# USER'S MANUAL AND HELP FILES

## FERET: The Fast Environmental Regulatory Evaluation Tool

### Version 1.0: Criteria Air Pollutants and Accidents June 2001

**Jointly developed by Carnegie Mellon University and the University of Washington**

**Welcome to FERET!**

We hope you are a user who has a vital interest in air quality issues. Some of you will know things about health, others about economics, technologies, cost of compliance, regulatory design, benefit-cost analysis, or other topics. FERET helps you bring all these things together, both the things you may know a lot about and some that you know less about. The FERET template, patterned after EPA's Costs and Benefits of the Clean Air Act, 1990 to 2010, can generate output with minimum data requirements of: the exposed population, a change in concentration, and costs if you accept default values like those used by EPA. Even these data requirements can be reduced in some circumstances while you can customize FERET to take into account greater specificity to your problem.

FERET is designed to help you develop, support or critique government and private sector actions affecting conventional air pollutants. This manual provides a brief summary of the material provided on the entire compact disk (CD), and then provides a worksheet by worksheet walkthrough of the FERET template.

What you will need to run FERET:

- A PC (or secondarily a Macintosh with a PC emulator is also possible)
- Microsoft Office 98 or higher (FERET uses EXCEL and WORD)
- Crystal Ball, an EXCEL add-on available from Decisioneering, Inc.
  (A 7 day trial version is included with the FERET CD.)
  1515 Arapahoe St., Suite 1311 Phone: 1-800-289-2550
  Denver, Colorado 80202 www.decisioneering.com

What is on the FERET CD:

- FERET User's Manual.doc (and FERET User's Manual.pdf)
- Introduction to FERET.doc (and Introduction to FERET.pdf)
- FERETzero.xls (the general template, in Excel format; save as a new file for use to preserve the master)
- Basic Example (a one worksheet example of FERET, in Excel)
- Visualization workbook (an appendix-help you observe differences in studies)
- FERETview.xls (the general template, in Excel format; viewable only)
- FERET2010.xls (an example based on an EPA analysis; in Excel format)
- Supplemental material (access with Adobe Acrobat Reader, also included)

## Overview of Material on the Compact Disk (CD)

### User's Manual

The User's Manual is intended to help a new user familiarize themselves with the analysis template. The manual summarizes its use of EXCEL and Crystal Ball and goes through each EXCEL worksheet page by page, explaining how it works, why it is included, any required inputs from you, and the optional inputs you might provide. This manual is intended to be most useful when used concurrently while in the FERET program (you can open the program from within EXCEL by clicking on FERETzero.xls. Full functionality is available only if you have Crystal Ball previously installed.)

### Introduction to FERET

The introduction is about 20 pages of text that gives information on how the FERET program links health and economics, and the science and theory behind the benefit-cost of human health and ecological effects. This version focuses on the six criteria pollutants, with exclusion of lead (particulate matter (PM), carbon monoxide (CO), ozone ($O_3$), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$)). It discusses the EPA benefit-cost reports on which the basic structure is built. You can read about topics such as the basic structure of FERET, the incorporation and quantification of uncertainty, and detailed documentation of assumptions and methodology to quantify impacts and valuations of impacts. It is most helpful to review the introduction before starting an analysis.

**FERETview.xls and FERETzero.xls** (version 1.0)

The FERET EXCEL file is the impact and benefit-cost template itself. The master file, FERETview.xls, is a viewable-only file that can be opened and used for reference. FERETzero.xls can be opened and saved under a different name to provide the template for a problem on which you wish to work. (Simply open FERETzero.xls and save the workbook under a name of your choosing, under File, Save As....) Crystal Ball from Decisioneering is also required to take advantage of the central features of FERET which are its uncertainty and modeling capabilities. Cells in FERET are color-coded--a blue background denotes a user input is needed or possible, and a green background denotes the presence of a statistical distribution (from Crystal Ball). Help is always close at hand either through a red triangle in the upper right-hand corner that denotes a "comment", an explanatory sentence or note, or help files available from the User Input worksheet or in this document. We have also provided an extended example, FERET2010.xls in which we have filled in the information to provide a FERET analysis parallel to that of EPA in its prospective study of the benefits and costs of the Clean Air Act Amendments of 1990.

Version 1.0 may have bugs and errors of computation although we have worked hard to eliminate them. Please contact us at feret@u.washington.edu and the numbers in the back of this manual if you find problems or have suggestions.

## Help Files

The help files at the end of this MS-Word document provide additional documentation and description. The information includes references for all the studies in the analysis and brief discussions of outstanding issues such as dose-response functions, discounting, benefit-cost analysis, welfare economics, compliance costs, and so on.

## PROJECT

You are asked in FERET to provide information on compliance costs. You may have information on costs from your own sources, but if not, we are providing an EPA computerized costing tool that has gone through judicial review as part of EPA's enforcement process. EPA's documentation on this and the related BEN model are provided on this CD. If you have trouble opening the executable file on the CD, you can download PROJECT from http://es.epa.gov/oeca/datasys/dsm2.html (the office of Enforcement and Compliance Assistance at epa.gov.)

## Supplemental Information

We have tried to provide supplemental information that may help you carry out an analysis. A great deal of information is available that is not copyrighted, such as guidance on benefit-cost analysis by the Office of Management and Budget, the EPA, the American Chemistry Council, and so on. We are restricted to providing material on this CD that are not copyrighted or for which we have permission, hence there is a great deal more information in the published literature which we have tried to reference. If you have suggestions for other material, please let us know at feret@u.washington.edu

## EXCEL and Crystal Ball

FERET actually operates in an EXCEL environment with a simulation add-on tool called Crystal Ball. Our purpose in doing this is to make FERET transparent, easily customizable by you, and to provide a standard working environment. Inside FERET you have access to all the power of EXCEL and Crystal Ball. FERET is merely a set of information and linked cells within the broader structure that helps you to carry out a benefit-cost, impact or cost effectiveness analysis. FERET's use of key aspects of each program are summarized below:

EXCEL (see www.microsoft.com/office/excel for more information)

- FERET is organized as a set of worksheets in the FERET workbook. As usual you can navigate among worksheets and cells by clicking appropriately and you can use any of the EXCEL help files. All EXCEL menu options and the ability to observe what is in each cell is available. Formulas and links to other cells are transparent.
- Mathematics and linkages: FERET uses equations, explained in more detail in the introduction, that are already programmed into EXCEL. Where possible, as with a present value calculation, FERET uses the EXCEL predefined equation for present

value and therefore help is available on that topic. Cells are linked by the relative or absolute addresses where appropriate, sometimes extending across worksheets. FERET also uses a random number generator in EXCEL.

Crystal Ball (see www.decisioneering.com for more information; a 7 day trial version is included with the FERET CD or trial copies can be downloaded from their web site.)

- As a commercially available EXCEL add-on, Crystal Ball adds two new pull-down menus (Cell and Run) and button bars. The usual Crystal Ball help files are available and the Crystal Ball user's guide is extremely helpful for new users. *This is a commercial program, but none of: Carnegie Mellon University, the University of Washington, Resources for the Future, the developers, authors, or editors of the book will gain from the sales of the program.*
- Uncertainty: Crystal Ball's Monte Carlo simulation capability is what allows FERET to incorporate uncertainty and the information from many studies instead of just one study. The basic building blocks are assumptions about the statistical distribution for a variable (such as the change in concentration of a pollutant or the value of a statistical life), and forecasts. FERET has a preset number of assumptions (in green boxes) and forecasts (the result of equations). Some assumptions, such as those on the User Input page, you must enter. Important forecasts include impacts such as the change in mortality cases and the net present value. FERET reports the distribution as well as the mean of these forecasts.
- Assumptions and forecasts: You are encouraged to read the user's manual for Crystal Ball for more detail but basically, assumptions and forecasts can be defined by selecting a cell and pulling down the Cell menu. Follow the steps to define an assumption (such as a normal distribution with a mean and a standard deviation that you provide) or a forecast, as appropriate.
- Regulatory design: What drives FERET is *your* regulatory design. A regulatory design worksheet that encourages you to think about several issues is provided but the core of your design will be entered in cells in the User Input worksheet and in the Cost worksheet. For instance, in the User Input worksheet (Worksheet 2), your regulation may change particulate matter, measured in PM10, by an average amount of 2 micrograms per cubic meter. However, you are unlikely to know this number exactly and so may wish to provide a distribution such as, but not limited to, a uniform, normal or lognormal distribution, for the impact of the regulation on concentration. You can do this by defining a Crystal Ball distribution, as above, in that cell.

## Worksheet Descriptions

This section describes each of the worksheets in FERET and some of their key aspects. It may be useful to print out and reference this section while you are using FERET.

The sample worksheets shown on these pages are from **FERET2010.xls**, the calibration analysis for EPA's prospective analysis of the Clean Air Act. This shows cells with data fully entered as in the User Input page. In contrast, when you build your own analysis using **FERETzero.xls**, you will find zeros entered as a default in the user input cells, some or all of which you will change as you enter your own regulatory design or analysis parameters.

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**Worksheet 0** **Welcome Page**

You can take a quick tour of the worksheets by pressing "First Time Users" or jump to the Regulatory Design page by pressing "Start." Experienced users will select the worksheet "User Input" from the worksheets at the bottom of the page.

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**Worksheet 1:** **Regulatory Design**

**Purpose**

To outline the sequence of worksheets and to encourage you to identify quantitative and qualitative impacts of your regulatory design. Space is provided to enter the qualitative impacts that will appear next to the quantitative impacts.

**Required User Inputs**

None

**Optional User Inputs and Assistance**

*Qualitative impacts*: Many users of benefit-cost analysis are concerned about impacts that cannot be translated into monetary terms. This worksheet provides an area to identify these impacts. These impacts are automatically copied and appear next to the quantitative results. In addition, a cell in the FERET Summary worksheet keeps track of the quantitative size and sign necessary for the qualitative impacts to change the sign of the net present value, the economic measure of the regulation.

**Worksheet 2: User Input**

**Purpose**

The impact of the regulatory design on pollutant concentration is entered here, as are key economic variables that establish consistency in application. Its purpose is to tailor the FERET analysis to your issue and a particular regulatory design. (Alternative approaches to impact analysis can be entered in Worksheet 13, Direct Impacts.)

**Navigation**

Within the spreadsheet, you can use arrows, the mouse, or click on worksheet tabs at the bottom of the page. You can also skip to other worksheets and the help files by clicking on the grey buttons which will take you directly to the other pages, data or help files you wish to examine. Only a single click is needed. There are "User Input" buttons available in the other pages that will take you back to this "home" page, the User Input page.

**Required User Inputs**
(Assistance is located in the red comment triangles within cells)

*Health parameters*: exposed population, baseline (current) concentrations and any reductions of particulate matter (measured as PM10), ozone, carbon monoxide, nitrogen dioxide, and sulfur dioxide. The concentration changes entered here drive the health improvements through concentration-response functions. The values you enter will be used no matter the time averaging measure used in various health studies so you may wish to look at the mortality and morbidity studies.
*Economic parameters*: years of implementation (default=1 but may be many years) and the number of firms in the industry (default set equal to 1 implying your cost data from Worksheet 3 are for the entire industry.)

**Optional User Inputs and Assistance**

*Economic parameters*: population growth rate, discount rate (default set at 5% as used by EPA), latency period (if any). You can also get summary data in something other than 1990 dollars by choosing a "Year in which to value." This default is set to 2000.
*Economic Studies used*—The default is the EPA distribution of the mean value of a statistical life (value of 1 in the EPA Distribution, 0 in the User Select.) You may optionally decide to choose from among the individual mortality studies located in the Econ Mortality worksheet. Two steps are necessary to do this. In the User Input page, first de-select the EPA distribution (set value =0) and select the User selection (set value = 1). Secondly, you then move to the Econ Mortality worksheet and select or deselect individual studies as described for Worksheet 10, Econ Mortality. Note: There is only one set of health studies, a combination of studies from the EPA's retrospective and prospective analyses. If you wish something other than the EPA default, you do so by entering a 1 or deselect (by entering a 0) any particular health study on the Health Mortality or Health Morbidity worksheets.

**Crystal Ball and Other Links**

This page is linked to all other pages in the workbook, help files and Crystal Ball. Many of the input cells are Crystal Ball assumption (input) cells. In these cells, you will typically enter a statistical distribution. Highlight the cell you want to define, then go to the menu at the top of the screen and select Cell→Define Assumption and enter data. Click "OK" when done. Help is available on-line or in the Crystal Ball user's manual.

**This Page Looks Like (only part is shown here):**

# THE FERET MODEL

**User Input Page: The FERET model allows the user to estimate the benefits and costs associated with changes in air pollution concentration. This model values benefits as damages saved by decreasing air pollution induced health and other effects. Compliance costs by industry and consumers make up the cost portion of the model.**

**This page allows you to input a regulatory design causing changes in air pollution concentration. This and the following cost page are the only required inputs. You must input all the information in the cells highlighted in blue. If you cannot model your problem as a change in concentration, consider the Direct Impacts Worksheet. The cost/benefit estimates from the user inputs are calculated on the Valuation Summary page. Red triangles are comments and hints for a particular cell.**

| **INPUT** | **We recommend inserting a mean value for your assumptions, and where possible, entering a distribution using the Cell menu on the toolbar.** | | **OUTPUT** |
|---|---|---|---|
| ***Population at risk*** | Total Exposed Population or Equity Population | **297,669,000** | **Present Value Benefit** |
| ***Air Pollution Impacts*** | **Reduction in PM10 concentration micrograms/cubic meter ( $^{m}g/m^{3}$)** | **2.85** | **Present Value Cost** |
| | **Baseline PM10 concentration ( $^{m}g/m3$)** | **30.00** | **Net Present Value** |
| | **Reduction in Ozone (ppb)** | **1.34** | |
| | **Baseline Ozone concentration (ppb)** | **105.00** | |
| | **Reduction in CO concentration (ppm)** | **1.68** | |
| | **Baseline CO concentration (ppm)** | **5.00** | |
| | **Reduction in NO2 concentration (ppb)** | **9.40** | **Qualitative impacts** |
| | **Baseline NO2 concentration (ppb)** | **20.00** | |
| | **Reduction in SO2 concentration (ppb)** | **1.15** | |
| | **Baseline SO2 concentration (ppb)** | **6.50** | |
| ***Regulatory, Demographic and Economic Inputs*** | Population growth rate (as proportion) | **0** | |
| | Discount rate (as proportion) | **0.05** | |
| | Years to implementation | **0** | |
| | Years of implementation | **1** | |
| | Latency period: PM mortality | **0** | |
| | Latency period: morbidity: *not active* | **0** | |
| | Net discount rate: *no user entry needed* | **0.05** | |
| | Number of Firms in the industry | **1** | |

**Worksheet 3: Cost**

**Purpose**

This worksheet samples from the cost of compliance to industry and to consumers (if they incur costs other than those of paying a different price for a good or service). Its purpose is to provide the cost element of the benefit-cost analysis. The present value of the cost of your regulatory design *in 1990 dollars* can be entered on this page. This is then deducted from the present value of the benefits in the Valuation Summary page.

**Required User Inputs**
(Assistance is located in the red comment triangles within cells)

Cost distribution: You must enter either a single point estimate or a Crystal Ball distribution for industry cost, consumer cost, or both.

There are several ways to develop your cost estimate. You may have data for your problem from earlier research. If so, you can enter it as a single value or as a distribution. We strongly encourage you to provide information as a distribution of cost values. As a supplemental tool, the cost estimation model PROJECT is included in the FERET package. PROJECT has its own user's manual (also included on the FERET CD) but in general, by developing a compliance plan based on fixed and operating costs, PROJECT will compute the present value of the cost of compliance. This is most straightforward for regulations that affect industry. If you wish for a separate analysis, you can compute the taxes paid.

As discussed in the Introduction and its Appendix, care should be taken in determining whether the quantity in the market place will change as a result of regulation so that costs can be evaluated at the correct quantity.

Consumer costs: these costs refer to external costs that the consumer might pay in addition to higher costs in the marketplace, say for automobiles. For example, an enhanced automobile emissions maintenance program may have costs to industry to buy equipment and pay personnel. Consumers may also bear an additional cost if there is additional travel time. These consumer costs are the external cost parallel to the external benefits the consumer receives, for instance, through reduced illness. Note that taxes can be broken out separately but for the standard analysis such taxes should be set to zero so that they are included in the cost of compliance. For more information, see the Introduction discussion on Welfare Economics.

**Optional User Inputs**

Your problem may only have industry, or only consumer cost. One of the cost categories is thus optional.

## Links

Number of firms: This is on the User Input worksheet but is linked to the cost distribution. If your estimate is for the entire industry, the number of firms is 1 (default). Otherwise, enter the number of firms to "scale up" your cost estimate.

PROJECT: to use the PROJECT model you would open that model separately. After your PROJECT analysis, you may choose to enter your results on this page. In a standard analysis you would set the PROJECT discount rate to that entered on the User Input worksheet. You would also set all taxes and the inflation rate to zero as discussed in the Introduction and FERET help files.

Other worksheets: There is a grey button to return to the User Input page.

## This Page Looks Like:

**Cost Worksheet**

**The cost to comply with regulations is a key component of benefit-cost analysis. FERET provides two cost components: costs to industry and external, consumer compliance costs. Industrial costs are either provided by you from an outside source or you may wish to use the PROJECT model (a supplemental file on the CD.) PROJECT provides a basic economic framework that includes: fixed and operating costs, a discount rate, life of equipment, and time to implementation. The result from applying this model is the present value of compliance and can be scaled up by the number of firms (on user input page). Various compliance scenarios can be evaluated to provide a distribution of compliance**

**(User Inputs On This Page)**

**TABLE ONE: input worksheet** **Optional**

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 | Scenario 7 | Scenario 8 | Scenario 9 | Scenario10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Industry** | | | | | | | | | | |
| **Consumer** | | | | | | | | | | |
| **Total** | | | | | | | | | | |
| **Probability** | | | | | | | | | | |

| **Input Data** | **Required** |
|---|---|
| **Cost Distribution** | 27,000,000,000 |

**Worksheet 4** **FERET Summary**

**Purpose**

This page is one of the two presenting output information on impacts, benefits, costs, and net present value-cost output from the FERET analysis. Its purpose is to give you key outputs of the analysis. While the entire power of Crystal Ball can be used to review output, including statistics, graphs, sensitivity analysis, optimization, and report writing, this page provides the information that many people look to first. Provided on this page are some summary data including the $5^{th}$, $50^{th}$ (median), and $95^{th}$ percentiles of key outcomes, including: total benefit, present value benefit, present value cost, and the net present value (the bottom line) in millions of 1990 dollars; the estimated health impacts, the value per case, and the present value of health impacts. Other summary material includes the qualitative impacts (previously entered on the Regulatory Design worksheet), and the economic summary material inflated to any year you choose between 1990 and 2000.

**Required User Inputs and Assistance**
(Assistance is located in the red comment triangles within cells)

There are no required inputs on this page.

**Optional User Inputs and Assistance**

There are no other inputs on this page.

**Information on Page and Links**

The information on this page are the $5^{th}$, $50^{th}$, and $95^{th}$ percentiles of the various health and economic parameters in the cost-benefit analysis. The qualitative impacts you identified in the Regulatory Design worksheet are presented next to the quantitative summary.

Note: The data on this page are only updated and current if the "FERET run" button, available on the User Input page, was used--see Crystal Ball below; and no changes have been made in row or column on the Valuation Summary page (next worksheet),

Crystal Ball: If you did not use the "FERET run" button (if you used the Crystal Ball Run option) then the data extraction capabilities of Crystal Ball can be accessed by going to the Run menu→Extract data, or by selecting "forecasts" from the Run menu. Other Crystal Ball capabilities such as report writing can also be accessed through the Cell and Run pull down menus.

The Valuation Summary worksheet page has more detailed data and output accessible by viewing individual forecasts defined on that page.

## This Page Looks Like (only part is shown here):

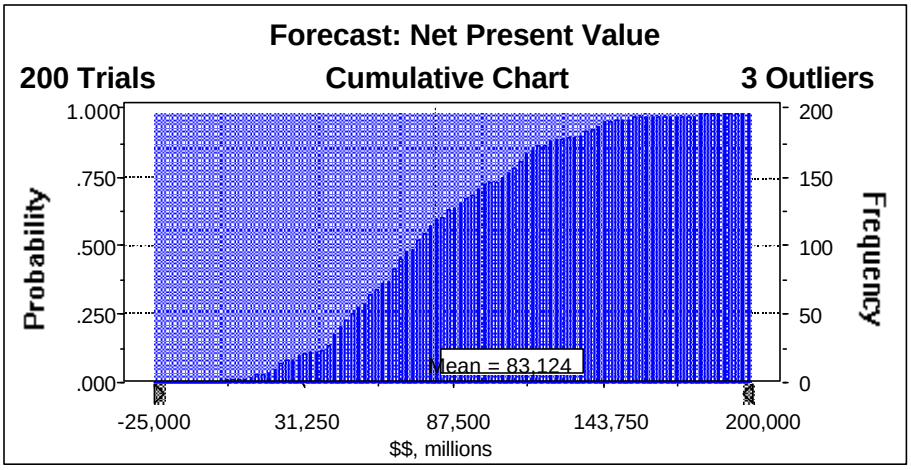
**FERET Summary Page:** This page summarizes your regulatory design in terms of health effects and economic v
These data, as well as additional data on forecasts of the impacts, valuations, and present value can be accessed thr
(This page is the output from the complete FERET model, **there are no user inputs on this page**)

| | 5th Percentile | 50th Percentile:Median | Mean | 95 Percentile |
|---|---|---|---|---|
| **Present value benefits, in millions of 1990 $** | **$54,048** | **$104,516** | **$110,120** | **$30,571** |
| **Present value costs, in millions of 1990 dollars** | **$23,707** | **$27,037** | **$26,996** | **$30,571** |
| **Net Present Value, in millions of 1990$** | **$26,542** | **$77,132** | **$83,124** | **$154,270** |
| **Chosen Year** | **1999** | **Qualitative Impacts** | Impacts on asthma for young children, deterioration of buildings, general equilibrium costs | |
| **Present value benefits, in million chosen year $** | **$68,377** | **$132,225** | **$139,315** | **$38,675** |
| **Present value costs, in million chosen year $** | **$29,993** | **$34,205** | **$34,153** | **$38,675** |
| **Net Present Value, in million chosen year $** | **$33,578** | **$97,581** | **$105,162** | **$195,169** |

***For all pollutants:***

| | | All Mortality | Chronic Bronchitis (CB) | Chronic Asthma (CA) |
|---|---|---|---|---|
| **Change in Cases** | 5th Percentile | 14,221 | 3,521 | 1,719 |
| | 50th Percentile: Median | 23,027 | 19,105 | 7,306 |
| | 95th Percentile | 31,702 | 32,749 | 12,669 |
| **Estimated Value per Case (1990$)** | 5th Percentile | $1,887,098 | ($46,455) | $20,785 |
| | 50th Percentile: Median | $4,453,969 | $200,998 | $24,579 |
| | 95th Percentile | $6,746,441 | $641,395 | $28,633 |
| **Present Value (1990$)** | 5th Percentile | $38,368,330,915 | ($859,424,149) | $41,651,031 |
| | 50th Percentile: Median | $89,407,525,487 | $3,290,322,696 | $181,531,898 |
| | 95th Percentile | $165,662,579,097 | $14,302,745,224 | $315,127,392 |

While running the simulation, you should also see some graphs showing the cumulative distribution of some of the forecasts (output). These graphs provide an excellent visual representation of your distribution. By selecting View on each graph's menu, you will also be able to examine alternate basic statistics for each forecast distribution. Below is an example of a cumulative distribution chart.


Forecast: Net Present Value
200 Trials
Cumulative Chart
3 Outliers
Probability
Frequency
1.000
.750
.500
.250
.000
200
150
100
50
0
Mean = 83,124
-25,000
31,250
87,500
143,750
200,000
$$, millions

**Worksheet 5** **Valuation Summary**

## Purpose

This is the second of the two output worksheet pages. Its purpose is to give you a location to look at key outputs and the way in which the model actually used your inputs in the analysis. Provided on this page are the simulated input concentration changes, present value benefits, costs, and present value, cost per life saved, qualitative impacts, and estimates of key parameters for all health endpoints and all pollutants. The numbers you see are not the mean values but the initial settings based on your input data. However, you can look at the distributions for the individual items on this page by going to the Run menu and selecting Forecasts.

## Required User Inputs and Assistance

(Assistance is located in the red comment triangles within cells)

There are no required inputs on this page.

## Optional User Inputs and Assistance

Cost per life saved: In EPA's default approach, only reductions in particulate matter reduce mortality. If your regulation reduces particulates, or you choose to select ozone studies that reduce mortality, then the cost per life saved provides a measure of the cost-effectiveness of the regulation. This cell in active in FERET2010.xls but NOT active in FERETzero.xls. You may activate the cell in FERETzero.xls by copying the formula from the red triangle comment into the cell, and defining the cell to be a forecast (Cell menu at top of worksheet.) If your regulation does not reduce mortality but you have activated the cost per life saved cell, you will get an error message "Division by zero." The other calculations are correct but it can impede error checking.

## Information on Page and Links

Provided on this page for each of the pollutants is a table listing the health endpoints considered, and for each endpoint there is a listing of the baseline incidence, estimated value per case in 1990 dollars, the beta (dose-response) coefficient used in modeling health effects, the change in cases expected, the total value (1990$), and the PV value. These data were separately calculated in the health and economic portions.

Since this is an output page, this worksheet incorporates links to the User Input page, the Health Monte Carlo page, the Economic Mortality page, the Economic Morbidity page, and Other Non-Health Impacts pages. Crystal Ball forecast (output) cells are also defined in this spreadsheet (teal background cells).

## This Page Looks Like (only part is shown here):

**Valuation Summary Page: There are no user inputs on this page.** This page contains the Crystal Ball fore
However, the numbers you see correspond to single point estimates corresponding to the point estimates you entered.
forecast from the RUN menu or go to FERET Summary. The data are arranged to illustrate the key parameters and o
Note: if you use the direct impacts approach, see comment.

| | | Output | |
|---|---|---|---|
| **Change in PM concentration ($\mu g/m^3$) =** | **2.85** | **Undiscounted Benefit (millions)** | **115,083** |
| **Change in O3 concentration (ppb) =** | **1.34** | **Present Value Benefit (millions)** | **106,851** |
| **Change in CO concentration (ppm)=** | **1.68** | **Present Value Costs (millions)** | **25,335** |
| **Change in NO2 concentration (ppb) =** | **9.40** | **Net Present Value = (millions)** | **81,516** |
| **Change in SO2 concentration (ppb) =** | **1.15** | **Net Cost per Life Saved (millions)** | **0.80** |
| **Qualitative impact to change sign: Millions** | **-81,516** | Impacts on asthma for young children, deterioration of buildings, general equilibrium costs | |

| **All Endpoints for *All Pollutants, All Endpoints*** | **Baseline Incidence** | **Estimated value per case (1990$)** | b |
|---|---|---|---|
| **Mortality** | 0.0130135 | $4.576.130 | See below |
| **Chronic Bronchitis (CB)** | 0.0518 | $190.400 | See below |
| **Chronic Asthma (CA)** | 0.0462 | $24.627 | See below |
| **Hospital Admissions** | | | |
| 1. All Respiratory | 0.01285 | $6.097 | See below |
| a. Chronic Obstructive Pulmonary Disease (COPD) | 0.00062 | $8.072 | See below |
| b. Pneumonia | 0.00489 | $7,926 | See below |
| c. Asthma | 0.00179 | $3.625 | See below |
| 2. All Cardiovascular | 0.01659 | $6.639 | See below |
| a. Ischemic Heart Disease | 0.00773 | $10,298 | See below |
| b. Congestive Heart Failure | 0.00357 | $8.280 | See below |
| c. Dysrhythmias | 0.00235 | $6.276 | See below |

**Worksheet 6** **Baselines**

**Purpose**

This page contains default incidence rates for mortality. The incidence rates for morbidity on this page only affect studies not used by EPA in their prospective report (those studies used by the EPA have the incidence rate incorporated into the change in cases calculation on the Health Monte Carol page.) When multiplied by the exposed population you entered in the User Input worksheet, the result is the baseline number of cases in the total population for each health endpoint. These data are necessary for most of the functional forms used in the concentration-response functions. Nationally representative data are used where possible and some regional data for the Pacific Northwest are also supplied. Data are also provided on the Consumer Price Index.

**Required User Inputs and Assistance**

There are no required inputs on this page.

**Optional User Inputs**

Baseline incidence rates can be adjusted to your specific study location. That information is often available from national, state or local health agencies. Of particular note is the non-accidental death rate. EPA used the Pope study which focuses on premature mortality for those over 30 years of age. The backcalculated baseline mortality rate calibration to the age 30 and older population for the year 2010 is .0130135 (see FERET2010.xls) in contrast to the 1990, all population mortality rate of .004651. The default incidence rate is set to the Pope/EPA default. If you change mortality studies, you should consider the consistency between the incidence rate for the population studied and your use of a study. For instance, if you use short term studies for the entire population, you may wish to use the alternative incidence rate provided. For morbidity health effects, baseline rates can be altered but the rates on this worksheet are only used in the calculation of the change in cases for those studies not used by EPA in their prospective study. For studies used by EPA (the default selection), the baseline incidence rate is already included in the calculation of the change in cases on the Health Monte Carlo page. More advanced users may wish to include alternate baselines there.

**Information on Page and Links**
Sources of data are indicated in comments on this worksheet.

Information is linked to the exposed population on the User Input worksheet and to the Health Monte Carlo worksheet in order to provide the baseline number of cases, a necessary piece of data for many of the concentration response functions. The Consumer Price Index information is linked to the User Input page and the FERET Summary page in order to update 1990 dollars to the chosen year for some summary data.

**This Page Looks Like (only part is shown here):**

## Baseline Health Data

These baseline health endpoint data can be used for a variety of locations, althou
Currently, only the non-accidental death rate is used to calculate a change in inci

default (mostly US)

| Health Endpoints | Incidence Rates | Baseline Incidence |
|---|---|---|
| **Non-accidental death rate** (.004651 for all; .0130135 for 30+) | **0.0130135** | 3873715.532 |
| **Chronic Bronchitis (CB)** | **0.0518** | 15419254.2 |
| **Chronic Asthma (CA)** | **0.0462** | 13752307.8 |
| **Hospital Admissions** | | |
| 1. All Respiratory admissions | **0.01284914** | 3824790.731 |
| a. Chronic Obstructive Pulmonary Disease (COPD) | **0.00061513** | 183105.5658 |
| b. Pneumonia | **0.00489063** | 1455789.964 |
| c. Asthma | **0.00178819** | 532288.4851 |
| 2. All Cardiovascular admissions | **0.01658745** | 4937570.641 |
| a. Ischemic Heart Disease | **0.00773136** | 2301386.547 |
| b. Congestive Heart Failure | **0.0035739** | 1063839.485 |
| c. Dysrhythmias | **0.00234637** | 698441.7886 |
| 3. Emergency room visits for Asthma | **0.0007** | 197867.3019 |
| **Respiratory Ailments Not Requiring Hospitalization** | | |
| 1. Upper Resp. Symptoms (URS) | **0.373** | 111030537 |
| 2. Lower Resp. Symptoms (LRS) | **0.431** | 128295339 |
| 3. Acute Bronchitis | **0.047** | 13990443 |
| 4. Asthma Attack | **0.027** | 8037063 |
| 5. Moderate or worse asthma | **na** | #VALUE! |
| 6. Shortness of breath, chest tightness or wheeze | **na** | #VALUE! |
| 7. Respiratory Illness | **0.804** | 239325876 |
| 8. Shortness of Breath | **0.056** | 16669464 |
| **Restricted Activity and Work Loss Days** | | |
| 1. WLDs-work loss days | **3.122** | 929322618 |
| 2. MRADs-minor respiratory restricted activity day | **2.438** | 725717022 |
| 3. RAD-Restricted Activity Day | **5.947** | 1770237543 |

| Year for dollar valuation | Adjustment based on Consumer Price Index | Selection |
|---|---|---|
| 1990 | 129 | 0.00 |
| 1991 | 134.3 | 0.00 |
| 1992 | 138.2 | 0.00 |
| 1993 | 142.1 | 0.00 |
| 1994 | 145.6 | 0.00 |
| 1995 | 149.8 | 0.00 |
| 1996 | 154.1 | 0.00 |
| 1997 | 157.6 | 0.00 |

**Worksheet 7** **Health Mortality**

## Purpose

This page contains the bibliography of studies from the peer-reviewed health literature with mortality (death) as an endpoint. Its purpose is to allow you to see some of the key variables in each study and, if you wish, to choose which studies you want to include or exclude from the analysis. These studies are grouped together by the criteria pollutant.

## Required User Inputs and Assistance

(Assistance is located in the red comment triangles within cells)

These are no required user inputs. Only the Pope study is selected as a default as it is the one used by EPA in their analyses. At least one study must be selected, otherwise no change in mortality health effects will be estimated.

## Optional User Inputs

Select or deselect studies: Listed under "Input Weights", and with a blue background, are weights to select/deselect or place greater weight upon a health study. A "0" will leave a study out of the analysis. A positive number, usually but not necessarily 1, will include the study in the analysis. Any weight can be used, not just 0 and 1. Those studies that have a positive weight will be sampled in the analysis in proportion to their share of the total weights. Thus if the selected studies all have weight 1, each study will be sampled approximately 1/N times, where N is the number of studies selected. You can give a study more weight by increasing the weight relative to other studies. This weighting scheme allows a particular study to be emphasized. There are also blank rows to allow new studies to be added to the analysis.

Impacted population: EPA estimated impacts only for the fraction of the population studied by each author (e.g. age-specific, sensitive subpopulations, or both). For example, the Pope study focused on premature mortality in those over 30 years of age. The exposed population for the purposes of the study is then a fraction of the population of all ages using the EPA approach although other researchers may wish to consider other parts of the population. The population fraction allows you to set the exposed population size for each particular study.

## Information on Page and Links

Study Information: The information on this page is grouped by the criteria pollutant. Under each section is listed a peer-reviewed study, with the name, citation, abstract, and input weight. Also listed are supplemental information to help a user determine which studies to include or exclude from the analysis. These include the measurement of exposure, the number of pollutants measured, the change in pollutant concentration, the location of the study, the study population, whether this was a short or long-term study, the ICD-9 codes used to determine incidence of mortality, the beta (response) coefficient

and its standard error, the relative risk reported in each study, and the equation used to calculate the change in cases from a change in pollutant concentration. We have also included data from a study unavailable to EPA at the time of their prospective analysis, the HEI reanalysis of the Pope and Dockery long-term studies (Krewski et al, 2000.) Information on the dose-response was inferred from the HEI report. This page is linked to the Health-Monte Carlo worksheet page.

## This Page Looks Like (only part is shown here):

**Health Mortality:** This portion of the health module consists of a library of air pollution related mortality studies.
is described by important variables, which are meant to assist the user in determining the weighting of the studies used in t
The cells highlighted in blue are the weight cells. The user may enter in any value for the weight, or 0 to exclude the stud
Optional user input: you can change health studies on this page.

**Particulate Matter: Mortality**

| Citation | Input Weights | Fraction of the Population of All Ages | Health Endpoint | Exp. Meas. | # Pollutants | Delta PM10 |
|---|---|---|---|---|---|---|
| Dockery et al, 1992 | 0 | 1 | mortality | 1-day lag | 1(PM10) | 100 |
| Dockery et al, 1992 | 0 | 1 | mortality | 2-day lag | 1(PM10) | 100 |
| Fairley, 1990 | 0 | 1 | mortality | same day ave. | 1(COH) | 1 |
| Ito &Thurston 1996 | 0 | 1 | mortality | same day ave. | 1(PM10) | 100 |
| Kinney et al, 1995 | 0 | 1 | mortality | same day ave. | 1(PM10) | 100 |
| Ostro et al,1996 | 0 | 1 | mortality | ave. 3 days prior | 1(PM10) | 10 |
| Pope et al, Utah 1992 | 0 | 1 | mortality | 5-day ave. | 1(PM10) | 100 |
| Schwartz, 1992a | 0 | 1 | mortality | previous day ave. | 1(TSP) | 100 |
| Schwartz, 1992b | 0 | 1 | mortality | 48-hr avg | 1(TSP) | 100 |
| Schwartz, 1991 | 0 | 1 | mortality | previous day ave. | 1(TSP) | 100 |
| Schwartz, 1991/92 | 0 | 1 | mortality | ave. prev.+current day | 1(TSP) | 100 |
| Schwartz, 1993a | 0 | 1 | mortality | ave. 3 days prior | 1(PM10) | 100 |
| Styer et al,1995 | 0 | 1 | mortality | 3 day mean | 1(PM10) | 10 |
| Schwartz et al, 1996a | 0 | 1 | mortality | 24 hr ave. | 1(PM10) | 10 |
| Schwartz et al, 1996a | 0 | 1 | mortality | 24 hr ave. | 1(PM10) | 10 |
| Schwartz et al, 1996a | 0 | 1 | mortality | 24 hr ave. | 1(PM10) | 10 |
| Schwartz et al, 1996a | 0 | 1 | mortality | 24 hr ave. | 1(PM10) | 10 |
| Schwartz et al, 1996a | 0 | 1 | mortality | 24 hr ave. | 1(PM10) | 10 |
| Schwartz et al, 1996a | 0 | 1 | mortality | 24 hr ave. | 1(PM10) | 10 |
| Woodruff et al, 1997 | 0 | 0.0138 | mortality | annual | 1(PM10) | |
| Pope et al, 1995 | 1 | 0.5931 | mortality | annual mean | 1(PM2.5) | 24.5 |
| Dockery et al, 1993 | 0 | 0.6592 | mortality | annual median | 1(PM2.5) | 18.6 |

**Worksheet 8** **Health-Morbidity**

## Purpose

This page contains the bibliography of studies from the peer-reviewed health literature with morbidity (non-death) as an endpoint. Its purpose is to allow you to see some of the key variables in each study and, if you wish, to choose which studies you want to include or exclude from the analysis. These studies quantify morbidity endpoints such as asthma, bronchitis and work-loss days (WLD) and are grouped by the criteria pollutant.

## Required User Inputs and Assistance

These are no required user inputs. As a default, all studies have already been selected. At least one study must be selected for each endpoint if you wish the health effect to be included in the analysis.

## Optional User Inputs

Select or deselect studies: Listed under "Input Weights", and with a blue background, are weights to select/deselect or place greater weight upon a health study. A "0" will leave a study out of the analysis. A positive number, usually but not necessarily 1, will include the number in the study in the analysis. Any weight can be used, not just 0 and 1. Those studies that have a positive weight will be sampled in the analysis in proportion to their share of the total weights. Thus if the selected studies all have weight 1, each study will be sampled approximately 1/N times, where N is the number of studies selected. You can give a study more weight by increasing the weight relative to other studies. This weighting scheme allows a particular study to be emphasized. There are also blank rows to allow new studies to be added to the analysis.

Impacted population: EPA estimated impacts only for the fraction of the population studied by each author (e.g. age-specific, sensitive subpopulations, or both). For example, the Abbey (1993) study focused on chronic bronchitis in those over 27 years of age. The exposed population for the purposes of the study is then a fraction of the population of all ages using the EPA approach although other researchers may wish to consider other parts of the population. The population fraction allows you to set the exposed population size for each particular study.

## Information on Page and Links

Study information: The information on this page is grouped by the criteria pollutant and then health endpoint. Under each section is listed a peer-reviewed study, with the name, citation, abstract, and the input weight. Also listed are supplemental information to help a user determine which studies to use in the analysis. These include the measurement of exposure, the number of pollutants measured, the change in pollutant, the location of the study, the study population, the ICD-9 codes used to determine incidence of morbidity effects, the beta (response) coefficient and its standard error, the relative risk reported in

the study, and the equation used to calculate the change in cases from a change in pollutant concentration. We have also included data from a study unavailable to EPA at the time of their prospective analysis, a meta-analysis of hospital admissions (Samet et al, 2000.) Information on the dose-response was inferred from the HEI report. This page is linked to the Health Monte Carlo page.

**This Page Looks Like (only part is shown here):**

**Health Morbidity:** This portion of the health module consists of a library of air pollution related morbidit is described by important variables, which are meant to assist the user in determining the weighting of the studies The cells highlighted in blue are the weight cells. The user may enter in any value for the weight, or 0 to exclude

Optional user input: you can change health studies on this page.

**Particulate Matter: Morbidity**

| Citation | Input Weights | Fraction of the Population of All Ages | Health Endpoint | Exp. Meas. | # Pollutants |
|---|---|---|---|---|---|
| **Chronic Bronchitis (CB)** | | | | | |
| Abbey et al, 1993 | 1 | 0.6328 | CB | annual ave. PM10 | 1(PM10) |
| Abbey et al, 1995 | 1 | 0.6328 | CB | annual ave. PM2.5 | 1(PM2.5) |
| Schwartz, 1993 | 1 | 0.5931 | CB | annual ave. PM10 | 1(PM10) |
| <blank> | 0 | 0 | CB | | |
| <blank> | 0 | 0 | CB | | |
| <blank> | 0 | 0 | CB | | |
| **Chronic Asthma (CA)** | | | | | |
| <blank> | 0 | 0 | CA | | |
| <blank> | 0 | 0 | CA | | |
| <blank> | 0 | 0 | CA | | |
| **Hospital Admissions** | | | | | |
| 1. All Respiratory | | | | | |
| Schwartz, 1995 | 1 | 0.1326 | All RI | same day | 2(PM10,O3) |
| Schwartz, 1995 | 1 | 0.1326 | All RI | same day | 2(PM10,O3) |
| Pope, 1991 | 0 | 1 | All RI | mean monthly | 1(PM10) |
| Schwartz, 1996 | 1 | 0.1326 | All RI | 24 hr ave. | 1(PM10) |
| Burnett et al, 1999 | 1 | 1 | All RI | daily ave. PM2.5-10 | 3(PM, NO2, O3) |
| Burnett et al, 1997b | 1 | 1 | All RI | daily ave. PM2.5-10 | 4(PM2.5, O3, NO2, SO2 |
| Delfino et al, 1994 | 0 | 1 | All RI | daily ave. PM10 | 1(PM10) |
| Thurston et al., 1994 | 1 | 1 | DRA | same day | 2(PM10, O3) |

## Function

In this worksheet page, the input weights and exposed population fractions for each study are used from the prior Health Mortality and Health Morbidity pages to sample from beta (response) coefficients through a simulation analysis and calculate estimates of the change in disease incidence. Its purpose is to take the information you have provided by selecting studies or using the default options to provide the dose-response coefficient and the change in the number of cases for each of the health endpoints in the analysis of health benefits.

## Required User Inputs and Assistance

There are no required user inputs on this page. *The study weights and population fractions on this page are merely links to default or user values chosen on the Health Mortality or Health Morbidity page.*

## Optional User Inputs and Assistance

There are no optional user inputs on this page.

## Information on Page and Links

This page contains Crystal Ball assumption cells (a distribution is defined in these cells) that we have entered based on EPA documentation (see Introduction.)

Using the information on this page, a distribution for the dose-response parameter and a distribution of the change in cases for the exposed population are calculated for each health endpoint, and for each pollutant. For a particular health endpoint and pollutant, e.g. mortality due to PM, first a study is selected, then a beta (response) coefficient is sampled from that study's beta (response) distribution. This distribution is defined by the information provided by the authors of the original articles or by the EPA. Then, the beta coefficient is used to calculate a change in incidence (say, of mortality due to PM) using the specified exposure-response relationship. . The incidence rate is either that used by EPA in its Prospective report, or if a study was not used, then the incidence rate from the Baselines worksheet is used. Over many iterations of this process, a distribution for the response parameter and a distribution of change in cases are created (in Crystal Ball forecast cells, which hold output distributions). This page contains direct links to the Valuation Summary output page.

See Figure 2 in the Introduction to FERET for a visual on the sampling activity that goes on in this page.

## This Page Looks Like (only part is shown here):

**Health Monte Carlo Page:** The equations on this page generate an overall distribution for each of th
Using the weights entered by the user, the model randomly selects a value from one study per trial. Over ma
a new distribution is created to give an estimate in the change in the number of cases for each respective end
on published scientific literature. **(There are no user inputs on this page)**

**Particulate Matter:**

Random Number = 0.50458061

| Mortality Study (PM) | weight | Pop. Frac. | EPA-Beta | EPA-s.e. | w/sum | number | Beta distribution N(mean,s.d) |
|---|---|---|---|---|---|---|---|
| Dockery et al, 1992 | 0 | 1 | 0.0016 | 0.00149 | 0.0000 | 0.0000 | 0.001573 |
| Dockery et al, 1992 | 0 | 1 | 0.00175 | 0.00067 | 0.0000 | 0.0000 | 0.001846 |
| Fairley, 1990 | 0 | 1 | 0.000924 | 0.00034 | 0.0000 | 0.0000 | 0.000900 |
| Ito &Thurston 1996 | 0 | 1 | 0.000583 | 0.000218 | 0.0000 | 0.0000 | 0.000553 |
| Kinney et al, 1995 | 0 | 1 | 0.000488 | 0.000266 | 0.0000 | 0.0000 | 0.000510 |
| Ostro et al,1996 | 0 | 1 | 0.000784 | 0.000197 | 0.0000 | 0.0000 | 0.000770 |
| Pope et al, Utah 1992 | 0 | 1 | 0.00147 | 0.00031 | 0.0000 | 0.0000 | 0.001464 |
| Schwartz, 1992a | 0 | 1 | 0.000556 | 0.000237 | 0.0000 | 0.0000 | 0.000567 |
| Schwartz, 1992b | 0 | 1 | 0.00082 | 0.000293 | 0.0000 | 0.0000 | 0.000811 |
| Schwartz, 1991 | 0 | 1 | 0.000952 | 0.000298 | 0.0000 | 0.0000 | 0.000941 |
| Schwartz, 1991/92 | 0 | 1 | 0.000972 | 0.000278 | 0.0000 | 0.0000 | 0.000963 |
| Schwartz, 1993a | 0 | 1 | 0.001044 | 0.000415 | 0.0000 | 0.0000 | 0.001096 |
| Styer et al,1995 | 0 | 1 | 0.0008 | 0.0004 | 0.0000 | 0.0000 | 0.000798 |
| Schwartz et al, 1996a | 0 | 1 | 0.001193 | 0.000252 | 0.0000 | 0.0000 | 0.001186 |
| Schwartz et al, 1996a | 0 | 1 | 0.000896 | 0.000431 | 0.0000 | 0.0000 | 0.000934 |
| Schwartz et al, 1996a | 0 | 1 | 0.000698 | 0.000532 | 0.0000 | 0.0000 | 0.000726 |
| Schwartz et al, 1996a | 0 | 1 | 0.000598 | 0.000228 | 0.0000 | 0.0000 | 0.000620 |
| Schwartz et al, 1996a | 0 | 1 | 0.000896 | 0.000379 | 0.0000 | 0.0000 | 0.000910 |
| Schwartz et al, 1996a | 0 | 1 | -0.0005 | 0.000744 | 0.0000 | 0.0000 | -0.000460 |
| Woodruff et al, 1997 | 0 | 0.0138 | 0.00392 | 0.00122 | 0.0000 | 0.0000 | 0.003911 |
| Pope et al, 1995 | 1 | 0.5931 | 0.006408 | 0.001509 | 1.0000 | 1.0000 | 0.006275 |
| Dockery et al, 1993 | 0 | 0.6592 | 0.0124 | 0.00423 | 0.0000 | 1.0000 | 0.011673 |
| **sum =** | 1 | | | | | | |

**Worksheet 10** **Econ Mortality**

## Purpose

This page contains the bibliography of studies from the peer-reviewed economic valuation literature with mortality (death) as an endpoint. Its purpose is to allow you to see some of the key variables in each study and, if you wish, to choose which studies you want to include or exclude from the analysis.

## Required User Inputs and Assistance

(Assistance is located in the red comment triangles within cells)

These are no required user inputs. *The default assumption of the EPA Distribution in the User Input worksheet will lead to using EPA's summary distribution located on this worksheet. If that collection was selected, no changes are necessary on this page.*

## Optional User Inputs

Select or deselect value of a statistical life studies: If you decide to select your own studies *and* you have indicated that choice in the User Input page under study selection, you will choose your studies on this worksheet. The cells with a blue background in Table 1 ("Input Weight" column), allows you to select, deselect, or place subjective weight on an economic study. A "0" will leave a study out of the analysis. A positive number, usually but not necessarily 1, will cause the study to be included in the analysis. Any weight can be used, not just 0 and 1. Those studies that have a positive weight will be sampled in the analysis in proportion to their share of the total weights. Thus, if the selected studies all have weight 1, each study will be sampled approximately 1/N times, where N is the number of studies selected. You can give a study more weight by increasing the weight relative to other studies. This weighting scheme allows a particular study to be emphasized. There are also blank rows to allow new studies to be added to the analysis.

If you do not wish to value mortality, you can set both your study selection preferences equal to zero. FERET will produce the health impacts, and also the net cost per premature death averted (non-mortality benefits less the cost, divided by the number of premature deaths averted. Alternatively, if your agency provides one number for mortality, for example, 2.8 million, you can enter 2.8 million as a User defined study in a blank row (FERET will assume this to be in 1990 dollars) as the mean value from a new study and put a weight of 0 on all other studies. There is no need to define a Crystal Ball distribution for a single value (point estimate) entered in a cell.

## Information on Page and Links

User Input worksheet: Your choice of study selection on the User Input page determines which cells will be used from the Econ Mortality worksheet.

Study Information: The studies are listed, with the name, citation and abstract (in red comment triangle). Also listed are supplemental information to help a user determine which studies to include or exclude from the analysis. These include the mean and standard deviation, the source of data, and the method of analysis such as whether it is based on a labor market study or on a contingent valuation (survey) study.

**This Page Looks Like (only part is shown here):**

**ECONOMIC MORTALITY MONTE-CARLO** **(Optional User Inputs On This Page)**

This worksheet summarizes the library of studies for the statistical value-of-life. The cells colored light blue are the weight cells. The default is the EPA's distribution. You can customize that choice by selecting User selection on the User Input page (cell C29 instead of cell C28). Then select or weight studies in column B of this page. The actual values for each study are in column K below. Blank rows are proved at the bottom.

| | |
|---|---|
| **Output from User Selected studies** | 5,472,529 |
| **The EPA distribution** | 2,764,098 |
| **Random number generator** | 0.753742173 |
| | |
| **Average Value-of-Life Estimate** | 4,967,560 |

**TABLE ONE: Economic Studies Available if Selection Option Chosen on User Input Page**

| Column #1 | Column #2 | Column #3 | Column #4 | Column #5 |
|---|---|---|---|---|
| **CITATION** | **USER SELECTION COLUMN ENTER 0 TO OMIT; 1 TO INCLUDE WITH EQUAL WEIGHT** | **ESTIMATED VALUE-OF-LIFE RANGE** | **ESTIMATED VALUE-OF-LIFE MEAN** | **ESTIMATED VALUE-OF-LIFE STANDARD DEVIATION** |
| **Garen, 1988** | **1** | Not Available | 9,200,000 (1982 U.S. dollars) | 1,982,759 (1982 U.S. dollars) |
| **Cousineau, Lacroix, and Girard 1992** | **1** | Not Available | 3,200,000 (1986 U.S. dollars) | 498,542 (1986 U.S. dollars) |
| **Herzog, Schlottman, 1990** | **1** | Not Available | 2,484,000 (1969 U.S. dollars) | Not Available |
| **Same As Above** | **1** | Not Available | 3,530,000 (1969 US. Dollars) | Not Available |
| **Same As Above** | **1** | Not Available | 3,130,000 (1969 U.S. dollars) | Not Available |
| **Same As Above** | **1** | Not Available | 5,024,000 (1969 U.S. dollars) | Not Available |
| **Viscusi, (1978)** | **1** | Not Available | 1,151,262 (1969 U.S. dollars) | Not Available |

**Worksheet 11** **Econ Morbidity**

## Purpose

This page contains the bibliography of economic studies used by EPA with morbidity (non-death) as an endpoint. Its purpose is to allow you to see some of the key variables in each study and, if you wish, to choose which studies you want to include or exclude from the analysis. These quantify valuation for morbidity endpoints such as asthma, bronchitis, and work-loss days (WLD).

## Required User Inputs and Assistance

These are no required user inputs. Each health endpoint has only one distribution that may be a composite of several studies as determined by the EPA.

## Optional User Inputs

Changing values: Should you wish to change the values for the morbidity end-points, you may replace the information in that row with the information you choose to enter. If you wish to retrieve the original EPA values, you can obtain that information from FERETzero.xls or FERETview.xls.

## Information on Page and Links

Study Information: The studies are listed, with the name, citation and abstract (in red comment triangle). Also listed are supplemental information to help a user determine which studies to include or exclude from the analysis. These include the mean and standard deviation, the source of data, and the method of analysis such as whether it is based on a labor market study or on a contingent valuation (survey) study.

## This Page Looks Like (only part is shown here):

**ECONOMIC MORBIDITY**

This portion of the economic module consists of a library literature for specific morbidity endpoints. The endpoints are from a EPA report (see 'Help Files'). TABLE ONE shows all the distributions; whereas, TABLE TWO and THREE provide supplemental information for the chronic bronchitis distribution presented in TABLE ONE. All values and descriptions cited from (1997 retrospective-draft, 1997 retrospective-final, and 1999 prospective-draft).

**(No User Inputs On This Page)**

**TABLE ONE: Economic Value of Morbidity**

| HEALTH ENDPOINTS | DISTRIBUTION (1990 U.S. Dollars) | DESCRIPTION OF DISTRIBUTION | SOURCE |
|---|---|---|---|
| **Chronic Bronchitis (CB)** | 190400 | A Monte Carlo-generated distribution, based on three underlying distributions, represented by cell B42, B43 and B44. | Viscusi et al., 1991 Krupnick and Cropper, 1992 |
| **Chronic Asthma** | 24627 | triangular distribution, centered at $25,000 on the interval [$19,000, $30,000] | Based on results reported in two studies (Blumenschein and Johannesson, 1998 and O'Conor and Blumquist, 1997). Assumes a 5% discount rate and reflects adjustments for age distribution among adults (ages 27 and older) and projected life years remaining. |
| **Hospital Admissions** | | | |
| **1. All Respiratory** | 6,097 | normal distribution, with mean =6,100 and s.d.=55 | Source of hospital charge estimate: AHCPR, 1993. Source of physician charge estimates: Abt Associations Inc., 1992 |
| **(COPD)** | 8,072 | normal distribution with mean=8,075 and s.d.=189 | Abt Associates Inc., 1992 and AHCPR |

**Worksheet 12** **Non Health Endpoints**

## Function

This page is a work in progress to demonstrate the application of this framework to non-health endpoints such as visibility. In this page, note that there is no exposure-response relationship, just direct changes estimated using outputs from other models.

## Required User Inputs and Assistance

Currently, there are no user inputs on this page.

## Optional User Inputs and Assistance

There are no other inputs on this page.

## Information on Page and Links

Listed on this page, e.g. for visibility, are the area of interest, the units used to measure visibility, the baseline and change in visibility, and the valuation specified for that non-health endpoint. As EPA focused on National Parks, the values may not apply in many cases. While rows are available in the Valuation Summary page, these data are not currently linked to that page. If you are interested in these or other endpoints, adding other endpoints and data is relatively simple. The data can be entered by row, distributions defined, and linked to the Valuation Summary page. Note: in the calibration study (FERET2010.xls) these impacts are entered as point estimates from EPA data.

## This Page Looks Like (only part is shown here):

### Non-Health Endpoints

Approximately 4 percent of the benefits in EPA's Prospective 2010 analysis
are from non-health endpoints. Of these, visibility accounted for about 60 percent
As EPA focused on changes in National Parks, the values may not apply in many cases.
This worksheet is a work in progress that currently begins with
estimates cited from EPA's 1997 retrospective-draft, 1997 retrospective-final, 1999
prospective-draft, and 1999 prospective-final of "The Benefits and Costs of the Clean Air Act."
Both effects and valuations are included on this page.

**Changes in Non-health Endpoints**

| Citation | Area | Area | Units | Baseline Measurement | Reduction in Endpoint |
|---|---|---|---|---|---|
| **Visibility** | | | | | |
| EPA, 1999 | Residential | Eastern US | deciview | 16.18 | 2.53 |
| EPA, 1999 | National Parks | Eastern US | deciview | 13.90 | 2.30 |
| EPA, 1999 | Residential | Western US | deciview | 18.50 | 1.83 |
| EPA, 1999 | National Parks | Western US | deciview | 9.85 | 0.47 |

**Worksheet 13** **Direct Impacts**

## Function

This page provides several alternative methods of computing benefits from a regulatory design. You may not have air quality information or be able to infer a change in air quality. However, if you can directly estimate the change in the number of cases or the reduction in tons of pollution (somewhat less preferable due to adding more assumptions about the transferability of studies), or if your problem is more related to accidents such as transportation safety, then the dose-response relationships of the earlier worksheets are not necessary. If you are interested in the costs and benefits of a decrease in asthma, for example, you might have information on the change in the number or distribution of cases which can be directly entered as data on this page. In general, the values per ton differ from those implied in the EPA Clean Air Act studies although the EPA implicit per ton values are included in the distributions.

## Required User Inputs and Assistance

There are no required inputs on this page.

## Optional User Inputs and Assistance

If you choose a direct impacts approach, you must enter data on the distribution of changes in health or "tons" endpoints. You can then use either the included valuations for each endpoint or include your own.

Depending on the desired complexity of the analysis, the Direct Impacts page can be easily modified within EXCEL although the assumption cells on this page may be “frozen” when you receive the program in order to increase operating efficiency. The comment triangle in the introduction to this worksheet provides specific suggestions on modification.

## Information on Page and Links

The information listed on this page include the endpoint under consideration, the change, and the valuation for that endpoint from the literature.

At this point, this page is not linked to the valuation summary. You can complete your own analysis using these direct endpoints and the valuations. For instance, you can compute the present value of your estimates by following the directions in the comment that is in the introduction to the worksheet.

## This Page Looks Like (only part is shown here):

## Direct Impacts

Use this page when the number of tons, health, accident, or other outcomes can be directly estimated (instead of through a concentration response function). This is a unit value approach involving the transfer of values from a study site to the regulatory application area. The first set of entries are useful if you know emissions only in tons and not their effect on concentrations. The second section includes the health endpoints already used in earlier worksheets. Following that are other health end-points identified by health policy researchers. You may wish to connect this page to the cost or summary worksheet.

**Note: all assumptions may be "frozen" on this page until you activate (unfreeze) them for this alternative benefits analysis.**

**Valuation: 1990 $ per unit per year**

| **Species of air emissions** | Metric tons emitted annually | Min | Mean | Max | Distribution of Value | Annual Total Value | Present Value |
|---|---|---|---|---|---|---|---|
| Carbon monoxide (CO) | 0 | 1 | 321 | 970 | 321 | $0 | $0 |
| Nitrogen Oxides (Nox) | 0 | 31 | 2,370 | 8,800 | 2,370 | $0 | $0 |
| Sulfur Dioxide (SO2) | 0 | 0 | 1,727 | 4,300 | 1,727 | $0 | $0 |
| Particulate Matter (PM) | 0 | 900 | 11,766 | 103,755 | 11,766 | $0 | $0 |
| Volatile Organic Compounds (VOCs) | 0 | 150 | 1,500 | 4,400 | 1,500 | $0 | $0 |
| Global Warming Potential (in CO2 equivalents) | 0 | 2 | 12 | 22 | 12 | $0 | $0 |
| Total, in millions | | | | | | $0.00 | $0.00 |

**Supplemental Worksheets**

**Worksheet Name** **Help**

This worksheet provides links to our on-line help, which includes full references and a discussion of various calculations in FERET, as well as other outstanding issues.

**Worksheet Name** **Datax**

This worksheet is the location to which an automated FERET macro extracts selected output (distribution) data. There are no user inputs. If you wish to track the source of data presented in the FERET summary page, their source is this worksheet.

**Worksheet Name** **Default**

This worksheet is where the default user inputs are stored. There are no user inputs on this page, and a change made on this page (and saved) will become the default set of inputs. When using the grey default button on the User Input page to reset your inputs, data from this page are copied and then pasted into the appropriate cells on the User Input, Cost, Baseline, Health Mortality, Health Morbidity, and Econ Mortality worksheet pages. A few words of caution: data will only be copied and pasted correctly if you have not added any new rows or columns to shift the data, otherwise it will paste this default data over your existing entries.

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# Other Workbooks

**Workbook Name** **Basic Example**

**Function**

In one worksheet, this demonstrates the basic concentration-response, valuation, and cost elements of FERET while also demonstrating the use of statistical assumptions and forecasts. You can modify all cells in the worksheet.

**Workbook Name** **Visualization Mortality and Valuation Studies**

## Function

This workbook first contains charts of the health response parameter and of the value of a statistical life to illustrate their variability across studies. Second, there are several worksheets that in the Dose-response Morbidity and Dose-response Mortality pages, list all of the health studies used. The dose-response relationship is graphed for a visual presentation of the differences between studies based on material in FERET2010.xls. Its purpose is to convey to you some of the quantitative differences in the response functions from different studies.

## Required User Inputs and Assistance

There are no required user inputs.

## Optional User Inputs and Assistance

Input weights, with a blue background, are listed for each study. Use a 1 or 0 to graph or not graph, respectively, the dose-response curve from a particular study. These input weights are completely separate from those in the Health Mortality and Health Morbidity pages, and are only for graphing purposes.

Depending on the complexity of the analysis, one can add new studies or examine the effects of a different dose-response relationship.

## Information on Page and Links

Included on this page are data regarding each health study, such as the beta (response) coefficient and standard error, relative risk, and change in pollutant concentration. The graphs are extremely informative, as the impact of different beta coefficients can be compared across studies and designs. These four pages are not linked with any of the other pages.

**That's all!**

There are no other worksheets in the FERET EXCEL set. You are encouraged however, to read the introduction, and browse the help section and supplemental material.

As was once written on a fortune cookie wrapper

“Never be diverted from the truth by what you would like to believe.”

If you wish to ask us questions (though only limited application support) we can be reached at:

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# HELP FILES: VERSION 1.0

## The Fast Environmental Regulatory Evaluation Tool: FERET

**Contents**

*(click to go to a section!)*

## 1.0 Common Abbreviations

**Pollutants**
PM10 – particulate matter with a diameter $\leq$ 10 µm
PM2.5 – particulate matter with a diameter $\leq$ 2.5 µm
TSP – total suspended particulates (alternate measure of PM)
COH – coefficient of haze (alternate measure of PM)
$O_3$ – Ozone
$NO_2$ – Nitrogen dioxide
$SO_2$ – Sulfur dioxide
CO – Carbon monoxide

**Statistics**
Beta ($\beta$) – regression coefficient
S.D. – standard deviation
S.E. – standard error

**Health Endpoints**
AB – acute bronchitis
CA – chronic asthma
CB – chronic bronchitis
CHF – congestive heart failure
COPD – chronic obstructive pulmonary disease
ERV – emergency room visit
IHD – ischemic heart disease
URS – upper respiratory symptom
LRS – lower respiratory symptom
WLD – work loss day
MRAD – minor restricted activity day
RAD – restricted activity day
RRAD – respiratory restricted activity day

**Economics**
PV - present value, the value of a stream of benefits and costs measured in today's dollars
NPV - net present value; present value benefits less present value costs
VSL - value of a statistical life

## 2.0 Health Studies

### Keywords

Epidemiology
Exposure
Relative Risk/Odds Ratio
Morbidity
Mortality
Regression Analysis (Logistic)
Monte Carlo

### Study Selection

FERETzero.xls and FERET2010 (version 1.0) use health studies that have been referenced by EPA in its reports, 'Benefits and Costs of the Clean Air Act' (1997 retrospective-draft, 1997 retrospective-final, 1999 prospective-draft, and 1999 prospective-final). Only studies selected by EPA are represented in the current model, however, you can add studies and we provide a bibliography of some additional research.

Most of the studies selected consist of time-series studies, which measure the incidence of disease with a short-term rise in pollution concentration. Cohort studies have also been added to the health study library. These studies focus on changes in yearly pollution concentrations and may be a better indicator of long-term effects of air pollution. Clinical studies are not used, unless those results find symptoms that have not been shown elsewhere in the literature. The investigation of the effects of air pollution is a growing field, so constant reviews of the literature will allow recent data to be included in the FERET model.

### Study Summaries

A library of the studies selected for the FERET model is located within the worksheets "Health-Mortality" and "Health-Morbidity". This library describes important characteristics of each of the studies, as well as including a full citation and abstract. Each study is grouped (example: Table 1) by the primary pollutant reported by the author. Within each group are several columns representing each variable (e.g. health endpoint, exposure measure, journal publication, relative risk, etc.). Health endpoints are categorized by ICD-9 codes reported in the original study.

**Table 1: Particulate Matter (PM) Mortality Studies**

| Citation | Health Endpoint | Exp. Meas. | # Pollutants | Delta PM10 |
|---|---|---|---|---|
| Dockery et al, 1992 | Mortality | 1-day lag | 1(PM10) | 100 |
| Dockery et al, 1992 | Mortality | 2-day lag | 1(PM10) | 100 |
| Fairley, 1990 | Mortality | same day ave. | 1(COH) | 1 |

This summary allows the analyst to determine which groups of papers apply to his/her defined scenario. Additional comments (red triangle in the upper right corner of the Excel spreadsheet cell) are added to cells that require further clarification. Each table is subdivided by health endpoint so that like studies are matched for comparison. A list of all references used in the FERET model is provided at the end of this document.

**Important Study Variables**

- Health Endpoint: the disease or health effect that the study reports as a consequence of exposure to air pollution.

- Exposure Measurement: The period over which the authors measured air pollution concentration. Time-series studies often use a 1-5 day measurement period, while cohort studies may use yearly averages.

- Number of Pollutants in the Model: Air pollution can be measured by individual components, however, air contains a mix of many co-pollutants. A model using multiple pollutants to estimate changes in health effects may be a more precise estimate than a study only analyzing single pollutants. This category lists the number of pollutants in the model and which pollutants.

- Delta (PM10, $O_3$ …): The delta or change in pollution concentration is the change reported that is associated with the health effect discussed in the report. The change in pollution concentration was important in verifying the $\beta$ (regression coefficient) for individual studies.

- Short or Long Term Study: Allows you to know whether the study focuses on acute or chronic health effects.

- U.S. Location: Describes the location of the study by U.S. city and state or region (Eastern US, LA County, etc.). If the study is outside the U.S., the country is noted.

- Peer Reviewed: This category shows if the study was peer-reviewed (i.e. published in a scientific journal).

- Study Population: Describes the ages and/or health status of the population used in the original study. Younger or more elderly people, or asthmatics may be more sensitive subpopulations of the US population. FERET uses the EPA default of using only the study population to predict changes in disease incidence rather than extrapolating effects to the entire population at risk. This can be changed by modifying the fraction of the population in the Health Mortality and Health Morbidity worksheets (see also the User's Manual regarding these pages).

- ICD-9 code: International Classification of Diseases, $9^{th}$ Revision. Medical identification code for the health effect used in the study. This category is important when grouping health endpoints, so that common studies are grouped together. Some

studies only used questionnaires, this is noted in the ICD-9 code column. Within a health endpoint, some studies may also have used fewer ICD-9 codes than another study, resulting in an underestimate if all the studies are combined. This should be noted by the analyst.

- Beta and Standard Error (s.e.): The beta is the regression coefficient derived from a particular peer-reviewed study. For the default equation, it represents the percentage change in cases from a one unit increase in pollution. The standard error yields a measure of the uncertainty associated with the mean beta estimate. See below.

- Form of the Exposure-Response Equation: Each study has a specific exposure-response equation associated with it. The majority fall under the "default" equation form, described in the introduction.

- Other Study Characteristics: The relative risk, reported change in disease incidence, and reported pollutant change are also described from each study, in order to derive the beta used in these analyses. See below for more details.

**Exposure (Concentration)-Response Coefficient (**b**)**

In the reports published by the EPA, researchers estimated response coefficients (β's) based on observed data. In the most common case, the EPA reported a coefficient from the reported relative risk or simply used the published coefficient indicated in the study. While we use the EPA reported coefficients, we attempted to duplicate every coefficient estimated by the EPA to ensure that the β's were reported correctly. A sample calculation is shown below:

| | | |
|---|---|---|
| **Schwartz et al, 1996** | | |
| Reported relative risk = 1.009 | | |
| Reported change in Particulate Matter = 10 ug/$m^3$ | | |
| EPA reported β coefficient = .000896 | | |
| Relative Risk = $e^{(\beta * \text{ change PM10})}$ | or | β = LN (RR) / Change PM10 |
| (1.009) = $e^{(.000896*10)}$ | | .000896 = LN(1.009) / 10 |
| **(1.009) = 1.009** | | **.000896 = .000896** |

The calculations presented above were most often used to replicate the β coefficients. On occasion, additional calculations were performed to obtain the β coefficient. These additional calculations are noted within each of the studies by comments in the Excel cells. For example, the EPA adjusted coefficients that were reported for changes in Total Suspended Particulate Matter (TSP). This is an alternative measure of PM10, with a ratio of 0.56 TSP = PM10. Studies using PM2.5 such as the long term mortality studies by Pope and Dockery use a ratioo of 0.55 PM10=PM2.5. In another case (Ostro & Rothschild, 1989), studies reported coefficients for several years of the study. A mean β was calculated from all years by weighting each coefficient by the inverse of its variance. If the regression coefficient was identical to that published in the original paper, no

calculation was necessary. The estimation of the β's is reported along with the study summary in the morbidity and mortality spreadsheets.

**Study Selection and Response Coefficient Algorithm**

We developed a process to include multiple studies in the analysis of health impacts and values by using simulation methods (see the Introduction for charts of this process). The following is a description of how the model works using PM mortality as an example.

**A.** In the User Input worksheet of FERET, you are asked to enter the change in PM10 concentration and the size of the exposed population. (You also can input concentration changes for other pollutants and economic variables). After these inputs, you can access a list of studies (in the "Health-Mortality" worksheet) that represents the studies considered by EPA in their analysis of PM mortality. You may use the EPA default or weight each study based on your view of its importance in determining the incidence of particulate induced mortality. You can enter any number (integer or fraction) for the weight of the study or a zero to exclude the study from the incidence estimation.

**B.** In the worksheet "Health Monte-Carlo, the weight entered for each study indicates to what extent that studies' distribution will be used to estimate mortality. The FERET model translates the weights into ranges in the 0 to 1 range and then uses a random number generator to select which study is chosen for a particular trial. For example, if you have 3 studies equally weighted, the range of study 1 is 0 - .33, study 2 is .34-.66, and study 3 is .67-1. The FERET model generates a random number between 0 and 1. The range that the random number falls between designates that study to be selected (e.g. if random number = .555, then study 2 is selected).

**C.** On that same worksheet is the study-specific exposure-response equation. Since in our example study 2 was chosen, that study's exposure-response distribution will be sampled from to describe the change in mortality for the first trial (among many) of the model.

**D.** When the analyst runs the FERET model, many trials are run (default = 100 although we frequently run 500 to 1000 trials). Each trial randomly selects a study and then samples from the response coefficient distribution. The large number of trials allows an overall distribution to be created from the distributions of all the studies selected. This overall distribution is shown to you in the output page. Similarly, the large number of trials allows an overall distribution for the reduction in mortality to be created from the studies selected. Changing the studies included changes the overall response coefficient.

**E.** The estimated number of cases is then multiplied by an economic valuation obtained in parallel to that of the health impacts. Economic studies are chosen, values sampled, and distributions generated by repeat passes through FERET. The final outputs

are distributions of health and economics measures. The same process is used for each of the air pollutants and each of the different health effects. Finally, a total economic valuation is computed by summing the costs avoided from the reduction of all health effects (the benefits). This is combined with the estimated costs and summed to calculate the net present value.

## 3.0 Economic Studies

### Keywords

Willingness to Pay (WTP)
Statistical Value-of-Life
Labor Market Studies
Contingent Valuation
Monte-Carlo

### FERET Input

*Default*: Do nothing. In that case, in the User Input worksheet the EPA Distribution is already selected with a 1 (and the User selection option is disabled with a zero.) This tells FERET to use the distribution fit by the EPA to the mean value of a statistical life from a set of studies (listed at the bottom of the Econ. Mortality worksheet in Table 2). The actual EPA distribution is located in the Econ. Mortality worksheet but you do not need to take any action.

*Optional*: Indicate you wish to choose your own studies and then select the studies. You first indicate that you wish to choose studies in the User Input worksheet by putting a 0 (zero) for the EPA distribution and a 1 for the User selected studies in the appropriate blue cell. To actually select the studies (or to add your own), you then go to the Econ Mortality worksheet, Table 1, and in the blue "User Select" column put a 0 (to deselect) or a positive value (such as 1) to select the economic study you wish included. Information is presented for each study as described further below.

### Economic Mortality and Morbidity: Study Selection

The economic mortality and morbidity studies use the economic studies designated by an EPA report, 'Benefits and Costs of the Clean Air Act' (1997 retrospective-draft, 1997 retrospective-final, 1999 prospective-draft, and 1999 prospective-final). The 21 economic mortality studies, reviewed in the EPA report, were originally summarized from Viscusi (1993). Two additional studies (Johannesson and Johansson (1996 and 1997) are included, which examine the Willingness to Pay (WTP) to increase the expected length of life by one year provided that the individual survives to the age of 75 years. Additional non-designated EPA studies are included from Viscusi (1993); they include Thaler and Rosen (1976), Brown (1980), and Arnould and Nichols (1983).

**Economic Mortality Studies: Summary**

The economic module incorporates 71 value-of-life estimates or distributions from 23 studies, which are represented on one spreadsheet, 'Econ Mortality'. The studies in the worksheet estimate the value of reductions in premature deaths - called the value of a statistical life. The statistical value-of-life measures how much people are willing to pay (WTP) for small reductions in mortality risk. The value does not indicate the WTP of a particular person to avoid death, but instead the WTP of a group of people to avoid one expected fatality among them. For example, the EPA study found the middle value-of-life to be $4.8 million; thus, a worker might be paid a wage premium of $480 per year to accept an added fatality risk on the job of 1 in 10,000 per year. An exposed population of 10,000 people are then expected to be willing to pay $4.8 million to avoid one death among them. (For further discussion see: Economic Outstanding Issues Summary.) These issues are discussed in more detail below.

**Valuing a Statistical Life**

In attempting to place a value on a human life, there are two approaches commonly used by labor economists. One is survey based, asking how much an individual would be willing to pay to reduce their probability of experiencing a fatal injury. These types of studies are known as willingness to pay or contingent value studies. Another approach, numerically more frequent in the database, is to estimate how much extra workers are typically paid for taking on a riskier job after controlling for factors such as experience, age, education, etc.

A typical model for estimating wage premiums due to risk is the following:

$$\ln Y = a + b_1 RISK + b_2 X + e \qquad (1)$$

$Y$ is a worker's real wage, $RISK$ is a numerical measure of risk such as a fatality rate and $X$ is a set of variables such as education, age experience, union status or race. Some studies deviate from using the natural log of real income as a left-hand side variable and instead use real income itself. The parameters of equation (1) are usually estimated using least squares procedures.

The mean wage premium for additional risk is typically a transformation of data from a statistical analysis. While the premium is the change in wage with respect to the change in risk ($\partial Y/\partial RISK$), the specific calculation depends on the mathematical form of equation 1. In the semi-logarithmic form above, the wage premium depends on the original wage level.

Computing the value of a statistical life (VSL) uses the wage-risk premium and scaling factors. These factors adjust for units of the variables as risk measures are typically measured in numbers of accidents or fatalities *per* year per 1,000 people (or 100,000

people depending on the data used). They also adjust the wage to an annual rate when necessary.

$$VSL = A * \partial Y / \partial Risk \quad (2)$$

Rearranging based on the definition of logarithms yields,

$$VSL = A * Y * \partial \ln Y / \partial RISK \quad (3)$$

In equation (3) $A$ is a scaling factor that is typically 1,000, 100,000, or 1,000,000 depending on the study. $Y$ is typically the mean real wage. Finally,

$$VSL = A * Y * b_1 \quad (4)$$

Where $\beta_1$ is from equation 1. The VSL in equation (4) is modeled to be normally (the same as $b_1$) because $A$ and $Y$ are treated as constants and thus have zero variance. Consequently the VSL in the case is distributed normally with mean equal to the VSL and a variance equal to $(AY)^2$*var($b_1$). While no author or the EPA reported estimates other than the VSL, we have computed the standard error as above where the necessary data exist.

In some studies used by FERET, VSL estimates are obtained from individual studies that used somewhat different definitions, in which case the basic approach above is relevant; or that used parameters from more sophisticated models. Several of the latter papers do not disclose the necessary information for deriving the standard error of the VSL estimate. In these cases, FERET uses a distribution based on what we think is the most transparent reading of what the author actually reported. In some cases this involves using a standard error reported by EPA; or if the author reported one, two or three different estimates, then we define a point, uniform or triangular distribution depending on the context of the original authors. For instance, Leigh and Folsom (1984) report a central estimate and estimates 0.5 standard deviations below and 1 standard deviation above the mean. They do this in part to avoid a negative statistical value of life. We also cannot reproduce the true distribution from their second order equation because they do not report covariances. Consequently we represent the author's intent as a triangular distribution with mean, lower and upper bounds as reported. This approach, as it is applied to those cases where we cannot exactly derive the distribution, allows for a range of values specified by the authors and reflects their published methodology.

**Additional Detail on the Study Selection**

The original EPA 1997 report used a Weibull distribution with a mean of $4.8 million for the statistical value-of-life and a standard deviation of $3.3 million as their best fit of the 26 estimates in their study.

To create a Weibull distribution to replicate that used by the EPA we used an approximation of the Weibull distribution cited from Johnson et. al. "Continuous Univariate Distributions", which approximated the parameters for scale and shape of the Weibull distribution. We based the location at 0. A mean of $4.8 million and a standard deviation of $3.3 million gave an alpha = $4.9 million and c = 3.63. Calculations are provided below:

Most readers may wish to skip to the next text

Given:
Var [Y] = a^2/c^2 * p^2/6
E[Y] = a[1 - 0.57722/c + 0.98905/c^2]
for large c (Source: (Johnson, Kotz, and Balakrishnan)
with a = alpha = scale in Crystal Ball
c = shape with Crystal Ball
p = pi = 3.14…
Std Dev [Y] = $3,302,505
Var [Y] = 1.E+13
E[Y] =$4,757,692

Solve for an equation for c:
c^2 = (a^2*p^2)/(Var[Y]*6)
p^2/(Var[Y]*6) = 1.5082E-13
c^2 = a^2 * D

Use c to solve for an equation for a:
E[Y] = a*[1 - 0.57722/(a*sqrt(D)) + 0.98995/(a^2*D)]
E[Y] = a - 0.57722/sqrt(D) + 0.98995/(a*D)
E[Y] + 0.57722/sqrt(D) = a + 1/a * 0.98995/D

Simplify:
E[Y] + 0.57722/sqrt(D) = $6,244,006.13
0.98995/D = 6.56375E+12
E = a + 1/a */F
0 = a^2 - E*a + F

Use Quadratic Equation to solve for a:
a = -E -/+ sqrt(E^2 - 4*1*F)/2
a = (with +) $ 4,906,143.66
and a = (with -) $ 1,337,862.47

Substitute value of a to solve for c:
c = 3.6303
c = 0.2700

Selected values for a and c within FERET:
a = $ 4,906,143.66
c = 3.6303

While you can choose the EPA distribution, the basic FERET methodology differs from the EPA methodology. The EPA calculated one mean value-of-life from each study and then collected these values to create one Weibull distribution from which estimates were

randomly selected for the EPA benefit-cost analysis. FERET provides the ability to sample from the distribution for the value-of-life from each study. FERET selects from among these distributions based on your choice of which studies to include.

Each study provides at least one mean or distribution estimate of the statistical value-of-life. For instance, four point estimates of $8.8 million, $12.6 million, $11.1 million, and $17.9 million (1990 U.S. dollars) are reported as preferred in Herzog and Schlottman (1990) although there was insufficient information on which to derive a distribution. In contrast, the EPA derived one point estimate from Herzog and Schlottman of $9.1 million (1990 U.S. dollars) that the EPA used in conjunction with the other study estimates to create its Weibull distribution.

**Spreadsheet: Econ Mortality**

If you left the study choice as the default, EPA Distribution, in the User Input worksheet, FERET will use the distribution in the Econ. Mortality worksheet but you do not need to do anything.
If you indicated User selected studies in the User Input worksheet, you need to select studies (or add your own) in the Econ Mortality worksheet that is explained in more detail here.

The column highlighted in green in TABLE ONE defines the distribution of the value of a statistical life for each study. Using the weights you enter, the model randomly selects an estimate from each distribution. From these selected estimates, FERET randomly selects one study for the statistical value-of-life on each trial using the weights you enter. When a study is selected, a sample is obtained from its distribution of the value of a statistical life. Over many trials a new distribution is created for the summary of the statistical value-of-life (see "Valuation Summary" spreadsheet).

**Descriptions of Study Information in the Econ Mortality Worksheet**

**Column #1: SOURCE**
FERET documents each study beginning with the first column, which list the author and the year of publication. A comment provides the full citation that is identified by a red triangle in the upper right corner of a cell. You move the mouse pointer onto the cell to read the abstract.

**Columns #2: USER SELECTION COLUMN**
The second column with cells highlighted in blue are the weight cells. If you choose User Selection on the User Input page, the second step for you is to enter in zero or any positive value to weight each of the estimates. You can type a zero to exclude the study from the simulation or a positive number to weight and to include the study in the simulation.

**Columns #3 - #9: ESTIMATED MEAN/STANDARD DEVIATION OR RANGE CONVERTED TO 1990 VALUES**

The variables show either a mean value-of-life, range of the mean value-of-life or standard deviations if provided respectively. The estimates are converted into 1990 U.S. dollars with the Consumer Price Index from the U.S. Department of Labor Statistics Washington, D.C. 20212.

**Columns #10 STANDARD DEVIATION DIVIDED BY MEAN IN 1990 U.S. DOLLARS**

While not currently used, this may be used to provide an estimate of a standard deviation missing from several studies. We are considering estimating the standard deviation for these studies by creating an average of the sum of all provided standard deviations divided by the sum of all provided means. This quotient could then be used to estimate the standard deviations that are not provided.

There is little statistical justification to support or reject this approach - it makes an assumption about how the study population of interest compares against all other populations for which data are available. From an uncertainty perspective, the assumption contributes little uncertainty to the total uncertainty in the model predictions.

**Column #11 ESTIMATED VALUE-OF-LIFE FROM DISTRIBUTIONS IN 1990 U.S. DOLLARS**

FERET runs Monte Carlo simulations using data from column #11 (the column highlighted in green). You can check the distribution by highlighting the cell and clicking on the green “normal” button on the menu bar. If the study provided a range then a uniform distribution was created from which a value was randomly selected. If a different distribution could be calculated from the data then that was provided as described above. Otherwise point estimates or distributions inferred from the author’s are used.

**Column #12 TYPE OF STUDY**

FERET includes two types of studies in the model: (1) Labor Market and (2) Contingent Valuation. Labor Market Studies utilize labor market data on the assumption that riskier jobs are expected to carry clearly identifiable wage premia as compensation for risk. The majority of the studies used in FERET are Labor Market Studies. Labor Market Studies are often referred to as 'compensating wage differential' or 'hedonic price' studies. Contingent valuation studies are those based on a questionnaire approach, which involve asking a sample of individuals more or less directly about their willingness to pay for various hypothetical changes in risk. (For further discussion see: Economic Outstanding Issues Summaries)

**Column #13 JOURNAL PUBLISHED**

**Column #14 DATA SOURCE**

The Labor Market Studies use data from sources such as the Panel Study of Income Dynamics (PSID) and the Quality of Employment Survey (QES).

**Column #15 RISK VARIABLE SOURCE**
Many studies infer the value-of-life estimates from wage premiums of risk of occupational injury. These calculations incorporate a fatal injury risk variable that is either calculated by the author or cited from another source by the author (e.g. Bureau of Labor Statistics). (For further discussion see: Economic Outstanding Issues Summaries)

**Column #16 POPULATION STUDIED**
Generally, the studies focus upon populations of blue collar, full-time, and white-male workers. Notable exceptions are the Contingent Valuation Studies, which administered questionnaires across populations.

**Column #17 DEPENDENT VARIABLE**
The dependent variables are wage premiums to a particular scale; for example, percent/year or dollars/week. In many cases the log is used to improve precision and to more accurately fit the data.

**Columns #19 - #36 INDEPENDENT VARIABLES**
All the studies used a regression analysis to calculate the statistical value-of-life. The Independent Variables are provided to help you understand the conditioning factors involved in that particular estimate. Researchers can return to these studies to add further control factors for benefit transfer. Column #18 is skipped.

**Columns #37-39 BLANK**

**Columns #40 - #42 RANDOM NUMBER SECTION OF STUDY**
These columns divide the unit line into the sum of the weights you have indicated. By comparing the intervals for each study with a random number (generated at the top of the worksheet), FERET decides which study (and which sample of the value of a statistical life) will be used for that trial. Only one value is selected for each trial.

## Economic Morbidity Studies: Summary

The economic morbidity studies are shown on the "Econ Morbidity" spreadsheet. The economic morbidity Microsoft Excel spreadsheet is based upon values presented in the EPA report, 'Benefits and Costs of the Clean Air Act' (1997 retrospective-draft, 1997 retrospective-final, and 1999 prospective-draft). The valuation of a specific short-term morbidity endpoint is generally obtained by representing the illness as a cluster of acute symptoms. For each symptom, the WTP is estimated based on studies used by the EPA.

## Spreadsheet: Econ Morbidity

The variables on this page include: citation, distribution, mean/standard deviation, and data source. All prices are in 1990 U.S. Dollars. The main purpose of the Economic Value of Morbidity spreadsheet is to provide the distribution of values for each health endpoint. The morbidity value distributions tend to come not from individual studies but from distributions created by the EPA (see Appendix H, especially of the Prospective Report.) Consequently there is not study selection algorithm for morbidity. You may however, change the distributions if you wish. The existing distributions are either normal, triangular, continuous uniform, or two Monte Carlo generated distributions. One distribution required a more detailed computation of its distribution.

The distribution of WTP to avoid a case of pollution-related CB was generated by Monte Carlo methods as described by EPA. It draws from each of three distributions: (1) WTP to avoid a severe case of CB is assigned a 1/8 probability of being each of the middle 8 deciles of the distribution of WTP responses in Viscusi et al., 1991; (2) the severity of a pollution-related case of CB (relative to the case described in the Viscusi study) is assumed to have a triangular distribution, centered at severity level 6.5 with endpoints at 1.0 and 12.00; and (3) the constant in the elasticity of WTP with respect to severity is normally distributed with mean =0.18 and standard deviation=0.0669 (from Krupnick and Cropper, 1992) These three distributions are shown in TABLE TWO and TABLE THREE.

**Further Readings**

Cullen, A.C. and C.H. Frey. Probabilistic Techniques in Exposure Assessment. Plenum Press, New York and London, 1999.

Hahn, R.W. et al. Risks, Costs, and Lives Saved. Oxford University Press, New York and Oxford, The AEI Press Washington D.C., 1996.

Hammitt, J.K. Valuing Mortality Risk: Theory and Practice, and other papers in Valuing the Environment, a special issue of Environmental Science and Technology, April 13, 2000.

Harrington, J.E. Jr., J.M. Vernon and K.W. Viscusi. Economics of Regulation and Antitrust, Second Ed. MIT Press, Cambridge, Massachusetts, 1995.

Revesz, L.R. Environmental Regulation, Cost-Benefit Analysis, and The Discounting of Human Lives. Columbia Law Review, Vol. 99, No. 4, May 1999.

## 4.0 Cost Module

### Keywords

Cost
Cost Effectiveness
Present Value
Discounting
Project Model
After Tax Analysis

### FERET Input

The active part of the Cost worksheet in FERET is simply one cell with a distribution of cost. Where do you calculate or obtain that distribution of cost?

### Suggested Approaches

1) Existing information: In the Cost worksheet, enter a distribution to represent the cost values if you have previous information as from surveys of industry, consumers, or academic or consulting reports. If your cost estimate is only for one firm you can scale up your estimate by entering the number of firms in the User Input page. If your estimate represents the total cost (say for all industries), then leave the number of firms at the default of 1 in the User Input worksheet
2) Assistance tool: If you don't have a source of cost estimates, you may wish to consider using EPA's PROJECT model provided with FERET to generate cost estimates (described in somewhat more detail below and with its own User's Manual on the FERET CD. If your estimate represents the total cost (say for all industries), then leave the number of firms at the default of 1 in the User Input worksheet.

### Background

A benefit-cost analysis is incomplete without an assessment of cost. Some analyses can be simplified if the benefits are the same for every regulatory alternative, in which case a cost effectiveness analysis is sufficient. In other analyses, the costs and benefits may be received concurrently (for instance, if there is no delay in receiving the benefits) in which case net benefits (benefits less costs) can be expressed on an annualized basis. However, the general case is to analyze the present value of the net benefits of the regulation which requires an assessment of the present value of the cost.

Analyzing the present value of the cost of a regulation requires defining the changes in cost with and without regulation (a compliance scenario). Numerous methods might be used to estimate the cost incurred from a regulation. Regulators sometimes survey industry, integrate existing studies, or develop one or several scenarios of compliance. In the first two cases, analysts may be able to directly enter a distribution for the present value of cost, such as a normal distribution with mean of $10 million and a standard error

of $2 million. Multiple distributions could be used for different industries. The costs should be estimated without deducting taxes from the cost of compliance (see Welfare Economics in the Introduction.)

FERET samples from the cost distribution to represent costs incurred from a regulation. The cost value is then multiplied by the number of firms (input by you on the User Input page.)

Statistical hint: Suppose the analyst assumes there are N similar firms in an industry. You compute one firm's distribution of cost as normal, mean $2 million, variance $.5 million. Since the industry is the sum over the N firms, and the sum of the expectation (mean) is the expectation of the sum, then the industry mean is the N*$2 million. The variance of a sum of independent normal random variables is also normal with a variance equal to the sum of the variance.

**Compliance Costs and the PROJECT Cost Model**

A useful tool for developing cost distributions is an EPA model called PROJECT. PROJECT was developed for use in enforcement actions and has gone through extensive court review. PROJECT computes the present value of compliance scenarios. Originally designed as an offshoot of an EPA model to estimate the private benefits of avoiding compliance (the BEN model), the PROJECT model focuses on the actual cost to the company of carrying out a supplemental compliance project. In the context of FERET, the supplemental compliance project can be a new regulation.

The PROJECT model, available on line with complete and updated documentation, can be found on the CD or at http://es.epa.gov/oeca/models/project.html. (The BEN model can be found at http://es.epa.gov/oeca/models/project.html.) Typical inputs are: 1) capital costs, 2) one-time non-depreciable costs, 3) operating costs, 4) tax rates (which should be set to zero for the basic analysis), 5) discount rate, and 6) time to implementation. PROJECT is familiar to many regulators, industrial, and environmental groups.

The model does or can take into account: repeat purchases of capital equipment over the life of the project (equipment lifetimes can be adjusted by the analyst), tax deductions, and discounting. The output of the model is the present value of the cost scenario based on a user supplied discount rate (EPA for other purposes provides a user cost of capital as an alternative discount rate.)

FERET users should take care to see that there is consistency between the benefit and cost estimates. Typically, one would estimate the cost model without inflation, a zero tax rate (see welfare discussion in the FERET Introduction), and provide the data in 1990 dollars.

**Further Readings**

U.S. Environmental Protection Agency, "Project User's Manual", Multimedia Enforcement Division, Office of Regulatory Enforcement, Office of Enforcement and Compliance Assurance, April 1999 (provided on the FERET CD.)

Zerbe, R.O. Jr. and D.D. Dively. Benefit-Cost Analysis in Theory and Practice. HarperCollins, New York, 1994.

Introductory statistics book such as: Mood, A., G. Graybill and D. Boes, Introduction to the Theory of Statistics, McGraw-Hill,

## 5.0 Discount Rates

### Keywords

Discount Rate
Real Rate
Nominal Rate
Present Value
Social Rate of Time Preference
Present Value
Opportunity Cost of Capital
Weighted Average Cost of Capital

### FERET Input

FERET discounts rates benefits and costs.

(1) To calculate the benefits, you input the desired real (excluding inflation) discount rate on the 'User Input' worksheet. FERET sets the default real value at 5% as used by the EPA in its analysis of the costs and benefits of the Clean Air Act.

(2) To input the cost discount rate, you also input the real discount rate into the discount rate assumption cell in the EPA cost model called PROJECT. (See Cost section)

### Introduction to Discount Rates

Benefit cost analyses require that future benefit and costs be reduced to present values for comparisons by use of a discount rate. A discount rate is simply an interest rate used to compare the benefits and costs incurred at different times by calculating the present value. The present value of a project or proposal is the worth of that project in today's terms. For example, a project that grants a one time benefit of $100 at the end of 10 years discounted at 10% yields $38.55 (PV = FV/(1 + DR)^T = $100/(1 + .10)^10 = $38.55). This $38.55 equates to the amount that one could invest today to yield $100 in ten years at a 10% interest rate. A large discount rate places more weight on the present versus future benefits and costs. The financial evaluation of a project is sensitive to the choice of discount rate. Thus, one's choice of discount rate is important for financial evaluation. A discount rate that reflects inflation-adjusted dollars is called a real discount rate and a discount rate that reflects nominal dollars is called the nominal discount rate.[1] A large literature discusses the appropriate choice of discount rates; further readings are listed at the end of this section.

[1] Zerbe, Richard O. Jr., and Lesser, Jonathan, "A Practitioner's Guide To Benefit-Cost Analysis", Published within "Handbook of Public Finance", Thompson, Fred and Green, Mark T. (editors), Marcel Dekker, Inc., 1998.

**Standard Practice**

The following assumptions are consistent with standard practice:
1. Use the same discount rate for benefits as for costs.
2. Use sensitivity analysis by evaluating the effect of using a range of discount rates.
3. Use the same rate regardless of project length.
4. For government projects, do not adjust the rate for risk or uncertainty.

**Rates for Private Firms**

Private firms generally use discount rates based on their cost of capital. The cost of capital is the rate set by the firm as the "hurdle" or "trigger" rate required. The terms, "hurdle" or "trigger" rate, are used because it signifies the rate by which a project's future payoffs surpass comparable investment alternatives. The return forgone by investing in the project rather than investing in securities is called the opportunity cost of capital (OCC).[2] The OCC has been approximately at a 7% real rate in recent years.[3] Standard practice is for firms to adjust the rate to reflect market risk (covariance risk). Although this is not done generally when analysis is by federal agencies, it would be consistent with standard private practice. The adjustments are commonly done using the Capital Asset Pricing Model (CAPM).

**Rates for Government Agencies**

Government agencies use different rates even within the same level and branch of government and the rate used by a single agency may change over time. For example, the rates used by the Corp of Engineers have varied from as low as 2.5% to as high as 10% over the period from 1950 through 1980. The Office of Management and Budget (OMB) for many years used a real rate of 10%, but lowered this to 7% in 1992 (see OMB circular A-94 revised 1972-1992). This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years.[4] The Congressional Budget Office uses a rate of 2%[5] (Thompson and Green, 1998). Municipal governments generally use a rate in the 2.5% - 3.5% range.[6] There also have been very peculiar practices required of the Army Corps of Engineers and the Bureau of Reclamation by which real rates are used with nominal benefits and costs. In general, there is little analysis provided for the selection of different rates by different government agencies. In short, there is a lack of consistency as well as a lack of rationale for most government uses of discount rates. The range of federal rates used by federal agencies is then from 2% to 7% in real terms. The justification for government rates has ranged from using the rate on government bonds (the government cost of capital) to using the rate on private capital to using the social rate of time preference.)

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[2] Office of Management and Budget, Circular A-94.
[3] Brealey, Richard A., and Myers, Stewart C., "Principles of Corporate Finance", Third Edition, McGraw-Hill, Inc., 1988.
[4] See Footnote 3
[5] See Footnote 1
[6] Dively, Dwight D., Zerbe, Richard O., "Benefit Cost Analysis In Theory and Practice", HarperCollins College Publishers, 1994.

**Recommendations**

1. **Use the standard practice assumptions**
2. **Use a discount rate ranging from 2.5% to 7% in real terms**
3. **Consider adjusting the rate for market risk using the CAPM**

**Discount Rates Within FERET**

Discount rates are used in FERET when discounting future costs and benefits to present values. The benefits are brought to present value using a discount rate with a default set at 5%. You can enter a different discount rate by typing in the values on the User Input worksheet.

The cost are discounted within the EPA cost model, PROJECT. (See Cost Section for guidance.) Within PROJECT, you can enter the real discount rate in the discount rate assumption cell of PROJECT.[7]

Although FERET allows you to input different discount rates, FERET advises users to enter the same discount rate for both the benefits and the costs.

**A Better Approach[8]**

**Rates for Government Agencies**

There is growing acceptance that the appropriate discount value for government projects is the social rate of time preferences which, practically speaking, is approximated by the cost of capital. Thus we suggest using the costs of capital for both private and public projects. The cost of capital for government is approximately given by the rate of return of long-term government bonds. This rate, in real or inflation adjusted terms, has varied between about 2.5% and 5% per year.[9] This is roughly consistent with a recent survey of economists on their preferred discount rate for global climate issues although that work suggests a time varying discount rate over several different time horizons[10].

The justification for the simple approach of using the rate on long-term government bonds comes from the sophisticated social rate of time preference approach. The social rate of time preference (STRP) is widely accepted as the correct approach after adjusting for the effect on private capital.[11] (For a derivation and a rationale for this approach see Zerbe and Dively, 1994, Chapter 13.) The SRTP is the rate at which society is willing to

[7] Environmental Protection Agency, "Project User's Manual", Multimedia Enforcement Division, Office of Regulatory Enforcement, Office of Enforcement and Compliance Assurance, April 1999 and FERET CD.
[8] There is literature that would support some alteration in all of the standard assumptions except for the use of sensitivity analysis—which is just good methodology. For the user who wishes to explore additional complexity with respect to these assumptions see further readings.
[9] See Footnote 1
[10] Weitzman, M., "Gamma Discounting," *American Economic Review*, 91(1):262-271, March, 2001.
[11] See Footnote 6, for a derivation and a rationale for this approach see Zerbe and Dively, 1994, Chapter 13

trade off present for future consumption. Although the discounting equation using the SRTP is somewhat complex, it reduces to an ordinary discounting equation when public investment does not affect the dollars available for private investment. It has been argued that this is in fact the case.[12] We adopt this assumption here. Nevertheless a fuller treatment is given below.

**Discount Rates: Appendix**

There is growing acceptance that the appropriate discount value for government projects as for private projects is the cost capital so long as the project investment funds do not substitute for private funds. This rate is equal to the rate of return for government bonds. In real terms the discount rate yields on long term government bonds between 3% and 5%.[13] The use of the cost of capital as a discount rate is based upon the correct rate being the social opportunity cost of capital, which takes into account time preferences and the displacement of private capital.[14]

The justification for the simple approach of using the rate on long-term government bonds comes from the sophisticated social rate of time preference approach. The Social Rate of Time Preference (STRP) is widely accepted as the correct approach after adjusting for the effect on private capital.[15] (For a derivation and a rationale for this approach see Zerbe and Dively, 1994, Chapter 13.) The SRTP is the rate at which society is willing to trade off present for future consumption. Although the discounting equation using the SRTP is somewhat complex, it reduces to an ordinary discounting equation when public investment does not affect the dollars available for private investment. It has been argued that this is in fact the case.[16]

The SRTP approach yields the following discounting equation with $B_t$ and $C_t$ representing the benefits and costs of year t and other terms as defined in Table 1:

$$\text{Net PV} = \sum (B_t [?_c V_t + (1- ?_c)] - C_t[?_b V_t + (1- ?_b)] ) / (1+i)^t \quad (1)$$

Where

$$\text{Shadow Price of Capital} = V_t = (1 - s)r / (i - sr) \quad (2)$$

The $V_t$ is the present value of the consumption from $1.00 of private investment. In other words, $V_t$ converts those public investments that displace private funds to consumption equivalents (crowding out).[17] The $1.00 public investment yield future benefits and may also return funds that are used in private investment so $V_t$ applies to benefits of public

[12] See Footnote 6
[13] Thompson, Fred and Green, Mark T. (editors), "Handbook of Public Finance", Marcel Dekker, Inc., 1998. References used in this analysis are from Zerbe, Richard O. Jr., and Lesser, Jonathan, "A Practitioner's Guide To Benefit-Cost Analysis", Chapter 7.
[14] See Footnote 1
[15] See Footnote 6
[16] See Footnote 1
[17] See Footnote 6

projects as well as the costs. $V_t$ incorporates both benefits and costs of an investment in consumption terms.

When, however, the $?_c$ and $?_b$ are zero or, practically small, then no adjustment needs to be made to ordinary benefits and costs and the use of the SRTP, i.e., "i" is the correct discount rate. When $?_c$ and $?_b$ are zero the above equation reduces to the following:

$$\text{Net PV} = \sum (B_t - C_t) / (1+i)^t \quad \text{(with sum from t = 0 to T)} \qquad (3)$$

The term Vt drops out. This is just the ordinary equation for discounting at rate i, which is the social rate of time preference.

Vt arises because of the possibility that a government project might affect the interest rate at which private capital is available. Lind (1982) and Zerbe and Lesser (1994) have argued that for most projects investment amounts will be small relative to financial markets and that, therefore, crowding out and crowding in are not factors in most project evaluations.[18] This is particularly the case now that financial markets are worldwide. The conclusion then is that $?_c$ and $?_b$ are essentially zero so that no adjustment is necessary to ordinary costs and benefits.

To provide additional background into the shadow price of capital and the SRTP, the formulas and a derivation of its value will be provided. Table 1 provides the five variables used to calculate the SRTP and the shadow price of capital.

TABLE 1[19]

| | |
|---|---|
| r = | the private investment rate of return, the Opportunity Cost Rate (OCR) |
| s = | the fraction of the proceeds of an investment that are reinvested in the excess of the amount needed to maintain capital |
| i = | the social rate of time preference (SRTP) |
| $?_c$ = | the fraction of a dollar of public spending that displaces private investments; i.e., the extent to which government project crowd out private capital |
| $?_b$ = | the fraction of a dollar of public spending that is returned to private capital; i.e., the extent to which government projects crowd in private capital |

The following table shows estimates of the ranges for i, r, and s.

TABLE 2[20]

| Variables | Expected Values | Bounds (2 std. dev.) |
|---|---|---|
| i | 3% | 2.5%-4.2% |
| r | 7% | 6.0% - 10% |
| s | 7.2% | 5.5% - 10% |

(Zerbe and Dively, 1994)

To approximate the shadow price of capital, Monte Carlo simulations were employed using Crystal Ball. The variables presented in Table #2 were represented with triangular distributions. For example, the min and max for R were set at 6% and 10% and the peak

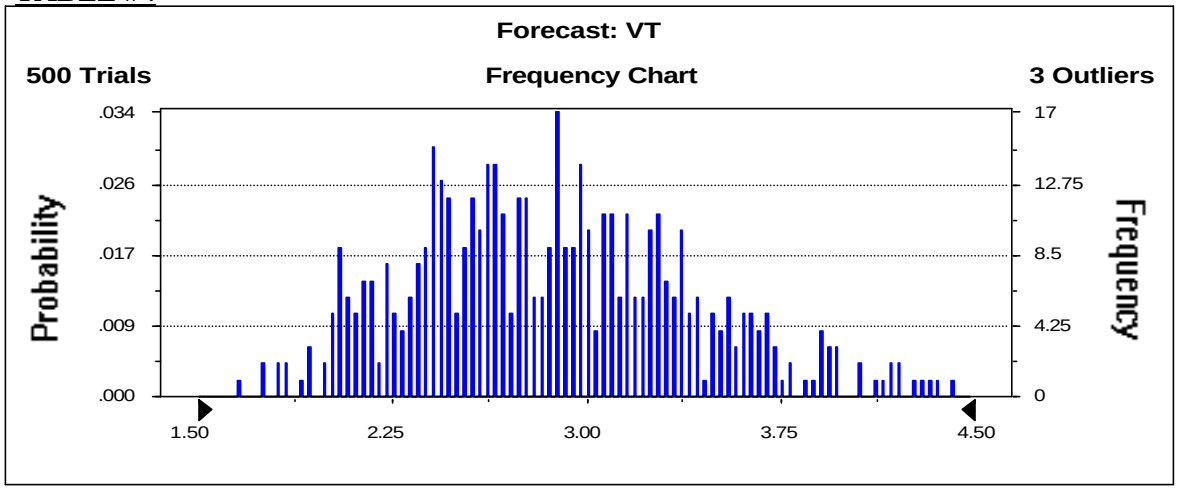
[18] See Footnote 1
[19] See Footnote 6
[20] See Footnote 6

at 8%. With $B_t$ and $C_t$ set at one, the Crystal Ball simulation yielded (after 500 trials) the characteristics for $V_t$ comparable to the discount rate on long term government bonds between 3% and 5%, consistent with the Best Practice approach supported by FERET.

TABLE #3

| | |
|---|---|
| Trials | 500 |
| Mean | 2.88 |
| Median | 2.85 |
| Mode | --- |
| Standard Deviation | 0.55 |
| Variance | 0.31 |
| Skewness | 0.52 |
| Kurtosis | 3.17 |
| Coeff. of Variability | 0.19 |
| Range Minimum | 1.67 |
| Range Maximum | 4.85 |
| Range Width | 3.17 |
| Mean Std. Error | .02 |

TABLE #4




**Further Readings**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Zerbe, R.O. Jr., and J. Lesser. A Practitioner's Guide To Benefit-Cost Analysis, in F. Thompson and M. T. Green, eds., Handbook of Public Finance. Marcel Dekker, Inc., 1998.

## 6.0 Present Value

### Keywords

Present Value of Benefits
Discounting
Population Growth
Latency Period
Time to Implementation

### FERET Input

Several economic input parameters in the User Input page affect the present value such as: discount rate, population growth rate, latency period, time to implementation. These variables are discussed below and their effect on present value.

### Purpose

These numbers, which may be constant or from a distribution, affect the timing of when benefits and costs are received. These changes in timing alter the present value of the net benefits which is the objective of the analysis. It is necessary to obtain the present value in order to add up like amounts of costs and benefits .

### Integration

It is assumed that the benefits are originally estimated for one year and that they increase at the growth rate of the exposed population. Discounting reduces the future value of impacts as does delaying the time to implementation and latency periods, while the growth rate of the exposed population increases the impact. The equation used in Excel is first presented, and then reconstructed step by step.

### FERET Present Value Calculation:

FERET uses the present value (PV) formula in Excel, defining the annual benefit B, discount rate r, population growth rate g, latency period b, delay until implementation of c, and number of periods when benefits received as, nper.

FERET defines the present value of the health benefit to be:

$PV(r-g, nper, -X,0,1)/((1+r)^{(b+c)}$.

The structure of this command is explained in the Excel help files but it basically applies the net discount rate (r-g), of a benefit (expressed as a minus sign in the Excel financial structure), received for nper number of periods. That present value is delayed until time (b+c) and so is further discounted.

The structure of this command is developed below. Each element is built into the basic equation for present value below using continuous compounding of interest (base e raised to a power r).

1. Basic equation for present value: $PV=Xe^{-rt}$

Where: PV is present value
X=annual benefit
r=discount rate
t=number of years in the future when the annual benefit is received.

2. Present value of an annuity: $PV=X/r$
It can be shown (by integration) that if X is received every year up to infinity, then the present value is X/r

3. Population growth rate: If X increases at the same rate as the population and g is the growth rate of the population, then
$PV=X(e^{gt}e^{-rt})$
$=Xe(g-r)t$
For an annuity: $=X/(g-r)$

4. Latency period: This delays the benefits of mortality reductions until $t_0 + b$. (Note: EPA uses a variable 5 year latency period for mortality which with a 5 percent discount rate is equivalent to multiplying the nominal value by .92)

5. Delay for implementation and latency: The benefits are not received until the end of the latency and implementation period, $t_0 + b + c$.

6. The present value of a stream of benefits taking net discounting, number of periods, implementation and latency is then:

$$PV=(X/(g-r))e^{(g-r)(b+c)} - (X/(g-r))e^{(g-r)(b+c+nper)}$$

While this could be programmed into Excel, FERET in practice uses the equation at the start of this section that incorporates the EXCEL PV command (noting its format that changes the sign of (g-r) and X) and then discounting from the end of the latency and implementation period.

7. Present value of costs: PROJECT allows the costs to be computed as of a date in the future which can take into account the delay to implementation. The latency period does not affect the present value of costs.

**Further Readings**

U.S. EPA, Office of Enforcement and Compliance Assurance, BEN and PROJECT User's Manual, April, 1999. Available at http://es.epa.gov/oeca/models

Zerbe, R.O. Jr. and D.D. Dively. Benefit-Cost Analysis in Theory and Practice. HarperCollins, New York, 1994.

Excel online documentation for the present value command, PV.

## 7.0 FERET Uncertainty Issue Summaries

### Aggregating Across Different Air Pollutants

The scientific literature focusing on the health effects of exposure to air pollutants is not easily comparable. Studies often choose one major pollutant to study and exclude others. For example, one study may look at mortality with increases of $PM_{10}$, while another may focus on ozone and mortality. How does one combine these two studies to determine an overall change in mortality?

EPA has several answers to this problem pertaining to different health effects. Mortality is based on PM alone. EPA suggests that particulate matter is a surrogate for the entire pollutant mix and therefore represents mortality from all pollutants as the Pope study only included effects of PM in the regression equation. Also, EPA suggests that research for ozone and carbon monoxide exposure is not fully substantiated to apply to mortality estimation.

For other health effects (e.g. hospital admissions, chronic disease) EPA prefers models that contain multiple pollutants in the estimation of the regression coefficient. They also sum up changes in incidence predicted by studies using only one pollutant.

### Double Counting Across Health Endpoints

In the FERET model, scientific literature is used to estimate changes in health effects due to exposure to air pollution. There are a large number of health effects cited in the literature and many of the studies use a range of health effects that may overlap with other studies. In addition, some lesser health effects may lead to more serious health effects. Therefore, a technique should be developed to make sure that no double counting across endpoints occurs.

EPA generally treats health endpoints as independent. There are a few cases where endpoints overlap as with mortality from PM and Ozone and in the treatment of several respiratory and cardiovascular endpoints. EPA only includes the PM mortality and they make some minor corrections, or use different indicators as alternatives of the same effect.

Below we outline a model that allows for pairwise correlation across health endpoints. Our initial work suggests that adjustments of this kind may have a modest effect on the net present value in this setting where mortality outcomes dominate the result.

# Correlation Coefficient Derivation

**Example:**

| Person with Disease X | Person with Disease Y | Frequency | X+Y |
|---|---|---|---|
| 1 | 1 | $\pi_{11}$ | 1 |
| 1 | 0 | $\pi_{12}$ | 0 |
| 0 | 1 | $\pi_{21}$ | 0 |
| 0 | 0 | $\pi_{22}$ | 0 |

2 x 2 Contingency Table

| | Y = 1 | Y = 0 | |
|---|---|---|---|
| X = 1 | $\pi_{11}$ | $\pi_{12}$ | $\pi_{1o}$ |
| X = 0 | $\pi_{21}$ | $\pi_{22}$ | $1-\pi_{1o}$ |
| | $\pi_{o1}$ | $1-\pi_{o1}$ | 1 |

If X=observed incidence of symptom A
If Y=observed incidence of symptom B
If XY=incidence of both symptoms (people who have both A and B)

Pearson Product Correlation Coeff. =

$$r = \frac{E(xy)-(E(x)*E(y))}{(SQRT(\sigma^2x-\sigma^2y))} = \frac{\pi_{11}-(\pi_{o1}*\pi_{1o})}{(SQRT(\pi_{1o}(1-\pi_{1o})*\pi_{o1}(1-\pi_{o1}))}$$

Suppose you want the risk of having either or both of the symptoms.
Let's call that T.

$T = (\pi_{o1}+\pi_{1o}) - \pi_{11}$
$\pi_{11} = r*(SQRT(\pi_{1o}(1-\pi_{1o})*\pi_{o1}(1-\pi_{o1}))+(\pi_{o1}*\pi_{1o})$
so

$T = (\pi_{o1}+\pi_{1o})-(\pi_{o1}*\pi_{1o})-r*(SQRT(\pi_{1o}(1-\pi_{1o})*\pi_{o1}(1-\pi_{o1}))$

In a supplemental Spreadsheet Model (2-d selection model v4a) available from us we define:
Cell G21 = Correlation = r
Cell G23 Probability of Mortality = $\pi_{1o}$
Cell G24Probability of Cardio. Disease = $\pi_{o1}$
Cell G 26 Probability of both diseases = $\pi_{11}$
Cell G 28 Total Incidence = T

Corrected Incidence = Mortality – Having Both Diseases (G23-G26)

**Sample Calculation Description (Correlation)**

Using the correlation coefficient derivation on the previous page, we have developed a sample model to estimate the corrected Net Present Value (not included with this version.) This model is essentially identical to previous models except for the additions of a correlation matrix, and incidence corrections tables.

In the area of the spreadsheet highlighted green is the example of the use of the correlation matrix. We have chosen seven endpoints to test this approach. On the right side is the correlation matrix, which allows you to input any correlation value. The current example only solves for two endpoints simultaneously. If multiple endpoints are to be considered, then additional derivations will need to be performed.

At present, each of the endpoints can be correlated with the other endpoints. The table on the left-hand side contains the correction table. This table estimates the number of cases, based on the correlation coefficient, that have two of the seven diseases. The table then calculates all the combined incidences, and then subtracts these incidences from the predicted baseline cases. The final result is a corrected number of cases of each disease. (Note: On occasion the value selected from the distributions are negative. These negative values cannot be used to correct for correlation. Thus, If-Then statements were used to make all negative values equal to 0.)

This represents the first implementation of the correction concept. The model in this file (not included with this version) will calculate the net present value for both the corrected and non-corrected incidences. The difference between these estimates will change depending on the strength of the correlation coefficients.

Two outstanding issues still need to be addressed within this approach.
1. Correlations between multiple endpoints will need further mathematical derivations.
2. Valuation of having more than one endpoint needs to be researched within the economics literature to see if there are appropriate studies to match suspected combinations of health endpoints.

**Distributional Assumptions**

Some authors report results based on distributions (often normal) that have some probability of generating negative values for health and economics that seem counterintuitive. For health, if negative outcomes appear they indicate a positive health impact of pollution, for economics, a negative outcome appears as a positive benefit of the (negative) health outcome, e.g. a preference for mortality or morbidity.

Standard benefit cost analysis doesn't face this problem when it only uses the mean values. In that case the mean is typically positive and no conflict arises, although, information about the distribution is not used in the analysis.

EPA treatment: EPA fit a distribution to the mean value of a statistical life that restricts the result to be positive. If you select to use the individual studies in FERET, we use the distributions reported or implied by the individual authors which may have a small probability of negative outcomes.

**Statistical Value-of-Life**

The reliability and purpose of measuring the statistical value-of-life is often commented upon the authors of many of the studies and other sources. A few of these comments are listed below.

Viscusi (Fatal Tradeoffs, 1993) notes the ultimate purpose of the value-of-life literature is to provide some basis for sensitive social decisions. He claims that before society can make decisions about saving lives, an analysis must be conducted to decide whether we can establish an empirical reference point for making trade-offs involving life and death. In these studies, the benefit is measured in the willingness-to-pay for the risk reduction. But what is purchased is not the certainty of survival, rather it is the incremental reduction in the probability of an adverse outcome that affects a random person in the community. At stake are statistical lives, not certain identified lives.

Carrothers, Graham, and Evans (Risk in Perspective July 1999, Volume 7, Issue 5) claim the use of statistical value-of-life assumes that the deaths attributed to air pollution are comparable to occupational deaths. There are differences within these contexts. Accidents in the workplace have a tendency to strike healthy, middle-aged adults, while deaths attributed to air pollution have a tendency to strike elderly persons with serious preexisting cardiac and respiratory disease. If length of life and quality of life are important to the valuation, then the statistical value-of-life may overestimate the benefits. (They support a Quality-Adjusted-Life-Year approach for analysts to overcome the drawbacks of statistical value-of-life.)

Revesz (Columbia Law Review Vol. 99:941, 1999) scrutinizes attempts to apply the statistical value-of-life with statistics derived from industrial accidents, as in Labor Market Studies, to the value-of-life from exposure to an environmental carcinogen with a latency period. He recognizes the difficulties in conducting studies of the value-of-life over latency periods due to the lack of data on latency, the lack of understanding of risks by individuals within the studies, and the variation of individual characteristics within a population. Nevertheless, he identifies several uncertainties in making extrapolations from current Labor Market Studies of the statistical value-of-life, which rely on a small subpopulation's willingness-to-pay for voluntary risks to mostly accidental deaths, to broader populations similar to the populations used in the FERET model.

First, the value-of-life estimate increases with income. As income increases with age then uncertainties exist in extrapolating the estimates to different income and age populations (Krupnick and Cropper, Resources for the Future, 1999.) Second, individuals who take risky jobs for higher premiums have lower-than-average income

and therefore problems exist in extrapolating estimates of the value-of-life from this subpopulation to a broader population. In fact, Revesz makes an argument that most studies only analyze a small subgroup of this subpopulation who take risky jobs because not all workers who accept risky jobs accept the work. Third, individuals who take risky jobs for higher premiums do so at a voluntary risk and then adjustments must be made to extrapolate this to broader populations exposed to involuntary risks. Fourth, deaths within Labor Market Studies are industrial accidents and therefore problems exist in extrapolating these estimates to broader populations exposed to risks of a dread nature.

**Reasons for Divergence in Statistical Value-of-Life**

Several studies speculate on the estimated divergence and variation in the statistical value-of-life. Gerking, DeHaan, and Schulze (1988) summarize the reasons for these wide divergences and conspicuous anomalies which include: (1) problems in estimating fatal and nonfatal job-related accident risks, (2) failure to adequately control for human capital and workplace characteristics, and (3) differential bargaining strength of non-unionized workers.

The variation of the value-of-life estimates are obtained from different studies and the variation can be attributed to several causes. (1) The value-of-life is not a natural constant. Different mixes of people have different value-of-life estimates. (2) The differences arise particularly because workers who are more willing to bear risks self-select themselves into the higher risk occupations. (3) Other sources of variation among the studies include difference in income level across the sample and difference in labor market conditions that will influence the amounts firms are willing to pay and the amounts workers are willing to accept for risky jobs (Viscusi, 1996).

One particularly important correlate with the value of life is the income level of the person at risk. The individual willingness to pay to avert risks is positively and approximately proportionally related to income. Including age and income in evaluating the value-of-life is more controversial than using uniform value-of-life. Nevertheless, suppressing those differences is clearly not a reasonable economic approach (Viscusi, 1996).

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## Additional Health References

These reports are not currently used in FERET which focuses on studies selected by the EPA for its reports, but may be of interest to users.

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