather

Studies Cited for Use in Quantification

Author, Date (Cohort)	Number of Times Experts Cited		
	Overall	For Median	For Uncertainty
Jerrett et al., 2005 (ACS Los Angeles)	13	8	5
Pope et al., 2002 (ACS Extended Analysis)	12	8	4
Dockery et al., 1993 (Six Cities Original)	11	6	5
Laden et al., 2006 (Six Cities Follow-up: Cross-Sectional Results)	5	4	1
Samet et al., 2000 (NMMAPS)	3	0	3
Laden et al., 2006 (Six Cities Follow-up: Change Results)	2	1	1

- Studies Least Frequently Relied Upon
  - Veteran's Cohort (Lipfert et al.)
  - Cohort of Elderly Californians (Enstrom et al.)
  - AHSMOG (Abbey et al; McDonnell et al.)
- New Evidence: Intervention Studies
  - Intermediate period of exposure (6 mo.–1 year) from intervening event
    - Dublin Coal Ban
    - Utah Valley
    - Hong Kong
  - Some experts used these studies to adjust median estimate upwards or as basis of causal relationship

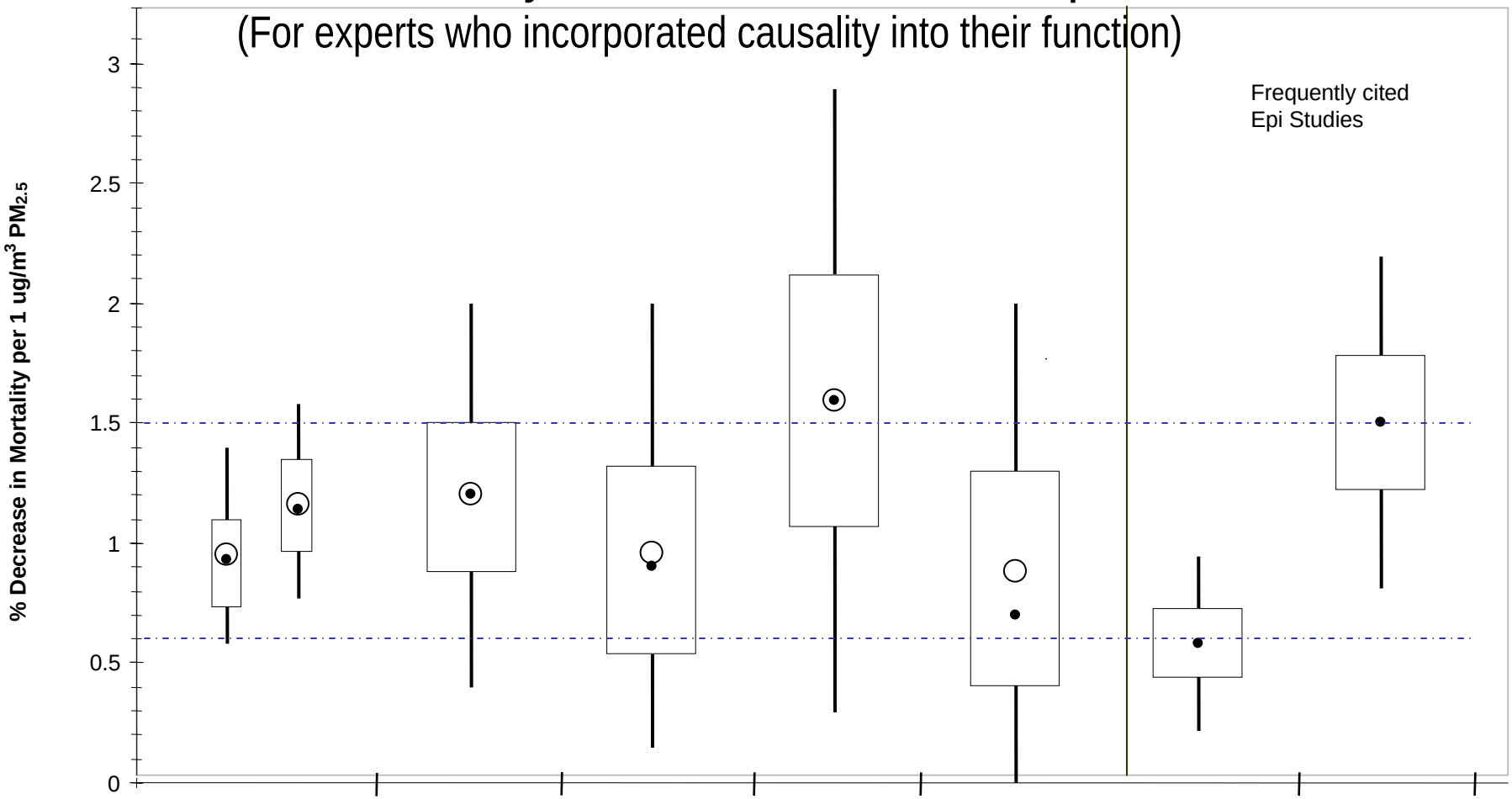
Shape of the C-R Function



Experts were provided flexibility in describing their views of the shape of the C-R function

PM Mortality Functions for Each Expert

(For experts who incorporated causality into their function)

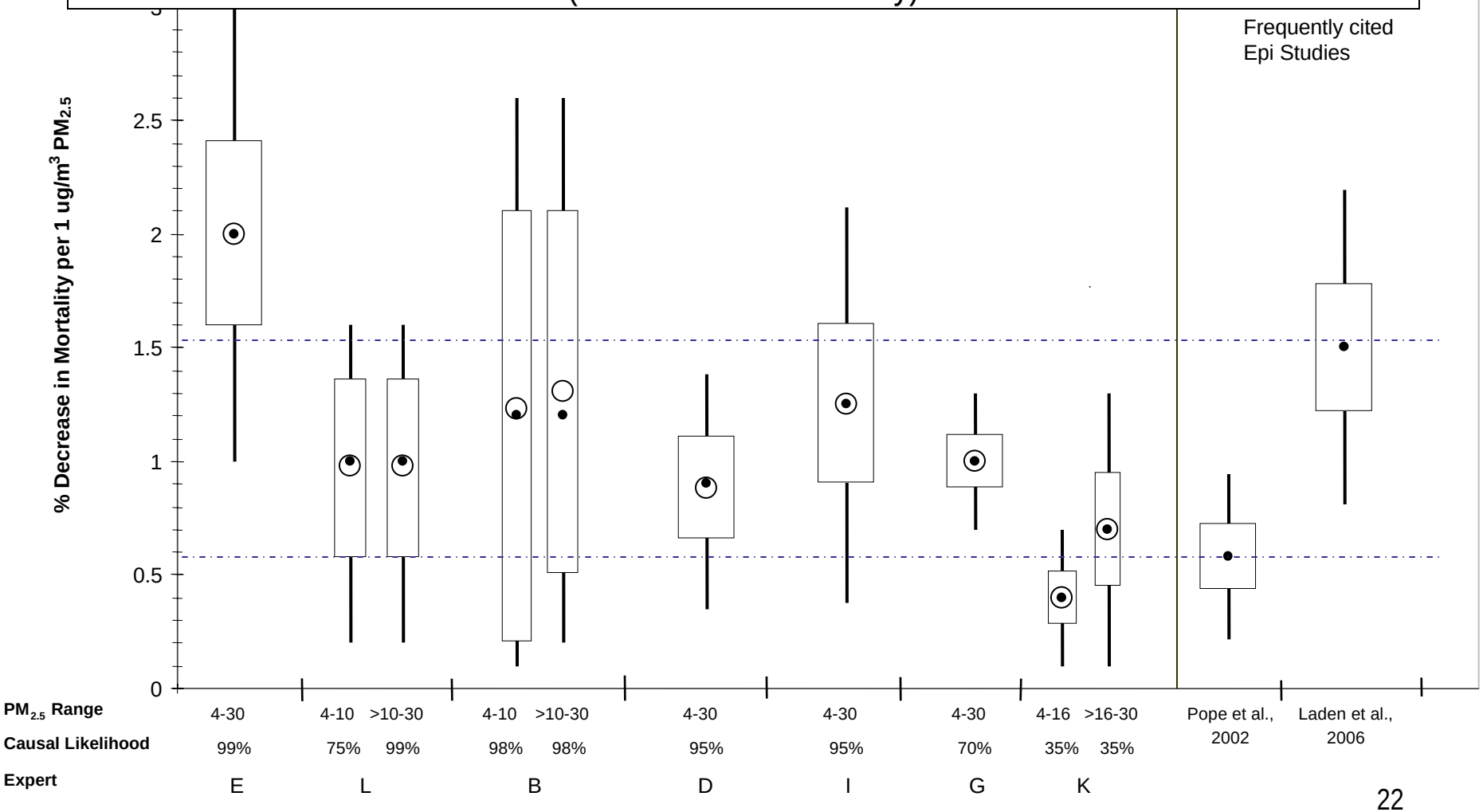


$PM_{2.5}$ Range	4-7	>7-30	4-30	4-30	4-30	4-30	Pope et al., 2002	Laden et al., 2006
Causal Likelihood	100%	100%	99%	99%	95%	90%		
Expert	F		C	J	A	H		

Key: Closed circle = median; Open circle = mean; Box = interquartile range; Solid line = 90% credible interval

PM Mortality Functions for Each Expert

(Conditional on causality)



Key: Closed circle = median; Open circle = mean; Box = interquartile range; Solid line = 90% credible interval

Peer Review

- A peer review was conducted on the Design and Content of the Elicitation
- Panel of six reviewers gave very favorable reviews
  - Stieb, North, Morgan, Wallston, Evans, and Crawford-Brown
- Available at: *www.epa.gov/ecas/benefits.html*

Questions for Reviewers

Please feel free to address other topics you consider important.

General topic: Is the EPA's expert elicitation defensible in terms of assumptions, methodology, and prevalent best practices in the expert elicitation field? What are the strengths and weaknesses of this elicitation?

Specific topics:

1. Selection of Experts
2. Design of the Elicitation Protocol
3. Background Materials/Briefing Book
4. Communication with experts pre- and post-elicitation
5. Elicitation
6. Summary of Findings and Final Study Report (IEc, 2006)
7. Responsiveness to reviewers
8. Overall Comments

The table below lists the topics for the review on the left with more detail on the issues you might address as part of the topic on the right.

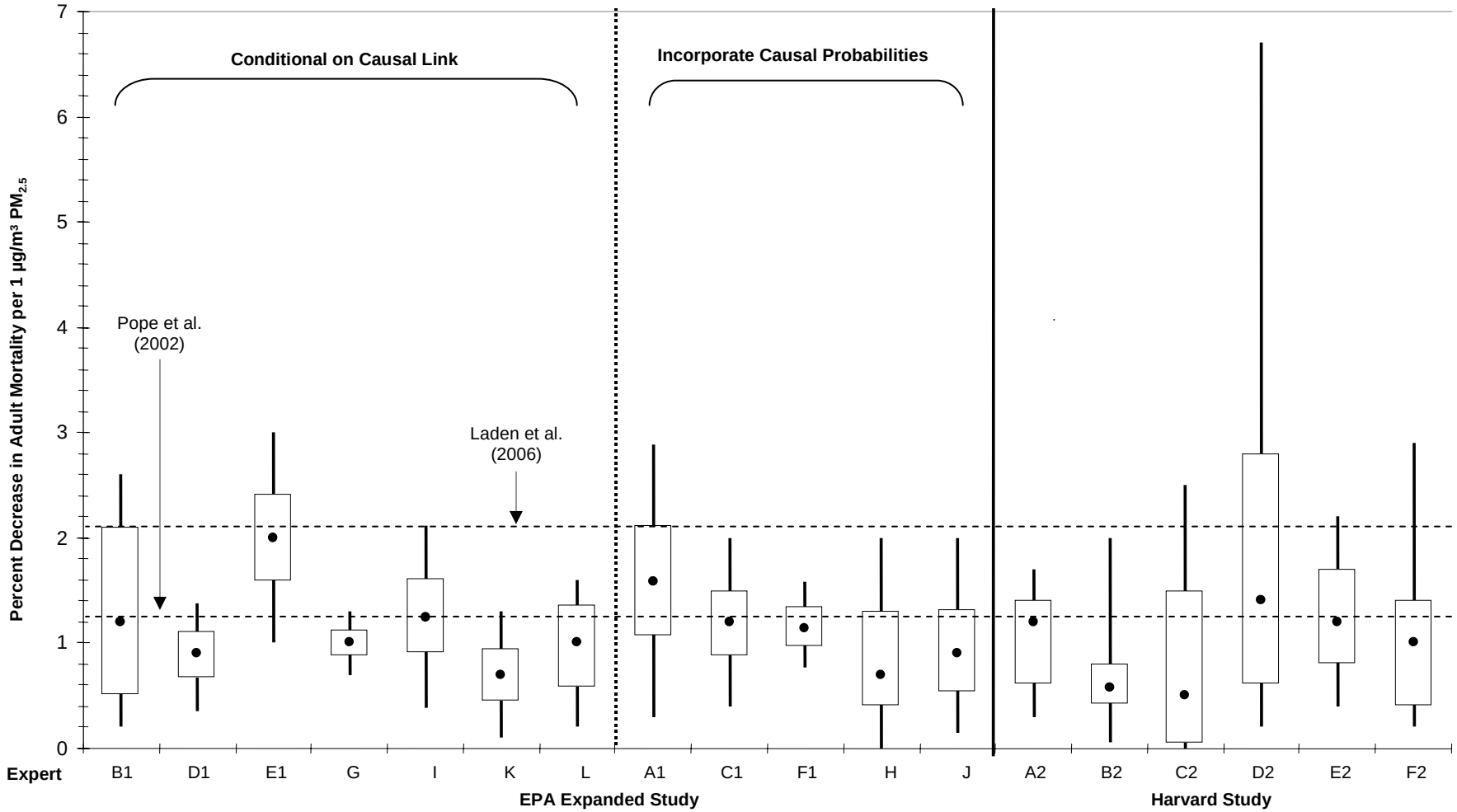
Journal Publications

- Journal article published in Environmental Science & Technology:

  "Expert Judgment Assessment of the Mortality Impact of Changes in Ambient Fine Particulate Matter in the U.S." (Roman et. al, 2008)
- Two other manuscripts are in development
  - Application of the elicitation to a benefit analysis
  - Comparisons of the recent PM-Mortality Elicitations

Comparisons between EPA's and Harvard's PM Elicitations

UNCERTAINTY DISTRIBUTIONS FOR $PM_{2.5}$ - MORTALITY C-R COEFFICIENTS AT AN ANNUAL AVERAGE $PM_{2.5} \geq 18\ \mu g/m^3$



Key: Closed circle = median; Box = interquartile range; Solid line = 90% credible interval

Note: Box plots represent distributions as provided by the experts to the elicitation teams. Some experts from the EPA Expanded Study preferred to give conditional distributions and keep their probabilistic judgment about the likelihood of a causal or non-causal relationship separate (these expert distributions are displayed on the left hand side of the graph). The rest of the experts in the EPA Expanded Study as well as experts in the Harvard Study preferred to give distributions that incorporate their likelihood that the $PM_{2.5}$ mortality association may be non-causal. Therefore, the expert distributions on opposite sides of the dashed line are not directly comparable.

Application of the PM Mortality EE in the 2006 PM NAAQS RIA

Overview:

- How we translated the expert's responses into concentration-response functions we could implement in estimating the benefits of PM air quality changes
- How we presented the results of the benefits analysis
- Interpretation issues

How did we generate the expert elicitation functions?

- 4 major issues
  - Form of the C-R function
  - Threshold
  - Distribution of effect estimate
  - Conditional or unconditional on probability of causal relationship

Specification of Non-threshold Functions

- 8 of 12 experts specified a continuous log-linear function, e.g.

$$\Delta y = y_0 \cdot \left(e^{\beta \cdot \Delta PM} - 1\right)$$

- 3 experts specified piecewise log-linear functions with no threshold, e.g. for a knot at 10 µg,

$$\Delta y = \begin{cases} y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) if\ Q_0 < 10 \\ y_{02} \cdot \left(e^{\beta_2 \cdot \Delta PM} - 1\right) if\ Q_0 \geq 10 \end{cases}$$

Specification of Functional Form with Threshold

- 1 expert specified a piecewise log-linear function with a probabilistic threshold.
- In order to properly implement this in BenMAP, three functions were created for expert K, one with no threshold, one with a uniform distribution of thresholds from 5 to 10 (in one microgram increments, each increment gets 20 percent probability) and one with a uniform distribution of thresholds from 0 to 5).

K1

$$\Delta y = \begin{cases} y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) if\ Q_0 < 16 \\ y_{02} \cdot \left(e^{\beta_2 \cdot \Delta PM} - 1\right) if\ Q_0 \geq 16 \end{cases}$$

K2

$$\Delta y = \begin{cases} y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 0.0\, if\ 0 \leq Q_0 < 1 \\ y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 0.2\ if\ 1 \leq Q_0 < 2 \\ y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 0.4\ if\ 2 \leq Q_0 < 3 \\ y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 0.6\ if\ 3 \leq Q_0 < 4 \\ y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 0.8\, if\ 4 \leq Q_0 < 5 \\ y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) if\ 5 \leq Q_0 < 16 \\ y_{02} \cdot \left(e^{\beta_2 \cdot \Delta PM} - 1\right) if\ Q_0 \geq 16 \end{cases}$$

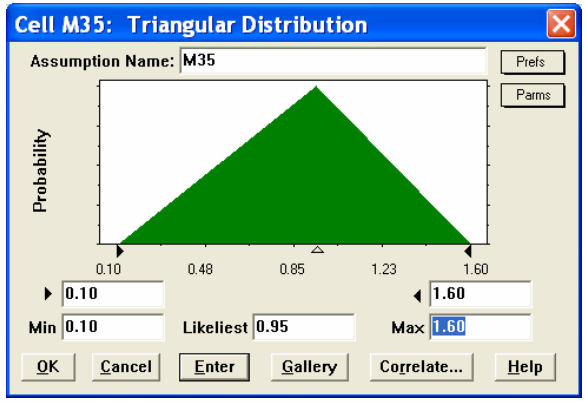
K3

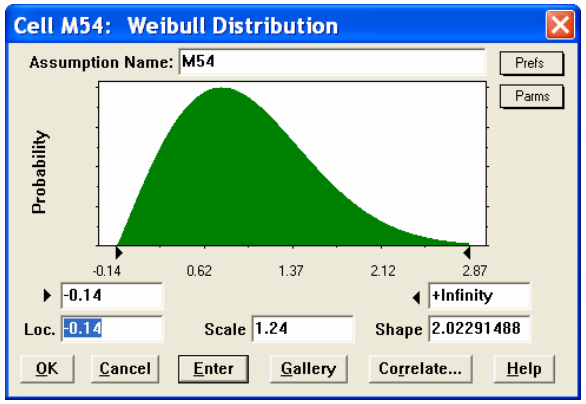
$$\Delta y = \begin{cases} y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 0.0\, if\ 0 \leq Q_0 < 6 \\ y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 0.2\ if\ 6 \leq Q_0 < 7 \\ y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 0.4\ if\ 7 \leq Q_0 < 8 \\ y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 0.6\ if\ 8 \leq Q_0 < 9 \\ y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 0.8\, if\ 9 \leq Q_0 < 10 \\ y_{01} \cdot \left(e^{\beta_1 \cdot \Delta PM} - 1\right) \times 1.0\, if\ 10 \leq Q_0 < 16 \\ y_{02} \cdot \left(e^{\beta_2 \cdot \Delta PM} - 1\right) if\ Q_0 \geq 16 \end{cases}$$

- In the pooling stage, the 3 incidence distributions are assigned weights, with the no threshold case getting 50 percent weight, the 0 to 5 threshold case getting 40 percent weight, and the 5 to 10 distribution getting 10 percent weight.

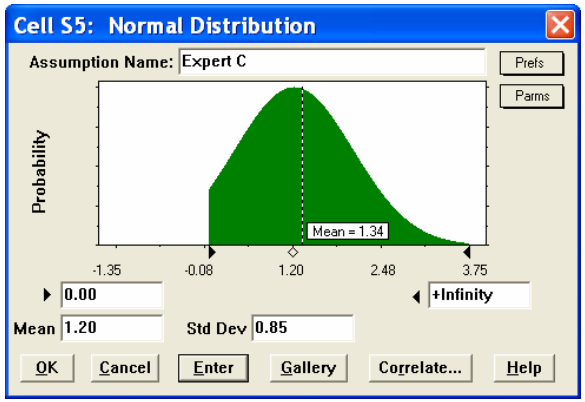
Distributions of Effect Estimates

- Six experts chose a normal distribution to represent the effect estimate.
- One expert chose a triangular distribution and one chose a Weibull distribution



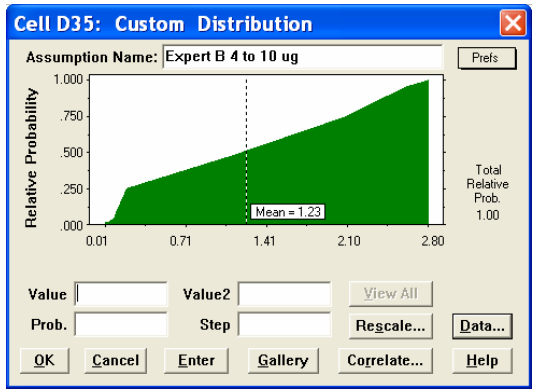


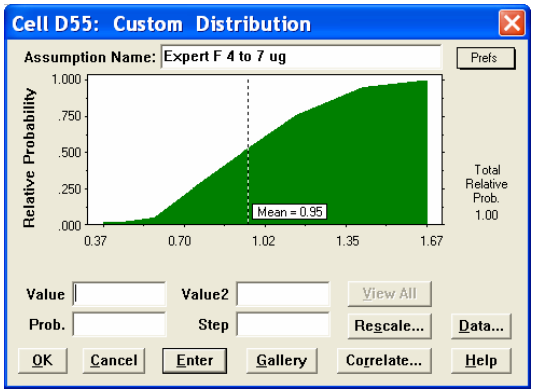
- Three experts specified normal distributions whose mean and std deviation implied negative values at the 2.5th or below percentiles, but also specified a minimum value of zero or greater. In these cases, we created truncated normal distributions.

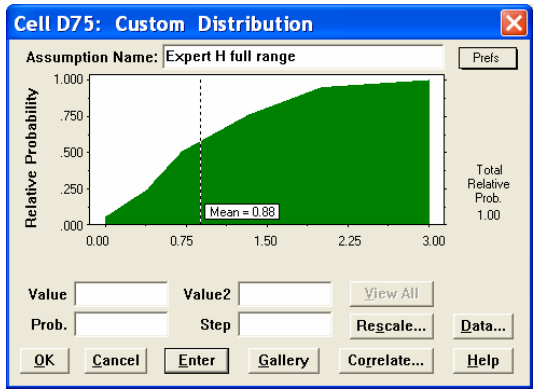


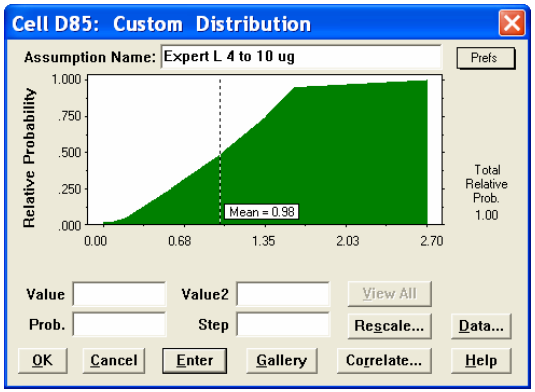
Distributions of Effect Estimates (continued)

- Four of the experts did not choose a parametric distribution, preferring instead to provide only effect estimates at particular percentiles of their distributions.
- In these cases, we constructed custom distributions to represent their percentiles. For these custom distributions, we assume a continuous and smooth transition of the distribution between the reported percentiles:





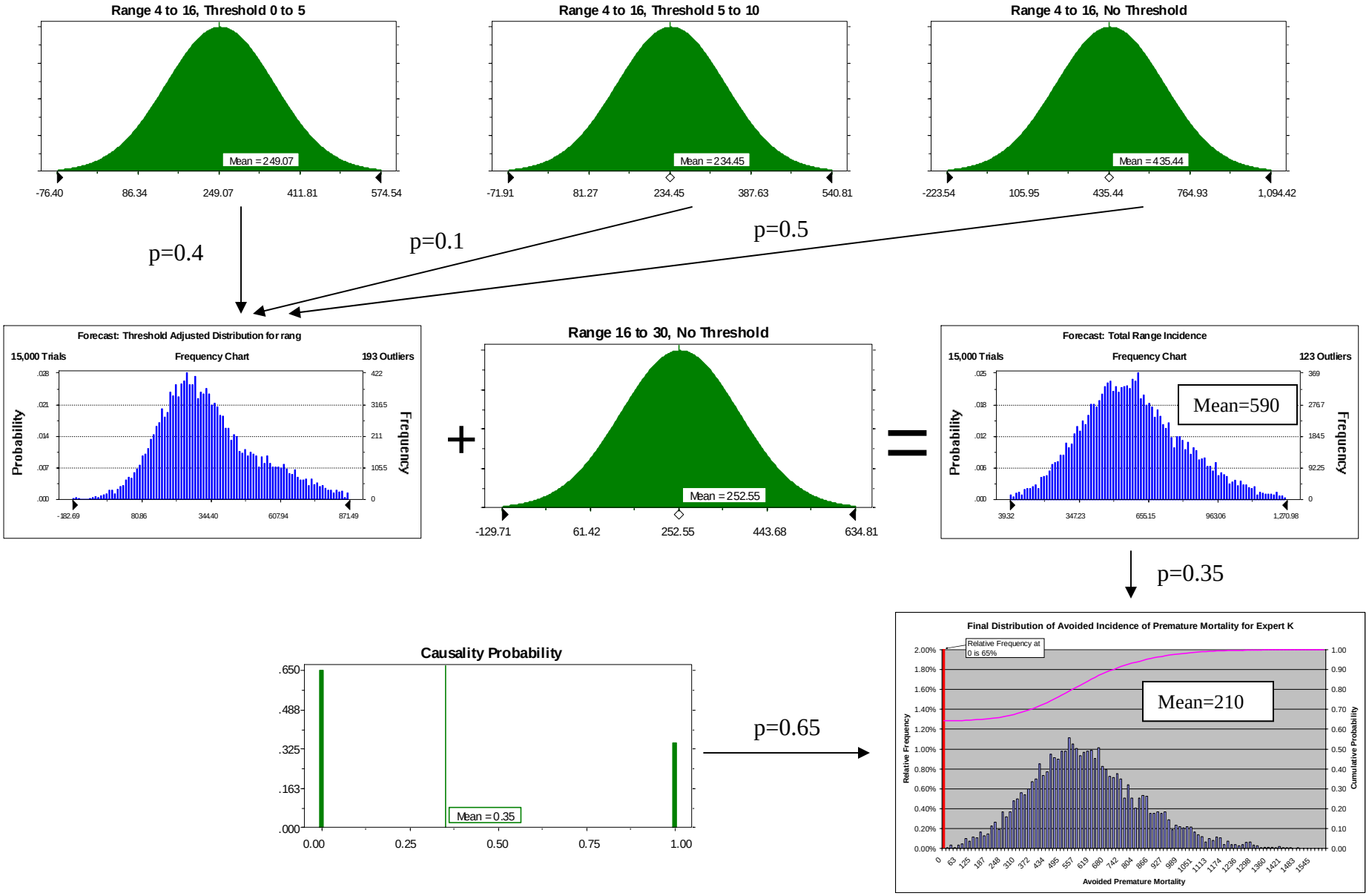




Applying Views on Causality

- 5 of the experts specified unconditional distributions – they incorporated the probability that the observed relationship is not causal directly into their percentiles
- The other 7 experts specified a conditional distribution (or distributions). In these cases, the final estimated distribution of avoided incidence of premature mortality will be the expected value of the unconditional distribution. In practice, we implement this by estimating each expert's conditional distribution and then, using Monte Carlo sampling, construct an unconditional distribution using the expert's reported probability of a causal relationship.
- For example, Expert K specified a causal probability of 0.35, indicating that he felt that the likelihood of a causal relationship is only 35 percent. As such, we calculate his final distribution of the change in incidence by sampling from his distributions of incidence with a weight of 0.35 and from a zero distribution with a weight of 0.65.

Initial Distributions:



Presentation of Results in the PM NAAQS RIA

- Focus on Probabilistic Presentation
- Throughout discussion and results, more focus on distributions for inputs and uncertainty in sources of data
- Results include 95 percent confidence intervals
- Results based on expert elicitation identified as distinct from those based on data, but given parallel presentation

Illustrative Strategy to Attain 15/35: Estimated Reduction in Premature Mortality Incremental to 15/65 Attainment Strategy (90th percentile confidence intervals)

	Eastern U.S.		*Western U.S.*	*California*	*National Total*	*National Tota*
	Modeled Partial Attainment	*Residual Attainment*				*Full Attainment*
Mortality Impact Functions Derived from Epidemiology Literature						
ACS Study	360 (140-600)	17 (7-27)				2,500 (1,000-4,100
Harvard 6-City	800 (450-1,200)	38 (21-55)				5,700 (3,100-8,300
Woodruff (infant mortality)	1 (1-2)	0.02 ((0.001-0.003)				8 (4-12)
Mortality Impacts Functions Derived from Expert Elicitation						
Expert A	1,700 (300-3,100)	41 ((8-75)				10,000 (1,900-16,00(

Table 5-16: Illustrative Strategy to Attain 15/35: Estimated Reduction in Premature Mortality (Incremental to 15/65 Attainment Strategy) 90th Percentile Confidence Intervals Provided in Parentheses[a]

	Eastern U.S.		*Western U.S. Excluding CA*		*California*		*National Total*		
	Modeled Partial Attainment	*Residual Attainment*	*Modeled Partial Attainment*	*Residual Attainment*	*Modeled Partial Attainment*	*Residual Attainment*	*Modeled Partial Attainment*	*Residual Attainment*	*National Total Full Attainment*
Mortality Impact Functions Derived from Epidemiology Literature									
ACS Study[b]	360 (140 – 600)	17 (7 – 27)	80 (30 – 120)	15 (6 – 24)	520 (200 – 830)	1,600 (610 – 2,490)	960 (370 – 1,500)	1,600 (620 – 2,500)	2,500 (1,000 – 4,100)
Harvard Six-City Study[c]	800 (450 – 1,200)	38 (21 – 55)	200 (90 – 300)	30 (18 – 50)	1,200 (640 – 1,700)	3,500 (1,900 – 5,000)	2,200 (1,180 – 3,100)	3,600 (1,900 – 5,100)	5,700 (3,100 – 8,300)
Woodruff et al., 1997 (infant mortality)	1 (1 – 2)	0.02 (0.01 – 0.03)	0.7 (0.4 – 1.1)	0.3 (0.2 – 0.5)	1 (1 – 2)	4.8 (2.3 – 7.2)	3 (1 – 5)	5 (3 – 8)	8 (4 – 12)
Mortality Impact Functions Derived from Expert Elicitation									
Expert A	1,700 (300 – 3,100)	41 (8 – 75)	1,400 (300 – 2,500)	370 (70 – 660)	1,600 (300 – 2,800)	5,100 (900 – 9,100)	4,600 (900 – 8,400)	5,500 (1,000 – 9,900)	10,000 (1,900 – 18,000)
Expert B	1,400 (200 – 2,800)	34 (5 – 67)	1,100 (100 – 2,200)	290 (30 – 600)	1,300 (200 – 2,500)	4,100 (600 – 8,200)	3,700 (400 – 7,600)	4,400 (600 – 8,900)	8,100 (1,000 – 16,000)
Expert C	1,400 (230 – 2,800)	34 (6 – 67)	1,100 (190 – 2,200)	300 (50 – 600)	1,300 (210 – 2,500)	4,200 (700 – 8,200)	3,800 (630 – 7,500)	4,500 (760 – 8,900)	8,400 (1,400 – 16,000)
Expert D	920 (190 – 1,500)	23 (5 – 36)	750 (150 – 1,200)	200 (41 – 320)	850 (170 – 1,400)	2,800 (570 – 4,400)	2,500 (510 – 4,000)	3,000 (610 – 4,800)	5,500 (1,100 – 8,800)
Expert E	2,100 (1,100 – 3,200)	52 (26 – 78)	1,700 (870 – 2,600)	460 (230 – 690)	2,000 (980 – 2,900)	6,400 (3,200 – 9,500)	5,800 (2,900 – 8,700)	6,900 (3,500 – 10,000)	13,000 (6,400 – 19,000)
Expert F	1,200 (820 – 1,700)	30 (20 – 41)	1,000 (660 – 1,400)	270 (180 – 360)	1,100 (760 – 1,600)	3,700 (2,500 – 5,100)	3,400 (2,200 – 4,600)	4,000 (2,700 – 5,500)	7,400 (4,900 – 10,000)
Expert G	750 (0 – 1,400)	18 (0 – 34)	610 (0 – 1,100)	160 (0 – 300)	690 (0 – 1,300)	2,300 (0 – 4,200)	2,000 (0 – 3,800)	2,400 (0 – 4,500)	4,500 (0 – 8,300)
Expert H	920 (0 – 2,200)	22 (0 – 53)	750 (0 – 1,800)	200 (0 – 470)	850 (0 – 2,000)	2,800 (0 – 6,500)	2,500 (0 – 6,000)	3,000 (0 – 7,100)	5,500 (0 – 13,000)
Expert I	1,300 (200 – 2,300)	32 (5 – 55)	1,100 (200 – 1,800)	280 (40 – 490)	1,200 (200 – 2,100)	3,900 (600 – 6,800)	3,600 (600 – 6,200)	4,300 (700 – 7,300)	7,900 (1,200 – 13,000)
Expert J	1,200 (310 – 2,300)	28 (7 – 56)	900 (250 – 1,800)	250 (66 – 490)	1,100 (280 – 2,100)	3,500 (930 – 6,800)	3,200 (840 – 6,200)	3,800 (1,000 – 7,300)	7,000 (1,800 – 14,000)
Expert K	190 (0 – 960)	5 (0 – 23)	160 (0 – 780)	41 (0 – 210)	200 (0 – 940)	580 (0 – 2,880)	540 (0 – 2,700)	630 (0 – 3,100)	1,200 (0 – 5,800)
Expert L	910 (100 – 1,700)	25 (5 – 42)	660 (0 – 1,400)	180 (10 – 380)	920 (200 – 1,600)	2,900 (500 – 5,200)	2,500 (300 – 4,700)	3,100 (500 – 5,600)	5,600 (800 – 10,000)

Table 5-20: Illustrative Strategy to Attain 15/35: Estimated Monetary Value of Reductions in Risk of Premature Mortality (3 Percent Discount Rate, in millions of 1999$) 90th Percentile Confidence Intervals Provided in Parentheses [a]

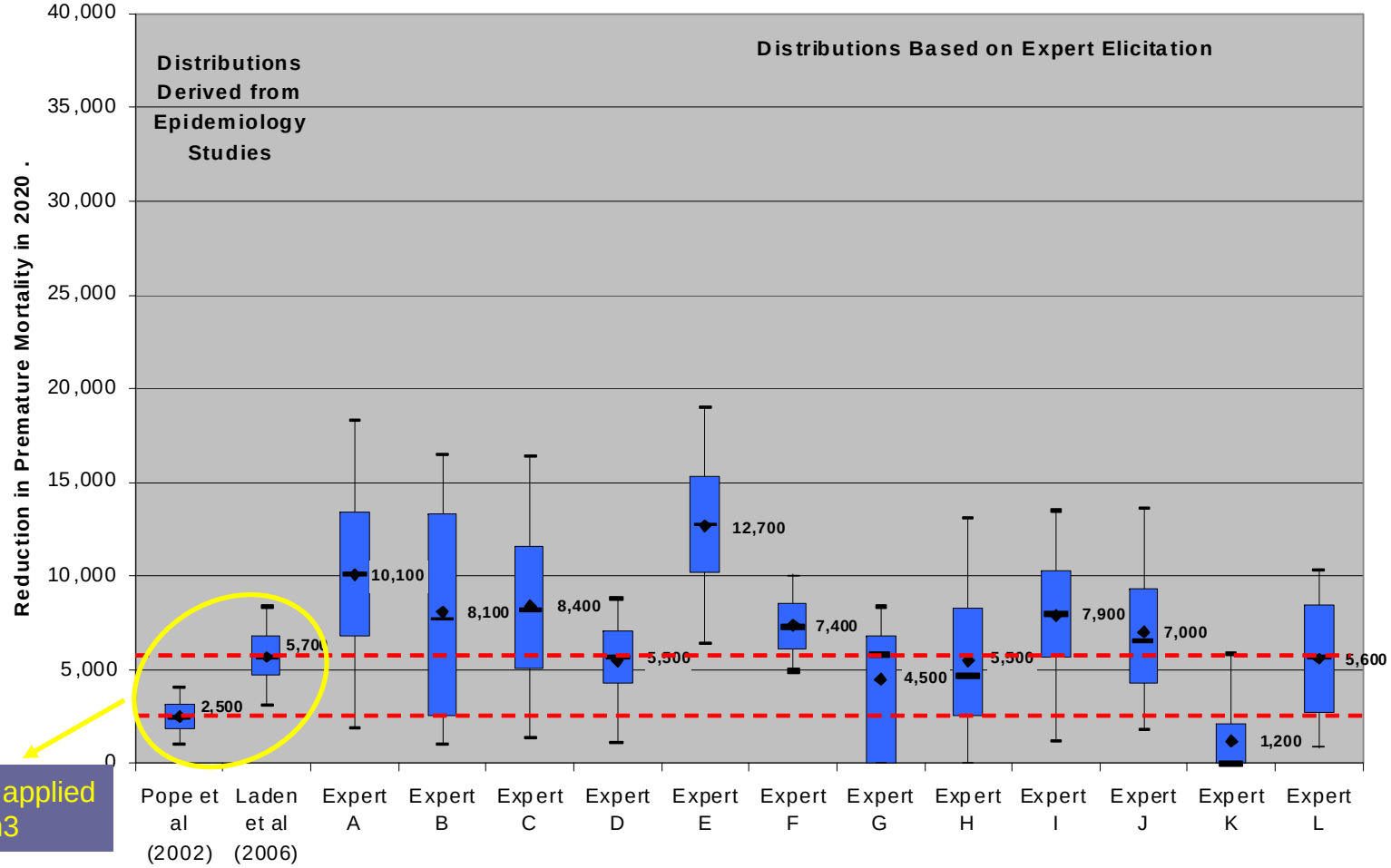
	Eastern U.S.		*Western U.S. Excluding CA*		*California*		*National Total*		
	Modeled Partial Attainment	*Residual Attainment*	*Modeled Partial Attainment*	*Residual Attainment*	*Modeled Partial Attainment*	*Residual Attainment*	*Modeled Partial Attainment*	*Residual Attainment*	*National Total Full Attainment*
Mortality Impact Functions Derived from Epidemiology Literature									
ACS Study[b]	$2,100 ($470 – $4,400)	$97 ($22 – $200)	$440 ($99 – $920)	$87 ($19 – $180)	$3,000 ($670 – $6,200)	$9,000 ($2,000 – $19,000)	$5,500 ($1,200 – $12,000)	$9,200 ($2,000 – $19,000)	$15,000 ($3,300 – $31,000)
Harvard Six-City Study[c]	$4,800 ($1,200 – $9,200)	$220 ($57 – $430)	$1,000 ($260 – $1,900)	$200 ($51 – $380)	$6,800 ($1,800 – $13,000)	$20,000 ($5,300 – $39,000)	$13,000 ($3,300 – $24,000)	$21,000 ($5,400 – $40,000)	$33,000 ($8,600 – $64,000)
Woodruff et al 1997 (infant mortality)	$6 ($1 – $11)	$0 ($0 – $0)	$4 ($1 – $8)	$2 ($0 – $4)	$8 ($2 – $15)	$28 ($7 – $55)	$17 ($4 – $35)	$30 ($7 – $59)	$47 ($12 – $94)
Mortality Impact Functions Derived from Expert Elicitation									
Expert A	$9,800 ($1,300 – $22,000)	$240 ($32 – $540)	$8,000 ($1,100 – $18,000)	$2,100 ($280 – $4,800)	$9,000 ($1,200 – $20,000)	$29,000 ($4,000 – $67,000)	$27,000 ($3,600 – $61,000)	$32,000 ($4,300 – $72,000)	$59,000 ($7,900 – $130,000)
Expert B	$7,800 ($650 – $21,000)	$200 ($21 – $510)	$6,100 ($390 – $17,000)	$1,700 ($120 – $4,500)	$7,400 ($740 – $19,000)	$24,000 ($2,300 – $62,000)	$21,000 ($1,800 – $57,000)	$26,000 ($2,400 – $68,000)	$47,000 ($4,200 – $120,000)
Expert C	$8,100 ($980 – $20,000)	$200 ($24 – $480)	$6,600 ($800 – $16,000)	$1,800 ($210 – $4,200)	$7,500 ($900 – $18,000)	$24,000 ($3,000 – $59,000)	$22,000 ($2,700 – $54,000)	$26,000 ($3,200 – $63,000)	$48,000 ($5,900 – $120,000)
Expert D	$5,300 ($800 – $11,000)	$130 ($19 – $270)	$4,300 ($650 – $9,100)	$1,200 ($170 – $2,400)	$4,900 ($730 – $10,000)	$16,000 ($2,400 – $34,000)	$15,000 ($2,200 – $31,000)	$17,000 ($2,600 – $36,000)	$32,000 ($4,800 – $67,000)
Expert E	$12,000 ($3,100 – $24,000)	$300 ($76 – $600)	$10,000 ($2,500 – $20,000)	$2,700 ($670 – $5,300)	$11,000 ($2,800 – $22,000)	$37,000 ($9,300 – $73,000)	$34,000 ($8,500 – $67,000)	$40,000 ($10,000 – $79,000)	$74,000 ($19,000 – $150,000)
Expert F	$7,200 ($1,900 – $13,000)	$170 ($47 – $330)	$5,800 ($1,600 – $11,000)	$1,500 ($420 – $2,900)	$6,600 ($1,800 – $12,000)	$22,000 ($5,900 – $40,000)	$19,000 ($5,300 – $37,000)	$23,000 ($6,300 – $44,000)	$43,000 ($12,000 – $80,000)
Expert G	$4,300 ($0 – $11,000)	$110 ($0 – $260)	$3,500 ($0 – $8,700)	$940 ($0 – $2,300)	$4,000 ($0 – $9,800)	$13,000 ($0 – $32,000)	$12,000 ($0 – $29,000)	$14,000 ($0 – $35,000)	$26,000 ($0 – $64,000)
Expert H	$5,300 ($17 – $15,000)	$130 ($0 – $370)	$4,300 ($14 – $12,000)	$1,200 ($4 – $3,300)	$4,900 ($16 – $14,000)	$16,000 ($52 – $46,000)	$15,000 ($47 – $42,000)	$17,000 ($56 – $49,000)	$32,000 ($100 – $91,000)
Expert I	$7,600 ($900 – $17,000)	$190 ($22 – $410)	$6,200 ($730 – $14,000)	$1,600 ($190 – $3,600)	$7,000 ($830 – $15,000)	$23,000 ($2,700 – $50,000)	$21,000 ($2,500 – $46,000)	$25,000 ($2,900 – $54,000)	$45,000 ($5,400 – $100,000)
Expert J	$6,800 ($1,100 – $16,000)	$160 ($28 – $390)	$5,500 ($930 – $13,000)	$1,500 ($250 – $3,500)	$6,200 ($1,100 – $15,000)	$20,000 ($3,500 – $48,000)	$18,000 ($3,100 – $44,000)	$22,000 ($3,700 – $52,000)	$40,000 ($6,900 – $95,000)
Expert K	$1,100 ($0 – $6,000)	$27 ($0 – $150)	$900 ($0 – $4,800)	$240 ($0 – $1,300)	$1,100 ($0 – $6,000)	$3,400 ($0 – $18,000)	$3,100 ($0 – $17,000)	$3,600 ($0 – $20,000)	$6,800 ($0 – $36,000)
Expert L	$5,300 ($480 – $13,000)	$140 ($20 – $330)	$3,800 ($110 – $10,000)	$1,100 ($59 – $2,800)	$5,300 ($720 – $12,000)	$17,000 ($2,100 – $40,000)	$14,000 ($1,300 – $36,000)	$18,000 ($2,200 – $43,000)	$32,000 ($3,500 – $79,000)

Table 5-27: Ranges of Total Monetized Benefits (Health and Visibility) Associated with Full Attainment of 15/35 and 14/35 Standards Incremental to Attainment of Current 15/65 Standards in 2020 (in millions of 1999$) 90th Percentile Confidence Intervals Provided in Parentheses[a]

	3% Discount Rate		7% Discount Rate	
Source of Mortality Effect Estimate	**15/35**	**14/35**	**15/35**	**14/35**
Data Derived				
ACS Study[b]	$17,000	$30,000	$15,000	$26,000
	($4,100 - $36,000)	($7,300 - $63,000)	($3,500 - $31,000)	($6,400 - $54,000)
Harvard Six-City Study[c]	$35,000	$62,000	$30,000	$52,000
	($9,400 - $70,000)	($17,000 - $120,000)	($8,100 - $59,000)	($14,000 - $100,000)
Expert Elicitation Derived				
Expert A	$61,000	$110,000	$51,000	$96,000
	($8,700 - $140,000)	($16,000 - $260,000)	($7,400 - $120,000)	($14,000 - $220,000)
Expert B	$49,000	$91,000	$42,000	$78,000
	($5,000 - $130,000)	($9,300 - $240,000)	($4,300 - $110,000)	($8,100 - $210,000)
Expert C	$51,000	$94,000	$43,000	$80,000
	($6,700 - $120,000)	($13,000 - $230,000)	($5,800 - $100,000)	($11,000 - $190,000)
Expert D	$34,000	$64,000	$29,000	$54,000
	($5,600 - $72,000)	($11,000 - $130,000)	($4,800 - $62,000)	($9,100 - $110,000)
Expert E	$76,000	$140,000	$64,000	$120,000
	($19,000 - $150,000)	($36,000 - $280,000)	($16,000 - $130,000)	($31,000 - $240,000)
Expert F	$45,000	$84,000	$38,000	$71,000
	($12,000 - $86,000)	($23,000 - $160,000)	($11,000 - $73,000)	($20,000 - $140,000)
Expert G	$28,000	$52,000	$24,000	$45,000
	($800 - $69,000)	($1,700 - $130,000)	($790 - $59,000)	($1,600 - $110,000)
Expert H	$34,000	$63,000	$29,000	$54,000
	($900 - $96,000)	($1,900 - $180,000)	($880 - $82,000)	($1,800 - $150,000)
Expert I	$48,000	$89,000	$40,000	$75,000
	($6,200 - $110,000)	($12,000 - $200,000)	($5,300 - $89,000)	($10,000 - $170,000)
Expert J	$42,000	$79,000	$36,000	$67,000
	($7,700 - $100,000)	($14,000 - $190,000)	($6,600 - $86,000)	($12,000 - $160,000)
Expert K	$9,000	$17,000	$7,900	$15,000
	($800 - $42,000)	($1,700 - $77,000)	($790 - $36,000)	($1,600 - $66,000)
Expert L	$35,000	$64,000	$29,000	$54,000
	($4,300 - $84,000)	($7,700 - $160,000)	($3,700 - $72,000)	($6,800 - $130,000)

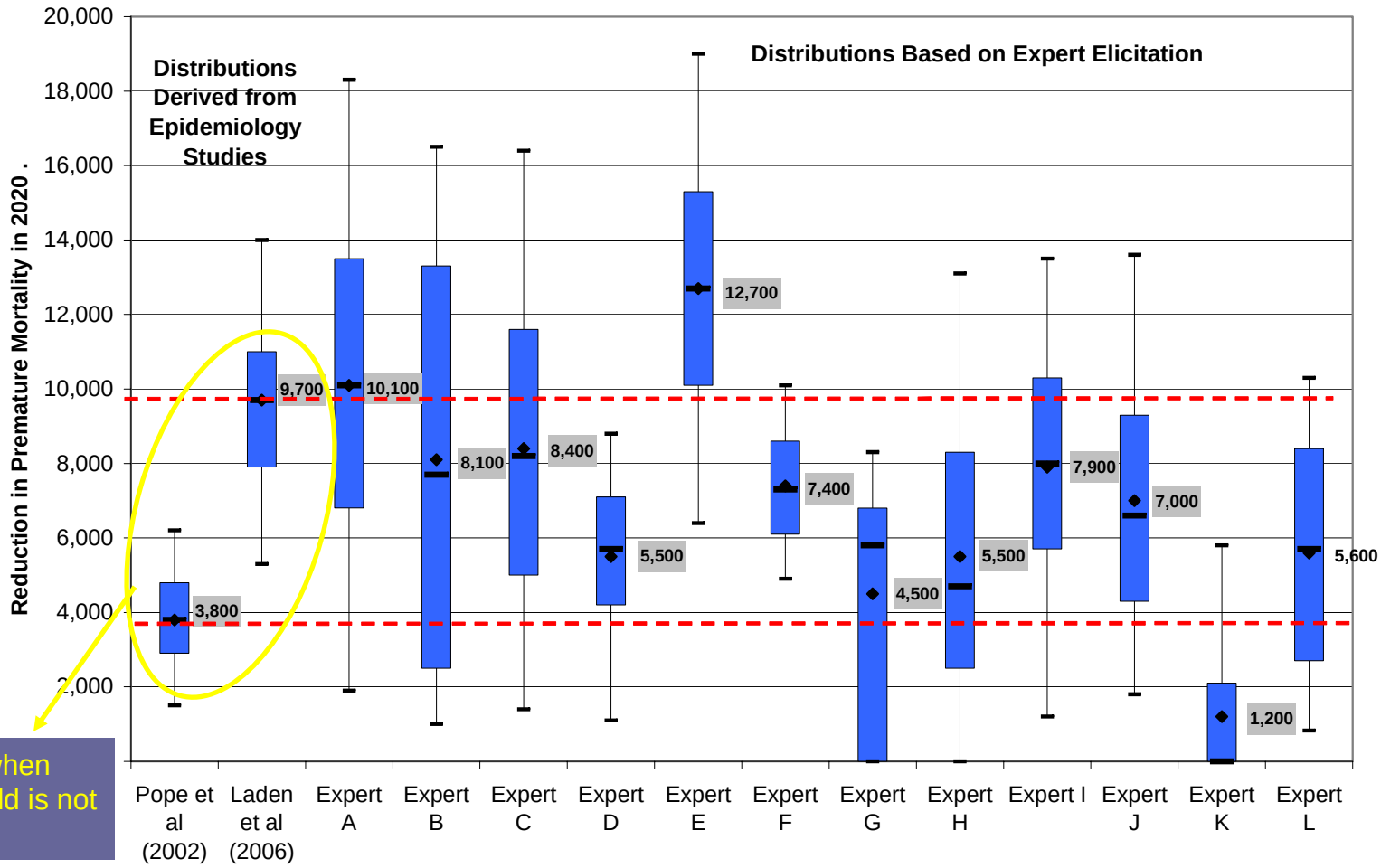
EPA also presents graphical results in RIAs

Figure 5-10. Results of Application of Expert Elicitation: Annual Reductions in Premature Mortality in 2020 Associated with Illustrative Strategies to Attain 15/35, Incremental to Attainment of the 1997 Standards



Threshold applied at 10 ug/m3

Note: Distributions labeled Expert A - Expert L are based on individual expert responses. The distributions labeled Pope et al. (2002) and Laden et al (2006) are based on the means and standard errors of the C-R functions from the studies. The red dotted lines enclose a range bounded by the means of the two data-derived distributions.

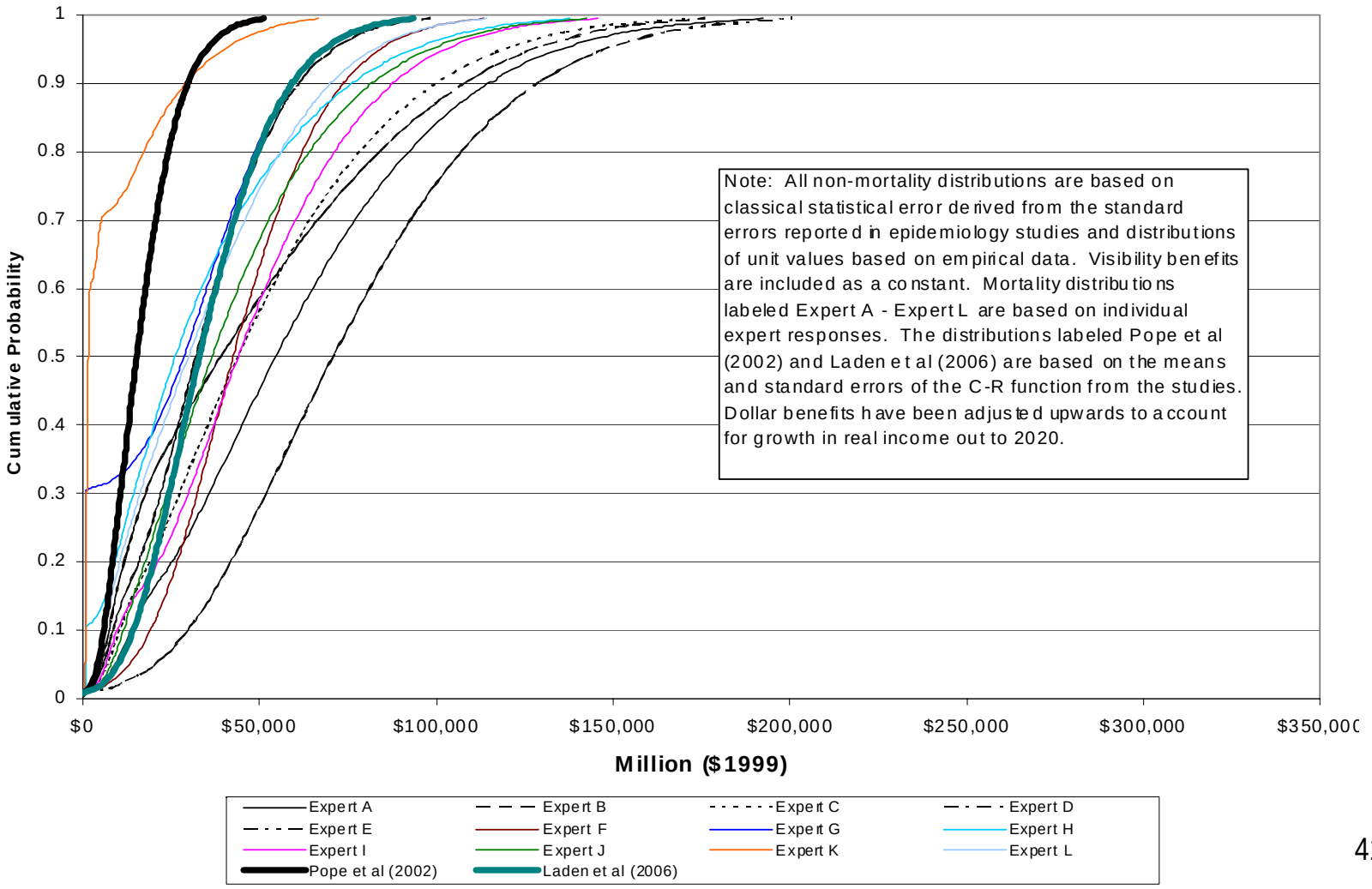


Results when a threshold is not applied

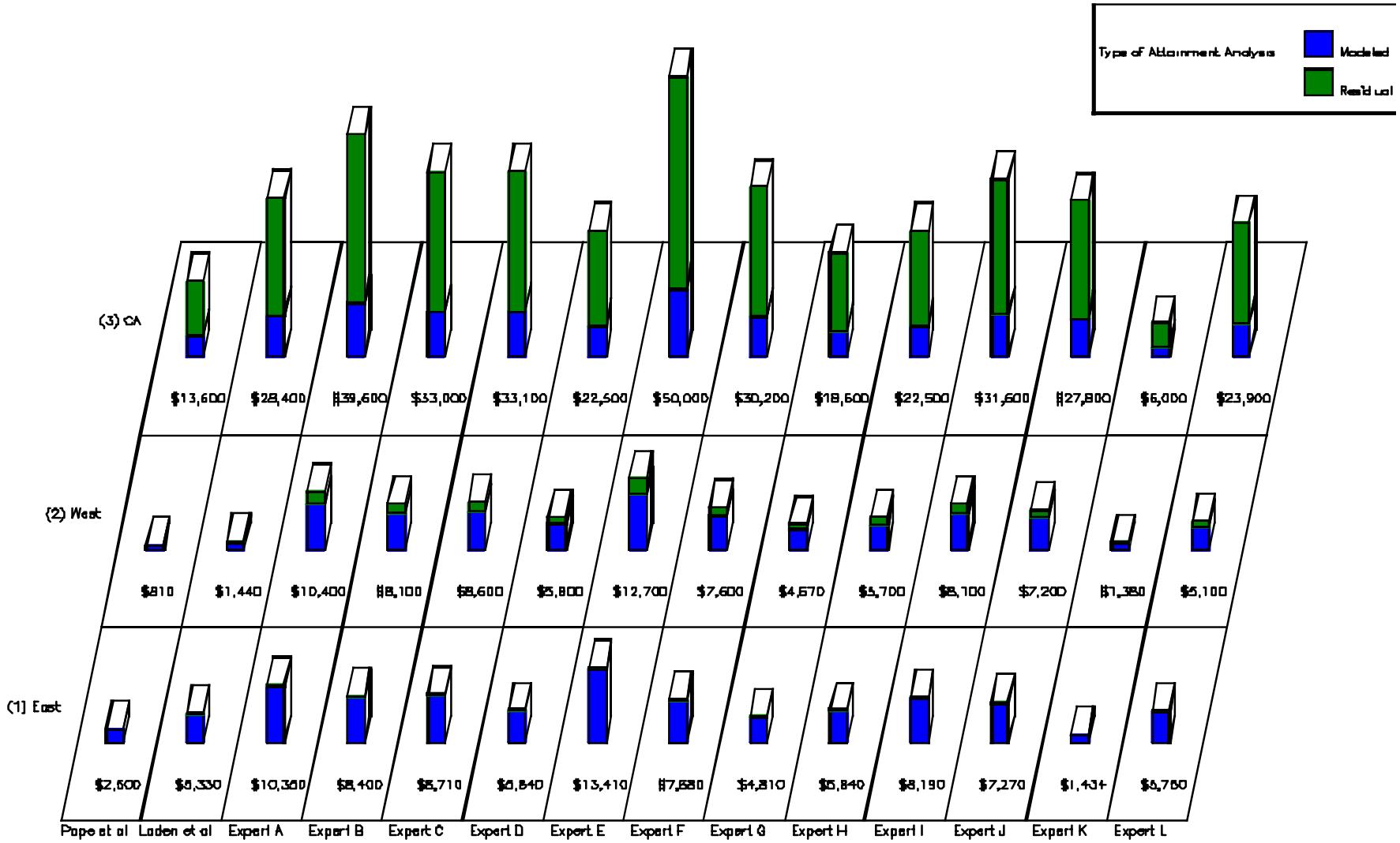
Note: Distributions labeled Expert A - Expert L are based on individual expert responses. The distributions labeled Pope et al. (2002) and Laden et al (2006) are based on the means and standard errors of the C-R functions from the studies. The red dotted lines enclose a range bounded by the means of the two data-derived distributions.

*Note: This graphic does not appear in the PM NAAQS RIA .

Figure 5-14. Results of Probabilistic Uncertainty Analysis: Cumulative Distributions of Dollar Value of Health and Welfare Impacts Associated with Illustrative Strategies to Attain 15/35, Incremental to Attainment of the 1997 Standards



Total Monetized Benefits of 15/35 Illustrative Attainment Strategy
(Millions of 1999$)



Presentation in the RIA Executive Summary

Table ES-1: Comparison of Full Attainment Benefits with Social Costs[f], Incremental to Attainment of 1997 Standards (Billion 1999$)

	Revised standard of 15/35 (μg/m³)					Alternative standards of 14/35 (μg/m³)					
	Benefits[a]		*Costs*[b]	*Net benefits*[c]		*Benefits*[a]		*Costs*[b]	*Net benefits*[c]		
Benefits Based on Mortality Function from the American Cancer Society Study and Morbidity Functions from the Published Scientific Literature[d]											
3%	$17		$5.4	$12		$30		$7.9	$22		
7%	$15		$5.4	$9		$26		$7.9	$18		
Benefits Range Based on Expert Elicitation Derived Mortality Functions and Morbidity Functions from the Published Scientific Literature[e]											
	Low Mean	High Mean		Low Mean	High Mean	Low Mean	High Mean		Low Mean	High Mean	
3%	$9	$76	$5.4	$3.5	$70	$17	$140	$7.9	$8.7	$130	
7%	$8	$64	$5.4	$2.4	$59	$15	$120	$7.9	$6.7	$110	

[a] Results reflect the use of two different discount rates: 3% and 7%, as recommended in EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b) and OMB Circular A-4 (OMB, 2003). Results are rounded to two significant digits

[b] Includes roughly $180 Million in supplemental engineering costs.

[c] Estimates rounded to two significant digits after calculations.

[d] based on Pope et al 2002, used as primary estimate in previous RIAs.

[e] Although the overall range across experts is summarized in this table, the full uncertainty in the estimates is reflected by the results for the full set of 12 experts. The twelve experts' judgments as to the likely mean effect estimate are not evenly distributed across the range illustrated by arraying the highest and lowest expert means. The distribution of benefits estimates associated with each of the twelve expert responses can be found in Chapter 5.

[f] For the purposes of comparison with the benefits, EPA uses the total social cost estimate which is slightly higher than the engineering cost

EPA's Press Release cites a range of estimates

Table ES-2. Estimated Reduction in Incidence of Adverse Health and Welfare Effects Associated with Attaining the Revised and Alternative Standards, Incremental to Attainment of the 1997 Standards (95 Percent Confidence Intervals Provided in Parentheses)

Estimate	Revised Standards (15/35)	Alternative Revised Standards (14/35)
Mortality		
Estimate based on American Cancer Society study[a]	2,500 (1,000 – 4,100)	4,400 (1,700 – 7,100)
Range based on expert elicitation results[b]		
Low Mean	1,200 (0 – 5,800)	2,200 (0 – 11,000)
High Mean	13,000 (6,400 – 19,000)	24,000 (12,000 – 35,000)

Table ES-3. Estimated Annual Monetized Benefits in 2020 of Illustrative Implementation Strategies for the Selected and Alternative $PM_{2.5}$ NAAQS, Incremental to Attainment of the 1997 Standards

Note: Unquantified benefits are not included in these estimates, thus total benefits are likely to be larger than indicated in this table.

	Total Full Attainment Benefits[a] (billions 1999$)			
	15/35 (μg/m3)		*14/35 (μg/m3)*	
Benefits Based on Mortality Function from the American Cancer Society Study and Morbidity Functions from the Published Scientific Literature[b]				
Using a 3% discount rate	$17 ($4.1 – $36)		$30 ($7.3 - $63)	
Using a 7% discount rate	$15 ($3.5 – $31)		$26 ($6.4 - $54)	
Benefits Range Based on Expert Elicitation Derived Mortality Functions and Morbidity Functions from the Published Scientific Literature[c]				
	Low Mean	High Mean	Low Mean	High Mean
Using a 3% discount rate	$9 ($0.8 - $42)	$76 ($19-$150)	$17 ($1.7 - $77)	$140 ($36 - $280)
Using a 7% discount rate	$8 ($0.8 - $36)	$64 ($16 - $130)	$15 ($1.6 - $66)	$120 ($31 - $240)

[a] Results reflect the use of two different discount rates: 3% and 7%, as recommended in EPA's *Guidelines for Preparing Economic Analyses* (EPA, 2000b) and OMB Circular A-4 (OMB, 2003). Results are rounded to two significant digits.

[b] The estimate is based on the concentration-response (C-R) function developed from the study of the American Cancer Society cohort reported in Pope et al (2002), which has previously been reported as the primary estimate in recent RIAs.

[c] Although the overall range across experts is summarized in this table, the full uncertainty in the estimates is reflected by the results for the full set of 12 experts. The twelve experts' judgments as to the likely mean effect estimate are not evenly distributed across the range illustrated by arraying the highest and lowest expert means. Likewise the 5th and 95th percentiles for these highest and lowest judgments of the effect estimate do not imply any particular distribution within those bounds. The distribution of benefits estimates associated with each of the twelve expert responses can be found in Chapter 5.

Presentation in the Fact Sheet/Press Release

- To estimate the benefits of meeting a standard, EPA uses peer-reviewed studies of air quality and health and welfare effects, sophisticated air quality models, and peer-reviewed studies of the dollar values of public health improvements.

  When fully met, the revised 24-hour $PM_{2.5}$ standards are estimated to yield between $9 billion and $75 billion a year in health and visibility benefits in 2020. This estimate is based on the opinions of outside experts on PM and the risk of premature death, along with other benefits information.

- Based on published scientific studies alone, EPA estimates that the most likely benefits of meeting the revised 24-hour PM 2.5 standards will range from $17 billion to $35 billion.

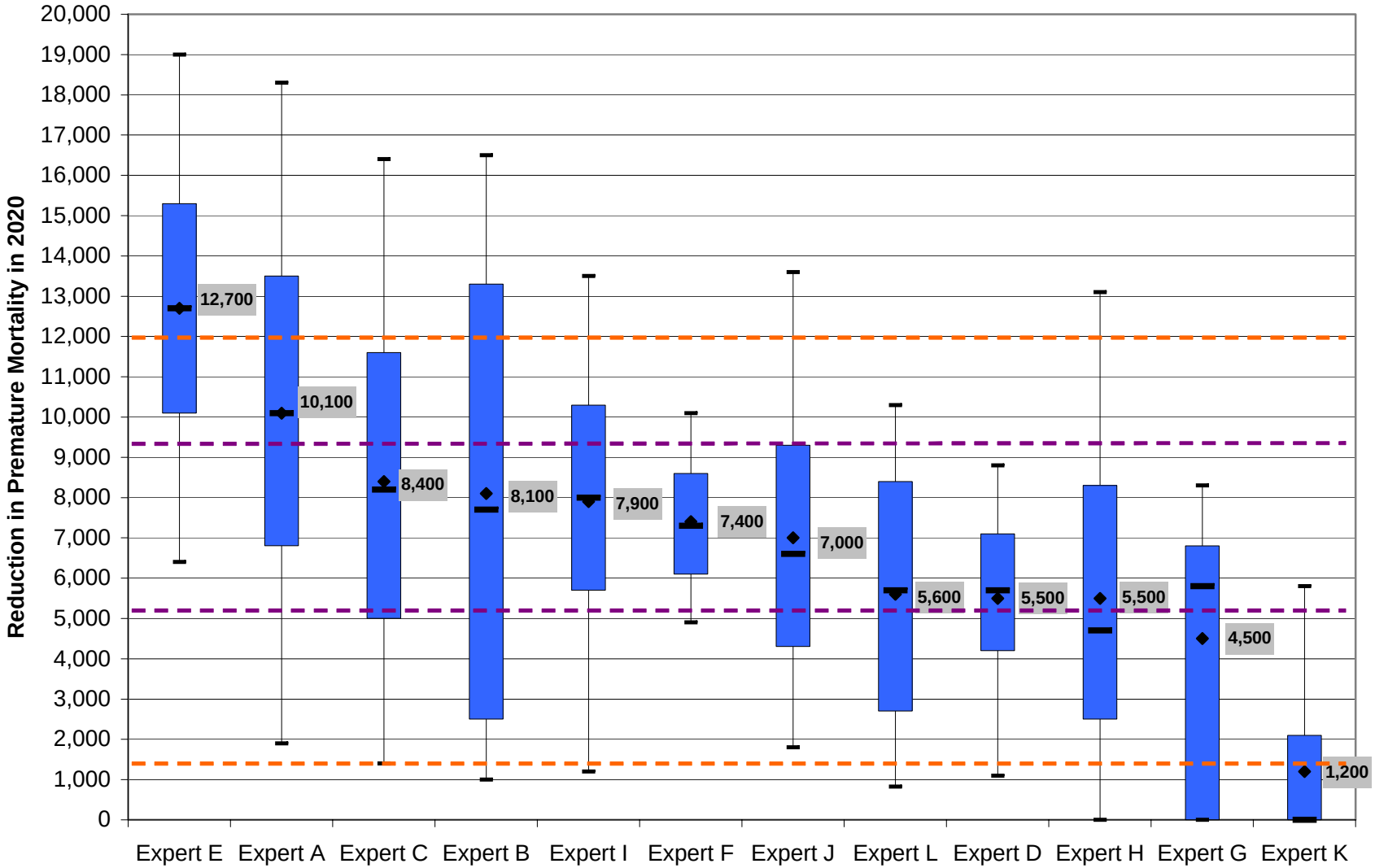
- The benefits of meeting the revised 24-hour $PM_{2.5}$ standards include the value of an estimated reduction in:
  - 2,500 premature deaths in people with heart or lung disease.
  - 2,600 cases of chronic bronchitis.
  - 5,000 nonfatal heart attacks,
  - 1,630 hospital admissions for cardiovascular or respiratory symptoms,
  - 1,200 emergency room visits for asthma,
  - 7,300 cases of acute bronchitis,
  - 97,000 cases of upper and lower respiratory symptoms,
  - 51,000 cases of aggravated asthma,
  - 350,000 days when people miss work or school, and
  - 2 million days when people must restrict their activities because of particle pollution-related symptoms.

- As with any scientific analysis, actual results could be higher or lower. EPA will outline the uncertainties inherent in these estimates in a Regulatory Impact Analysis, which the Agency will issue shortly.

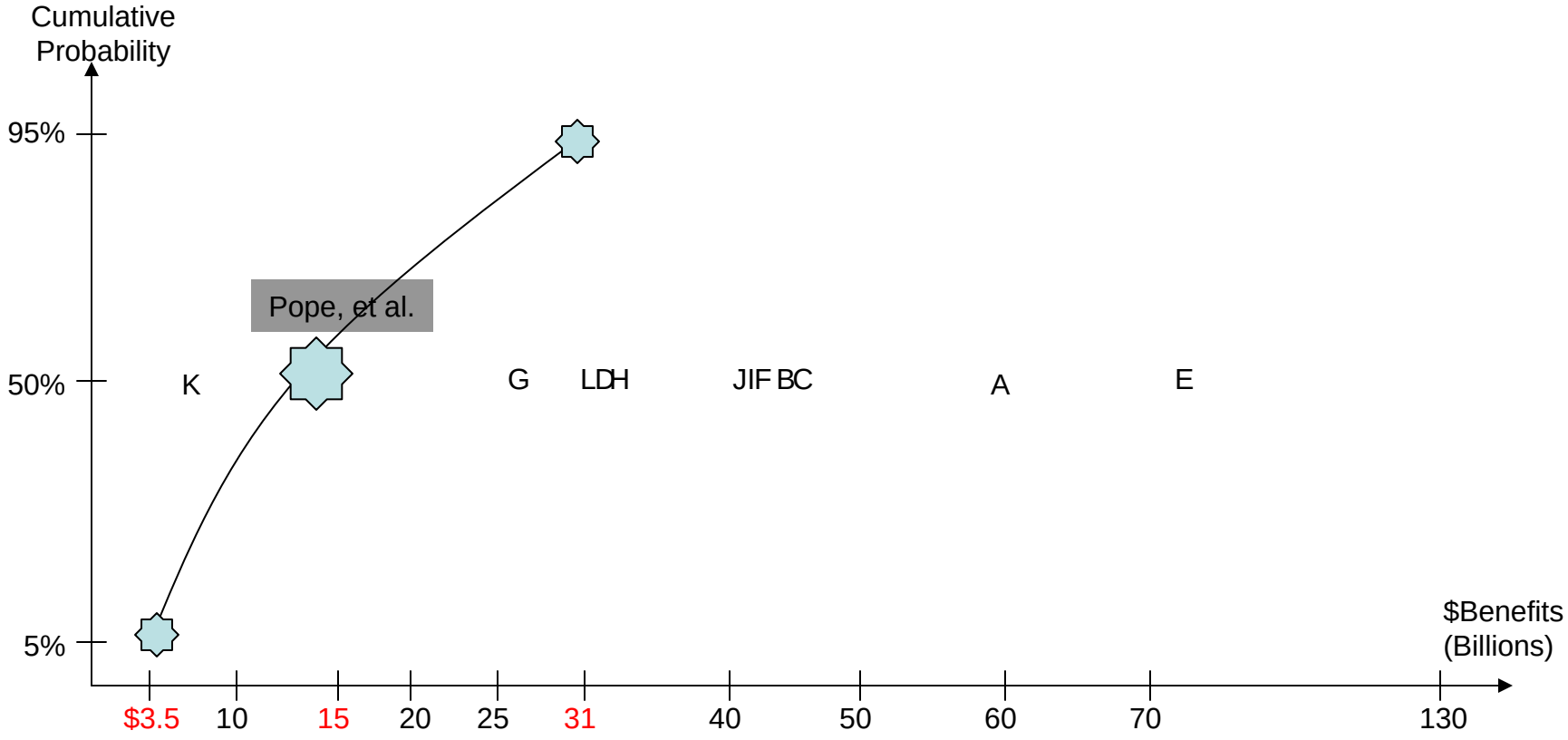
Alternative Presentation Options?

- Thinking outside the box
- Other observations on the findings
- The following representations of the results are not in EPA's current RIA presentations

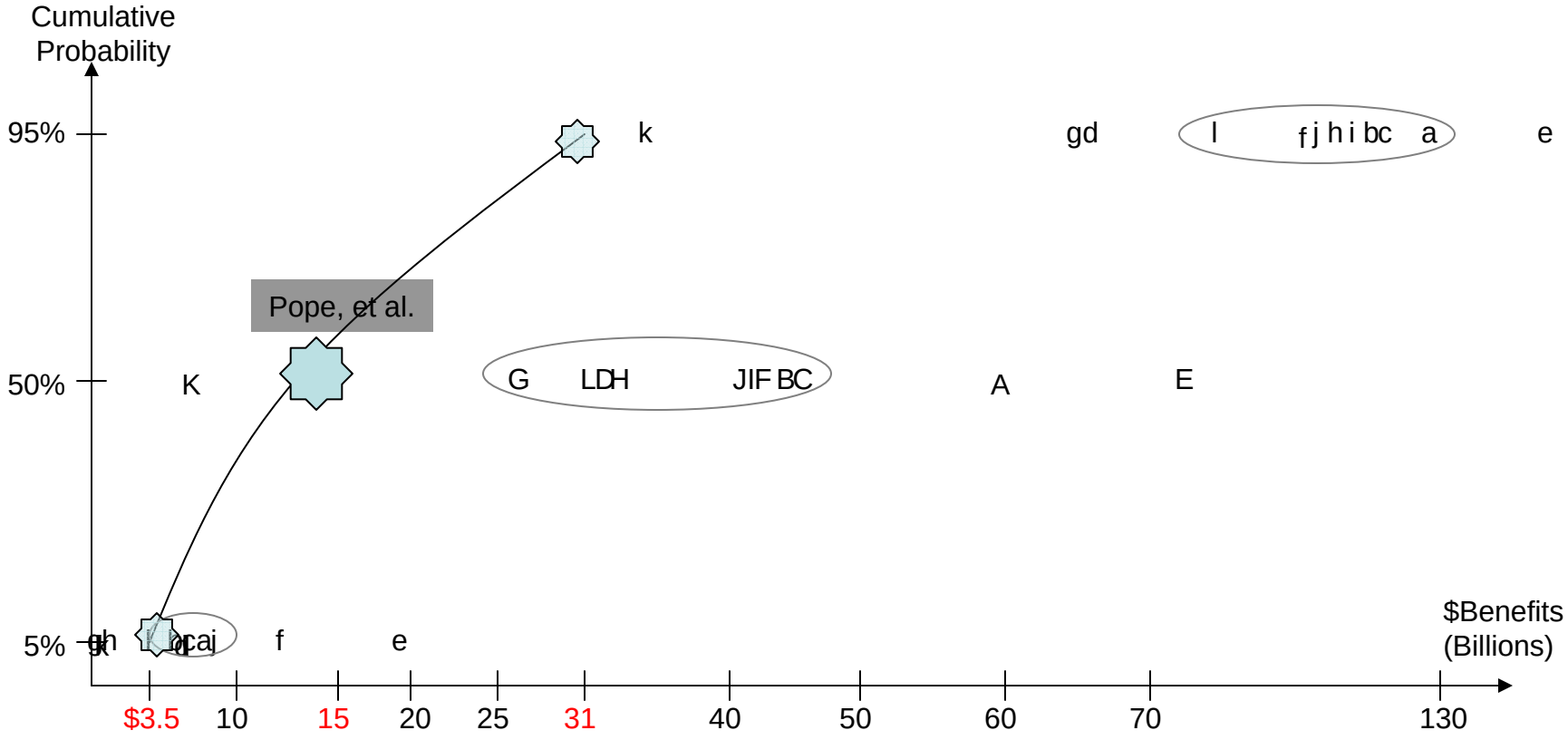
Sorting Elicitation Results



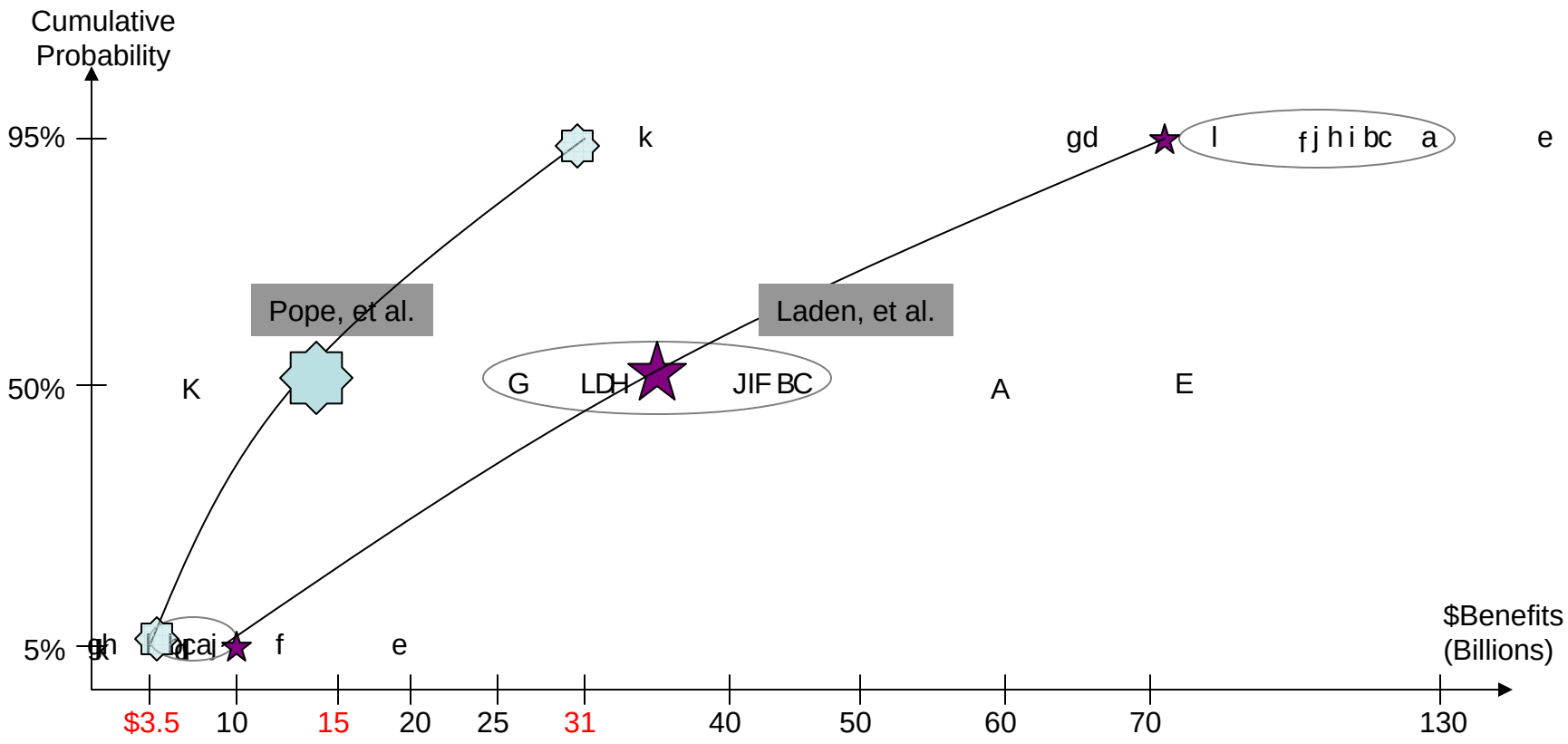
PM NAAQS RIA – Valuation of Benefits



PM NAAQS RIA – Valuation of Benefits



PM NAAQS RIA – Valuation of Benefits



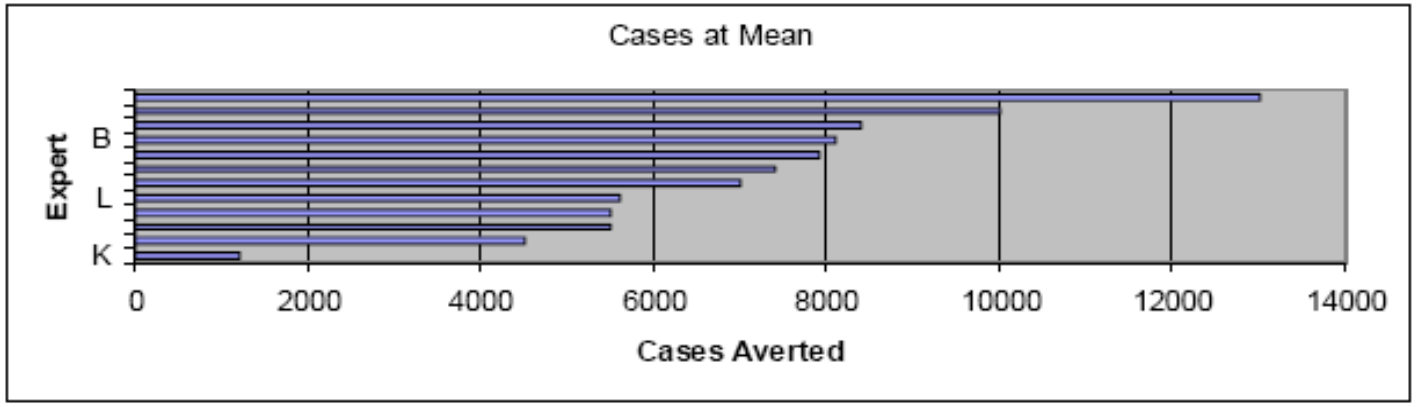
Observations of the Findings

Expert Elicitation Results

4. When the mean values are compared from the expert elicitation, the estimates of the cases of premature mortality avoided for the final rule range from 1,200 to 13,000, varying by a factor of more than 10.

- However, as illustrated in the exhibit and bar graph below, if we compare each estimate to the next highest estimate, most differ by less than 25 percent, many times by less than 5 percent. The key exceptions are the highest and lowest values.

Expert	Mean Cases Averted	Increase from Adjacent Value
K	1,200	N/A
G	4,500	375%
D	5,500	122%
H	5,500	100%
L	5,600	102%
J	7,000	125%
F	7,400	106%
I	7,900	107%
B	8,100	103%
C	8,400	104%
A	10,000	119%
E	13,000	130%
Source: EPA 2006, Table 5-16		



- If we eliminate the lowest (1,200) and highest (13,000) estimate, the range narrows 4,100 to 10,000 cases avoided, varying by a factor of 2.4.

- These remaining estimates are all higher than the mean derived from the ACS study (2,500 cases), and the mean from the Six Cities study is at the low end of this range (5,700 cases), indicating that many of the experts believe that the mean estimates from these studies are too low.

  -- The results from all but one of the experts suggest that the mean is above that from the ACS study.

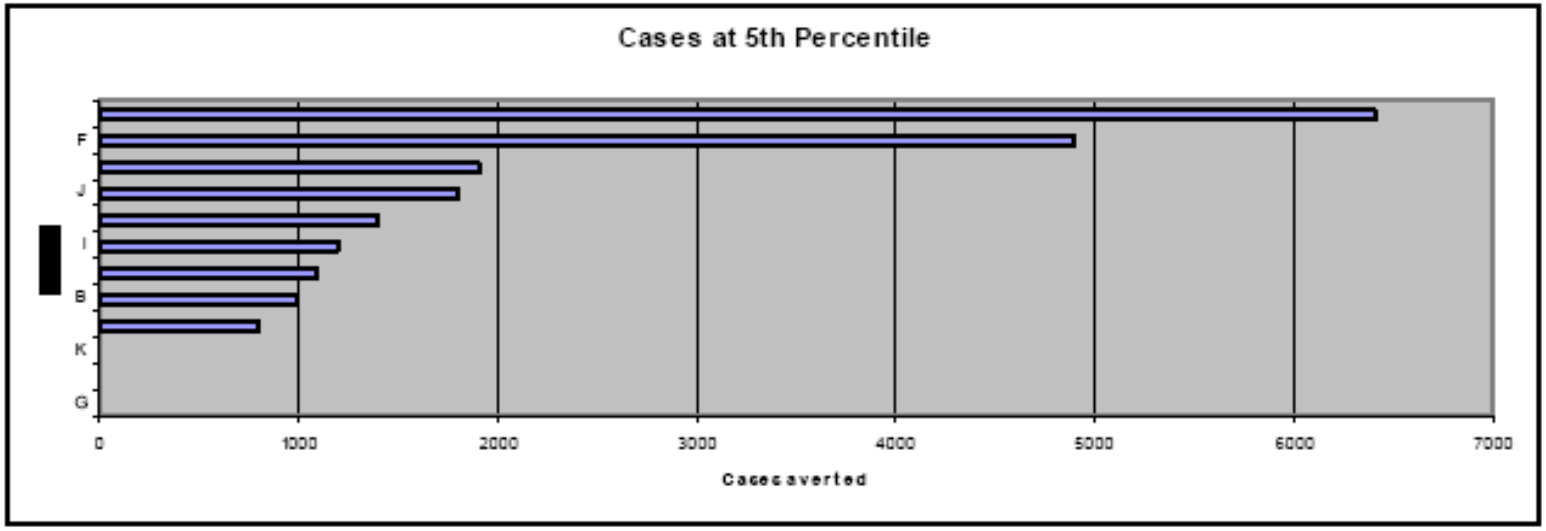
  -- The results from 7 of the 12 experts suggest that the mean is above that from the Six Cities study, with the results from 3 of the 5 remaining experts leading to means that are very close to the mean from the Six Cities study.

Observations at the 5th Percentile

5. When the low end values for the 95 percent credibility interval (i.e., the 5th percentile) are compared from the expert elicitation, the estimates of the cases of premature mortality avoided for the final rule range from 0 to 6,400, varying by about a factor of 6. The highest value is roughly in the middle of the mean values discussed under item 4 above.

- However, as illustrated in the exhibit and bar graph below, if we compare each estimate to the next highest estimate, most differ by less than 30 percent. The key exceptions are the two highest values and the three zero values.

Expert	Cases Averted at 5th Percentile	Increase from Adjacent Value
K	0	
H	0	N/A
G	0	N/A
L	800	N/A
B	1000	125%
D	1100	110%
I	1200	109%
C	1400	117%
J	1800	129%
A	1900	106%
F	4900	258%
E	6400	131%



- If we eliminate the three lowest ("zero") and two highest estimates, the range narrows to 800 to 1,900 cases avoided, varying by a factor of 2.4.

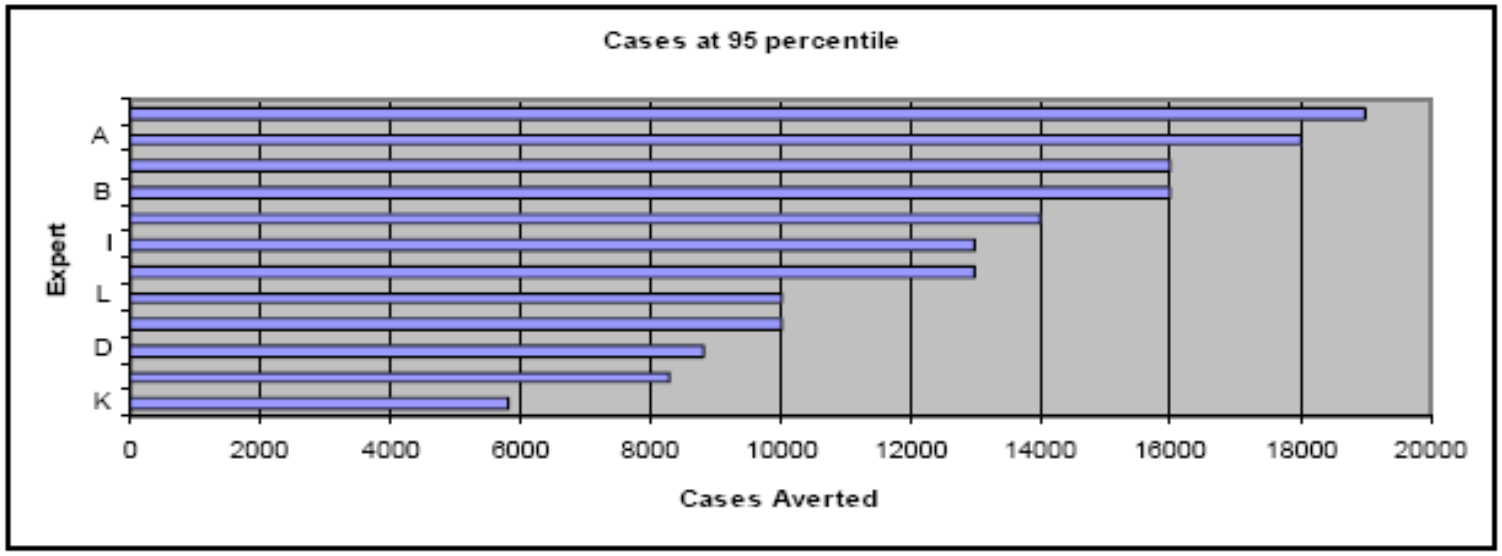
- The low end of the remaining estimates is roughly equal to the 5th percentile value derived from the ACS study (1,000 cases), while the 5th percentile value from the Six Cities study is higher than this range (3,100 cases), indicating that many of the experts believe that the low end estimates from the latter study are too high.

- Because the experts varied in the width of their credibility intervals, the ordering of the expert results for the 5th percentile varies from the ordering of the mean values. However, Expert K consistently reports the lowest values, and Expert E consistently reports the highest.

Observations at the 95th Percentile

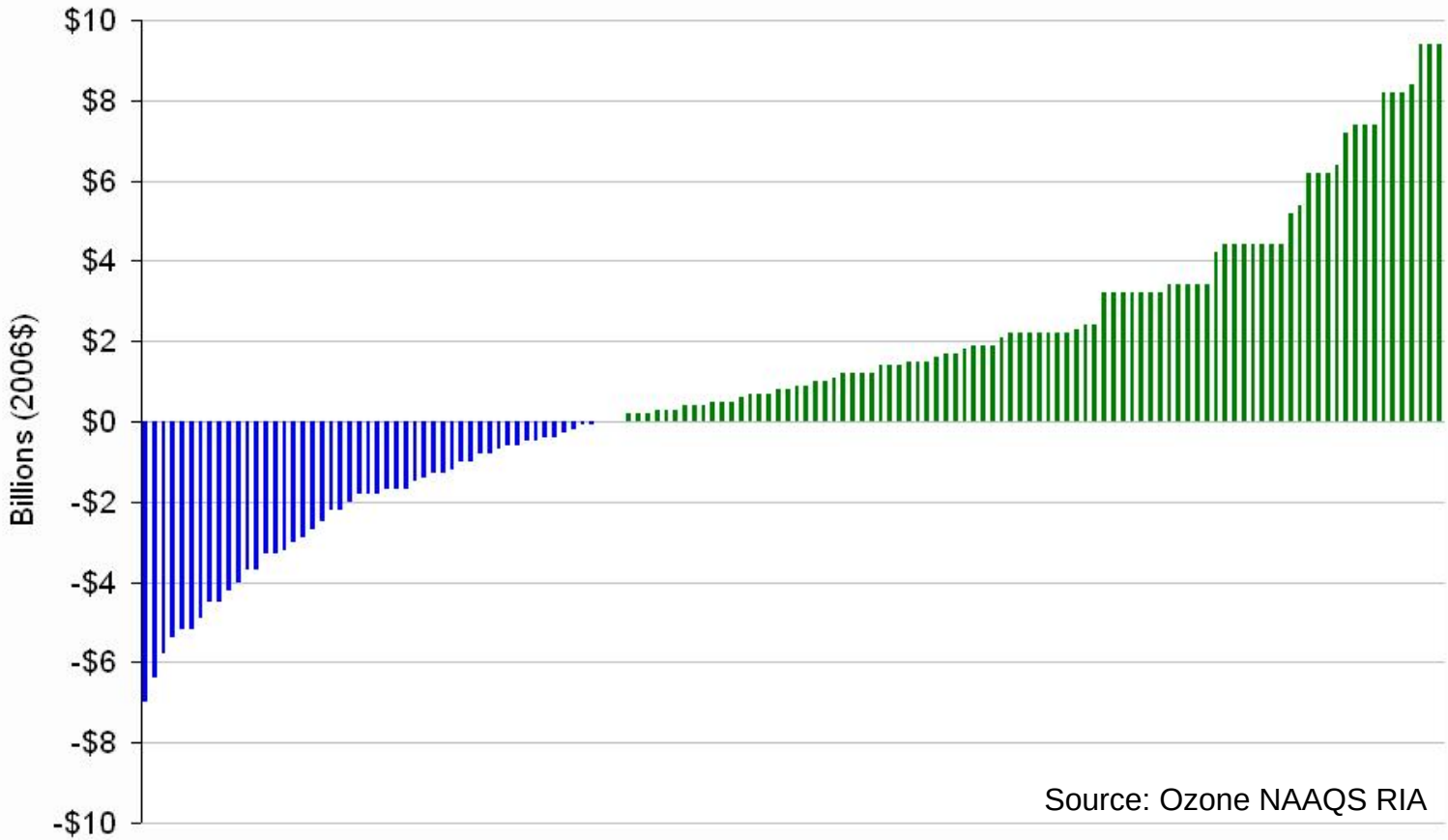
- As illustrated in the exhibit and bar graph below, if we compare each estimate to the next highest estimate, the values most differ by less than 15 percent, except for the lowest estimate (5,800 to 8,300) and the estimates (10,000 to 13,000) in the middle of the range.

Expert	Cases Averted at 95% Percentile	Increase from Adjacent Value
K	5800	N/A
G	8300	143%
D	8800	106%
F	10000	114%
L	10000	100%
H	13000	130%
I	13000	100%
J	14000	108%
B	16000	114%
C	16000	100%
A	18000	113%
E	19000	106%



- If we eliminate the lowest (5,800) estimate, the range narrows to 8,300 to 19,000 cases avoided, varying by a factor of 2.2.
- The low end of the remaining estimates is roughly double the 95th percentile value derived from the ACS study (4,100 cases), and identical to the 95th percentile value from the Six Cities study (8,300 cases) suggesting that most of the experts believe that the high end of the range is above that estimated in the epidemiological studies.
- As was the case with the other values, Expert K and Expert E report the lowest and highest values respectively, whereas the ordering of the other experts varies.

Ozone RIA: Range of Net Benefits for 0.075 ppm (All Combinations of Costs and Benefits at 7% Discount Rate)



* This graph shows all 140 combinations of the 5 different ozone mortality functions and assumptions, the 14 different PM mortality functions, and the 2 cost methods. All combinations are treated as independent and equally probable.

For the selected standard of 0.075 ppm, the median value of all of the independent point estimates is $0.8 billion, and the majority (64%) of the combinations indicate positive net benefits for this standard.

Should Elicitation Results be Combined?

- A Pilot Expert Elicitation study was conducted in 2003/04 that considered the options for combining elicitation results into a single estimate
  - The Pilot Elicitation included judgments from 5 experts that were applied to the Non-Road Diesel Rule, Appendix 9B
- EPA considered the following options for combining the Pilot results
  - Equal weighting of the C-R function
    - A. Uniform distribution – simple average of experts' responses at each percentile
    - B. Normal distribution – based on the population-weighted annual average $PM_{2.5}$ concentration
    - C. Distribution based on average across experts at different levels of $PM_{2.5}$
  - The "Pooled" Approach – simple average of the resulting incidence estimate

Table 9B-3. Methods for Combining Expert Judgments: Combined C-R function with Uniform Distribution and a Population-Weighted Distribution

Percentiles	Combined Expert Judgments using a Uniform Distribution of Baseline Annual Mean $PM_{2.5}$ Concentrations	Combined Expert Judgments Based on Population-Weighted Distribution of Baseline Annual Mean $PM_{2.5}$ Concentrations in U.S.
95th %ile	1.05	0.93
75th %ile	0.65	0.59
50th %ile	0.33	0.3
25th %ile	0.17	0.16
5th %ile	0.00	0
Minimum	0.00	0
Maximum	1.71	1.5

Table 9B-4. Combined Concentration-Response Function Conditional to PM Concentrations

Percentiles	8 ug/m3	12 ug/m3	15 ug/m3	20 ug/m3
95th percentile	0.82	0.99	1.08	1.20
75th percentile	0.56	0.61	0.64	0.76
50th percentile	**0.30**	**0.30**	**0.30**	**0.42**
25th percentile	0.16	0.16	0.16	0.24
5th percentile	0	0	0	0

Source: Non-Road Diesel RIA, App. 9B

Limitations of Combining Expert Judgments

- Combining the C-R functions requires the analyst to alter the true response given by some experts when the experts do not share the same beliefs on the shape of the function
- The decision to use calibration methods, as well as, self- or peer-weighting methods must be during the design phase of the elicitation
  - Must be explained to the experts at the beginning of the process
  - Options other than equal weighting may be viewed by the experts as devaluing their judgment.
- Combined estimates do not provide an illustration of the breadth of views across experts
  - Aggregate results average out the extremes
  - Would the experts agree with the resulting estimate?

Peer Reviewers Comments on Combining Expert Judgments

- Peer Review of the Pilot Elicitation asked for views on combining the results of the Pilot study
  - Several of the reviewers preferred that the expert opinions not be combined or stated that they knew of no agreed-upon method for combining results from expert elicitations.
  - Two of the reviewers indicated that they were reasonably comfortable with the method used in this study to combine the results, while the other two reviewers offered comments on the combined result of the elicitation.
  - One reviewer states that the combined distributions do not adequately capture the opinions of individual experts, but rather average them out. It is possible in such cases that the combined judgments may generate results that none of the experts could agree on.
  - Another reviewer stated that expert elicitation studies typically do not combine judgments, but if one were to combine them, he recommended that the response of each be maintained independently from the other experts and run through the benefits model completely prior to combining the results.

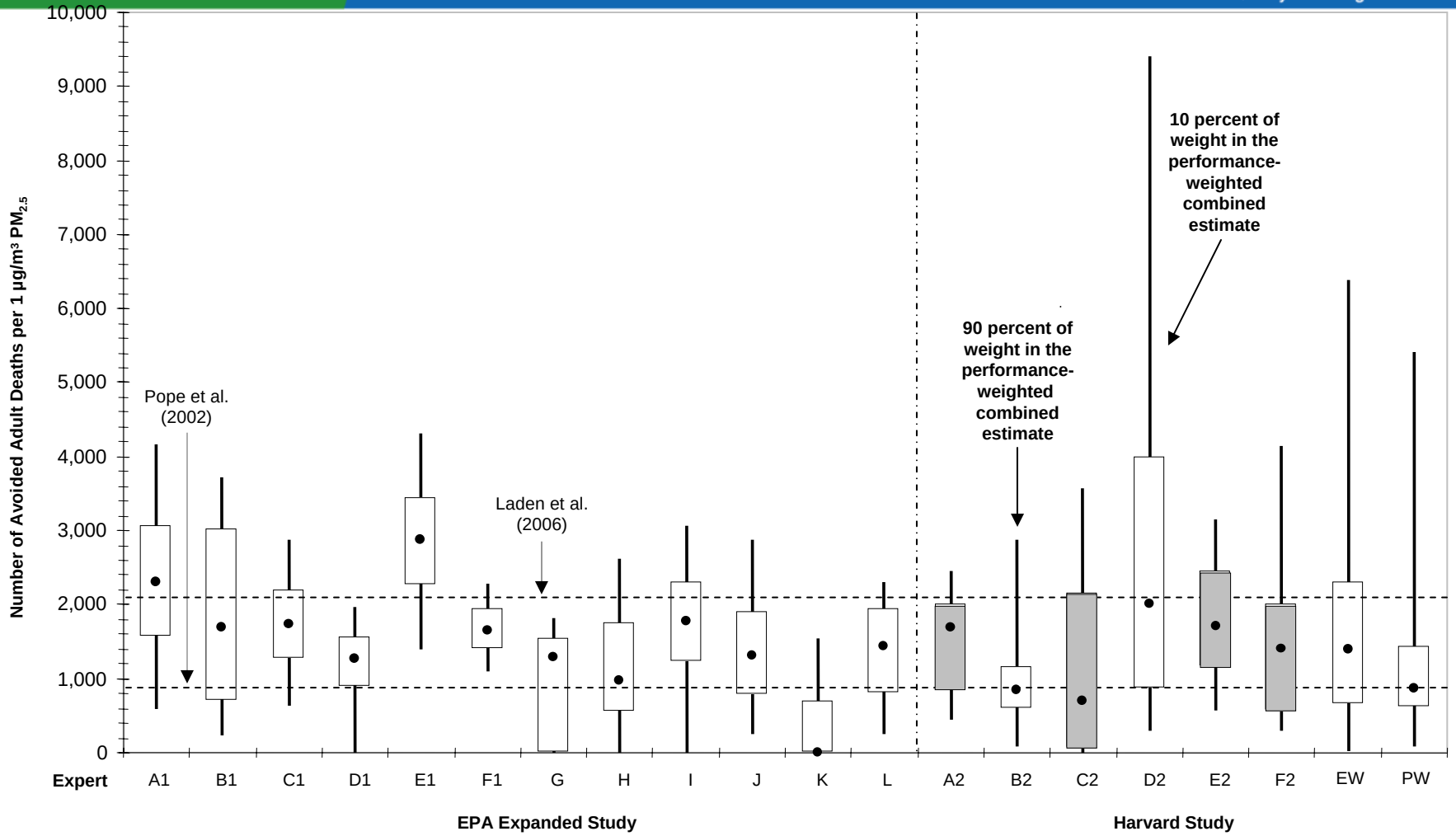
Other Combination Methods Considered

- Calibration
  - Questions using real data are used to quantify the experts' ability to provide accurate estimates that encompass uncertainty
  - Harvard's PM Elicitation
- Other Methods
  - Self weighting
  - Peer weighting
  - Trimmed Mean

ANNUAL AVOIDED ADULT DEATHS IN THE US DUE TO A 1 $\mu g/m^3$ CHANGE IN ANNUAL AVERAGE $PM_{2.5}$ CONCENTRATIONS $\geq$ 18 $\mu g/m^3$

United States Environmental Protection Agency

Office of Air Quality Planning and Standards



Key: Closed circle = median; Box = interquartile range; Solid line = 90% credible interval; Shaded box = Experts from the Harvard Study that were not given any weight in the performance-weighted combined estimate; EW = Harvard Study combined estimate with equal weighting; and, PW = Harvard Study combined estimate with performance weighting.

Note: The calculation of avoided annual deaths assumes that the entire population of adults in the U.S. experiencing annual average $PM_{2.5}$ exposures greater than 18 $\mu g/m^3$ would be at risk from PM-related mortality. The percentage of the population experiencing annual average $PM_{2.5}$ levels above 18 $\mu g/m^3$ was determined from the distribution of annual average $PM_{2.5}$ values in the U.S. in 2004.

Questions & Discussion?

Thank You!

For Additional Information, contact:

Lisa Conner, Office of Air Quality Planning & Standards

conner.lisa@epa.gov