

Welcome

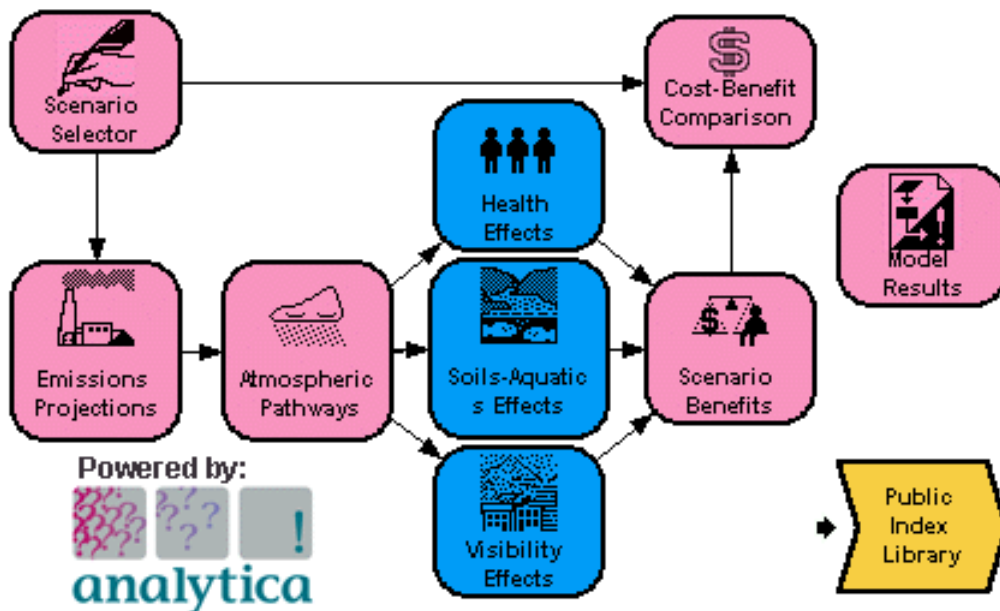
The **Tracking and Analysis Framework (TAF)** is an integrated modeling framework developed to assess, inform, and guide U.S. regulatory policies on emissions of precursors to acid rain.



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Navigate the **TAF Model** by clicking on one of the modules below

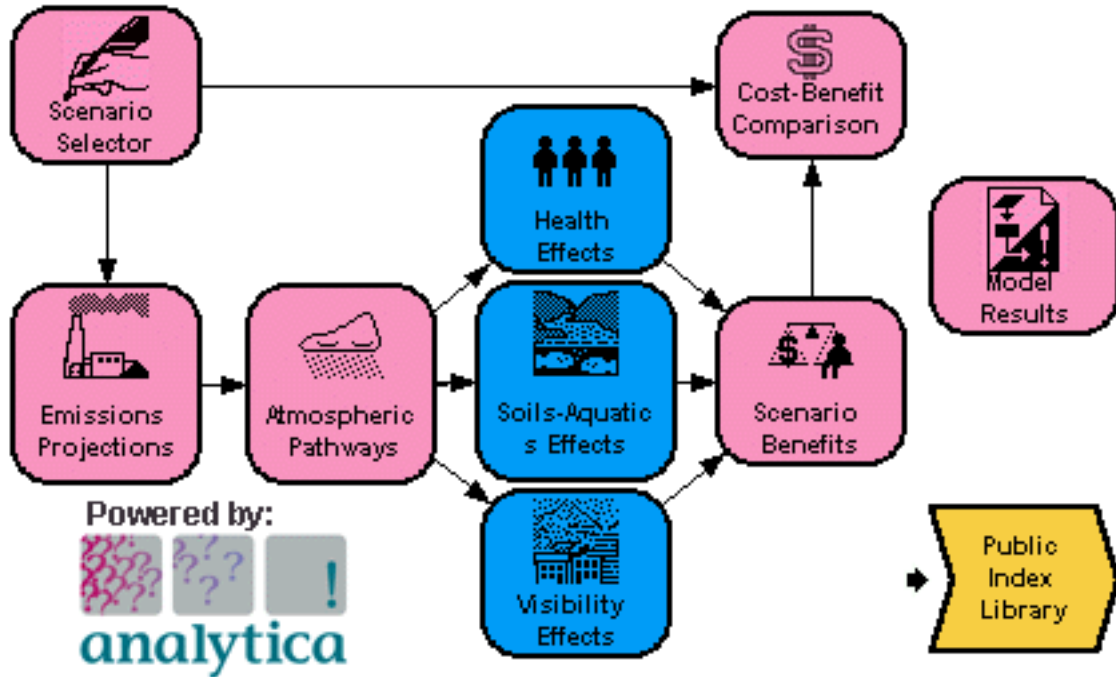


The TAF model is a collaborative effort of over 30 scientists from 11 institutions. All model components have been created with Analytica®, a modeling and simulation tool. The primary sponsor of TAF is National Acid Precitation Assessment Program (NAPAP), the primary funder of TAF is the Department of Energy (DoE).



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### Assessing the "Grand Experiment"

With the passage of the 1990 Clean Air Act Amendments, the United States embarked on an acid-deposition control policy that has been estimated to cost at least \$2 billion. Title IV of the Act created a major innovation in environmental regulation by introducing market-based incentives — specifically, trading among electric utility companies in allowances to emit sulfur dioxide. The National Acid Precipitation Assessment Program (NAPAP) has been tasked by Congress to assess what Senator Moynihan has termed this "grand experiment". Developing a comprehensive assessment of the economic and environmental effects of this legislation is a major challenge. To help NAPAP face this challenge, the US Department of Energy has sponsored the development of an integrated assessment model, known as the Tracking and Analysis Framework (TAF). This paper provides a brief overview of the objectives, design, and current status of TAF.

### The Objectives of TAF: A Bridge between Science and Policy

The primary objective of TAF is to help NAPAP fulfill its mandate under the 1990 Clean Air Act Amendments :

- to evaluate the status of implementation, the effectiveness, and the costs and benefits of the acid-deposition control program created by Title IV of the Act, and
- to determine whether additional reductions in deposition are necessary to prevent adverse ecological effects.

TAF integrates credible models of science and technology into an assessment framework that can directly address key policy issues and, in doing so, acts as a bridge between science and policy. This bridge between science and policy is designed to facilitate discussion in both directions: Policy should be informed by the best available science; and scientific research should be focused on those issues most relevant to the policy questions of primary concern. Accordingly, TAF has a set of secondary objectives:

to support coordination among scientists, to help them share, review, and assess models and data; to support communication with policy makers, about key results and insights, and

- to ensure that the model reflects their concerns; and
- to provide guidance for prioritizing research needs based on policy concerns and the most critical sources of uncertainty and gaps in data.

TAF is designed to be easily accessible, comprehensible, and usable so that scientists and analysts from public and private sectors can use TAF to review, understand, and contribute to the assessment. It is also flexible and extensible so that it can easily be modified to incorporate changing assumptions and to address newly emerging policy issues.

### The Components of TAF

TAF links together into an integrated framework the key acid deposition components of pollutant emissions; control costs; atmospheric transport and deposition; environmental effects on visibility, lakes, soils, and human health; and valuation of these effects. TAF has been developed by a collaboration of ten different organizations, including national laboratories, universities, nonprofit organizations, and consulting firms. Each component has been developed by a different group of scientists with special expertise in those issues. Table 1 lists these components, plus the TAF management, framework design, coordination, and integration tasks, with their corresponding authors and organizations. The influence diagram on the title page also depicts the key modules with arrows representing relationships between them.

**Table 1:** Authors and organizations responsible for TAF Modules, integration and project management

<b>Modules</b>	<b>Authors</b>	<b>Organizations</b>
Emissions scenario selector	Rich Sonnenblick, Kevin Soo Hoo and Max Henrion	Lumina Decision Systems, Inc., (Lumina) Los Gatos, CA
Emissions projections and cost 1	John Molburg and Jeff Camp	Argonne National Laboratory (ANL) Argonne, IL
Emissions projections and cost 2	Jayant Kalagnanam & Stuart Siegel	Carnegie Mellon University (CMU) Pittsburgh, PA
Pathways and Deposition	Jack Shannon and Ron Marnicio	ANL, Foster-Wheeler
Visibility effects	Jack Shannon and Jeff Camp	ANL
Aquatics effects	Mitchell Small and Rajarishi Sinha Tim Sullivan	CMU E&S Environmental Chemistry, Corvallis, OR
Soils effects	Pat Ryan and Robb Turner	Oak Ridge National Laboratory
Health effects	Alan Krupnick and Dierdre Farrell	Resources for the Future (RFF) Washington, DC
Benefits	David Austin, Dallas Burtraw, Alan Krupnick, and Erin Mansur	RFF
Project management	Cary Bloyd, John Formento, and Guenter Conzelmann	ANL
System architecture, coordination and integration	Max Henrion, Rich Sonnenblick and Kevin Soo Hoo	Lumina

TAF is not a single model, but rather a flexible framework for modeling an integrated assessment. Effective integrated assessment requires progressive refinement, adaptation, and restructuring of technical models for purposes of policy evaluation. No single model will be

adequate for all purposes. As science progresses, new understanding will justify revised or new models. It is therefore desirable to compare the implications of several different model formulations, based on different scientific views. As new policy questions emerge, information needs will evolve. To meet these challenges, the TAF framework is designed to accept replacements so that other modules can be slotted in to replace existing modules or to expand the model to address new issues. Additional modules are currently under development or planned. TAF provides a framework that allows a variety of models to be developed and coexist in a flexible, yet coordinated, manner.

## **TAF's Innovative Methodology for Integrated Assessment**

The successful creation of TAF in such a short time is a result of our development of an innovative methodology for integrated assessment modeling comprising a suite of interrelated methods. We believe that this methodology would be of value for other integrated assessment projects.

Too often, computer models are overly large and complicated and tend to obscure rather than illuminate the important issues. But, complexity seems unavoidable if the models are to provide credible representations of complex environmental and economic systems. TAF solves this dilemma by using **reduced-form models** — that is, models that are relatively simple in themselves, but derived from large, scientifically validated models. The small size of these models makes them fast to execute on a personal computer, comprehensible, and easy to modify. They derive their scientific credibility from the fact that they are constructed from and provide a demonstrably good approximation of the original detailed models.

The accessibility, transparency, and ease-of-use of TAF derives from its software architecture and user interface. The model is designed as a hierarchy of modules, created and displayed graphically as a **hierarchy of influence diagrams** (demonstrated on the front cover of this document). Each influence diagram shows variables and submodels as nodes, with arrows depicting the qualitative dependencies among the variables. Behind each module and variable is a card documenting its title, units, description, mathematical definition, and other information. Highly visual organization and **integrated documentation** are what make TAF uniquely accessible.

TAF is implemented in Analytica, a general software modeling environment developed by Lumina Decision Systems specifically to support this kind of integrated assessment modelling. Analytica provides general facilities for hierarchical influence diagrams, integrated documentation, probabilistic analysis, and modular development.

TAF is unusual among integrated-assessment models in being developed as a collaboration between many scientists and organizations distributed over many sites across the US, as shown in Table 1. In the past, the difficulty of assembling computer models from separate components developed by different teams has made this kind of collaboration challenging at best. In this project, we adapted and refined a variety of methods from software engineering to ensure that the modules would be successfully integrated. We used a common language, provided by the Analytica modeling environment, whose graphical influence diagrams support rapid model construction. When the project began, we first agreed on the interfaces between the modules and created a shared Public Index Library that specifies the key dimensions of

arrays, such as time steps, source and receptor sites and regions, chemical species, and so on. We developed the framework and modules through progressive refinement with multiple iterations to identify incompatibilities, missing elements, and other integration problems. We also made extensive use of the Internet and particularly the World Wide Web, for sharing information, management, and coordination, as well as for exchanging successive module versions.

Download the complete [TAF User's Guide](#) (300+pp.) in Acrobat format (requires [Adobe Acrobat](#))

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## What's New?

### December 7, 1998

Updated the [TAF documentation library](#) to include journal articles and conference papers authored by the TAF team.

### November 4, 1998

Unveiled an updated TAF website with a new look (designed and implemented by [Jason Harlan](#) of Lumina), and the most recent version of the [TAF Analytica model](#).

### November 12, 1997

Added the [final documentation](#) for the 1996 TAF model in Adobe Acrobat Format.

### June 18, 1996

Added a new guideline for [Comparing Data & Results](#).

### January 31, 1996

Added the [TAF Users Guide Documentation](#).

### January 25, 1996

Added the [TAF Peer Review Executive Summary](#) with embedded hotlinks to the full reviewer comments for each module.

Added [Lumina's response](#) to some of the peer reviewers concerns regarding the chosen TAF framework.

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### Download the TAF Analytica® Model

[TAF1998.zip](#) (780 KB) compressed for Windows 95/98/NT 4.0 machines

[TAF1998.sea.hqx](#) (780 KB) compressed for Macintosh machines

The TAF Model is built in Analytica®, a visual modelling and simulation tool by [Lumina Decision Systems](#) ([download a free trial for use with the TAF model here](#)). Once you have extracted the files on your computer, open the file *1998TAF.ana* with Analytica.

### Documentation

Download the complete [TAF User's Guide](#) (300+pp.) in Acrobat format (requires [Adobe Acrobat](#))

Read a summary of the [electric utility emissions simulation model](#), written in Analytica by Resources for the Future and Lumina.

Review the 1997 NAPAP/DOE [Peer Review](#) of TAF, and the TAF team's [comments on the peer review](#)

Read an [Online Tutorial](#) and learn how to navigate the model in Analytica

### Presented Conference Papers *Require [Adobe Acrobat](#)*

[Expanding the Horizons of the Visibility Assessment Scoping Model](#); Jack D. Shannon; Presented at the *10th Joint Conf. on Applications of Air Pollution Meteorology of the American Meteorological Society* and the *Air and Waste Management Conference on Acid Rain and Electric Utilities*; January 1998

[Innovations in Integrated Assessment: The Tracking and Analysis Framework \(TAF\)](#); Max Henrion, Ph.D.; Richard Sonnenblick, Ph.D.; Cary Bloyd, Ph.D.; Presented at the *Air and Waste Management Conference on Acid Rain and Electric Utilities*, January 1997

[Lessons in the collaborative construction of an environmental integrated assessment model: The Tracking and Analysis Framework](#); Richard Sonnenblick, Ph.D.; Max Henrion, Ph.D.; Kevin Soo Hoo; Presented at the *Air and Waste Management Conference on Acid Rain and Electric Utilities*, January 1997

[Modeling Air Pollution in the Tracking and Analysis Framework \(TAF\)](#); Jack D. Shannon; Presented at the *10th Joint Conf. on Applications of Air Pollution Meteorology of the American Meteorological Society* and the *Air and Waste Management Conference on Acid Rain and Electric Utilities*; January 1998

[Uncertainty in the Tracking and Analysis Framework Integrated Assessment: The Value of Knowing How Little You Know](#); Richard Sonnenblick, Ph.D.; Max Henrion, Ph.D.; Presented at the *Air and Waste Management Conference on Acid Rain and Electric Utilities*, January 1997

[The Welfare Impacts of Restructuring and Environmental Regulatory Reform in the Electric Power Sector](#); Dallas Burtraw, Karen Palmer, Anthony Paul; Prepared for presentation to the *Southern Economics Association Meetings*, November 8-10, 1998 in Baltimore, Maryland

### Published Journal Articles *Require [Adobe Acrobat](#)*

[The Costs and Benefits of Reducing Acid Rain](#); Dallas Burtraw, Alan Krupnic, Erin Mansur, David Austin, and Deirdre Farrell; *Contemporary Economic Policy*, vol. 16, October 1998

[Electricity Restructuring and Regional Air Pollution](#); Karen Palmer and Dallas Burtraw; *Resource and Energy Economics*, vol. 19, 1997.

[Modeling Visibility for Assessment](#); Jack D. Shannon, Edward C. Trexler, Jr., Richard Sonnenblick; *Atmospheric Environment*, vol. 31, No. 22, 1997

**Reduced-Form Modelling of Surface Water and Soil Chemistry for the Tracking and Analysis Framework;** *Water, Air and Soil Pollution*, vol. 105: pp.617-642, 1998

**Discussion Papers** *Require [Adobe Acrobat](#)*

**[The Benefits of Reduced Air Pollutants in the U.S. from Greenhouse Gas Mitigation Policies;](#)** Dallas Burtraw, Michael Toman; November 1997

**[The Benefits of Air Pollutant Emissions Reductions in Maryland: Results from the Maryland Externalities Screening and Valuation Model;](#)** David Austin, Alan Krupnick, Dallas Burtraw, and Terrell Stoessell; October 1998

**[The Impact of Electricity Restructuring on NOx Emissions Affecting the Environment in Maryland;](#)** Dallas Burtraw, Karen Palmer, Anthony Paul; September 25, 1998

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## Acid Rain Links

### Specific Papers and Programs Dealing with Acid Rain

- [Acid Rain Program](#)
- [EPA's Clean Air Power Initiative](#)
- [Acid Rain's Effect on Mayan Pyramids](#)

### General Environmental Information Sites

- [United States Environmental Protection Agency](#)
  - [The Institute for Global Communications acid rain information page.](#)
  - [United States National Oceanic and Atmospheric Administration](#)
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