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ABSTRACT

The life cycle analysis toolbox is a valuable integration of decision-making tools and supporting materials developed by Oak Ridge National Laboratory (ORNL) to help Department of Energy managers improve environmental quality, reduce costs, and minimize risk. The toolbox provides decision-makers access to a wide variety of proven tools for pollution prevention (P2) and waste minimization (WMin), as well as ORNL expertise to select from this toolbox exactly the right tool to solve any given P2/WMin problem.

The central element of the toolbox is a multiple criteria approach to life cycle analysis developed specifically to aid P2/WMin decision-making. ORNL has developed numerous tools that support this life cycle analysis approach. Tools are available to help model P2/WMin processes, estimate human health risks, estimate costs, and represent and manipulate uncertainties. Tools are available to help document P2/WMin decision-making and implement programs. Tools are also available to help track potential future environmental regulations that could impact P2/WMin programs and current regulations that must be followed. An Internet-site will provide broad access to the tools.

I. INTRODUCTION

Pollution prevention (P2) and waste minimization (WMin) are keys to reducing the impacts of our technological society on the environment. Achieving these goals requires innovation, keen insights, and sound implementation plans. In the majority of cases, difficult trade-offs need to made among important process design variables and significant uncertainties in performance and cost need to be identified and addressed. Relevant environmental regulations, both current and expected, need to be incorporated into proactive P2/WMin programs. For both public sector and private sector P2/WMin program administrators, thorny contracting and regulatory compliance problems need to be tackled up-front in order to minimize delays and contracting costs. As with most human endeavors, grand goals must overcome the "devils in the details."

Oak Ridge National Laboratory (ORNL), lead by its Center for Life Cycle Analysis, is building a toolbox of methods, computer software, primers, and case studies to assist P2/WMin programs around the country. The centerpiece of the toolbox is the life cycle analysis system (LCAS). The LCAS consists of a user-friendly, cost-effective, and analytically-sound decision-aiding process and a complementary suite of automated tools to handle data administration and multiple criteria life cycle analysis (LCA). LCA is a systematic and comprehensive process for identifying, assessing, and comparing alternatives for deactivation and decommissioning (D&D), P2, and asset recovery at government sites, and for selecting and documenting a preferred alternative. An LCA includes all of the impacts (benefits and costs) that result from a course of action over the entire period of time affected by the action. The LCAS also includes a visualization component that has been proven to aid communication and stakeholder involvement in the decision-making process.

Originally developed for use at the Oak Ridge East Tennessee Technology Park (ETTP), the LCAS was refined through application at Ohio Operations Office sites and has now been successfully implemented at a number of DOE sites to produce better decisions resulting in lower costs to the taxpayer and improved environmental quality.[1-5] In one of the first applications of LCA, DOE relied on a detailed LCA to decide to recycle more than 100,000 tons of scrap metal at the ETTP rather than dispose of it. This decision alone prevented about 5,000 trucks of metal traveling across the country from Tennessee to Nevada to dispose of the metal. The LCAS has also been used to support decisions on disposition of structural steel and copper at the Fernald Environmental Management Project, and concrete and soil from the West Valley Demonstration Project. The National Metals Recycle Program has successfully used the LCAS to leverage Cold War legacy equipment and materials to accelerate cleanups and promote reindustrialization activities at DOE sites. Specifically, the program has used LCA to support recycle of scrap metal at the Weldon Spring Site and the Oak Ridge National Laboratory Tower Shielding Facility, and reuse of drums, B-25 boxes, and metal pallets. For these and many other activities at ORNL, a comprehensive set of tools has been developed that can have broad application to the P2/WMin community.

The motivation behind the LCAS is to help DOE make better decisions by helping decision-makers to understand all impacts of decisions, by making the decision-making process transparent, and by facilitating substantive involvement in the decision-making process. Our approach to LCA differs from other approaches by taking into consideration all the factors important to stakeholders. In addition to life cycle cost, we consider health and safety impacts, environmental impacts, programmatic impacts, and other factors. Consideration of these impacts need not be extensive or excessively burdensome; it should be commensurate with the potential benefits. However, the simple process of considering each of the alternatives on each of the relevant attributes will ensure that all factors important to the decision have been considered and will help avoid unintended consequences.

In the DOE complex, as well as in our personal lives, poor decisions are often the result of focusing on a single, particularly salient objective (e.g., minimizing near-term cost), without fully considering other possible impacts of our actions. As a result, for example, P2/WMin initiatives that would payback the initial investment many times over, as well as produce environmental benefits, have gone unfunded. In addition, an LCA does not consider the color of money. For example, many P2/WMin proposals will incur an additional investment by one DOE program, only to produce an even larger saving in another DOE program (as well as significant environmental benefits). By looking at the total benefit to the government, LCA seeks to ensure that such beneficial projects will be funded. Use of the LCAS will help to ensure that we do not miss these cost-saving opportunities in the future and that we do not inadvertently create tomorrow's environmental challenges.

Often a detailed LCA will suggest a different decision from a more limited investigation. For example, some DOE sites were crushing contaminated drums in order to reduce volume. Using LCA, the National Metals Recycle program has developed a cost-effective method of reuse of drums – however drums that have been crushed cannot be cost-effectively reused and must be disposed of. So the old decision rule "crush drums" has been replaced with the new decision rule "reuse drums," which saves the government money. As a second example, some sites were imploding buildings. But once the building is imploded, the metal becomes so mangled that it is too costly to decontaminate, and it must be disposed of. Dismantlement of the building, while having a larger initial cost, would have allowed for cost-effective reuse. A third example concerns the ETTP K770 scrap yard, a pile of scrap metal located in the middle of prime commercial real estate. The pile had not been addressed because of the cost of doing so – but allowing the pile to remain has significantly delayed the reindustrialization of a large tract of prime real estate. An LCA showed the reindustrialization benefits of removal of the pile and identified recycling strategies to make removal of the pile cost-effective.

There are several other advantages to using the LCAS. The framework aids communication in public meetings by helping focus discussions, and facilitates the process of gaining substantive public input in decision-making. Further, rather than decisions being made without the benefit of all stakeholders and all relevant facts being assessed, we seek to make the decision-making process transparent. The LCA approach helps to make decisions understandable and defensible by making clear the data and reasoning underlying the decision. The LCAS provides a systematic and standardized process so that cross-site/program comparisons are possible. Finally, the decision-aiding framework is robust. It can be tailored to meet site and project conditions and can easily be applied to P2/WMin problems across the nation.

To present the process and tools that comprise the toolbox, this paper is organized into three major sections. The central element of the toolbox is the LCA framework. This framework includes numerous factors that must be considered when making P2/WMin decisions. This framework is presented in Section II along with brief descriptions of several models and methodologies that can be used to generate inputs for this decision-aiding framework. Section III takes a step back and presents tools useful for anticipating potential future environmental regulations that might impact P2/WMin programs and identifying and understanding current environmental regulations. Section IV describes our plans for an Internet-based toolbox. The paper concludes with several observations.

II. DECISION MAKING TOOLS

Life Cycle Analysis Framework

The ORNL LCA approach has its foundations in the field of decision analysis.[6] Fundamentally, the goals of decision analysis are, simply stated, to help people: understand the problems they face; construct decision alternatives (options) to solve the problems; specify criteria (attributes) over which to judge decision alternatives; and make trade-offs among decision alternatives and criteria to arrive at reasonable and defensible decisions. The LCA approach considers each of the alternatives on each of the relevant attributes in order to ensure that all effects are considered when making decisions and reduce the likelihood of unintended and unforeseen consequences.

DOE program managers do not have the time and the resources to conduct exhaustive data collection and assessment efforts to evaluate all potential alternatives over all potential decision criteria related to P2/WMin. They need a practical and streamlined yet analytically structured approach to this class of decision problems. Specifically, the decision-aiding approach itself needs to meet the following criteria:

- *Cost-Effectiveness.* Data needed for the LCAS must be straightforward to collect and the collection efforts must not require undue time and money. The process must be systematic and easily implemented;
- *Comprehensiveness of Decision Factors.* The LCAS needs to encompass a range of decision factors to allow decision makers to understand the complex context of their decisions;
- *Defensible Results.* The outputs of the system must be rigorous and replicable; and
- *Standardization.* The approach must be standardized so that cross site/program comparisons are possible.

The ORNL LCA approach was developed to meet these criteria.

Many factors influence P2/WMin decisions; six decision criteria which have been identified as of key importance in many similar situations are:

- life cycle cost;
- environmental impacts;
- public and worker health and safety impacts;
- pollution prevention;
- programmatic impacts; and
- reindustrialization impacts.

In the LCA approach, decision alternatives are evaluated on each of these criteria and the results are summarized in a decision matrix. An example decision matrix for a P2/WMin application is presented in Figure 1.

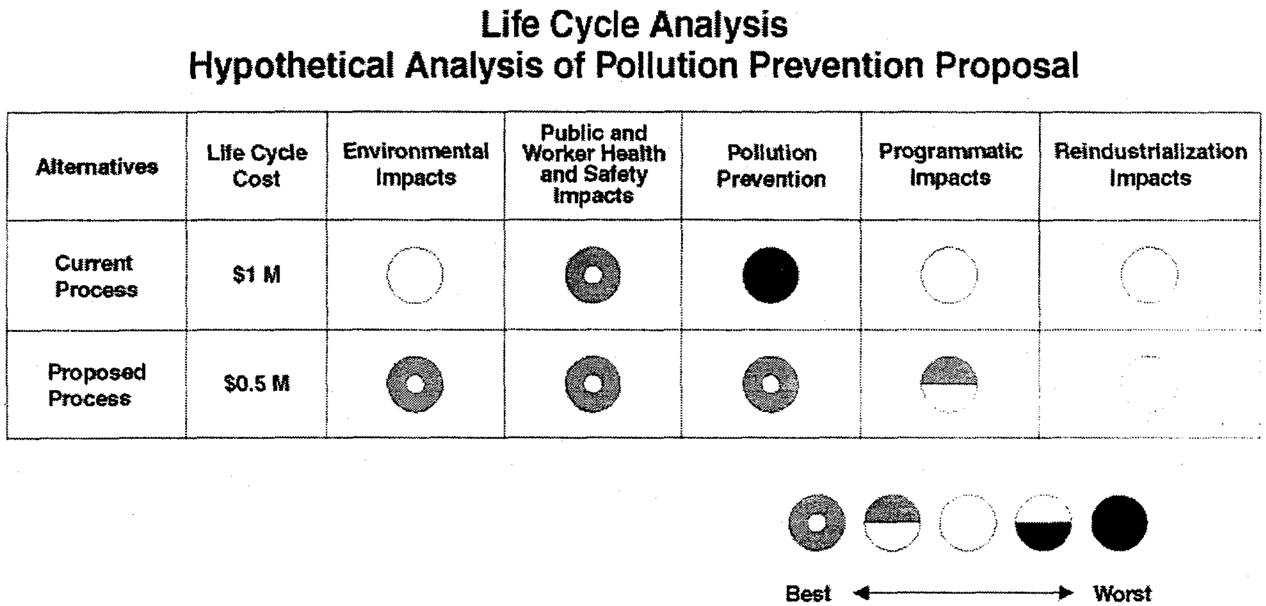

Fig. 1. Example Life Cycle Analysis Decision Matrix

The LCA decision-aiding framework provides a proven structure to organize data pertinent to the decision. Specifically, it is straightforward to build a matrix that contains rows of decision alternatives and columns for the decision criteria. The cells of the matrix would hold the assessments of how well a particular alternative met a particular criterion.

In general, the size and level of detail of the analysis should be determined appropriate to the problem, based on the size of the problem, its importance, complexity, imminence, the quality and quantity of available information, the nature of the statutory language, sensitivity of the results to the choice of alternatives, and the likelihood that the analysis may influence the eventual decision. Ultimately, the choice of tools should be make in consultation with the stakeholders and will depend on both the desired size of the overall analysis and judgments about which decision criteria should receive the greatest attention.

To obtain the data for the cells in the matrix, P2/WMin analysts may need access to a comprehensive set of decision input models or tools. The following subsection describes several such models available at ORNL.

Decision Input Models

The toolbox consists of a wide variety of proven tools. This makes it possible for ORNL researchers to select exactly the right tools to solve any given P2/WMin problem. A selection of these tools is summarized here.

ORNL has several cost estimating models and tools to assess the total life cycle costs of P2/WMin decision alternatives. To begin, comparison of alternatives as part of a selection process is expedited if the life cycle cost estimates are generated on a "level playing field" or comparable basis. This means using the same values for such factors as interest rates, inflation, labor costs, etc. as appropriate for the given constraints. This desired result is ensured from the outset if Cost Estimating Guidelines are provided for each technology prior to the generation of life cycle cost estimates. ORNL has provided such Guidelines for DOE programs in Plutonium Disposition, Advanced Nuclear Power, and Tritium Production. These guidelines can also be used to help P2/WMin analysts ensure that the technology options they are considering are properly compared. A good example of guidelines prepared for a DOE sponsor for electric power generation costs is available.[7]

In addition, ORNL has developed a generic software tool capable of modeling the basic physics and chemistry factors associated with P2/WMin processes. For advanced energy and waste handling process technology, basic physics and chemistry factors may drive potential costs and plant sizing more than typical economic factors such as financing costs and labor costs. Using EXCEL spreadsheets or FORTRAN (depending on process complexity) an integrated model can be built which considers all of the above. Generic instructions for such model building are available in a comprehensive Oak Ridge report.[8-11] A typical output of such a model is a unit cost or a performance-related parameter such as a plant's availability. These outputs could go directly into the decision matrix. Inputs typically include physics or chemistry parameters, the desired plant capacity, and cost-scaling relationships. The utility of such models is enhanced by the use of multivariable sensitivity analysis tools such as the ORMONTE code mentioned next or EXCEL-compatible commercial software such as @RISK.

The ORMONTE Multivariable Sensitivity Study (MVSS) Code is a FORTRAN-based code which "drives" any type of FORTRAN model with multiple uncertain input variables. Statistical probability distributions can be input for up to 100 uncertain input variables. The user can select any desired output variables for display of uncertainty statistics. This model is meant for use on supercomputers or workstations and with very large simulation models. These applications are beyond the capabilities of most commercial risk analysis software tools such as "@RISK" or "Crystal Ball". This type of Monte Carlo driver code has been used in conjunction with models of complex physical and engineering systems such as advanced uranium isotope separation plants and fusion reactors. The model has extensive documentation[12] and a sample problem to aid the user.

In many instances, developing cost estimates is not a straightforward process, especially when social and environmental costs need to be considered. In 1993, ORNL and Resources for the Future developed a technique for factoring health-related, environmental, and accident-related costs into the overall cost of electricity from several types of plants including nuclear.[13] For technologies, such as nuclear, which have low accident probabilities but high cost and social consequences, the probability of a severe accident and its projected costs can be factored into a time averaged unit cost. This same concept and suite of estimation methods can applied to P2/WMin contexts outside of power plants.

Many production and waste management tasks that normally would be entirely funded (design, construction, operations, and D&D) by the Federal Government are now being at least partly funded by the private sector with the Government paying for the product or waste-disposal service during the operational phase of the project's life cycle. This "privatization" concept allows reduced Government expenses during the construction phase by letting the private contractor finance the capital investment. Later payments by the Government to the Contractor then cover operational and amortization expenses. ORNL has developed a model[14], which was originally developed to calculate the cost of electric power generation from various types of plants (coal, nuclear, natural gas, etc.) that can be adapted to any type of project where a product or service is provided uniformly over several years of facility operation. Inputs include the financing structure, projected capital cost, amortization and operational lifetime, tax rates, annual operating cost, D&D cost, and plant throughput and availability. The output is the unit cost (such as cents/kwh) that pays the operating costs, pays back the capital investment, and compensates financial stakeholders. This model was recently used by DOE to investigate the alternatives for the disposition of surplus weapons-grade plutonium from Government stockpiles. The model is available as an EXCEL spreadsheet and needs minimal tailoring for adaptation to different "products".

The toolbox also contains methods to help contract managers estimate how much contracted work will cost and to estimate the price of sale contracts. Specifically, ORNL uses an activity-based approach to contract cost estimating. The concept involves dividing the scope of work for the proposed project, usually presented in the request for proposals, into a detail level Work Breakdown Structure (WBS). For each WBS item the labor, material, and equipment requirements are identified. Unit labor, unit material, and equipment costs are then applied to the overall WBS matrix. This type of model has been built by ORNL to calculate the expected costs of qualifying mixed oxide (MOX) fuel for use in commercial power reactors.[15] The total cost calculated is then used as a Government benchmark cost against which to compare actual "bids" for the same scope of work. As a second example, a detailed life cycle cost analysis performed by the Center for Life Cycle Analysis was used to support the sale of scrap metal and equipment at the ORNL.

In addition to cost estimation, ORNL has tools and expertise in risk analysis to aid in estimating health and safety and environmental impacts of alternatives. The health and safety portion of the toolbox produces the estimates of public and worker health and safety impacts needed to support the decision-making process. Such analyses estimate radiological as well as non-radiological impacts (e.g., transportation, chemical exposures, occupational accidents, etc.) to the total exposed population. For example, ALARA analyses incorporating detailed human health risk analysis have been performed to support DOE decisions to recycle metal at the ORNL Tower Shielding Facility and the Weldon Spring Site.

ORNL has developed a user-friendly Internet platform for disseminating risk tools and current risk information to an unlimited audience in a timely and efficient manner. This system is called the Risk Assessment Information System (RAIS) and its main purpose is to consolidate or link all risk tools currently available and to develop for incorporation into the site other risk tools that will benefit risk assessment users. This site was initially developed for the Oak Ridge

Operations Office, but has been expanded to the entire Department of Energy complex, providing an on-line central repository for risk tools and information. The ease with which this system will disseminate risk tools and other technological information will not only reduce the cost of risk analyses but will also provide a platform for standardizing, where beneficial, basic techniques utilized in risk analyses. In addition, this system provides Department of Energy managers with a user-friendly system supporting risk management decisions through the use of risk screening tools.

Taking advantage of searchable and executable databases, menu-driven queries, and data downloads, using the latest WWW technologies, the RAIS offers essential tools that are used in the risk assessment process or anywhere from project scoping to implementation and can be tailored to meet site-specific needs. The RAIS tools can be located directly at http://risk.lsd.ornl.gov/homepage/rap_tool.htm or through the Department of Energy Center for Risk Excellence homepage at http://www.doe.gov/riskcenter/home.html. RAIS tools and information resources include: 1) Preliminary Remediation Goals (PRGs), 2) Regulatory Limits, 3) Toxicity and Chemical Factors, 4) Human Health Risk Exposure Models, and 5) Ecological Benchmarks.

A default set of PRGs and the means for producing customized PRGs have been developed and are maintained on the RAIS. The default PRGs, which are concentration goals for individual chemicals for specific medium and land use combinations, can be used during project scoping, for screening evaluations to support early action or No Further Investigation decisions, and in baseline risk assessments in the selection of chemicals of potential concern. These risk-based concentrations are available for all chemicals (including radionuclides) for which slope factors, reference doses, and reference concentrations are available through the Integrated Risk Information System (IRIS) or Health Effects Assessment Summary Tables (HEAST). Employing the latest default EPA exposure parameters, the PRGs are determined for the standard use scenarios; however, the user may modify the parameters to meet site-specific needs. The PRGs are accessible for viewing but are also downloadable in tab-delimited or comma-delimited format for application purposes. The user is able to query the on-line database with options for selecting chemical(s) or CAS number(s), media, land use, exposure route, and risk level.

RAIS also includes Federal and State Drinking Water Standards including those proposed and promulgated at the Federal level. In order to determine clean-up standards at the various complexes, minimum regulatory requirements must be made available in a ready format for cost-effective decision making. Currently, these standards are cumbersome to locate given the status, in particular, of state regulations. A compilation of these standards enable risk comparisons to maximum contaminant levels (MCLs) in an expeditious manner to facilitate remedial response in compliance with applicable or relevant and appropriate requirements or standards under federal and state environmental laws.

The toxicity and chemical factors component of RAIS assembles all of the available human health toxicological information. This database has been developed and maintained to include state and/or regional modifications as necessary. Specifically, this system includes all developed nonradionuclide reference doses and slope factors for both nonradionuclides and radionuclides, as well as dermal references doses, dermal slope factors, and toxicity profiles that have been developed at ORNL. In addition to reference doses and slope factors, other chemical parameters necessary for conducting risk-related activities are included in the database. Examples of some of these chemical-specific parameters include: volatilization factors, soil saturation concentrations, gastrointestinal absorption factors, permeability constants, and soil-to-plant dry uptake factors. With unlimited expansion, the database standardizes the chemical-specific factors necessary for risk-related activities reducing the cost and time for the search and selection process.

The human health exposure models module of RAIS provides standard and adjustable exposure models under configuration control for risk assessment activities, eliminating duplication of effort and cost by providing these models to risk users in an automated program. The exposure scenarios evaluated which are crucial to the development of remedial goal options at the clean-up sites are representative of both current and future land use considerations. Default parameters for the models are utilized based on the latest guidance available; however, site-specific considerations allow for model customization within land-use, media, and exposure route combinations where feasible. Concentration data are input into menu-driven automated model simulations to produce risk assessment output. Finally, the ecological benchmarks module provides ecological benchmarks, the basis for all ecological risk assessments. They are currently available for aquatic biota, sediment-associated biota, terrestrial plants, soil and litter invertebrates and heterotrophic processes, and wildlife.

Another tool, developed by ORNL and the University of Tennessee, is the Spatial Analysis and Decision Assistance (SADA) software package. SADA provides a suite of powerful, concise environmental methods that directly support decision-making processes in environmental characterization and remediation efforts. These methods have been proven to save DOE both time and money while providing investigators with technically rigorous, scientifically defensible results for making informed decision at the project level. In general, SADA provides added value to DOE by streamlining standard procedures such as statistical analysis, data screening, and human health risk. Currently SADA is comprised of six core functions that can be used independently or interactively to support the decision or analytical needs of the project: data visualization and analysis; human health risk assessment; geospatial analysis; determining optimal cleanup areas; cost/benefit analysis; and secondary sampling strategies.

ORNL has also developed a simulation tool, FLOW, which has been used to support LCA. FLOW provides rigorous and accurate systems engineering calculations for potential technical solutions to P2/WMin problems. FLOW is an easy-to-use process simulator and is well suited to modeling P2 and waste management technologies. It allows more detailed analysis of technologies and integrated flowsheets. Its graphical user interface allows one to connect various unit operations that are represented by icons (e.g. preheaters, condensers, reactors, scrubbers, etc.) and to build flowsheets that model specific process technologies. The user can then quickly alter the various unit operations to study their effect on the process. This user-friendly interface allows the user to rapidly construct and evaluate many different flowsheets. From these models, the user can obtain the basic information on their performance, risks, and life-cycle costs. FLOW provides the data, including mass flows and concentrations, needed to determine the process performance parameters (e.g., volume reduction, secondary waste generation, and final contaminant concentrations of the wastes).

The relevant characteristics of FLOW include (1) high capability to simplify those processes that have a great deal of complexity using the nesting properties of some of the icons that can represent an entire flowsheet; (2) sensitivity analysis, and (3) uncertainty analysis, including Latin Hypercube, Monte Carlo, and Wosniosky algorithms. FLOW was initially designed for steady-state simulation, but it has also been used for discrete-event simulation. FLOW has been used for engineering analysis of traditional waste management processes, innovative technologies, counterproliferation activities, transportation for uranium and plutonium disposition, and pollution prevention studies. Figure 2 illustrates the FLOW graphical interface that indicates the nesting capability of the unit operation icons.

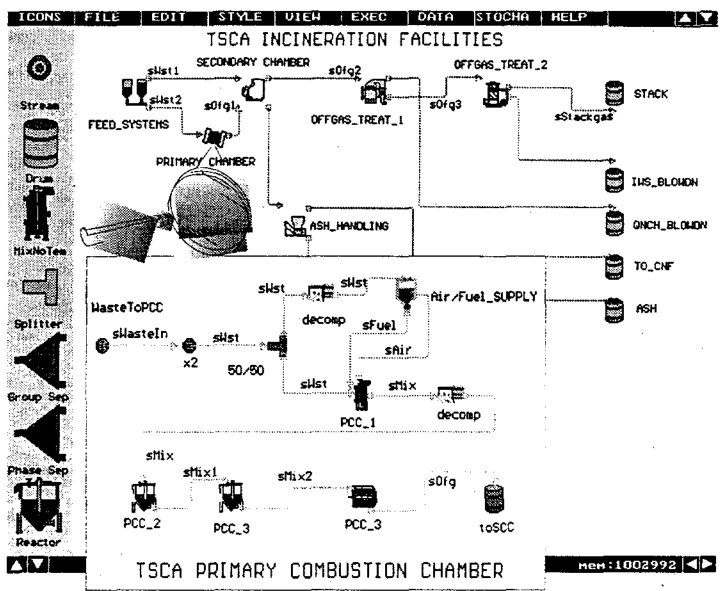

Fig. 2. FLOW Graphical Interface Illustrating the Nesting Capability

FLOW is an important tool to perform LCA because it provides accurate quantitative analysis of technology options and the capability of integrating analytical tools that allow assessment of (a) life-cycle costs, (b) risk to the health of the worker and the environment, (c) technical performance, and (d) other evaluation criteria. The cost-analysis models deliver preliminary total life- cycle cost estimates, thus providing a relative comparison between technology alternatives and scenarios. These comparative estimates are consistent across technology alternatives and scenarios. The risk-analysis models provide comparative, not absolute, estimates and are sensitive to stream constituent changes. Calculations provide on-site and off-site occupational and general public risks. The technical performance analyses for processes and the waste forms include waste treatment capacity, production rates, plant availability, plant maintainability, volume reduction, contaminant concentrations, secondary waste and effluent generation, waste-form activity, waste-form stability, waste-form contaminant release characteristics, etc.

FLOW has been successfully implemented to perform decision analysis to solve waste management problems at ORNL. An integrated-systems-analysis approach was needed because of the complexity of system interactions, the diversity of alternatives to be studied, and the variability and uncertainty of constraints. Many possible combinations of treatment and disposal options exist, each of which results in a different cost, schedule, quality of waste form, risk to workers and the public, acceptability, etc. The analysis addressed all the significant aspects of waste management, including on-site treatment, transportation, off-site treatment, and disposal.[16,17]

Finally, ORNL has experience with and a substantial library of computer codes that search large solution spaces for optimal decisions. It may be the case, for example, that there are too many variables and too many potential solutions involved in deciding upon a new P2/WMin process design. In fact, it is not uncommon for the designers to be facing a situation where different combinations of design factors can literally produce millions of potential designs. To combat this situation, for example, ORNL used a genetic algorithm code to find lower cost solutions to help design the International Thermonuclear Experimental Reactor (ITER).[18] ORNL has also applied genetic algorithms to study the construction of technology roadmaps[19] (see Figure 3) and other optimization methods to study a plethora of design and logistics problems.

Uncertainty Representation Tools

Uncertainty is an important issue in P2/WMin decision-making. Every assessment in every cell of a decision matrix may be uncertain, from only slightly uncertain to extremely uncertain. How uncertainty is dealt with in the models to produce the assessments is also a major source of concern. ORNL can bring to a P2/WMin toolkit many methods for representing and manipulating uncertainties. One such method, Monte Carlo analysis, was mentioned above. ORNL has also worked with the University of Tennessee-Knoxville (UTK) to build sophisticated generalized (or imprecise) probability methods (i.e., methods that use lower and upper probabilities) to: find consensus among expert judgements[20]; up-date probabilities as new information is gained[21]; condition expert judgements with statistical information[22]; combine pieces of probabilistic evidence pertaining to systems diagnosis[23]; measure the amount of information available to a decision maker; and gauge the degradation in knowledge one may have about the future values of key decision variables[24]. These and other methods allow P2/WMin analysts to attack problems that have any amount of uncertainty.

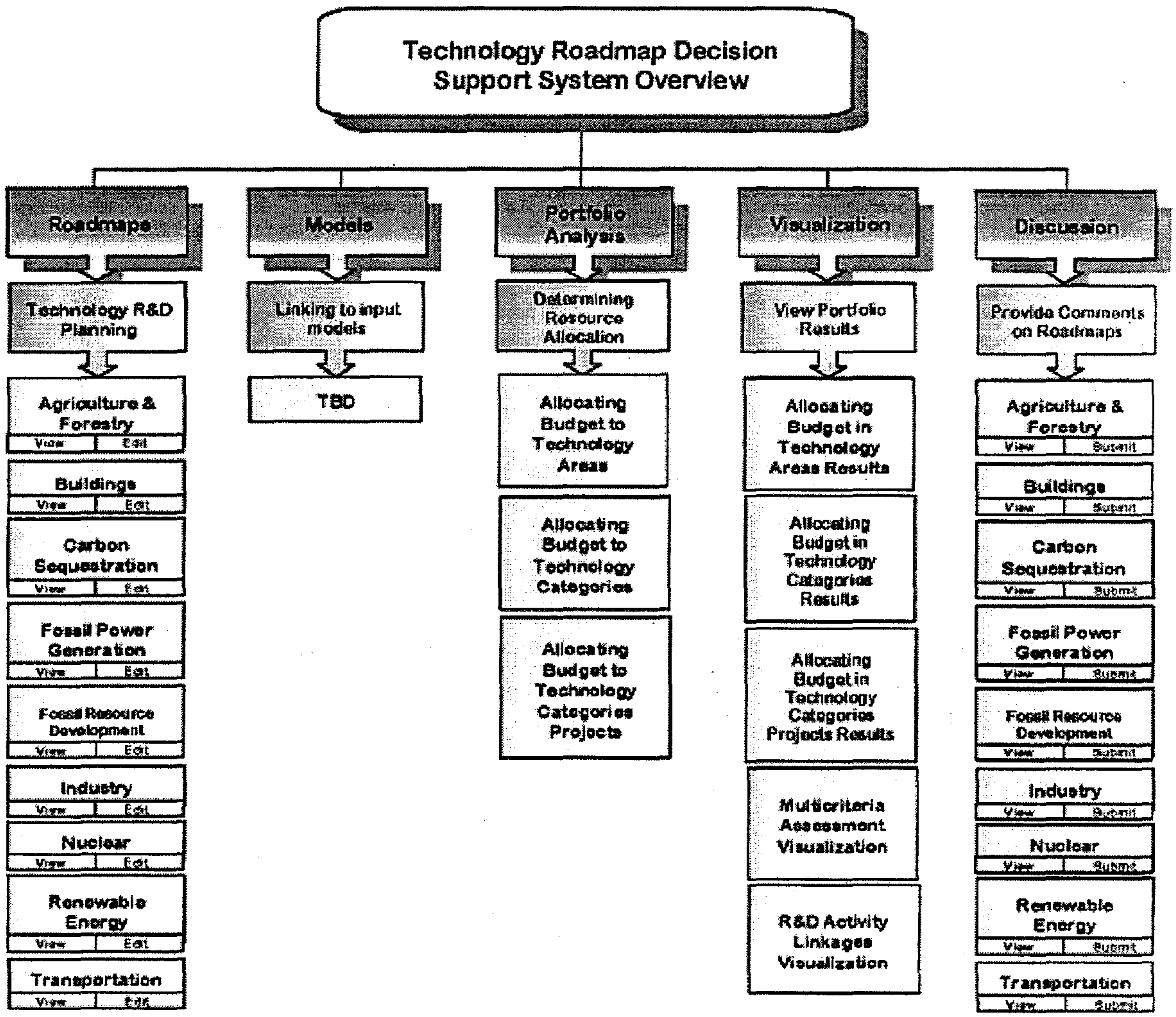

Fig. 3. Technology Roadmap Decision Support System

III. FORESIGHT AND PROBLEM IDENTIFICATION TOOLS

Often lost in the bustle of making decisions and implementing programs is the fact that at some point in time, someone somehow determined that a problem existed for which a decision needed to be made. In the best of circumstances, the problem would have been diagnosed way before it had become a crisis. Early intervention can save money and time and most effective organizations try to follow this advice. Unfortunately, for many reasons, most organizations rarely practice effective foresight.[25] Thus, the P2/WMin toolkit needs a couple of tools related both to foresight and problem identification.

Regulatory Event Tracking Tool

For the Tennessee Valley Authority (TVA), ORNL and UTK developed a methodology to assess potential future environmental legislative, regulatory, and judicial events.[26] TVA was interested in a broad range of regulatory events that could impact its business. The methodology has four components. First, definitions are given to the terms "issues," "events," "scenarios," and "drivers." Second, a four element tracking category is developed that tracks events from over the horizon to on the horizon to on the screen to on the agenda. Third, how to represent and manipulate uncertainties about when events may occur is addressed. Fourth, an approach to assessing action priorities is developed. This method is useful for any organization needing to track future environmental regulations and can be generalized to track any events that could significantly impact an organization or community. The method is ideally suited to track the many potential future environmental regulatory events that could impact P2/WMin programs, investments, and strategies.

Problem Identification Tools

Lastly, the toolbox will provide the user with applicable references and links to regulations, guidance documents, web sites, and data bases that collect and report P2/WMin information. This component of the toolbox will help users determine applicable regulations and identify potential compliance problems. This component will also help users better understand their P2/WMin situations through the use of case studies and links to the world of P2/WMin. This information provided will help users understand the sources of their P2/WMin problems, be they technical or legal or management-based. This component will help users to clearly define and state the decision problems they face, which is an absolute pre-requisite for good decision making and effective use of the multiple criteria decision methods discussed above.

IV INTERNET APPLICATION

ORNL has the intention of making the toolbox accessible to users over the Internet. ORNL already has developed and manages several websites that provide information, access to scientific databases, statistical tools to conduct data analyses, and help to users to make environmental decisions. However, the P2/WMin toolbox would be much more comprehensive, seamless to the user, and fortified with intelligent automated support.

The hub of the LCA website is the LCA decision matrix. Already, the site allows users to build their own decision matrices. The site would then provide access to the decision input models. Users could run the models remotely, with intelligent decision support modules in assistance. On top of this framework would be a decision path module, that could help first time users walk through their P2/WMin problem from beginning to end.

The site would provide automated support to develop decision documentation materials (e.g., forms would be provided as necessary). The site would allow frequent users to build an electronic version of a decision tracking trail, to facilitate assessment of decision processes as well as outcomes. Users would have access to sample contract language text for downloading. Contract cost estimation models would also be accessible to users. Lastly, to the maximum extent possible, the site will provide users with data and information visualization tools for them to use to improve the communication of their work.

V. CONCLUSIONS

P2/WMin is an exciting and important endeavor. A plethora of tools exist to help people engaged in designing, developing, implementing, and administering such programs. These people do not have the time and resources in most cases to be able to access and integrate all the tools they might need into a coherent system to help them make complicated P2/WMin decisions. The ORNL toolbox provides P2/WMin decision-makers access to a wide variety of proven P2/WMin tools as well as ORNL expertise to select from this toolbox exactly the right tool to solve any given P2/WMin problem.

VI. ENDNOTES

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