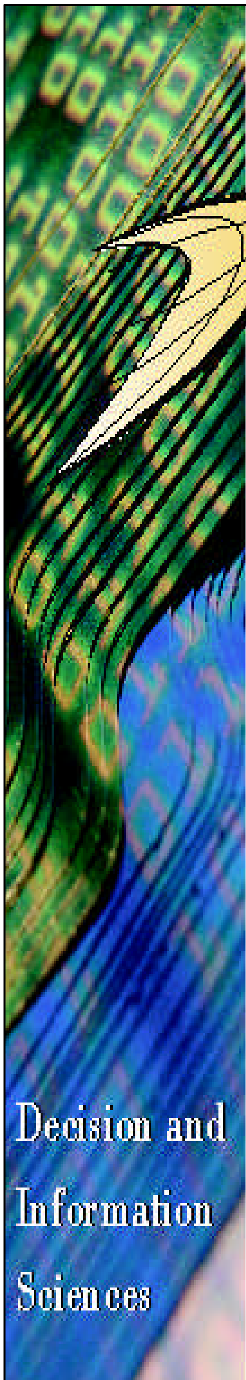

Argonne National Laboratory

Center for Energy, Economic, and Environmental Systems Analysis

ANALYTICAL TOOLS FOR REGIONAL, NATIONAL, AND INTERNATIONAL APPLICATIONS

Argonne, Illinois, USA

Argonne National Laboratory

Argonne National Laboratory
Center for Energy, Economic, and Environmental Systems Analysis (CEEESA)

ANALYTICAL TOOLS FOR REGIONAL, NATIONAL, AND INTERNATIONAL APPLICATIONS

Argonne National Laboratory is a research and development laboratory operated by the University of Chicago for the U.S. Department of Energy. Among the Laboratory's research activities is the development of tools for analyzing energy, economic, and environmental systems. These tools include computer-based simulation and optimization models of an energy system and databases that support the use of these models for regional, national, and international applications.

Argonne's approach to energy, economic, and environmental systems analysis involves three steps:

Develop Tools

Innovative tools address key technical and policy issues of interest to analysts and decision makers.

Apply Tools

Argonne experts perform many analyses with these tools, producing results that contribute to the energy, economic, and environmental decision-making process in the United States and the global community.

Transfer Tools

Transfer of its analytical tools to other users is a major priority for Argonne. Laboratory-sponsored training courses and technical support programs help users in the United States and other nations apply the Laboratory's specialized software tools.

This booklet provides a brief synopsis of the many tools that have been developed by Argonne for conducting energy, economic, and environmental systems analyses. Interested parties are encouraged to inquire about making arrangements for obtaining and using any of these tools and/or obtaining support from Argonne staff in analyzing specific problems.

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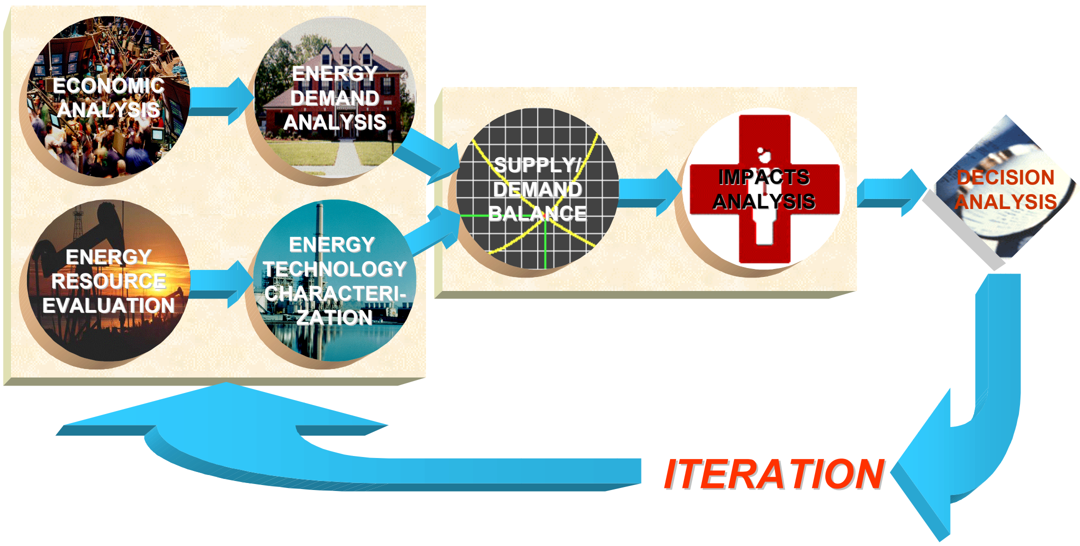
ENERGY SYSTEMS ANALYSIS

Characterizing energy systems is a complicated process. Argonne National Laboratory's innovative analytical tools simplify that process. The schematic provides a broad characterization of the kinds of activities involved in this process. Each activity is then briefly summarized.



Economic Analysis evaluates growth and development in various sectors of the economy. It considers the historical behavior of macroeconomic features (e.g., gross domestic product, employment, and population) and how they might change in the future.

Energy Demand Analysis considers the activities in individual energy-consuming sectors of the economy (e.g., industry, transportation, residential, and commercial buildings). It relates macroeconomic developments to the energy needed to support those developments in each sector.

Energy Resource Evaluation looks at potential energy resources, including fossil fuels, renewable resources, nuclear materials, and imported energy.

Energy Technology Characterization addresses various technologies that might be used to supply energy. Issues such as technology performance, life-cycle cost, and environmental discharge are thoroughly considered. Through characterization, analysts are able to assemble information in a consistent and usable form.

Supply/Demand Balance is the process of matching available energy resources with technologies to meet the demands generated by each sector of the economy. This step integrates the supply and demand elements of the analysis.

Impacts Analysis addresses environmental impacts that relate to energy system configurations, including consideration of emissions, transport of pollutants, exposure, effects on people and ecosystems, and valuation of those effects.

Decision Analysis is used to (1) assemble vast amounts of information generated by other parts of the analysis and (2) combine this information into a form suitable for decision making.

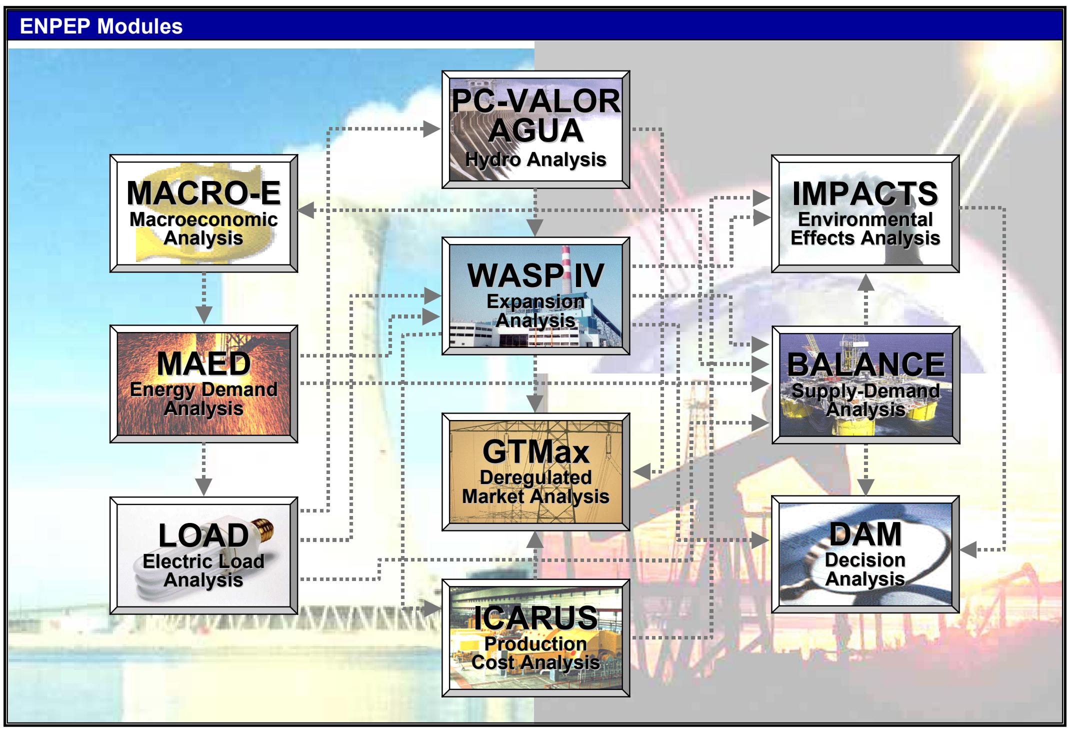
Clearly, these activities overlap in many ways, and some feedback and iterations are not shown in the diagram. Nevertheless, this structure is useful for categorizing the steps required for the energy system analysis process. The table on the following page provides a quick look at the tools Argonne has developed for conducting these analyses.

Typical Issue	Applicable Models	Page
Economic Analysis		
Macroeconomic effects of energy policies (conservation, emission taxes, technologies)	AMIGA	6
Power Systems Analysis		
Deregulated power market analysis	GTMax, EMCAS, APEX-SMN	15, 17, 19
Reliability analysis	ICARUS, ENPEP-WASP	18
Capacity expansion analysis	ENPEP-WASP, APEX-PACE, DECADES	5, 10, 18, 19
Electricity demand forecasting + analysis	ENPEP-MAED, ENPEP-DEMAND	8, 9
Optimization of hydropower resources	APS, PC-VALORAGUA	19, 20
Production cost analysis	ICARUS, PC-VALORAGUA	18, 20
Marginal cost analysis	ENPEP-WASP, ICARUS, PC-VALORAGUA	18, 20
Interconnections + power pools	GTMax, APEX-SMN, PC-VALORAGUA	15, 19, 20
Transmission analysis	ALF	20
Natural Gas Systems Analysis		
Gas market projections	ENPEP-BALANCE	14
Gas network flow analysis	GASMAP, NGview, NGflow	11, 12
Loss of gas network nodes and links	NGview, NGpressure, NGdepletion	11, 12
Complete site isolation analysis	NGview, NGcut	11, 13
Network vulnerability analysis	GASMAP, NGlocator, NGanalyzer	11, 13
Total Energy Systems Analysis		
Energy demand forecasting	ENPEP-MAED, ENPEP-DEMAND	8, 9
Energy systems analysis (all sectors)	ENPEP-BALANCE	14
Transport sector analysis	IMPACTT, EV-LCM, GREET, AirCred	7, 21
Industrial sector analysis	LIEF, Census Data	8, 9
Residential sector analysis	DIAM	8
Environmental Analysis		
Emissions projections	ENPEP-BALANCE, ENPEP-WASP	14, 18
Greenhouse gas mitigation	ENPEP-BALANCE, ENPEP-WASP, GREET	14, 18, 21
Environmental effects	RAINS-Asia, TAF, AIRPACTS, CASRAM, FIREPLUME, SMOKE, SACTI, ACA	22, 23, 24
Emissions trading	APEX, ENPEP-BALANCE	5, 14
Hazardous and Radioactive Waste Analysis	WasteSIMS, WASTE_MGMT, WASTE_ACC, RISKIND, RISKCHEM, RESRAD	25, 26
Decision Analysis	DAM, IDEA, PASS, ARAM, STATS	27

Integrated Models

Several of the Argonne modeling packages are *integrated* tools, which means that each model is composed of a series of modules that cover a number of analytical steps.

ENPEP — ENergy and Power Evaluation Program. The ENPEP modules allow users to evaluate the entire energy system (supply and demand side) and to perform a more detailed analysis of the electric power system. ENPEP's interconnected modules efficiently transfer data from one module to another.

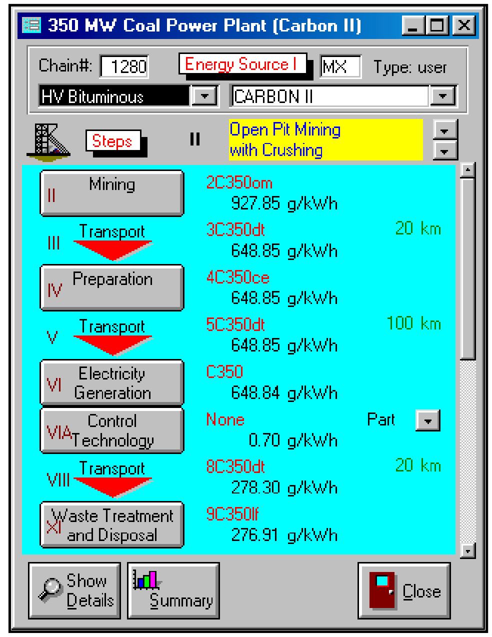


Training courses for various ENPEP modules are scheduled on a regular basis. About 1,000 experts from more than 80 countries have been trained in the use of individual modules, and ENPEP is actively in use in many of these countries. Visit CEEESA's web site (www.energycenter.anl.gov) to view an updated list of courses.

Distributed by the U.S. Department of Energy, The World Bank, and the International Atomic Energy Agency, the newest ENPEP version takes full advantage of the Windows operating environment. Recent applications have focused on climate-change–related issues. ENPEP climate change study reports can be downloaded at various web sites, including the United Nations Framework Convention on Climate Change (UNFCCC) and the U.S. Environmental Protection Agency (EPA).

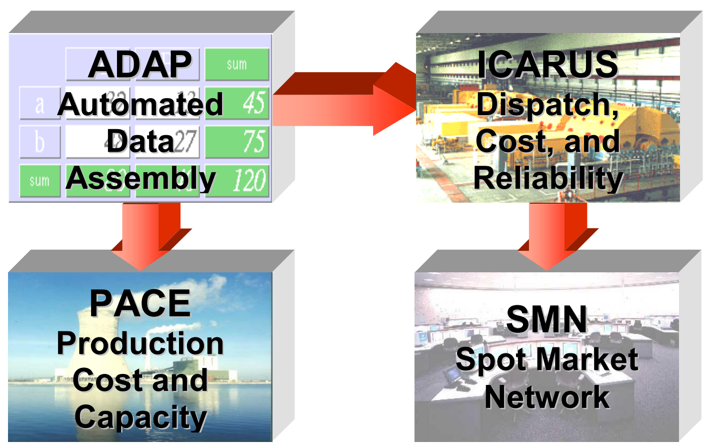
UNFCCC site: http://www.unfccc.de/resource/natcom/index.html
EPA site: http://www.epa.gov/globalwarming/publications/international/index.html

DECADES Tools — Databases and Methodologies for Comparative Assessment of Different Energy Sources for Electricity Generation. Developed and distributed by the International Atomic Energy Agency, the DECADES software tools include the DECPAC model, which integrates electric system expansion planning with the analysis of primary energy supply chains and computes the resulting environmental emissions.



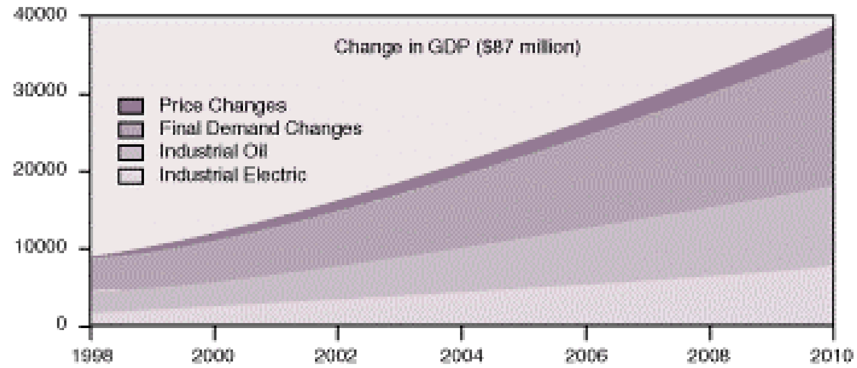
The model provides several levels of analysis (e.g., power plant, fuel chain, and electric power system) and facilitates comparative assessment of different energy sources for generating electricity. The DECADES databases include the Reference Technology Database (RTDB), the Country Specific Database (CSDB), the Toxicology Database (TOXDB), and the Health and Environmental Impacts of Energy Systems (HEIES) database. Argonne's training programs and technical expertise support the use of this software.

APEX — Argonne Production, Expansion, and Exchange Model for Electrical Systems. APEX integrates several modules that are used to evaluate production costs, reliability, transmission, and expansion alternatives for electric utilities. These modules are set up to transfer data among themselves. User-friendly menu systems allow for information input and evaluation of results. Each of the APEX modules shown in the figure is discussed later in this booklet.



Macroeconomic Models

AMIGA — Argonne Multi-sector Industry Growth Assessment Model. Based on general equilibrium principles and Milton Friedman's permanent income hypothesis, AMIGA assumes that prices will rise in a market to the point at which a commodity balance occurs — when supply equals demand. This macroeconomic analytical tool is used to investigate the impacts of advanced technologies and key policies on the economy.



AMIGA can be used to analyze many issues, such as energy consumption and supply, emission taxes, conservation measures, development of sustainable technologies, and new advanced technologies. In a study of the National Climate Change Action Plan, for example, analysts used AMIGA to identify the employment and gross domestic product (GDP) benefits of energy efficiency. The GDP change shown in the figure is related to impacts on intermediate variables (e.g., price changes, final demand changes, imported oil reductions, and resource allocation in electricity generation).

Currently, AMIGA integrates six major modules that focus on the areas listed below:

- Demand for goods and services
- Production and employment by sector
- National income accounts for calculating GDP
- Cost and pricing of commodities
- Labor market response
- Motor vehicle stocks and fuel consumption

AMIGA's modular structure contains more than 200 sectors and product lines that focus on the materials, energy, and manufacturing sectors. AMIGA uses data on domestic final demands, exports and imports, intermediate demands, sector outputs, employment, and fuel usage and its corresponding emissions. Special-purpose sectors can be added easily, and new technologies can be characterized in terms of sector input required for the product. Furthermore, AMIGA is designed to work along with data from an input/output model from a specified country.

When assessing the degree or level of impact, AMIGA relies on a larger set of more detailed data and accounts to determine the feedbacks and secondary effects among sectors. AMIGA can also be used to broaden or narrow the scope of an analysis; for example, researchers can study the impact of a new technology or policy for all sectors of the economy or for a single sector. The advantage of having a narrow focus is that the analysis can be extended through links with other sectors of the economy included in the model.

Energy Demand Models and Databases

Transportation Sector

IMPACTT — Integrated Market Penetration and Anticipated Cost of Transportation Technologies Model. IMPACTT is a stock adjustment model used to assess on-road changes in fleet fuel consumption and emissions, as the new light-duty vehicle mix of technologies changes over time. The model has been used to analyze infrastructure costs for Argonne's Partnership for a New Generation of Vehicles. In general, IMPACTT simulates survival and usage of vehicle stock. The model maintains vintage and technology-specific information and thus can estimate vehicle stock and use, energy use, and emissions by disaggregate categories such as fuel type, vehicle type, and technology.

IMPACTT can produce secondary outputs by fuel, vehicle type, size class, and technology. It also has been used to assess the impacts of engine technologies, alternative fuels, and lightweight materials. In one of its specialized versions, the model simulated the use of new and recycled aluminum and the resulting changes in energy use over a vehicle's life cycle.

IMPACTT was developed and is distributed by Argonne's Center for Transportation Research. For more information, visit http://www.transportation.anl.gov/ttrdc/assessments/energy.html.

EV-LCM — Electric Vehicle Life-cycle Cost Model. The EV-LCM estimates the life-cycle costs of electric vehicles (EVs) for their buyers in the United States. The model is based on an analysis of conventional vehicle costs, costs of drive train and auxiliary components unique to EVs, and battery costs. Conventional vehicle production and marketing costs are allocated to subsystems such as body, chassis, and power train. Since an electric drive replaces the conventional power train in EVs, a procedure for amortizing purchase price, replacement battery costs, and operating costs over a vehicle's lifetime is part of the methodology.

The procedure computes power requirements, purchase price, initial and replacement battery costs, and operating costs (e.g., electricity usage and maintenance). Battery costs are allocated to the individual pack's lifetime usage. The EV's discounted salvage value is deducted from the purchase price, excluding the cost of the first battery pack, and the balance is allocated to the lifetime distance traveled. Finally, the lifetime costs of an EV are compared with the costs of similar conventional vehicles, which identify the range limitation of EVs. EV-LCM has been used repeatedly to prepare comparative cost estimates for various types of electric-drive vehicles, with considerable sensitivity investigations.

The EV-LCM was developed and is distributed by Argonne's Center for Transportation Research. For more information, visit http://www.transportation.anl.gov/ttrdc/assessments/index.html.

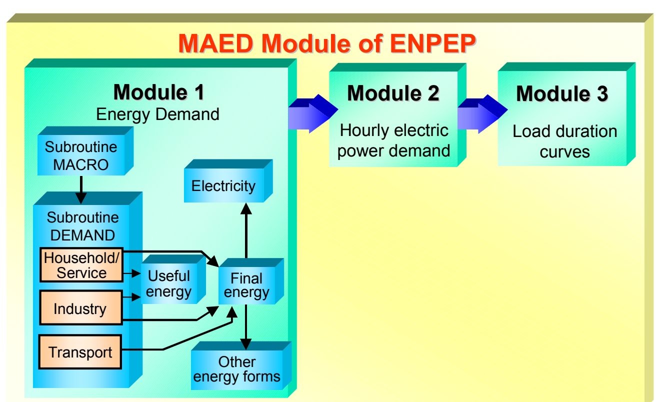
Industrial Sector

LIEF— Long-term Industrial Energy Forecasting Model (Version 2.0). The LIEF model addresses the penetration of production and energy-using technology into the industrial sector. The changes in energy intensity in industrial subsectors (11 manufacturing and 6 nonmanufacturing) are driven by price-independent technological improvement trends, energy price expectations, and investment behavior. Investment behavior is characterized by a hurdle rate for capital recovery and a penetration rate, reflecting normal or accelerated capital stock turnover. LIEF computes a target, or idealized, ratio of energy use to output. The gap between the ideal and the actual energy intensity changes over time, as reflected by the user inputs for investment behavior, price changes, etc. LIEF enables a direct comparison of results with conservation supply curves from detailed engineering analyses. The latest version is calibrated to a base year of 1998, making use of the most recent industrial energy and production data available from the Manufacturing Energy Consumption Survey and the Annual Survey of Manufacturing.

Residential Sector

DIAM — Distributive Impacts Assessment Model. DIAM is an analytical tool that quantifies the impact of energy policies on minority energy consumption, expenditures, and economic welfare. DIAM assesses energy consumption differences among diverse population groups. The model has been used for the Residential Energy Consumption Surveys provided by the U.S. Department of Energy's Energy Information Administration.

Multisector Models



ENPEP-MAED Module — Model for Analysis of Energy Demand. Described as a strategic, scenario-based, simulation model, MAED performs long-term energy and electricity demand forecasting. Future energy demand is estimated by using a bottom-up approach in which useful energy demand needs for specific activities are projected. Energy consumption levels for individual activities are then aggregated to project total future demand for fossil fuels, electricity, district heating, coke, and feedstocks in each sector/subsector of the economy.

Designed to reflect the structural changes in energy demand, MAED performs detailed analyses of social, economic, and technological developments, as well as policy issues. The latest version is spreadsheet-based and offers much more flexibility in defining a country's energy system representation.

ENPEP-DEMAND Module. The DEMAND module allows analysts to define a base-year energy consumption pattern that includes fuel use and useful energy requirements. The future demand for energy is determined by relating the growth in energy demand to one or more economic and/or demographic variables through an elasticity relationship. The DEMAND module is applicable to all energy-using sectors of the economy.

U.S. Bureau of the Census Industrial Data. Argonne has entered into a partnership with the Chicago Federal Reserve and three area universities — the University of Chicago, Northwestern University, and the University of Illinois, Chicago — to establish a research center. The purpose of this regional data center (RDC) will be to access the micro-data that underlie the population and economic surveys collected by the Census Bureau. Under Title 13 of the U.S. Code, these data are confidential; however at the RDC, Argonne staff with "special sworn access" can use these confidential micro-data. As long as the analysis does not identify a specific person's or firm's activities, analytic results can be released publicly. The ability to access micro-level data, rather than aggregate data, significantly enhances the information that can be obtained.

Plant-level economic data come from the Longitudinal Research Database (LRD). This database consists of annual economic activity data (e.g., labor energy and materials cost, plant and equipment investment, and total shipment of output in manufacturing plants) from the Census of Manufacturers and from the Annual Survey of Manufacturers, linked to form an unbalanced longitudinal panel. Examples of other micro-data sets that can be linked to the LRD are listed in the table. These enriched data sets provide researchers with new tools to test hypotheses and examine policy options.

For many years, researchers have come to the Census Bureau to use confidential demographic micro-data (i.e., not public-use files), which have restricted geography and which "top code" many continuous variables such as income. Making confidential demographic data (e.g., Decennial Census Long Form Data, American Community Survey, and others) available at RDCs constitutes a major expansion of access.

Information in these data sets can be linked to other sources of information, either public or private, or can be geocoded to provide more geographic detail, which enhances research potential. These data sets comprise the most detailed information available in the United States for policy studies, including energy demand and other studies of consumer behavior.

Examples of micro-data sets that can be linked to the Longitudinal Research Database
Survey of Manufacturing Technology Database
Pollution Abatement Cost and Expenditures Database
Manufacturing Energy Consumption Survey Database
Research and Development

Energy Technology Characterization Models and Databases

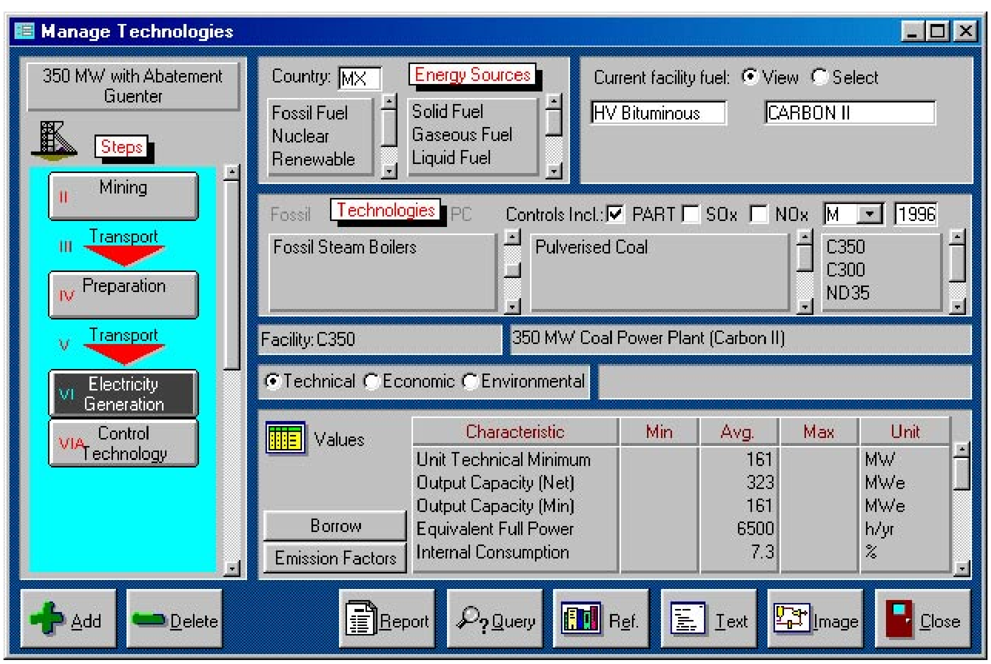
Electric Power Technologies

APEX-ADAP — Automated Data Assembly Package Module. Coupled with a database that contains general information about all of the operating power plants in the United States, ADAP's data assembly and query system includes information on various elements of each unit. Information is included on:

- Design – size, technology used, fuel type, and operational date;
- Performance – heat rates, forced outage rates, and maintenance requirements;
- Costs – capital, operating, and fuel;
- Historical loads – annual, monthly, and peak; and
- Administrative information – owner and power pool participation.

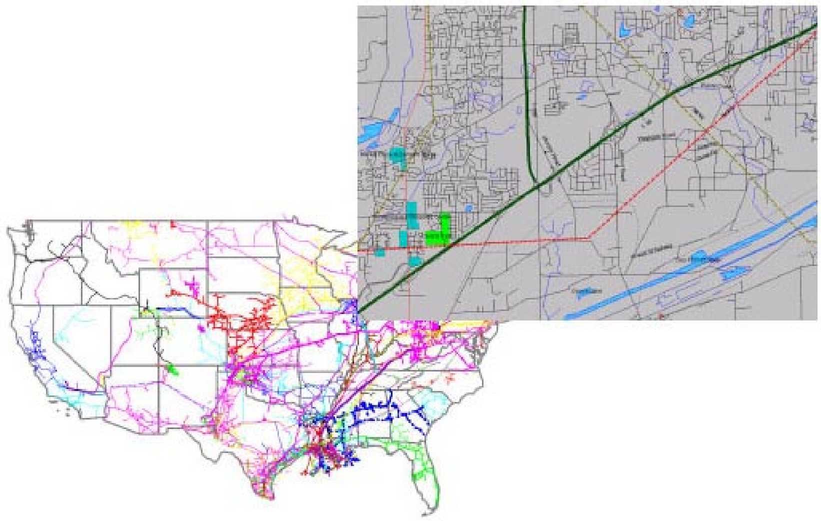
ADAP extracts this information for use in other models.

DECADES RTDB/CSDB — Reference Technology Database and Country Specific Database. Maintained by the International Atomic Energy Agency, the DECADES databases contain information on a wide range of electric power generation technologies: performance, cost, operation and maintenance requirements, and environmental residuals generated. In addition, the databases have information on portions of the fuel supply chain that provide the energy for each power generation system. The RTDB contains generic information, whereas the CSDB contains country-specific information from around the world.



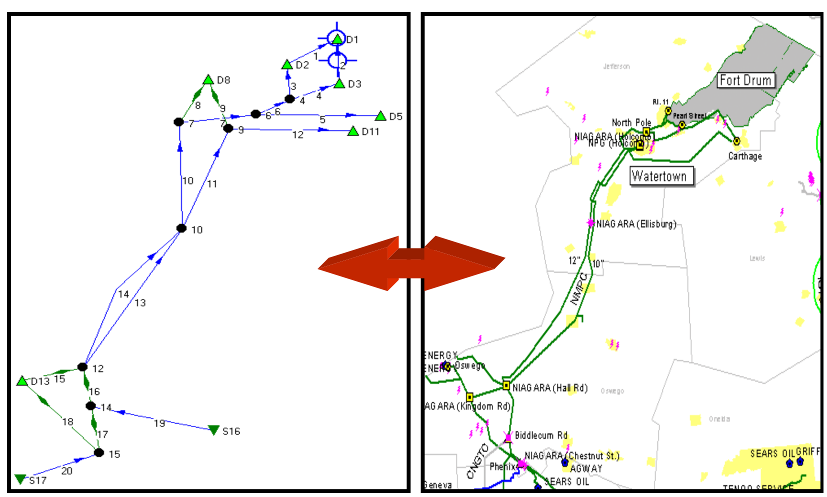
Natural Gas Technologies

GASMAP — Geographic Analysis System for Market Assessment and Planning. GASMAP combines a geographic information system and a relational database system that provide information on the U.S. natural gas infrastructure. GASMAP can be used to locate the pipelines of any gas transmission company on a map at varying levels of detail. Information can then be accessed on capacity (pipe diameter, length, and maximum operating pressure); flows (peak day, average day, receipt and delivery points, storage, and delivery volume); and financial parameters (gas purchases, gas prices, sales volumes, operating and maintenance costs, and balance sheet). Because GASMAP is loaded on a remote server, multiple users can access information from their own locations.



NGview. NGview decreases the time required to develop a natural gas (NG) network topology, including pipeline links (uni- or bi-directional) and pipeline nodes (e.g., delivery points, supply points, and interconnections). NGview helps link spatial and relational data sets, which could include thousands of pipeline segments and points. Once these links have been established, data can be updated with minimal effort, providing quick turnaround time for studies.

The model's database interface links to simulation tools, such as NGflow and NGcut. NGview greatly improves the viewing and under-standing of simulation results because analysts can toggle between schematic and geographical information system views.

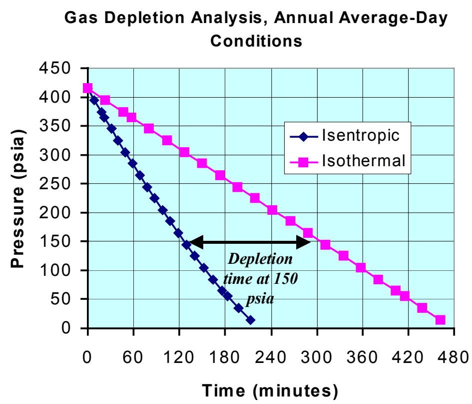


NGflow. NGflow identifies critical links and nodes in a network topology. This tool provides an alternative to using very detailed, data-intensive commercial flow simulation models.

NGflow simulates steady-state gas network flows and provides gas flow movements under various operating conditions based on gas flow balancing algorithms and available system flow data. The model also gives a unique snapshot of the gas transmission infrastructure that supports a certain location or site. NGflow is used extensively in analyses of U.S. natural gas network issues.

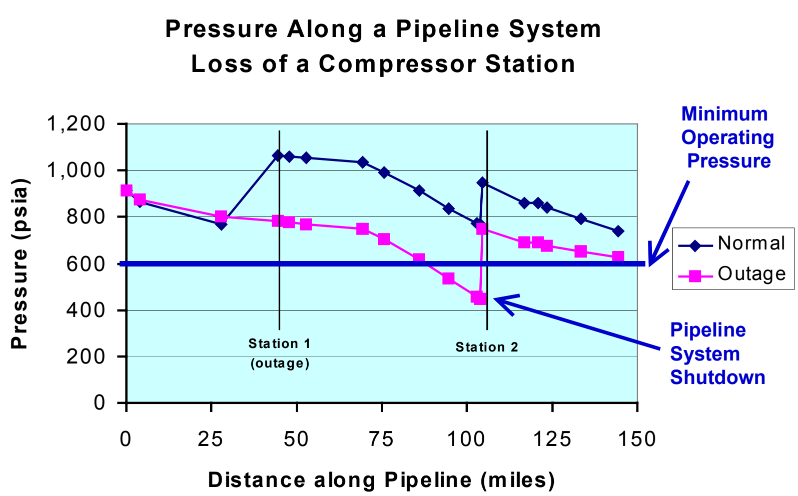
NGdepletion. NGdepletion addresses outage duration times and determines whether and when a component outage will affect a specific location or site. The model computes the amount of time that the line pack will be able to continue to supply gas.

NGdepletion is used extensively in analyses of U.S. natural gas network issues and in studies of electricity-gas interdependency issues.

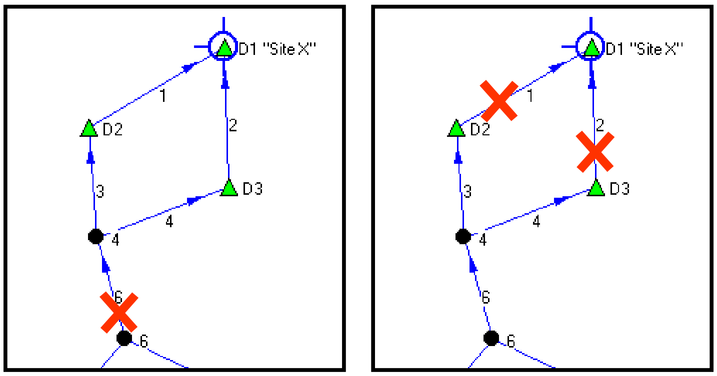


NGpressure. NGpressure determines how the loss of a critical link or node under various operating conditions might affect a natural gas system. The model addresses central issues such as: "Can the system continue to deliver gas to a certain location or site if a key city-gate is disrupted under both average and peak day conditions?"

The model is based on the premise that the ability of a pipeline to deliver natural gas depends directly on operating pressure. NGpressure uses standardized industry equations and various data sources, and is used extensively in analyses of issues associated with the U.S. natural gas network.



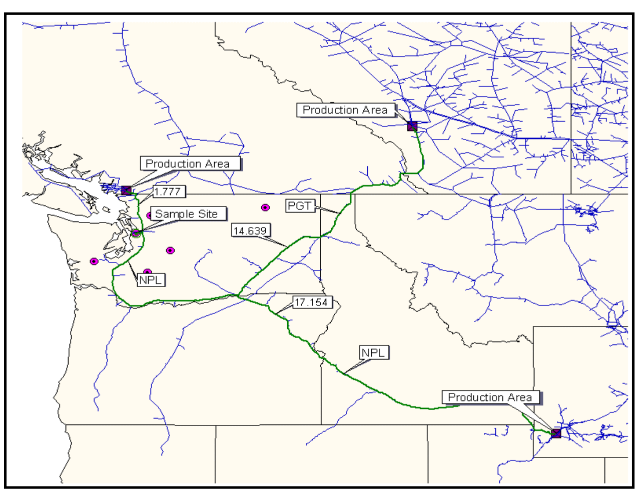
NGcut. NGcut determines network component failure sets that could isolate a specific location or site from all supply sources. One of the advantages of using this model is that it significantly decreases the time needed to analyze site isolation issues by automating the construction of failure sets. The model also allows analysts to consider a larger number of failures and to broaden an analysis. NGcut is used extensively in analyses of issues associated with the U.S. natural gas network.



Primary Failure Set   Secondary Failure Sets

NGlocator. This GIS-based tool quickly identifies distribution companies for areas or sites. It improves the efficiency of natural gas analysis by reducing the time needed to identify local distribution companies and to assemble background data for the local infrastructure network. It also provides reports and maps that are helpful in conducting analyses.

NGanalyzer. NGanalyzer assists in analyzing identified gas engineering vulnerabilities, such as the number of city-gates, available storage, and pipeline capacity and interconnection. The figure shows an example of the shortest path distance from major gas supply areas to a sample site as calculated by the model. NGanalyzer is used extensively in analyses of issues associated with the U.S. natural gas network.



Supply/Demand Balance Models

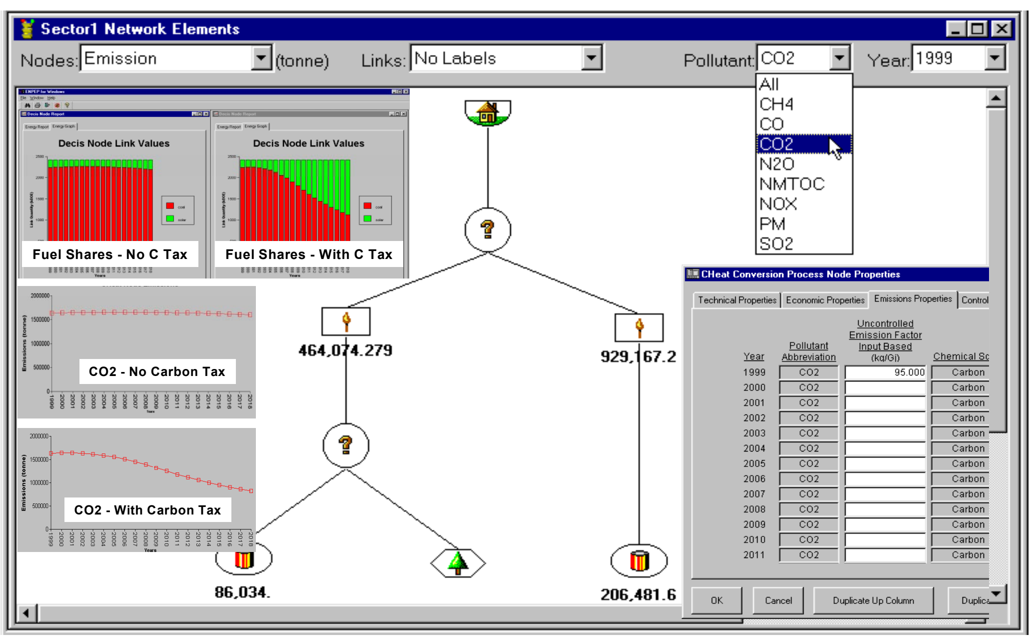
Total Energy Systems Analysis

ENPEP-BALANCE Module. The nonlinear equilibrium BALANCE module matches the demand for energy with available resources and technologies. Its market-based simulation approach allows BALANCE to determine the response of various segments of the energy system to changes in energy prices and demand levels. The model relies on a decentralized decision-making process in the energy sector, and can be calibrated to the different preferences of energy users and suppliers.

ENPEP uses a network that consists of different nodes and links, which represent various energy systems. Nodes in the network represent depletable and renewable resources, various conversion processes, refineries, thermal and hydro power stations, cogeneration units, boilers and furnaces, marketplace competition, taxes and subsidies, and energy demands. Links connect the nodes and transfer information among nodes.

ENPEP is very versatile in that the analyst starts with an empty workspace and builds an energy system configuration of nodes and links. ENPEP's powerful graphical user interface makes it is as easy as "drag and drop" to build networks of regional, national, or multinational scope. Drop-down menus can be used to display model inputs and results directly within the energy network. Double-clicking the nodes allows access to more detailed information.

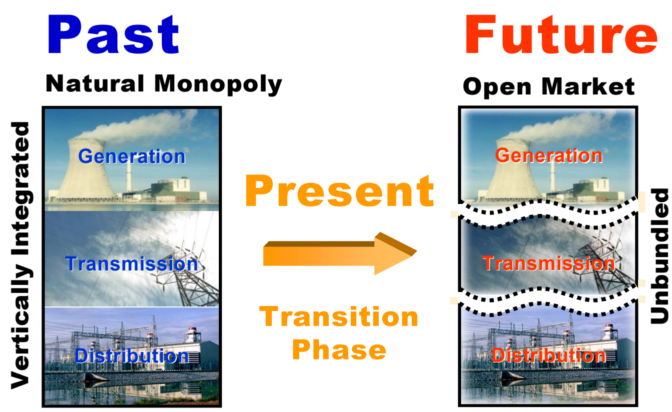
The latest BALANCE version also incorporates calculations of environmental residuals, such as atmospheric pollution, water effluents, and waste generation. Greenhouse gas emissions can be reported in a format that is compatible with the Intergovernmental Panel on Climate Change. BALANCE is used extensively in the global community to conduct greenhouse gas mitigation analyses, energy policy studies, and natural gas market analyses.



Electric Power Systems Analysis

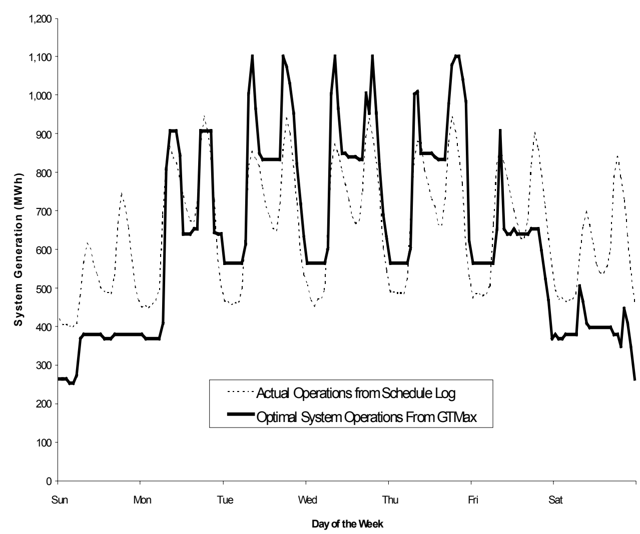
GTMax — Generation and Transmission Maximization Model. In the global community, operators and managers are challenged daily by complex and ever-changing physical, environmental, economic, and institutional constraints, especially when determining how to use utility power systems most effectively. In many countries, vertically integrated power systems are being transformed into open power markets in which generation, transmission, and distribution are unbundled. Utility system planners are now recognizing the benefits — economic, financial, and reliability — of entering into power and energy transactions with neighboring countries and systems. These advantages can be realized through firm contracts, spot market transactions, and emergency intertie agreements.

The GTMax model helps researchers study complex marketing and system operational issues. With the aid of this comprehensive model, utility operators and managers can maximize the value of the electric system, taking into account not only its limited energy and transmission resources, but also firm contracts, independent power producer (IPP) agreements, and bulk power transaction opportunities on the spot market.



GTMax maximizes net revenues of power systems by finding a solution that increases income while keeping expenses at a minimum. At the same time, the model ensures that market transactions and system operations remain within the physical and institutional limitations of the power system. When multiple systems are simulated, GTMax identifies utilities that can successfully compete in the market by tracking hourly energy transactions, costs, and revenues.

An added benefit of GTMax is that it simulates some limitations, including power plant seasonal capabilities, limited energy constraints, transmission capabilities, and terms specified in firm and IPP contracts. Moreover, GTMax also considers detailed operational limitations, such as power plant ramp rates and hydropower reservoir constraints.



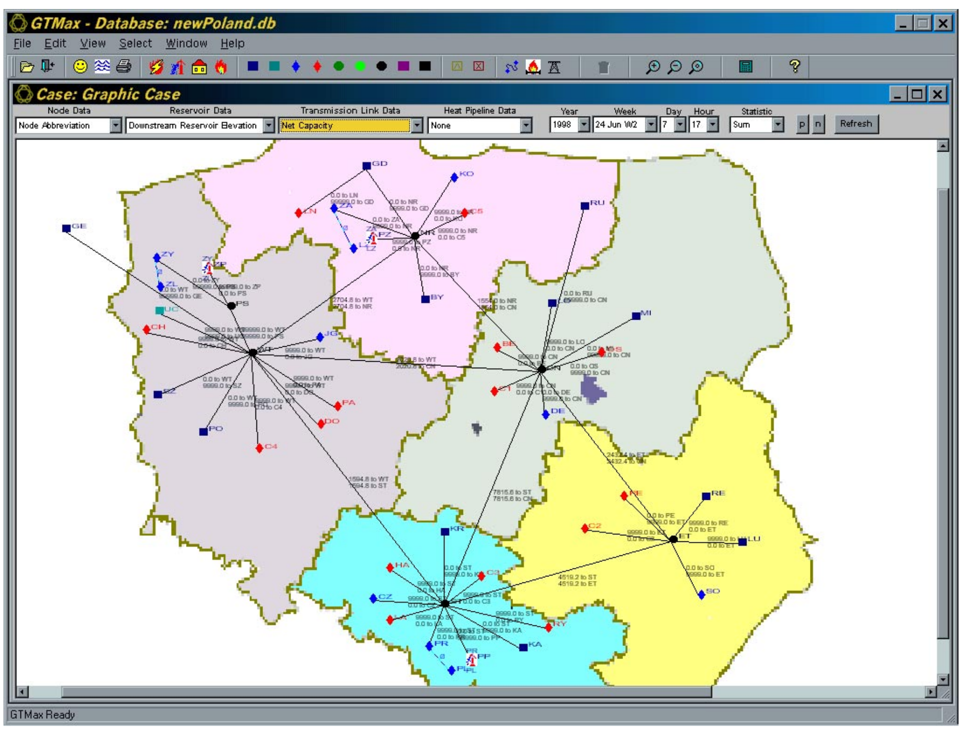
Currently, utilities are using GTMax to determine hourly, weekly, and seasonal power and energy offers to customers and to compute the costs of environmental legislation. GTMax can also be used to fine-tune hourly resource generation patterns, spot market transactions, energy interchanges, and power wheeling on the transmission system.

An added value of the GTMax model is that it produces financial reports, which help dispatchers identify operational strategies to optimize the value of the system's resources, while continuing to take full advantage of market opportunities.

Data from GTMax are presented in easy-to-understand tables and graphs, providing information such as which units should be dispatched, how much power should be generated and sold on an hourly basis, when to buy and sell power on the spot market, the cost of alternative power plant operations, the incremental value of water, and the value of demand-side management programs.

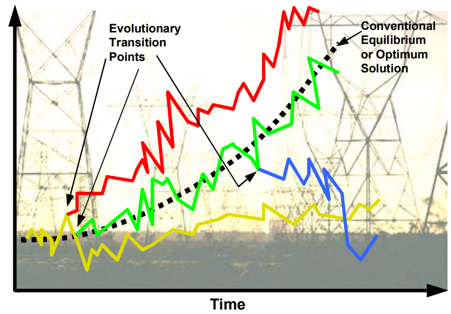
GTMax also gives financial market clearing prices, which can be used to determine whether an investment is financially viable, given the prevailing market rules for bidding, capacity credits, and ancillary services. In addition, GTMax looks at locational issues when building new power plants or transmission lines, identifying regions with high marginal values that may be more attractive for future investments.

This user-friendly model operates under a Windows environment and employs a geographical information system interface. Users can point and click on a map of utility power plants to modify input data and obtain optimization results, while simultaneously viewing two or more scenarios. Hourly energy flows from supply resources such as generators and IPP firm contract purchases to load centers and spot market delivery points are graphically displayed on a map (see example).



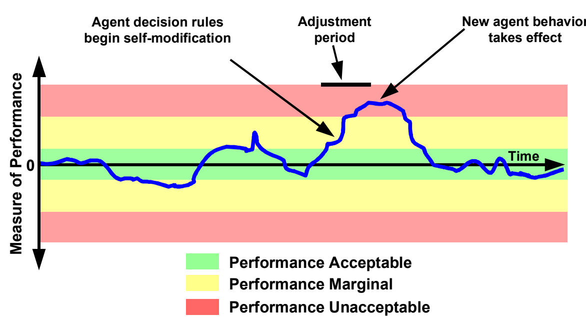
EMCAS — Electricity Market Complex Adaptive Systems Model. As energy systems are privatized and deregulated, control shifts from a single decision maker, such as a government-owned electric utility, toward an open market with many new participants. Each participant seeks independent objectives and uses different decision-making methods.

Conventional optimization techniques used in energy systems analysis are based on a single decision maker who wants to either maximize or minimize a particular objective. Standard equilibrium simulation techniques assume that systems gravitate to an equilibrium point at which all participants reach a common ground — one that represents the best compromise for all parties.



Neither of these techniques can capture transitory fluctuations driven by system evolution, nor identify inflection points, phase transitions, or critical conditions under which systems diverge from the past in totally new and unanticipated ways. The State of California's struggle with electricity deregulation is an example of the shocking instability that cannot be adequately simulated by current analysis techniques.

EMCAS utilizes agent-based modeling (ABM) rather than traditional optimization or equilibrium techniques. ABM incorporates many individual decision-making agents each of which is a self-directed entity. Until now, most ABM applications have been in the social and biological sciences, with very simple agents and few decision rules. In EMCAS, agents have complex decision rules with access to an array of historical (e.g., past power prices) and projected (next-day weather) data. The complex adaptive systems (CAS) approach empowers agents to learn from previous experiences and change their behavioral strategies when future opportunities arise. Genetic algorithms provide a learning capability for specific agents. An emerging research field, CAS modeling is just beginning to be applied to energy systems analysis.



One of the primary differences between CAS modeling and traditional approaches is the strong focus on dynamics, which enhances the ability to investigate change. Most large-scale systems are moderately stable until they reach a crisis; however, this stability is often chaotic and unpredictable. Creating models of these systems requires careful balancing of the "forces" that contribute to dynamic stability. This work focuses on the electricity and natural gas systems because they are undergoing dramatic changes and are a focal point, given the latest developments in energy markets around the world.

EMCAS will simulate up to a 30-year period at a one-hour resolution using a large number of input parameters. This scale of deployment requires the development of new distributed ABM techniques and new and efficient XML-based data retrieval and manipulation techniques for distributed environments. XML allows highly flexible data exchange, is easily reusable for new processes, is hardware and software independent, and leverages many emerging technologies. EMCAS is envisioned to operate in a distributed ABM environment with potentially one workstation per agent group.

By using ABM, EMCAS empowers its users to understand the emerging privatized and deregulated energy systems. This improved understanding can lead to better decisions and enhanced outcomes.

ENPEP-WASP Module — Wien Automatic System Planning Package Model. This widely used model analyzes generating system expansion options, primarily to determine the least costly expansion path that will adequately meet the demand for electric power, subject to user-defined constraints. To measure the economic performance of alternate expansion plans, WASP uses the present value of total system costs, including the capital cost of new generating units, fixed/variable operation and maintenance costs, fuel costs, and costs of unserved energy.

Probabilistic simulation is used to calculate the production costs and reliability parameters for numerous possible future system configurations, and a dynamic programming technique is used to determine an economically optimal expansion path for the electric power system under consideration. System reliability is evaluated on the basis of three indices: reserve margin, loss-of-load-probability, and unserved energy. These indices, along with the maximum number of thermal or hydroelectric units that can be added each year, are user-specified constraints required for acceptance of an expansion plan.

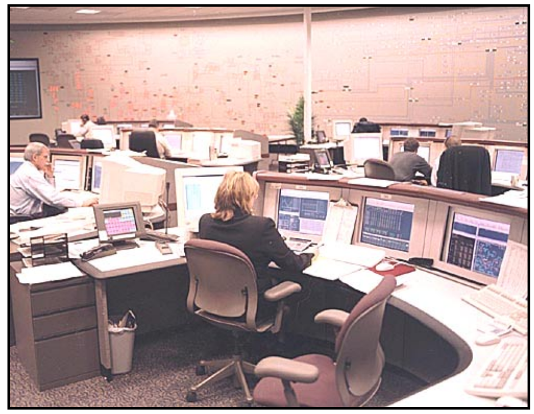
WASP's modular structure permits users to monitor intermediate results during the iterative optimization process. A new Windows version (WASP-IV) is now available. WASP-IV considers pumped-storage plants; allows specification of a fixed maintenance schedule for units in the system; computes atmospheric emissions; and introduces new constraints on total emissions, fuel consumption, and electricity generation. WASP was developed and is distributed by the International Atomic Energy Agency. Argonne provides technical support.

DECADES-DECPAC Module. The DECPAC module generally follows the same analytical procedure as WASP, but its computational routine is simplified. Users evaluate not only electric power generation technologies, but also the fuel supply chain for each technology. DECPAC allows comparative analyses of alternative power generation technologies. Developed and distributed by the International Atomic Energy Agency, DECPAC receives technical support through Argonne.

ENPEP-APEX ICARUS — Investigation of Cost and Reliability in Utility Systems Module. The ICARUS module is an energy-system planning tool that assesses the reliability and economic performance of alternative expansion patterns of electric utility generating systems. This detailed dispatch model calculates (1) a system maintenance schedule (if not fully specified), (2) system loss-of-load probability, (3) unserved demand for electric energy, (4) reserve capacity needed to meet a specified reliability criterion, (5) effects of emergency interties, (6) expected energy generation from and cost of each unit and block, (7) total generating system costs, and (8) fuel use.

The simplified probabilistic simulation technique provided by ICARUS significantly reduces computational requirements. Its calculations are based on system loads, unit-level generating resources, system operational constraints, and capacity and energy transfers among utility systems.

APEX-SMN — Spot Market Network Model. The SMN multipurpose power network analysis tool can be used for a wide range of applications. At a relatively high level of aggregation (e.g., company level), the model determines the level of economic energy transactions between utility companies so that overall costs are minimized. At a finer level of detail (e.g., unit level), the SMN determines the optimal dispatch of units, while considering unit-level operational restrictions and transmission limitations.



The SMN network consists of a set of nodes and links. Nodes in the network represent generating resources and load centers. Generating resources are characterized as piecewise linear marginal cost curves, while load centers are represented by estimates of hourly electricity demand. Nodes are connected via links that correspond to transmission lines with limitations and line losses for power flows between nodes.

The model minimizes production costs subject to the utility-specific minimum profit margins that trigger spot market transactions. The SMN also recognizes line rights and includes wheeling, sales-for-resale transactions, and line usage reserved for long-term firm transactions. Inadvertent power flows can be factored into the simulation by adjusting line capacities in one or both directions or by using power transfer distribution factors derived from power flow models.

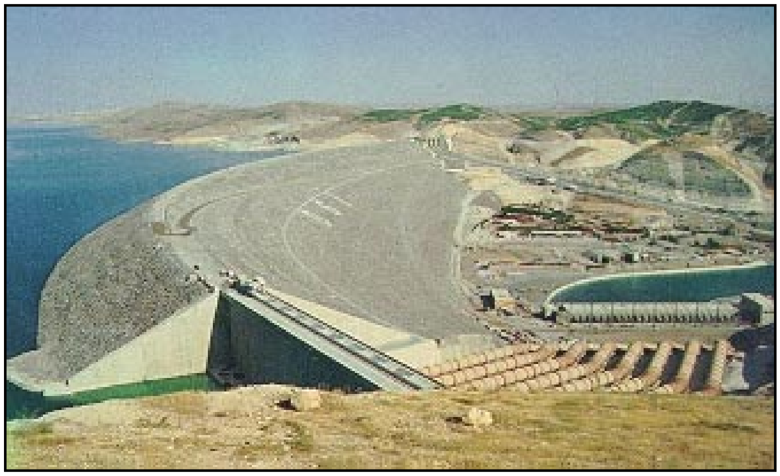
APEX-PACE — Production and Capacity Expansion Model. The PACE model is a dynamic program used to determine long-term utility capacity expansion schedules. New units are added on the basis of existing supply resources, candidate technologies, load growth estimates, and long-term firm contracts. The model also expands system capacity so that reliability constraints are not violated.

PACE uses the ICARUS model to estimate unit-level generation, production costs, and system loss-of-load probabilities for possible capacity expansion paths. The model then takes these costs, along with the costs of capital investments and fixed operations and maintenance, to estimate the least-cost expansion path and suboptimal expansion paths.

APS — Argonne Peak Shave Model. The APS model simulates hourly electricity generation from hydropower plants, thereby minimizing the maximum load on a utility's thermal resources. The algorithm accounts for minimum flow requirements, maximum plant capacity, and up- and down-ramp rates. Peak loads are minimized over a user-specified time frame (i.e., day, week, month, or season).

PC-VALORAGUA (Value of Water) Model. The primary objective of this model is to determine the optimal generating strategy of mixed hydrothermal electric power systems. The optimal operation strategy is obtained for the system as a whole, with an emphasis on detailed simulation and optimization of the hydro subsystem operation.

PC-VALORAGUA can simulate the operation of all types of hydropower plants (run-of-river, weekly, monthly, seasonal, or multiannual regulation), including pumped-storage plants and multipurpose hydro projects. The model calculates possible production of hydropower plants based on either a historical series of monthly water inflows or synthetic water inflows with associated probabilities of occurrence.



This versatile model works with the hydraulic network of a country (or region) and can determine the optimal operation of up to 50 reservoirs in as many as 18 hydro-cascades in the system. The most outstanding feature of PC-VALORAGUA is that it can calculate the marginal value of water in reservoirs at all times of the year. The mathematical expectancy of the future value of water is the basis for deciding whether to use the water from the reservoirs now or to retain it for later use.

ALF — Argonne Load Flow Model. The ALF model simulates real and reactive power flow through individual lines and transformers, as well as voltage magnitudes and angles at all network nodes. The model helps predict the response of a system to changes in load, generation, and line reinforcements (or outages).

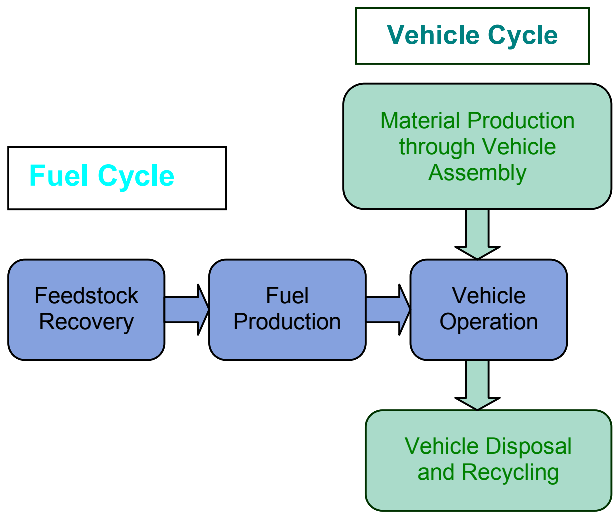
ALF uses either the Fast Decoupled or the Newton-Raphson iterative technique to solve simultaneous node voltage equations describing the network. The submodules for network reduction and for conversion into a DC model enhance the value of the model.

This PC-based system can handle up to 20,000 buses and 30,000 branches (lines and transformers).

Impact Assessment Models and Databases

Energy System Residuals Generation

GREET — Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model. Designed to analyze energy and emission effects of new transportation technologies and the use of alternative transportation fuels, GREET evaluates technologies on the basis of what is commonly referred to as the "total energy cycle." It estimates per-mile energy-cycle emissions and energy use of both near- and long-term transportation technologies, while calculating energy-cycle emissions for five criteria pollutants and three greenhouse gases. The model also calculates the total energy, fossil fuel, and petroleum consumption that results from the use of various transportation fuels.



The U.S. Department of Energy's Office of Technology Utilization has used this full fuel-cycle model for light-duty vehicles in rulings on alternative fuels. Currently, more than 100 organizations use the model and its results, including car manufacturers, oil companies, government agencies, universities, and research institutions in North America, Europe, and Asia.

The GREET model was developed and is distributed by Argonne's Center for Transportation Research. For more information about the model, visit http://www.transportation.anl.gov/ttrdc/greet/.

AirCred — A Tool for Calculating Alternative Fuel Vehicle Emission Reduction Credits for Air Quality Planning. An official model of the U.S. Environmental Protection Agency (EPA), AirCred allows fleets and metropolitan areas to estimate emissions credits via introduction of alternative-fuel vehicles (AFVs). AirCred was originally developed to assist the U.S. Department of Energy's Clean Cities coalitions in estimating the ozone precursor emission reduction credits earned by acquiring original equipment manufacture AFVs.

AirCred is a graphical user interface-based calculation model that provides an easy, straightforward way to total the values of those credits with Voluntary Mobile Source Emission Reduction Program (VMEP) credits given for other local voluntary strategies and programs earned pursuant to the EPA's October 1997 guidance about VMEP initiatives. AirCred is based on EPA's MOBILE5b model, combined with emission test certification data for new vehicles and their gasoline- or diesel-fueled counterparts.

Recently, the EPA has proposed an expansion of AirCred to compute AFV emission reduction credits for ozone in state implementation plans, and the U.S. Department of Transportation has approved its use for estimating the benefits of AFV acquisition in applications for Congestion Mitigation and Air Quality program grants. Further enhancements and updates to the model are funded jointly by DOE/EPA. AirCred was developed and is distributed by Argonne's Center for Transportation Research.

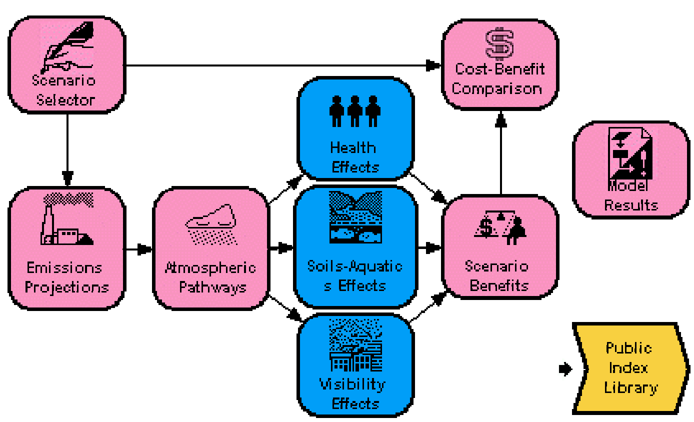
For more information, including the Users' Guide and details about the AirCred model, visit http://www.transportation.anl.gov/ttrdc/assessments/ct24-AIRCRED.html.

Air Pollutant Transport and Effects

RAINS-Asia — Regional Air Pollution Information and Simulation Model for Asia. RAINS-Asia assesses the effects of atmospheric emissions on human health and ecosystems throughout Asia. Currently, Argonne staff use the model to assess various energy and environmental issues in Asia, especially China. Typically, researchers study energy and coal-use policies and how they influence atmospheric emissions; assemble emission inventories of various species using energy and other activity data; investigate long-range transport of pollutants in the region; assess the costs of mitigation strategies; estimate the human health impacts of air pollution in Asian cities; and estimate the long-term damage to ecosystems.

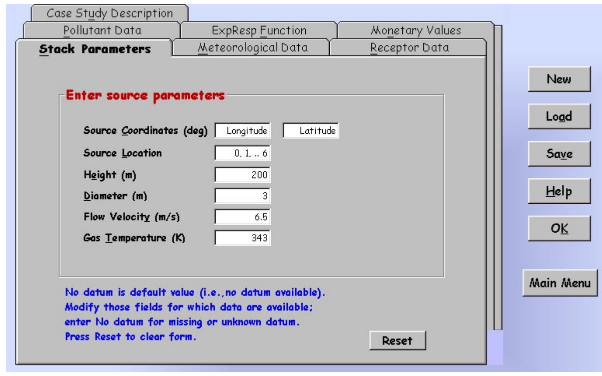
The RAINS-Asia model is installed in government agencies throughout Asia as a planning tool. It has also been used by The World Bank and the Asian Development Bank to guide project investment decisions. Developed under funding from The World Bank and the Asian Development Bank, the model is maintained by the International Institute for Applied Systems Analysis in Laxenburg, Austria. Argonne was part of a consortium that initiated the project and helped construct the model.

TAF — Tracking and Analysis Framework. This integrated assessment framework evaluates the status of implementation, the effectiveness, and the costs and benefits of acid deposition control programs such as those created by Title IV of the U.S. 1990 Clean Air Act Amendments. The TAF set of modules includes seven submodels: (1) scenario selector, which specifies alternative control strategies; (2) emissions projections, which determines the emissions of air pollutants on a spatially defined basis; (3) compliance costs, which calculates the costs for each emission source to comply with the control strategy under study; (4) atmospheric pathways, which calculates pollutant dispersion, chemical transformation, and deposition to determine expected concentrations; (5) effects modules, which determine the effects of exposure to the calculated concentrations on health, soils and aquatic environments, visibility, crops, forests, and materials; (6) benefits evaluation, which estimates the monetary value of the effects; and (7) model results, which displays the output of the analyses.



Argonne collaborated with ten other institutions in developing TAF. For more information about this model, visit http://www.lumina.com/taf/index.html.

AIRPACTS — A Simplified Tool for Assessing the Impacts and Damage Costs to Human Health, Agricultural Crops, and Materials from Atmospheric Releases. AIRPACTS calculates the physical impacts and the associated damage cost for particulate matter, sulfur dioxide, nitrogen oxides, carbon monoxide, and secondary species such as nitrate and sulfate aerosols. A detailed environmental impacts analysis typically requires a very complex, data-intensive multidisciplinary study, including emissions projections, local and regional dispersion analysis, estimation of physical impacts using exposure-response functions, and monetarization of impacts. Large uncertainties often occur because required data are either incomplete or missing.



AIRPACTS provides a simplified approach that helps analysts develop a first estimate of potential damage from air pollution, both physical and economic. The model is adaptable to data availability because several levels of simplifications have been built in. At the simplest level, it requires only four input variables. As more information becomes available (e.g., local population and meteorological statistics), users can develop a more detailed analysis framework.

This design is especially valuable to developing countries that have little data available but over time may acquire more detailed information. AIRPACTS is currently used in more than 20 countries. The model was developed and is distributed by the International Atomic Energy Agency. Argonne's programs and technical expertise support the use of this software.

CASRAM — Chemical Accident Statistical Risk Assessment Model. CASRAM uses stochastic routines to simulate energy system and other industrial accidents involving hazardous substances. It estimates chemical release rates, vapor cloud transport and dispersion, and downwind public health consequences and health risks from chemical-specific exposures. The model simulates pressurized and nonpressurized liquid spills onto surfaces, evaporation from pools, and the dispersion of the resulting vapor cloud, and then predicts hazard exposure zones. Releases can be modeled from ruptured vessels of hazardous materials either in transit or at a fixed facility.

CASRAM uses a Monte Carlo statistical approach, whereby certain input parameters are selected at random. Stochastic parameters include accident location and time, spill fraction for selected container types, and spill coverage area. Statistical distributions of meteorological conditions, for the location and time of each modeled accident, are generated from five years of National Weather Service observational records of surface and upper-air recording stations. Together, these data characterize source strengths and transport and dispersion conditions, which are utilized to produce the hazard-zone distributions.

This model has been used to quantify health risks to the public that are associated with hazardous material shipments in the continental United States. A deterministic version of CASRAM, called the Chemical Accident Deterministic Consequence Assessment Model, assesses consequences from a single or small set of chemical accident scenarios associated with a plant location or process site. The CASRAM model was developed and is distributed by Argonne's Environmental Assessment Division.

FIREPLUME Model. An advanced stochastic code, the FIREPLUME model simulates atmospheric plume dispersion and estimates the downwind consequences of toxic substances generated in industrial facility (e.g., petroleum refinery) fires and/or explosions. The model accounts for plume rise from the thermal buoyancy induced from chemical-accident–generated fires and also provides concentration time histories. FIREPLUME is an extension of the Monte Carlo Lagrangian Dispersion Model (MCLDM).

Of particular value is FIREPLUME's ability to match the rising centerline phenomenon (thermal liftoff) that has been observed with plumes from surface releases under convective conditions (convective liftoff). The model has been extended to treat dispersion in stable and near-neutral conditions and incorporates a refined Monte Carlo treatment of surface layer physics to better estimate ground-level concentrations. The FIREPLUME model was developed and is distributed by Argonne's Environmental Assessment Division.

SMOKE. The SMOKE model predicts the dispersion of aerosols and gases over complex terrain and takes account of the effects of vegetation. The model accepts data in a wide range of forms and levels of detail and predicts concentrations with time, dosages, and isocontours. Currently being considered as a guideline model for intermittent releases, SMOKE was developed and is distributed by Argonne's Environmental Assessment Division.

SACTI — Seasonal-Annual Cooling Tower Impacts Model. The SACTI model predicts seasonal-annual impacts of the vapor plume, fogging, icing, shadowing, and drift deposition from natural and mechanical-draft cooling towers. Applied by more than 100 user groups in the United States and worldwide, including Korea and China, SACTI was developed and is distributed by Argonne's Environmental Assessment Division.

ACA — Air Compliance Advisor. The ACA model helps environmental personnel develop cost-effective air pollution compliance strategies for specific installations. ACA has analytical capabilities for (1) evaluating the applicability, technical feasibility, and cost of various air pollution control technologies and (2) estimating emissions of volatile organic compounds, hazardous air pollutants, and particulate matter from a multitude of industrial and energy production sources. Users can perform "what if" analyses to help discern the advantages and disadvantages of control and/or mitigation options.

The model also has a number of prototype-level features, including databases and applicability matching engines for regulations, emissions trading, and pollution prevention alternatives. The ACA model was developed and is distributed by Argonne's Environmental Assessment Division.

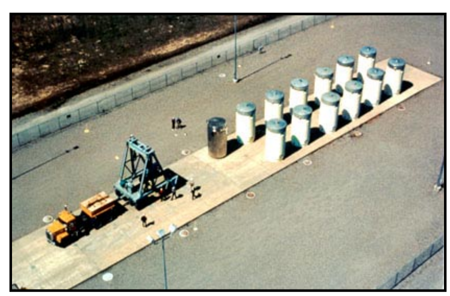
Hazardous and Radioactive Waste Generation and Management

WasteSIMS. WasteSIMS, an interactive modeling tool, is designed to assist in toxic waste processing. The system analyzes the costs and risks of treatment, storage, and disposal of toxic waste and then quantitatively describes the risks, possible health effects, and costs of different waste processing alternatives. The quantitative results are based on many factors, including the chemical composition of the waste, the radionuclides present, the short- or long-term contaminant dose-response of individuals or populations, respectively; the costs of processing facilities and waste transportation; and the geographical configurations of the waste processing alternatives. The WasteSIMS model is composed of a client/server geographic information system interface connected to independent cost and risk models.

WASTE_MGMT. This computational database tracks waste streams and emissions from storage through various prescribed treatment technologies to disposal. Inputs include amounts, radiological and hazardous contaminant profiles, physical characterizations of the wastes to be processed at each site, and specifications of treatment processes and key partitioning factors. Outputs consist of final disposition of wastes, including amounts, radiological and hazardous contaminant profiles, physical form of the final waste products, and radioactive and hazardous contaminant emissions that accrue at each process step.

WASTE_ACC. This computational database tracks prescribed accident sequences at waste management treatment and storage facilities and calculates radiological source terms and human health effects and risks. Inputs include frequencies of initiating accidents and event-tree–based conditional probabilities of the sequences following the initiating accident and leading to radiological release source terms; volumes and radiological profiles of the inventories comprising the material at risk; fractions of the material-at-risk (MAR) involved in the various accident sequences; respirable airborne release fractions for each radionuclide and sequence that depends on the MAR and relevant accident stresses; leak path factors for each radionuclide and sequence; and dose conversion factors for each population or receptor, which are dependent on the site meteorology assumed and site demographics. Outputs include the in-facility and atmospheric radiological airborne source terms with the frequency of occurrence, and human health effects and risks for each receptor or population.

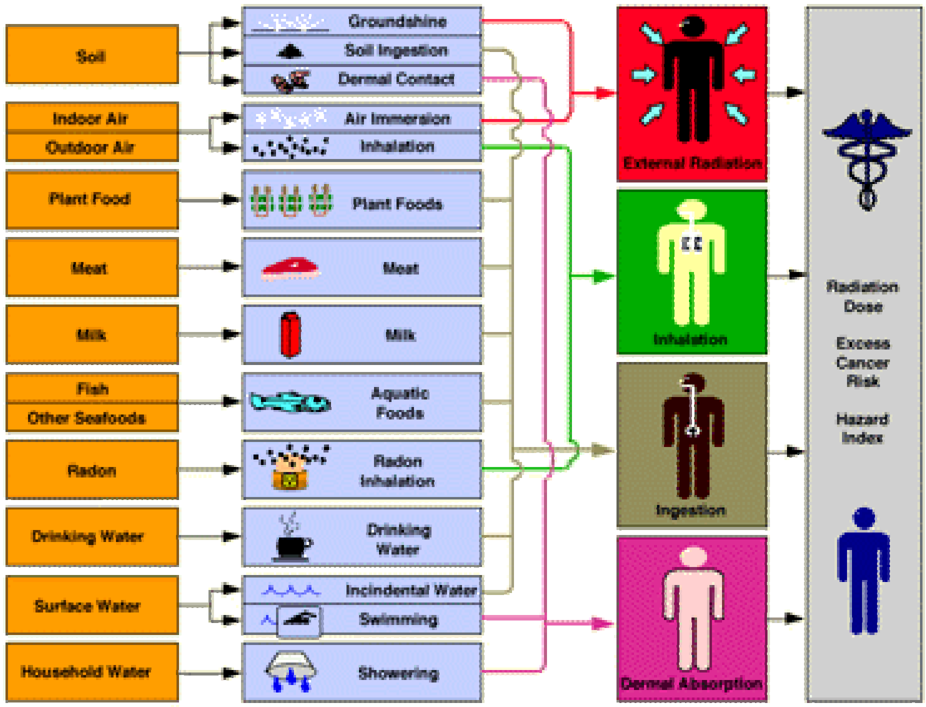
RISKIND. Developed to assess radiological health consequences from potential scenarios associated with the shipment of spent nuclear fuel, this code incorporates accident scenarios and is equipped with user-friendly features. The code's capabilities have also been expanded for other radioactive materials and waste types. The RISKIND model was developed and is distributed by Argonne's Environmental Assessment Division.



RISKCHEM. This suite of models predicts the impacts of chemical spills and releases, including (1) a single-event spill into water, (2) a single-event spill onto land, and (3) the probabilistic impact of water- and land-based spills. The RISKCHEM model was developed and is distributed by Argonne's Environmental Assessment Division.

RESRAD. The RESRAD modules are used to evaluate radioactively contaminated sites. Each is briefly described. RESRAD-BUILD analyzes the radiological doses caused by the remediation and occupancy of buildings contaminated with radioactive material. It considers external exposure, inhalation of dust and radon, and ingestion of soil/dust.

RESRAD-CHEM evaluates sites contaminated with hazardous chemicals. It calculates cancer incidence risks and hazard indexes to an on-site exposed individual and derives site-specific soil cleanup criteria for hazardous chemicals. The database in RESRAD-CHEM contains chemical properties, transfer factors, and toxicity data for 151 chemicals.

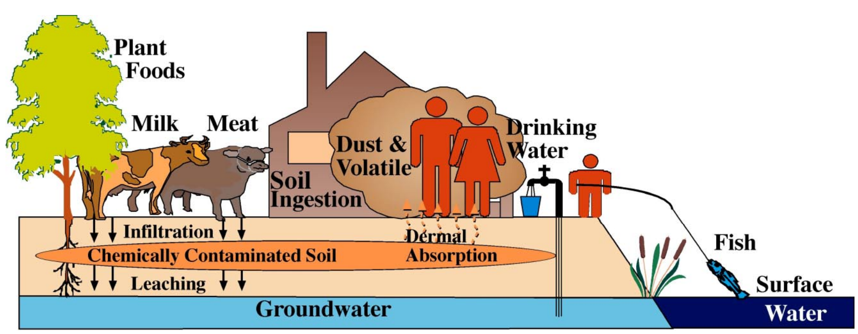


RESRAD-Baseline produces a baseline risk assessment based on measured concentrations in the environmental media.

RESRAD-RECYCLE assesses radiological doses that result from recycle of contaminated material and reuse of contaminated equipment. The recycle processes considered are initial transportation, smelting, transport to fabrication plants, product fabrication and distribution, and use of consumer products.

RESRAD-PROBABILISTIC has a Monte Carlo preprocessor and a postprocessor for parameter uncertainty analysis.

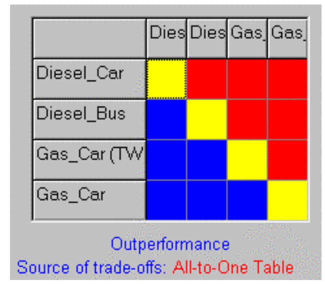
RESRAD-ECORISK estimates risks from contaminant exposure to ecological receptors. Species-specific life history information (ingestion rate, body weight, and diet composition) is used to calculate the applied daily dose and ecological effects quotient.



The RESRAD model was developed and is distributed by Argonne's Environmental Assessment Division.

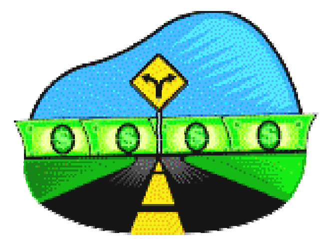
Decision Analysis Models

DAM — Decision Analysis Methodology. DAM was developed to aid decision analysts in solving multiple-criteria decision analysis problems. This Windows-based software allows analysts to view a decision problem and find the best solution from different perspectives; performs standard, but time-consuming, tasks quickly and efficiently; offers a range of decision analysis and trade-off methods that cannot be performed manually; and presents results in convenient graphical and numerical formats. DAM also allows for imprecise or interval trade-offs.



IDEA — Interactive DEcision Analysis. IDEA is a PC-based software package used for a wide variety of decision problems. Features include easy data entry via customized forms, cues and prompts for each input field, detection of invalid entries, on-line help, control of screen attributes, and graphical display of results. In addition, on-line "consultants" assist in quantifying probability distributions over uncertain variables, determining the strength of preferences for different amounts of an individual attribute, and determining the preferences for changing the amount of one attribute in comparison to changing the amount of another attribute.

PASS — Portfolio Analysis Support System. PASS helps users effectively allocate limited resources — funds, personnel, and facilities — by better understanding the pros and cons of different proposals. An easy-to-use, computer-based decision support system for portfolio analysis, PASS helps define and analyze strategies for allocating limited budgets among competing projects or program areas. The model identifies alternatives that best achieve objectives and examines project sequencing and equity through the use of portfolio constraints. PASS provides many benefits, including defensible resource allocations, quick answers to "what if" questions, a focused decision-making process, insights into priorities, and enhanced communications.



ARAM — Argonne Risk Allocation Model. The ARAM system aids decision makers in negotiating the allocation of programmatic risks between two parties — the principal (who pays for services) and the agent (who performs services for payment). Users first describe the risks, such as technical performance, permitting, and force majeure, and then develop several alternatives for allocating each risk. For each risk and alternative allocation, users describe the mitigation and prevention measures that each party is likely to take. The model addresses risk dependence and financial market responses to uncertain outcomes. It uses Monte Carlo simulations to express cost results in probabilistic form.

STATS — Stochastic Analysis of Technology Systems. Originally developed to estimate composite cost and performance uncertainty distributions for various systems and technologies, STATS provides a convenient approach for treating combinations of component uncertainties and potential correlations between cost and performance components. The approach has the capacity to improve comparisons based simply on combinations of best point estimates. The additional information developed in uncertainty analysis is useful when considering the relative risks and benefits of technology or system expansion options.