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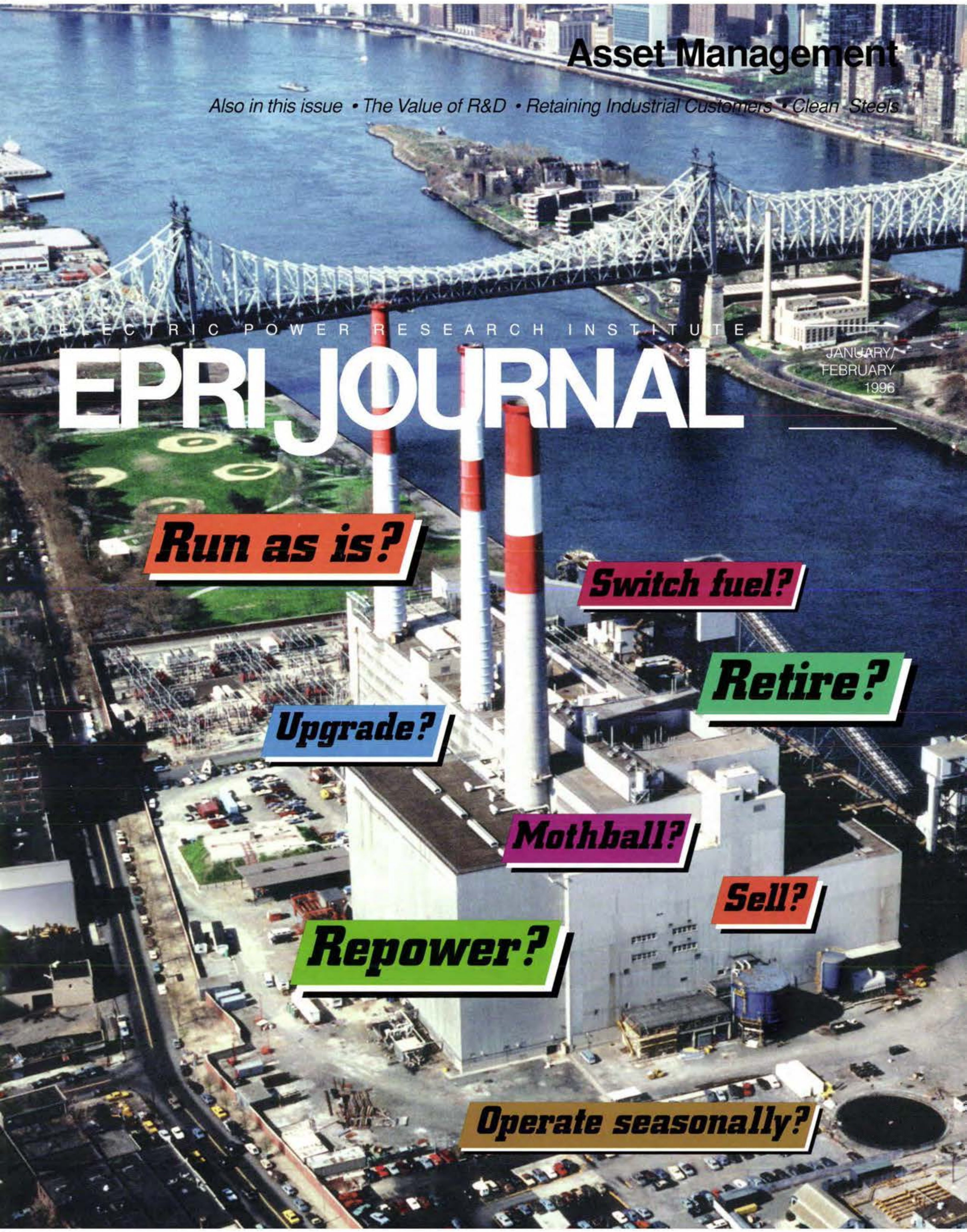
Asset Management

Also in this issue • The Value of R&D • Retaining Industrial Customers • Clean Steels



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Cover: Deciding what to do with older fossil power plants can be key to a utility's bottom-line profitability.

EPRI JOURNAL

Volume 21, Number 1 January/February 1996

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PRODUCTS

EPRI-sponsored deliverables now available to utilities and their customers

An ideal solution for the trenching needs of utilities and their customers, TUFCOV is a convenient, lightweight replacement for the heavy steel trench covers typically used in construction —some of which require cranes to install. Developed under the sponsorship of EPRI and the American Water Works Association, the TUFCOV cover plates are made of durable fiberglass composite and weigh only 150 pounds each. The modular units are designed to span a 5-foot trench and can withstand loads of up to 32,000 pounds. Each unit is easily handled by two people, so there is no need for cranes. Individual units can be joined securely to cover larger areas.

For more information, contact Tom Rodenbaugh, (415) 855-2306. To order, call Don Carmichael at CompositAir, (805) 389-4600.

Information Superhighway: Business Opportunities and Risks

The new telecommunications and information technologies of the information superhighway—formally known as the National Information Infrastructure (NII)—offer utilities the opportunity to become more competitive. Yet along with such opportunity comes risk. And it is important for utilities to understand the potential long-term impacts of telecommunications strategies before they make any major decisions. This report (TR-104539) offers an in-depth analysis of the technology, market, regulatory, and financial issues utility decision makers must consider as they investigate the opportunities of the NII. The report defines five major strategic options and discusses such measures as phased implementation and forming alliances to help manage risk and reward.

For more information, contact Ron Skelton, (415) 855-8753. To order, call the EPRI Distribution Center, (510) 934-4212.

MarketTREK 2.0

The decision to launch a new marketing program, promote a new technology, or offer a new energy service involves the careful evaluation of costs and benefits. To make the right choices, utility decision makers need to know which programs and services meet customer needs. EPRI's MarketTREK software, a Microsoft Windows–based analysis tool, provides a framework for predicting the choices customers will make, analyzing their decision-making processes, and simulating the effects of utility marketing activities on their decisions. MarketTREK's flexibility allows users to customize market forecasts on the basis of available data. Market planners can produce "back of the envelope" forecasts using expert-judgment techniques or undertake more-rigorous analyses based on market research and primary data collection. *For more information, contact Paul Meagher, (415) 855-2420. To order, call the Electric Power Software Center, (800) 763-3772.*

Global Warming Video

The greenhouse effect is a continuing source of concern for the electric utility industry, since carbon dioxide, a major greenhouse gas, is released in the burning of fossil fuels. As a way to counteract some of this CO_2 release, scientists have assessed the potential for using halophytes—plant species that thrive on salt water—to absorb large quantities of CO_2 from the atmosphere. This video (VT-103538) examines the potential for using halophyte farms to sequester CO_2 and showcases a test farm in Puerto Peñasco, Mexico, where scientists from the University of Arizona, the Salt River Project, and EPRI have conducted experiments to learn more about halophytes. *For more information, contact Louis Pitelka, (415) 855-2969. To order, call the EPRI Distribution Center, (510) 934-4212.*

Profitable Rate Options

Information on area- and time-specific costs can enable a utility to design innovative rate options that decrease customers' electric bills while simultaneously increasing utility earnings. This report (TR-104375) describes one utility's use of area- and time-specific costs to develop such rate options. The utility, Central Power and Light Company, identified potential high-transmission-cost areas and selected rate options offering incentives for customers in those areas to shift their electricity use from high-cost time periods. The report includes a description of the process used to evaluate the utility's margin on the basis of a relatively small set of data. Such data are available to nearly all vertically integrated investor-owned utilities.

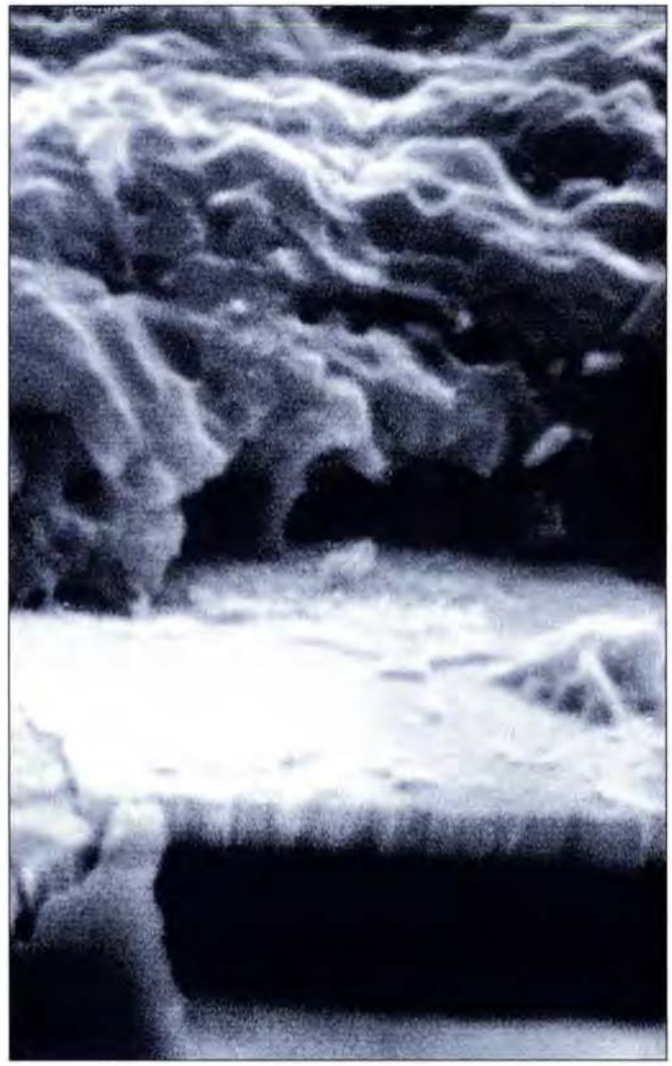
For more information, contact Grayson Heffner, (202) 293-6340. To order, call the EPRI Distribution Center, (510) 934-4212.

Next-Generation Photovoltaics

The most-promising photovoltaic (PV) technologies for cost-effective, near-term utility applications include high-concentration PV with small, high-efficiency crystalline silicon cells and multijunction thin-film PV with less-expensive but lower-efficiency amorphous silicon modules. Ten to 15 years in the future, however, attention will likely be focusing on a new generation of PV devices now appearing on the research horizon. This advanced technology promises to have the low cost associated with thin-film manufacturing while featuring efficiencies as high as today's best crystalline cells.

Two fundamental changes from today's PV devices will be involved. First, the new technology will not be silicon based; rather, devices will be created from thin films of compound semiconductor alloys, such as those based on copper indium diselenide (CIS). Second, the microstructure will be polycrystalline—that is, composed of crystal grains about 1–5 micrometers in diameter. In comparison, today's silicon cells are made from huge single crystals up to 8 inches across, and current amorphous silicon films are homogeneous with their silicon atoms randomly arranged.

To explore the commercial potential of such polycrystalline PV materials, EPRI's Strategic R&D Business Unit is sponsoring an integrated program of research at four universities. Scientists at the University of South Florida are studying materials problems that limit the performance of CIS alloys. At Pennsylvania State University, researchers are conducting computer simulations of CIS-based PV devices to better understand them. Improved ways to grow polycrystalline thin films are being investigated at the University of Delaware. And researchers at the University of Illinois are using their materials-characterization tools to help the other centers better understand CIS films and make improved thin-film samples and devices.



Copper indium diselenide film

This research has now reached a stage in which scientists can create materials with good optical and electronic properties and can make decent single-junction PV devices. In particular, Don Morel and his colleagues at the University of South Florida have found ways to tailor these properties by selectively substituting gallium for indium and sulfur for selenium in the polycrystalline CIS thin films. The next major step will be to create multijunction PV cells, which can increase conversion efficiency by absorbing different wavelengths of light in each layer.

"Our team approach to this complex field of research has proven very successful," says Terry Peterson, EPRI manager for the project. "A lot of work remains to be done, but we're very optimistic about eventually creating a superior, competitive product. Amorphous thin-film PV modules are expected to be available soon in an 8-square-foot size with a net conversion efficiency of over 8%, evolving to efficiencies of 10% to 12%. Within a few years, they may achieve EPRI's 15% target efficiency for flat-plate PV. However, polycrystalline thin-film modules seem a good bet to eventually achieve about the same manufacturing cost—but with efficiencies of over 25%."

■ *For more information, contact Terry Peterson, (415) 855-2594.*

Finding New Superconductors Faster

In the decade since the discovery of so-called high-temperature superconductors, a variety of such materials have been identified. An ongoing problem for research in this area, however, has been the difficulty of identifying just the right combination of elements needed to produce the best results. Out of thousands of possible proportions of the constituent materials, only a few may exhibit superconductivity. Now, with EPRI funding, Professors Sheldon Shultz and Ivan Schuller and their colleagues at the University of California, San Diego, have developed a novel procedure to allow rapid scanning of a wide range of candidate superconducting compounds.

First, the research team deposits the components individually but simultaneously in a thin film on the surface of a substrate. By the use of multiple evaporators and the continuous adjustment of substrate position, these materials are spread out in gradually varying concentrations across the sample—creating a wide variety of combinations. Next, the sample is scanned to detect signs of superconductivity in particular areas, as indicated by microwave absorption. By this method, a region of superconductivity can be pinpointed to within a cubic micrometer, and the particular set of element concentrations in that region can be determined to within a few percentage points.

Using this phase-spread alloy thin-film (PSATF) method, the researchers examined a variety of yttrium-nickel-boron-carbon compounds and determined which combinations were superconducting. The lanthanum-nickel-boron-nitrogen series was also examined, and no superconductivity was found, thus eliminating that series as a source of new superconductors. Work continues, using the PSATF method on new elemental combinations in the hope of finding likely compounds for the next round of high-temperature superconductors.

■ *For more information, contact Paul Grant, (415) 855-2234.*

How to Make a Better Ice Cream

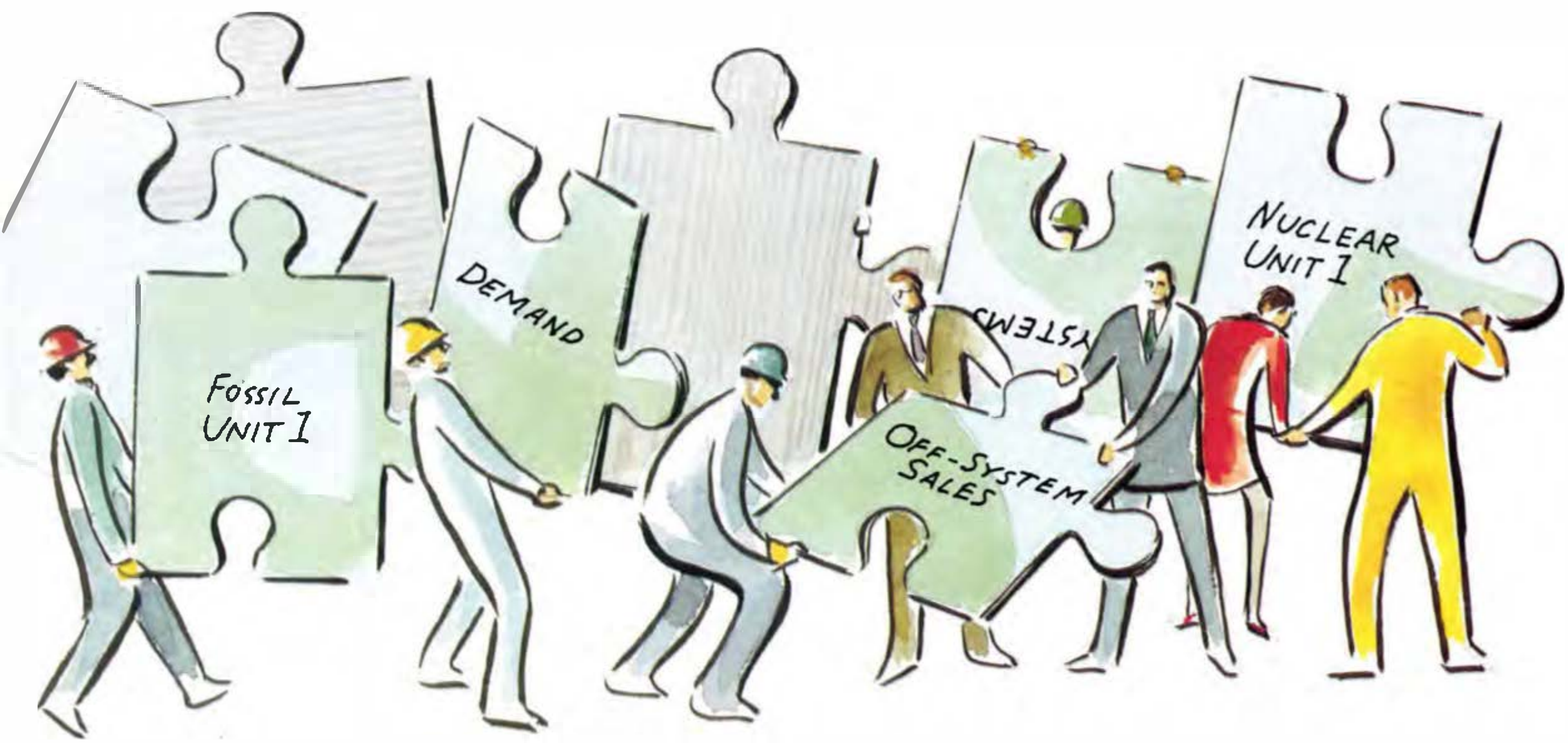
In many commercially produced foods containing dairy products—such as ice cream, milk chocolate, white sauce, and salad dressing—water must be removed from the raw ingredients because the total solids content of the finished product needs to be relatively high. Typically, some thermal process, such as heat evaporation or oven drying, is used to remove the water. Such processes, however, create unwanted flavors, which are usually masked by adding additional flavoring—for example, by putting more vanilla in ice cream. Now EPRI has received a patent on the use of freeze-concentrated dairy products to improve the flavor and other properties of these manufactured foods.

Freeze concentration involves cooling a dairy product, such as milk, below its freezing point and then removing ice crystals as they form on the surface of a heat exchanger. The total solids content of the remaining liquid product can be varied from 20% up to about 50%. EPRI received a patent on this basic process in 1990 and licensed the technology to NIRO Process Technology, which built a commercial-scale process development unit capable of removing about 1000 pounds of water per hour from milk. The resulting milk concentrate—whose trade name is Snomilk—was consistently judged superior in taste to the nearest comparable commercial product, evaporated milk.

Research attention then shifted to finding out how freeze-concentrated dairy ingredients could be used in commercial food products. Blind taste tests yielded the following results. Ice cream containing Snomilk had significantly better overall taste with less need for added flavorings. Creating milk chocolate from skim milk solids made by the freeze concentration process improved the aroma, overall flavor, and flavor balance and produced better "melt in mouth" characteristics. Improved taste was also demonstrated in cream cheese, sour cream, and soft-serve ice milk. A patent on the process for producing these improvements was issued in August 1995.

■ *For more information, contact Ammi Amarnath, (415) 855-2548.*

THE STORY IN BRIEF Deregulation of the bulk power market is prompting many electric utilities to reexamine their older fossil generating units to see how they fit into the company's overall operating strategy and whether they should be retired or modified to help the company become more competitive. EPRI's Fossil Assets Management methodologies provide a formal value-analysis process for determining which investment and utilization options for fossil plants provide the greatest benefits at the corporate level. Three major types of asset management decisions are involved: how to deploy each unit in a utility's fossil plant fleet, what investments should be made at specific plants, and how to modify operation and maintenance practices in view of present equipment condition. EPRI has also developed the Strategic Asset Management methodology, which focuses on even broader alternatives for allocating budgets and staff time across the utility. The FAM and SAM methodologies can be used together to analyze a full suite of asset management decisions, ranging from corporate-level reorganization to key equipment purchases at specific plants.



by John Douglas

Fossil Assets Management

Making Decisions on

Older Plants

When the Federal Energy Regulatory Commission issued its March 1995 Notice of Proposed Rulemaking (NOPR), providing open access to utility transmission networks for wholesale transactions by third parties, the effects were felt far beyond the bulk power market. Of particular concern to many utilities is the problem of stranded assets—that is, the loss of asset value for facilities that would no longer be competitive in a deregulated electricity market. Although FERC's "Mega-NOPR"—so called because of its size and complexity—proposes allowing utilities to recoup their losses in prudently acquired assets, the actual magnitude of potential losses and recoveries remains highly uncertain and controversial. The prospect of adding state-level deregulation of distribution systems further complicates the situation.

Older fossil generating units seem especially vulnerable. Roughly 77% of the current utility fossil fleet is more than 20 years old, and many of the units are exhibiting declining performance. In fact, the heat rates of these older plants can run 20–30% higher than those of more-modern facilities. Furthermore, with average capacity factors for fossil units hovering around 50%, many of the older plants are not being base loaded; the result is a significant additional heat rate penalty.

Still, Tony Armor, director of EPRI's Fossil Power Plants Business Unit, believes that most of these older units are unlikely to represent a large stranded capital investment for utilities. "There's little outstanding capital debt left on these old fossil plants," he says. "The real issue is operating cost. A utility needs to carefully assess the cost of generation from each fossil unit to see whether further investment or changes in operation and maintenance practices are required in order to maintain or lower production costs to achieve competitive levels. But analyzing those decisions requires good cost data, market and fuel forecasts, and other key decision information. EPRI provides asset management methodologies that enable a utility to understand the value a unit provides to the company and that support decision making about what to do with older plants."

Several options

For those utilities seeking to upgrade existing power plants so that they can compete in a deregulated market, several options are available. Some older units, of course, will continue to generate power at a competitive cost for some years to come. Others can be made competitive through upgrading or by adding new equipment. Repowering—for example, by adding combustion turbines and heat recovery steam generators—can improve heat rates by as much as 50% at some older units, while simultaneously reducing NO_x levels by more than half. For other units, seasonal peaking operation may prove to be the most economically attractive alternative. And at some plants, a manageable reduction in O&M costs can make the difference between a stranded asset and a competitive generating unit.

Traditionally, decisions about which of these options to choose have been made in the context of how regulators would treat the investment during a rate case. Furthermore, in a regulated environment with fixed benefits, asset management has emphasized retrospective, cost-based budgeting. Such methods, however, are already inadequate for dealing with the challenges of competition, where new revenue-enhancing opportunities must be balanced against cost cutting. A utility may, for example, identify additional off-system sales as a viable way to increase revenues and use more power from an older plant. In this case, more-inclusive asset management methodologies are needed to determine what level of additional investment in the plant could be justified by the new business opportunity—while also taking into account the greater uncertainties involved. Above all, such decisions must be based on how any specific plant investment will contribute to overall corporate goals.

"Good business practice demands that decisions about investing in power plant assets be well supported, documented, and defensible," says Michele Blanco, manager for EPRI's Fossil Assets Management (FAM) target. "Without a formal value-analysis process, utilities may find themselves throwing good money after bad. What our FAM tools provide is an approach to analyzing plant investment and utilization options on a companywide basis to determine which of the available alternatives creates the most value for all corporate stakeholders."

Blanco outlines three major, interrelated types of plant asset management decisions that need careful scrutiny. Fleet deployment decisions determine the best long-term investment and operation strategy—run, refurbish, repower, retire—for each unit in a utility's fossil plant fleet. Within this context, resource allocation decisions determine the appropriate level of capital and O&M investment at a specific plant in order for it to fulfill its role in the overall fleet strategy. Finally, given the level of investment available for an individual unit, decisions can be made about how to modify O&M practices in light of present equipment condition.

For this asset management process to work effectively, linkages are clearly needed between the steps just described. Revised O&M costs, for example, must be considered in each iteration of resource allocation decisions for a unit in order to make sure its condition can be maintained appropriately. Similarly, the resource allocation process must provide feedback for fleet deployment decisions so that overall strategy is aligned with the realities of current and future unit cost and performance.

Developing core concepts

In support of the specific guidelines and software being prepared for each type of asset management decision, two case studies were conducted to develop what Blanco calls "core concepts" related to how utility decisions are made in general. These concepts help determine the requirements for a utility decision support system and also provide a better understanding of how the people and processes in a particular corporate culture can affect a decision outcome.

The case study conducted at San Diego Gas & Electric Company focused on a capital budgeting process that had become stalled because traditional analysis did not adequately relate a proposed retrofit project to long-term goals for the plants involved. The project had been initiated to replace obsolete pneumatic control equipment at five generating units with modern distributed control systems. Company engineers were unable to gain approval to make the improvements, however, until they could provide an explicit link to the companywide goal of making older plants cost-competitive. In particular, they lacked a way to balance the perceived benefits of retrofit, such as improved heat rate and greater operator flexibility, against the perceived risks, such as the possibility of cost overruns or the effect of a later decision to repower.

One of the first tasks of decision analysis in this case was to clarify and quantify some of the intangible benefits whose value had been questioned. The benefit of improved operator flexibility, for example, was clarified by relating it to the ability to operate units safely at lower minimum power. This advantage was then quantified in terms of the dollar saving realized from minimum load reduction. The analysis also revealed a critical missing link in the decision chain—an overall modernization strategy that would translate corporate competitive goals into specific plant improvement objectives. Once these and other factors had been taken into account, the analysis indicated that the proposed retrofits would be cost-effective only at units not targeted for repowering. On the basis of this result, the company was able to realize estimated savings of more than $7 million by revising plans for the distributed control systems retrofit project.

The second core concepts study, conducted at Minnesota Power Company, focused on how to apply a particular analysis technique—cost mapping—to utility asset management decisions. A cost map is a type of influence diagram that graphically depicts the major factors that can affect a decision outcome and indicates by arrows how they affect each other. Cost maps can serve as templates to help guide the initial formulation of a decision, can then help build spreadsheets during the evaluation phase of decision making, and can finally summarize the important relationships

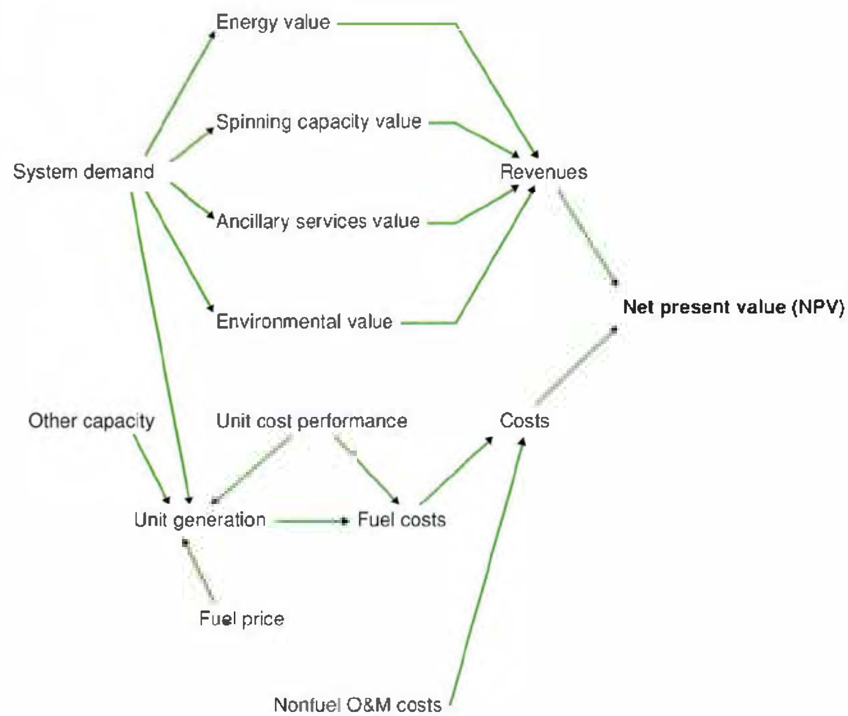
LOCATION, LOCATION, LOCATION Many older fossil plants, such as the Ravenswood generating facility of Consolidated Edison in New York City, have added value because of their proximity to a major load center. Location is one of the factors that should be taken into account when making asset management decisions about aging fossil units.

FOSSIL ASSETS

As electric utilities face increasingly difficult decisions about how best to use older fossil power plants in an era of deregulation, EPRI's FAM tools provide a

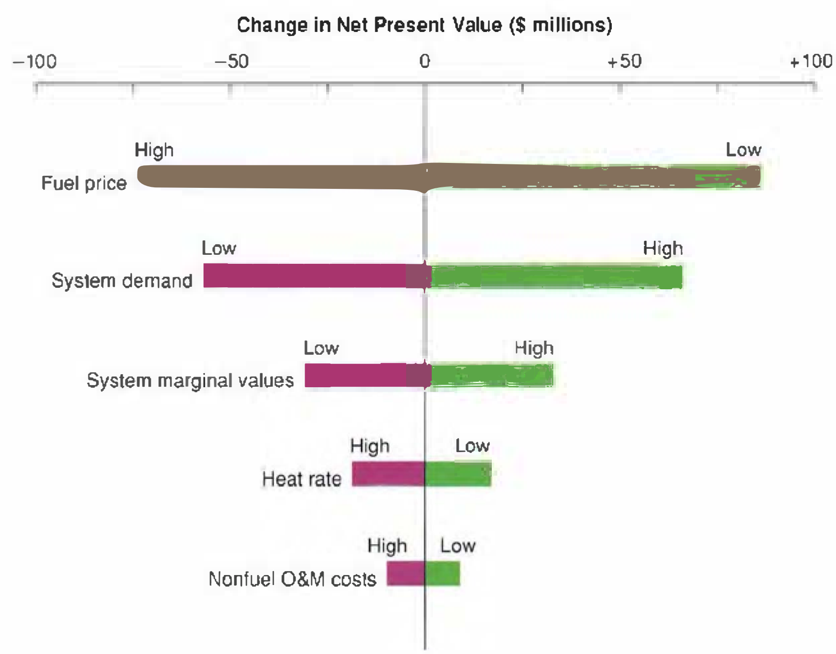
DECISION STRUCTURE

The first step in making asset management decisions is to construct a value map showing how the economic variables that influence a decision are related to each other. When these variables are quantified for a particular investment alternative, the net present value (NPV) of a power plant under that option can be calculated by subtracting costs from revenues.

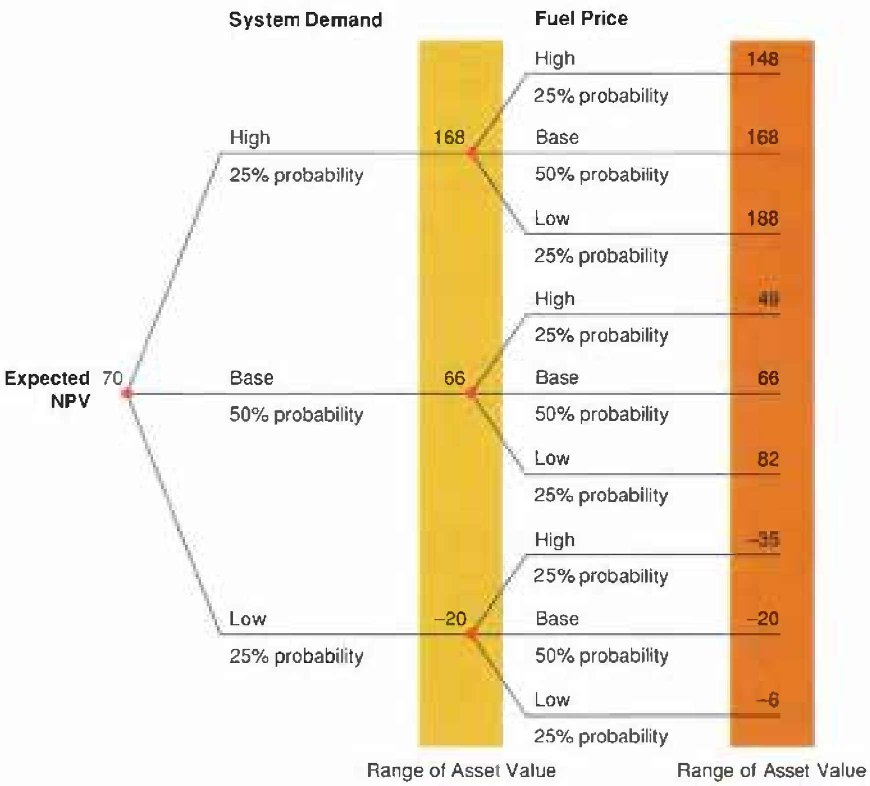


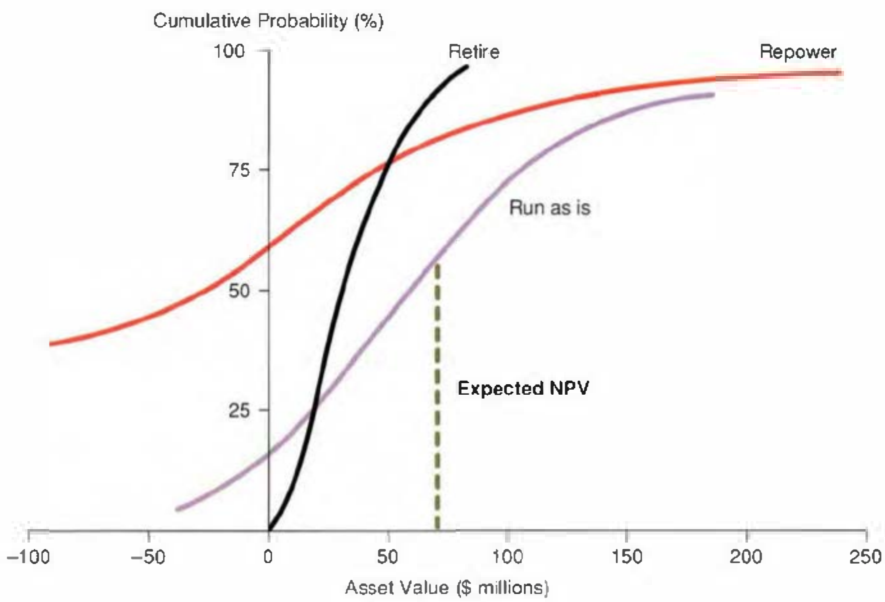
SENSITIVITY ANALYSIS

Uncertainties about some variables can significantly influence the outcome of a decision. A tornado diagram (so called because of its shape) shows how strongly changes in particular variables affect the calculated NPV of a plant for a given option. In this example, uncertainties in fuel price and in systemwide demand have the most effect on the outcome.



way to determine the corporate-level value of investment alternatives at each generating unit.





PROBABILISTIC ASSESSMENT

A decision tree makes it possible to calculate the probable range of the plant's asset value in light of the key variables identified in the sensitivity analysis. In this example, the decision tree is for the alternative of continuing to operate the plant as in the past, with minimal additional capital investment. At the outset, the plant has an expected NPV (from the value map) of $70 million; possible changes in system demand and fuel price could reduce the plant's asset value to as low as -$35 million or increase the value to as much as $188 million.

RISK-RETURN OF ALTERNATIVES

Assessments like the one above can be run for various alternative investment and dispatch strategies and the outcomes compared to give a better picture of risk and return for all options. In this example, continuing to run a plant in its current state has a higher expected value than retiring the plant, but maintaining the status quo also has a higher chance of a negative outcome. Repowering the plant could produce the highest NPV, but this option also involves the greatest level of risk. Other options that could be assessed include switching the plant to seasonal or cycling operation, mothballing it for a fixed period, or upgrading plant systems to lower operating and maintenance costs.

used in mathematical models in the appraisal phase.

The work on cost maps in the Minnesota Power case study revealed their usefulness in showing how utility decisions with different time frames can be related to each other. For example, a short-term decision about whether to repair a defective piece of equipment immediately or to wait until the next scheduled maintenance period can have important medium-term consequences for a power plant, such as increasing the risk of a forced outage. During the study, cost maps were used to analyze decisions related to increasing off-system energy sales, providing automatic generation control for load following, and investing in a cooling-tower upgrade. In the latter case, for instance, a capital investment of $1.5 million in a variable-speed motor for the cooling tower was found to produce an annual short-term net value of $675,600 (mainly through reduced fuel costs) and an anticipated value of medium-term benefits of more than $3.6 million (mainly through a reduction in forced outages).

Fleet deployment

Deciding how to deploy the diverse fossil units in a utility's generation fleet is an inherently complex process. This is particularly an issue when determining what to do with marginal or at-risk units. The attractiveness of different alternatives may be viewed from conflicting perspectives by various stakeholders—customers, shareholders, employees, and society. Each decision at this level will have important implications for long-term operational plans at individual units. And numerous uncertainties have to be taken into account, from immediate costs to future changes in the business environment. The FAM methodology for fleet deployment is thus designed to provide a utility with critical information on the value of each generating unit, how changes in each unit will affect its value, and how these changes, in turn, can affect the value of other units.

One valuation measure used by the FAM methodology to fulfill these requirements is net installed value (NIV)—the net change in total system value attributable to having the unit available for use. How the NIV of a unit on a particular system is calculated depends primarily on the size of the system. For small systems, a system operation model—usually based on a production costing simulation—is run repeatedly to see how total costs change incrementally with each proposed investment or operating modification at a particular plant. This "bundled" method of unit valuation is less reliable and sometimes misleading for larger utility systems (because of the insensitivity of most production costing models to relatively small changes in one unit). An unbundled method has been developed that relies on separating the unit change from the larger system analysis.

The bundled method of unit valuation for making fleet deployment decisions was used in a case study at Central Illinois Public Service Company, with a particular emphasis on what to do about underperforming units. Several options were considered for eight units by using EPRI's MIDAS production costing model to determine the systemwide effects of proposed changes at each plant. During the initial screening phase, which considered only the utility system in its present state, two plants (Grand Tower and Hutsonville) were identified as underperforming plants and the most likely candidates for removal from service.

A subsequent sensitivity analysis revealed, however, that an increase in off-system sales could make the two plants profitable. Specific scenarios for various sales options were then considered for each plant. It was determined that the best decision would be to continue to operate both plants while pursuing 300 MW in additional off-system sales. The fact that 64 production costing runs of the MIDAS code were needed to perform the sensitivity analysis for each plant is an indication that this bundled valuation method is suitable mainly for considering changes at a small number of generating units.

The full unbundled methodology for use with large utility systems is now ready for utility demonstration, and a key PC software element—the Asset Utilization Tool—was the subject of a case study at Consolidated Edison Company of New York. In this study, Con Edison wanted to evaluate long-term operational plans for a particular unit in light of its contribution to systemwide value at a time when energy development projects are expected to lead to excess generating capacity in the Northeast. Six options were considered: seasonal operation during summer peak months, continued operation without capital improvements, retirement, mothballing for five years, capital investment for heat rate improvement and life extension, and repowering.

Using data on Con Edison's forecast demand, fuel costs, and the cost of environmental externalities, the Asset Utilization Tool calculated a base-case NIV for each of the six operating options. The clear winner was seasonal operation, providing far more value than the second-ranked alternative, which was to continue operation without capital improvements. When a sensitivity analysis was conducted, however, it became clear that there were several key variables driving the decision outcome. Unexpectedly high demand or low fuel costs, for example, could make repowering the preferred option. Lower-than-expected demand, on the other hand, would result in a preference for retiring the plant. A decision tree was assembled to indicate NIV for all possible outcomes as each key variable changed from the base case to its highest and lowest estimated values. Finally, a probability distribution was assessed for the NIV of each option to indicate the expected value of each option and tradeoffs between risk and return. This analysis showed that, while the repowering option has a higher upside potential than seasonal operation, it also has a 50% chance of actually losing money—compared with only a 25% chance of losses with seasonal operation and virtually no loss potential with immediate shutdown.

"The Con Edison case study clearly illustrates the power of even a limited application of our fleet deployment methodology," according to Michele Blanco. "Understanding the relative values of all the options clarified the decision for the study team; then treating uncertainty in a way that showed the ranges of potential outcomes provided the necessary insight to move the decision forward. We are now working on the next step with several utilities—looking at multiple units in a large system."

Resource allocation

Once unit deployment goals have been established, the challenge of resource allocation is to ensure that the company makes the best investment of capital and O&M resources to keep units performing in accordance with these goals. Structuring the optimal portfolio of projects and activities requires choosing among diverse projects that could each improve value, but perhaps in very different ways. One project, for example, might improve the heat rate at plant A; a second might lower O&M costs at plant B; and a third might increase availability at plant C. EPRI's work in resource allocation has focused on identifying a common basis for evaluating such candidate projects, incorporating both tangible and intangible values and uncertainties in technical, financial, and system variables.

As in other FAM methodologies, the focus here is on comparing the attractiveness of specific projects in terms of their mar-

Hutsonville plant

FLEET DEPLOYMENT DECISIONS When Central Illinois Public Service faced increased competition in a region with ample generating and transmission capacity, the utility used EPRI's FAM approach to conduct a fleet deployment case study. While initial screening indicated that retiring the Grand Tower and Hutsonville plants from service gave the greatest overall benefit, subsequent sensitivity analyses showed that the best decision would be to continue to operate both plants while pursuing 300 MW in additional off-system sales.

Grand Tower plant

ginal value to the company as a whole, and on treating the uncertainty inherent in decision variables. Such an expanded approach first requires a systematic evaluation of each project in terms of incremental improvement in basic attributes, such as capacity increase or safety improvements. Marginal value analysis is then used to translate these attributes into system-level value measures, generally expressed as benefits and dollar costs. In addition, a sensitivity analysis is performed to show how calculated benefits might be affected by changes in the attribute improvements from those assumed for a base case. Finally, projects can be ranked on the basis of their benefit/cost ratios, taking into account their sensitivity to attribute uncertainties.

This general methodology has been applied in two case studies. At Public Service Company of Colorado, the primary concern was how to increase the efficiency of the capital budgeting process, which was considered too time-consuming and overly influenced by subjective advocacy. By using the resource allocation approach just described, the company was able to simplify and standardize its budgeting process, as demonstrated in a side-by-side comparison with the old method during planning for the 1995–1996 budget cycle. A case study at Northern Indiana Public Service Company focused on choosing capital projects with the greatest potential to increase profit margin. The EPRI-utility team developed simple spreadsheet models to link each project's effect on plant attributes to the present value of resulting changes in the profit margin. In applying these models to the 1995 budget cycle, the company moved from an annual budget event to an improved, peer-reviewed business-oriented process for both capital and O&M investments.

Out of the work from both case studies has emerged a software product—the Resource Allocation Tool (RAT)—now available to EPRI members for use on Windows-based PCs. This tool integrates information from various data sources and provides a graphical interface that allows utility managers to review and prioritize projects on the basis of customized company preferences. Economic benefits for RAT analysis are either imported directly from other models or calculated inside RAT with benefit tables created by other models. In either case, users need not learn new calculation tools to use the program.

A demonstration of the RAT program was hosted by Kansas City Power & Light Company for capital resource allocation at its La Cygne plant. The utility supplied a list of 30 projects to include in the study, 12 of which were already considered must-do budget items. The remaining projects varied widely in cost and attributes. Replacement of a feedwater heater tube bundle, for example, would cost only $7000 and reduce O&M expenditures by about $156,000

a year. Extensive instrument replacements, on the other hand, would cost more than $317,000 and increase plant availability by 0.6% while reducing O&M costs by $80,000 a year. In addition, the new instruments would contribute important intangible attributes, which were judged on a five-point scale. On this scale, safety impacts were given a score of 2, and environmental impacts, a score of 4. Such intangible attributes were then incorporated into benefit/cost calculations by assigning a dollar value to each score point on the basis of decision makers' willingness to pay for the perceived benefit.

Benefit tables for the two La Cygne units were constructed by using a production costing model, which translated improvements in heat rate, plant availability, and capacity into dollars saved by the system per year for the next 18 years. When these and other relevant data were introduced into the RAT model, it produced a list of projects prioritized by present-value benefit/cost ratio. At the top of the list (after the must-do projects) was installation of a new feedwater heater extraction valve with a benefit/cost ratio of 48. Instrumentation replacement ranked tenth, with a benefit/cost ratio of 4.2, while feedwater heater replacement—although the least expensive project on the list—earned a benefit/cost ratio of only 1.5–1.9, depending on which unit was selected.

The RAT portfolio management capability is now being incorporated into the more comprehensive Resource Allocation Framework (RAF), which will include linkages to costing and financial models. This is a collaborative effort involving eight utilities to date.

O&M practices

One measure of just how fundamentally things are changing in the electric power industry is the extent to which the effects of competition and shifting load factors are increasing pressure to improve O&M practices at individual fossil plants. Specifically, many older baseload plants are being converted to cycling units, which may require extensive plant modifications and changes in the way equipment is maintained. Because of the diversity of analyses needed to guide decision makers in planning O&M practices for separate plants, the FAM approach in this area has been to create a toolbox of products that can be applied to meet a utility's particular needs.

An underlying methodology for this toolbox and the RAT model is the Plant Modification Operating Savings (PMOS) model. PMOS is a software package that allows planners to calculate the benefits of various plant modifications on the basis of their contribution to systemwide marginal value, as discussed earlier. A major advance in the design of PMOS is that, unlike traditional methods, it can take into account both the direct benefits of modifications to a plant (such as lower operating costs) and the indirect benefits (such as greater dispatch flexibility). These benefits are calculated by PMOS in terms of changes in the net operating value (NOV) of a plant —that is, the value to the utility system as a whole of having the plant on-line. Using this information, PMOS can then calculate benefit/cost ratios and payback periods for different proposed modifications so that they can be ranked by decision makers.

A case study using PMOS to rank candidate plant modifications at Wisconsin Power and Light Company demonstrated both the advantages of this software tool and the importance of taking indirect benefits into account. The utility was particularly interested in modifying older fossil plants to improve their cycling capability and decrease their operating costs. At one plant, for example, there was a proposal to install adjustable-speed drives on fans and pumps to reduce auxiliary power consumption and yield a corresponding heat rate improvement. It was anticipated that such improvements would lead to more-extensive use of the plant. PMOS calculated that a $60,000 investment in adjustable-speed drives would yield a $320,000 improvement in NOV and would pay for itself in about one and a half years.

Overall, the utility used PMOS to evaluate more than a dozen unit modifications at four fossil plants and compared the results of this analysis with similar calculations made with previously standard methods. The company determined that the PMOS approach, because it is more comprehensive, calculated additional savings of $4.4 million from the modifications, which would not have been realized using conventional analysis. The case study also concluded that conventional methods, by focusing only on direct cost reductions, could seriously underestimate the indirect benefits due to increased operating flexibility —which become increasingly important when a plant is to be used for cycling duty.

A case study at Duke Power Company showed how PMOS can also be used to expedite a program of enhanced maintenance at older fossil plants. In this application, PMOS calculates the NOV of a unit and shows how it can be improved by various maintenance activities. Working with EPRI, Duke developed the Value-Centered Preventive Maintenance (VCPM) model, which takes the NOV output from PMOS and uses it to evaluate alternative strategies for optimizing maintenance. For example, to evaluate options for repairing or rebuilding a boiler feedpump, Duke calculated the NOV of a plant at different levels of feedpump efficiency and then used VCPM to construct a decision tree that balanced the cost of maintenance against the cost of pump failure at various times. As a result of this analysis, the utility determined that the highest-value strategy for the current feedpump was to rebuild it in about one and a half years. The case study also concluded that deferring maintenance on the pump might be the more attractive option at a plant with a lower capacity factor and, more generally, that this sort of value-centered approach can provide critical help in choosing the right strategy.

"Our next study in the O&M practices area is now being launched with National

Power, in the United Kingdom," Michele Blanco concludes. "In that study, we will be developing a methodology for value-based outage scheduling. Together with the studies using PMOS, this work will contribute to the O&M toolkit we will supply to members. In addition, during the next year, our FAM R&D will focus on building an industry experience database related to plant cycling and startup, make refinements in our Resource Allocation Tool, extend the Resource Allocation Framework, and begin case studies related to determining the cost of providing ancillary services required by the Mega-NOPR. We will sponsor an industrywide conference that will enable utilities to see how the various FAM components can be integrated into their generation business planning."

Strategic asset management

While the FAM project was being developed, a companion project was applying the same kind of methodology to other kinds of decisions utilities increasingly have to make on the basis of their effects on corporate value. This Strategic Asset Management (SAM) methodology focuses on even broader alternatives for allocating budgets and staff time—comparing, for example, the value trade-offs involved in an organizational realignment. In one case study, an entire division of a utility was reorganized from technical areas to customer-focused groups, and SAM was used to reallocate resources to reduce costs while increasing customer satisfaction.

"SAM and FAM are complementary," says Charles Clark, director of EPRI's Utility Resource Planning & Management Business Unit. "Some utilities may want to use SAM first to consider changes in their overall business and then use FAM to decide how best to make capital improvements in the fossil portion of the fleet. Other utilities may use FAM first to develop a cost map of relationships among the factors that determine generation cost and then use these as input to strategic decisions about how to plan for future generation expansion. Beyond developing the two methodologies, EPRI's SAM and FAM project teams have maintained a close working relationship in conducting utility case studies."

Tony Armor agrees: "A utility must be clear about how it wants to operate as a company and must identify what business opportunities it should pursue in the future. Our FAM methodologies can help a utility make these strategic decisions by assessing the value to the company of an aging fossil fleet. This value assessment leads to such tactical decisions as how to deploy the entire fleet of units and how specific unit investment decisions should be made. I believe that such value-based decision making is a prerequisite to success in the new era of deregulation and competition." ■

Background information for this article was provided by Michele Blanco, Tony Armor, and Dave O'Connor of the Generation Group's Fossil Power Plants Business Unit and by Charles Clark of the Power Delivery Group's Utility Resource Planning & Management Business Unit.

R&D AND THE DIMENSIONS OF VALUE

BY KURT YEAGER

At the end of a century that has been wholly transformed by the development of new technologies, our nation—and our industry—finds itself engaged in an unexpectedly fierce debate. As the competition for capital continues to grow in our constrained economy, the long-held idea that research is intrinsically useful in all areas and circumstances is giving way to a more discriminating assessment of its benefits to business and society. At issue is whether thousands of research and development initiatives, both public and private, across the country will continue to be funded. It is important that we resist the impulse to merely defend the status quo—that we instead become actively involved in helping to renegotiate the "social contract" for science policy. Still, to those of us who have been intimately involved in the work of technological progress, such basic questioning of the R&D process is deeply disturbing.

At no other time in history, it would seem, has the value of science and technology development been more evident. During the last half of the twentieth century alone, R&D has yielded a broad range of critically important advances, from the harnessing of solar and nuclear energy for power to the development of computers and lifesaving vaccines and medical diagnostics. In an era when robots take over hazardous tasks, satellites relay sight and sound anywhere in the world instantaneously, and organ transplants are performed regularly and successfully, the place of R&D in our society would seem to be assured.

But in fact what we're seeing is a sort of disenchantment with research as a concept, and this feeling is leading to widespread policy changes, at least in this country. On the government side, growing budget deficits have compelled policymakers to scrutinize any and all programs that can be trimmed or eliminated. In recent months, we have seen both the Department of Energy and the entire national laboratory system face wrenching attack and change. Federal financing of nonmilitary scientific research in the United States is expected to decline by one-third within seven years, according to a recent report issued by the

LIKE A RIPPLE IN A POND, THE VALUE OF RESEARCH AND DEVELOPMENT EXPANDS OUTWARD FROM THE SOURCE OF INNOVATION AS BENEFITS PASS THROUGH TO A GROWING

RANGE OF BENEFICIARIES, COMPOUND OVER TIME, AND SPARK FURTHER ADVANCEMENTS IN SCIENCE AND TECHNOLOGY. EPRI'S EXECUTIVE VICE PRESIDENT DISCUSSES RESEARCH IN LIGHT OF INDUSTRY CHANGE AND SUGGESTS A MULTIDIMENSIONAL FRAMEWORK FOR CONSIDERING THE TRUE VALUE OF R&D.

American Association for the Advancement of Science. The report notes that deep cuts in R&D projected over the next decade represent "the most significant across-the-board funding cuts to the research and development enterprise in the post–world war era."

Similarly, technologically intensive companies, facing burgeoning competition from around the world, are carefully evaluating every dollar spent, including every dollar invested in research and development. For the utility industry in particular, the question of R&D value has gained urgency. Competitive pressures are relatively new to our industry, and as deregulation becomes increasingly inevitable, many utilities find themselves running out of time in the struggle to find a competitive edge. As a result, the focus at many companies has sharpened to near-term concerns over cutting costs and developing new markets—and virtually nothing else. In this environment, R&D investments must be justified, and not just for the long term. Indeed, as competition intensifies, strategic planning horizons are shrinking. For many utilities, it's a question of how an investment will pay off not three or five years down the road but over the next six months or year—in cost savings, costs avoided, or expanded revenues.

The importance of controlling costs in a deregulated environment is undeniable. Even when utilities enjoyed a "natural monopoly" status, this was an important target of EPRI research, and a tremendous amount of the value EPRI has delivered over the years has come from research results that have lowered the industry's costs. The danger comes when the problem at the top of the list totally eclipses all other concerns and opportunities. By focusing too sharply on the most immediate value, or the value that is easiest to quantify, we can easily miss the boat on what gives the *greatest* value. History has shown over and over that the fortunes of industry are much more complex and subtle than the statement of quarterly earnings.

Part of the problem today's decision makers face is that while the cost of R&D is easy to measure, its value is not. I believe that if common ground exists between the imperatives of economic pressures on the one hand and the importance of technological progress on the other, it must be found in a broader, more-thoughtful consideration of the true value of R&D. Let me propose a framework incorporating three dimensions of value that go beyond the quarterly earnings report. The first dimension is breadth of value—the multiplicity of beneficiaries for a technical advance. The second is time—the compounding value and expansion of applications and benefits over an extended period. The third is the inclusion of intangible as well as tangible benefits. Although all three of these dimensions typically come into play with technological advances, let me give you a few discrete examples of each.

The breadth dimension

Breadth of value relates to the expanding array of beneficiaries for research results. Improvements in environmental quality are often cited as an example of the broad reach of research value, with good reason: we all breathe the air, we all drink the water. But we also work for a living, we buy and use products, we are concerned with the welfare of our families. In short, we are invested in our quality of life. And in this modern age, our businesses, health, possessions, and recreation are largely built on a substrate of technological developments. The value of these developments can be traced through a broad web of beneficiaries, starting with the company that invested in the research and branching out to larger and larger segments of society.

A case in point would be a pharmaceutical company that develops a successful drug based on some pioneering research. How would one gauge the value of this development? To the company in question, the benefit would be the cumulative stream of profit in comparison with the cumulative stream of investment in research. To the pharmaceutical industry as a whole, the real value of this research might be the basic advances in knowledge that spur other discoveries or applications that advance the industry at large. To society, the benefits would include the value of individual lives saved and health restored, the subsequent value of these individuals' contributions to society, and the overall effect of a healthier workforce on economic prosperity. In this case, the benefits realized by the pharmaceutical company are not only those that flow back directly in short order but those that flow back indirectly over time through other pathways in the economy.

As a well-known example shows, *failure* to innovate can also have a pass-through effect on society. In the 1970s and 1980s, the U.S. automobile industry missed important cues to incorporate advanced technology in its manufacturing and business practices. As a result, the quality of its product suffered in comparison with Japanese cars, and the U.S. companies lost critical market share. Meanwhile, the American steel industry, also wedded to outmoded technology, floundered as orders for automotive steel decreased and lower-cost imported steel became available to U.S. manufacturers. These failures severely depressed the economy of the northern Midwest and the living standard of its population for two decades. While U.S. automakers and steelmakers have come back strong in the 1990s with greatly increased quality and forward-looking technical improvements, Big Steel has ceded some key markets to agile, high-tech minimills.

Such a cascading effect, positive or negative, underscores the importance of capturing the full spectrum of beneficiaries in considerations of R&D value. This very concern—the importance of science and technology to the social and business fabric of the country—has led the American Association for the Advancement of Science to warn in its report that "the long-term effects of dismantling a coherent scientific enterprise could be very harmful."

The time dimension

The time dimension captures the cumulative and expansionary nature of technological advancement over an extended period. If you buy a microwave oven to save time fixing dinner, you save time every time you use it, not just on the day you buy it. Similarly, an adjustable-speed drive installed to increase the efficiency of an assembly line saves money every day the line operates. Advanced systems—even those offering only incremental improvements—are quiet but relentless providers of value, although they are rarely appreciated as such.

The cumulative aspect goes further over time, however, as new applications are developed that multiply the value of the original discovery. For example, the most unusual aspect of lasers when they were first developed was that they could project very straight, tight beams of light for long distances; as a result, their primary value was seen to be in advanced surveying instruments. Their far greater value as a new foundation technology for microsurgery, precision welding, data storage, and fiber-optic information transmission came a good deal later.

The importance of controlling costs in a deregulated environment is undeniable. The danger comes when the problem at the top of the list totally eclipses all other concerns and opportunities.

This inability to correctly gauge the future value of a new development is not unusual. Indeed, the history of technology is rife with examples of researchers who grossly underestimated the value of their work because they could not see beyond their immediate concern—an individual product. Celluloid, the first polymer plastic, was developed specifically as a cheap substitute for ivory in making billiard balls. Nylon, the granddaddy of all synthetic fibers, for years was used as nothing more crucial than a substitute for silk in stockings. The first computer scientists doubted that their new programmable machines would find application outside accounting functions and military operations research.

A narrowing of focus also narrows peripheral vision, and that is where the potential for huge advancement lies. Development of broad as well as deep knowledge, integration of concepts, synergy between advances in different scientific disciplines—these are the tools that, over time, exponentially increase the value of research.

These examples tell us something important about R&D focus. Solving immediate, sharply defined problems is typically of critical interest, but more often than not, the value of the advancement is incremental. One reason is that a narrowing of focus also narrows peripheral vision, and that is where the potential for huge advancement lies. Development of broad as well as deep knowledge, integration of concepts, synergy between advances in different scientific disciplines—these are the tools that, over time, exponentially increase the value of research. And they provide the connections involved in the third and perhaps most powerful dimension of value—intangibles.

The value of intangibles

This dimension involves the value not of products but of ideas, basic discoveries, knowledge, and expertise—concepts like hybridization in agriculture, quantum mechanics in physics, parallel processing in computer science, DNA structure and gene splicing in biology, satellite relays in communications. Each of these groundbreaking ideas revolutionized entire industries. But as valuable as individual breakthroughs are, it is the combination, synergy, and building of ideas that provide the most-powerful advances.

The development of the computer provides an interesting example. It's not at all surprising that early computer engineers failed to predict the eventual capabilities and reach of their invention. After all, the expansion of the computer's usefulness has been largely a question of reducing its physical size, and how can you envision a pocket-size computer when the only element of your room-size machine that will fit in a pocket is 1 of its 17,000 vacuum tubes? The invention of the transistor, advances in materials science, the concept of microminiaturization, the creation of the integrated circuit, the development of information theory—foreseeing all these and more would have been required for a vision of what computers would become. This is how R&D works: the results of technological research become enabling tools for further technological progress.

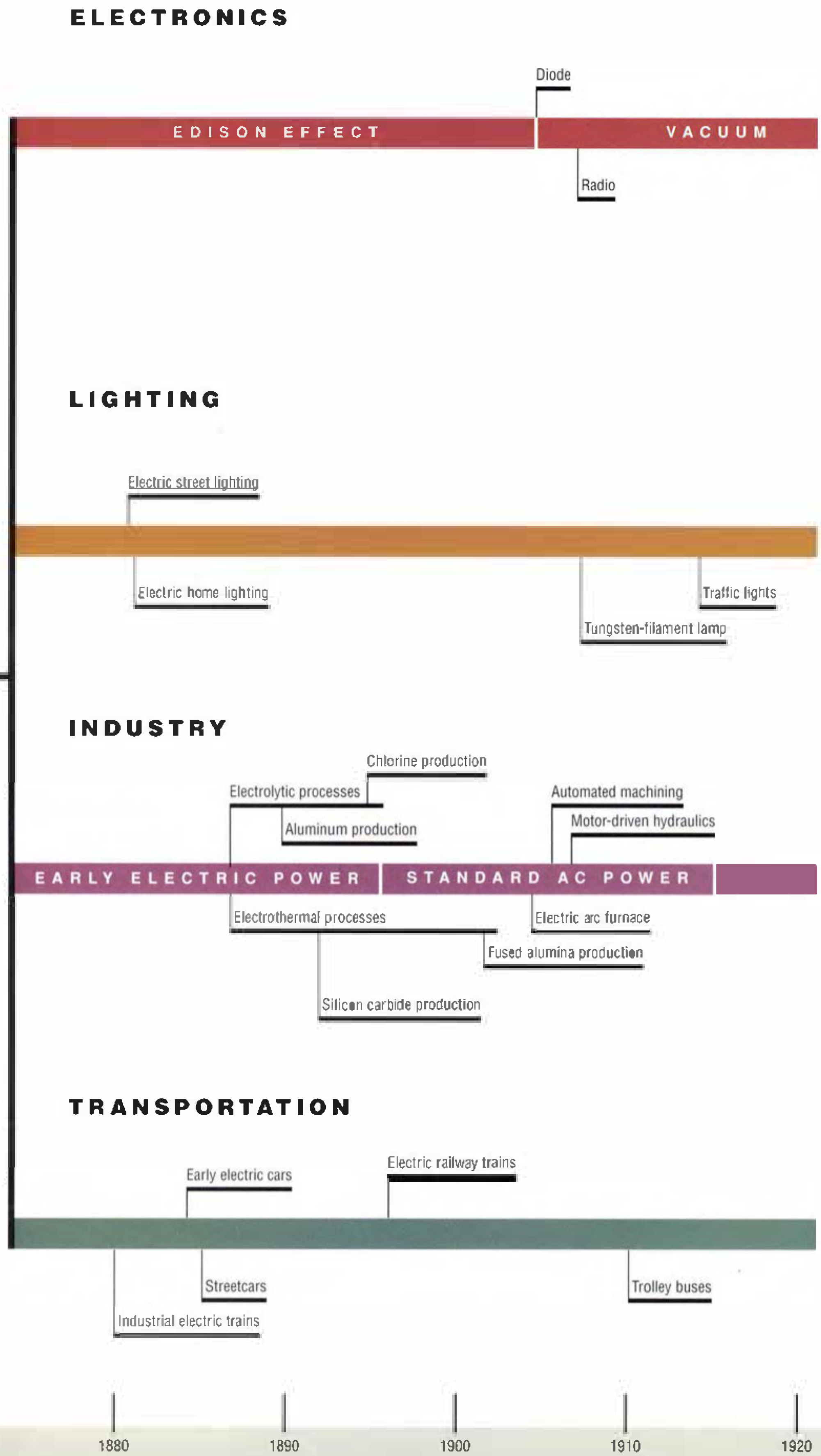
This integration and building of concepts and applications can deliver tremendous value. The strongest example I know is, in fact, the seminal development in our industry's history—Thomas Edison's development of a practical incandescent lightbulb and the electricity delivery system needed to support it. Just imagine trying to assess the future value of Edison's electric system from the vantage point of 1899, 20 years after the lights first went on. Certainly the growing infrastructure and increase in productive capacity that was taking shape hinted at important benefits. Long-distance transmission had begun at Niagara Falls in 1885, a signal that a regional, even a national, power grid might someday be possible. But a larger value lay just out of sight over the horizon: no one could have anticipated the effect of small, electrically powered unit drives, which would revolutionize industrial production in the 1920s; nor could anyone have foreseen the development of the electronics that have led to today's information age. None of this could have been seen in 1899, but looking backward today, we realize that the cumulative value that sprang from Edison's work is almost beyond measure.

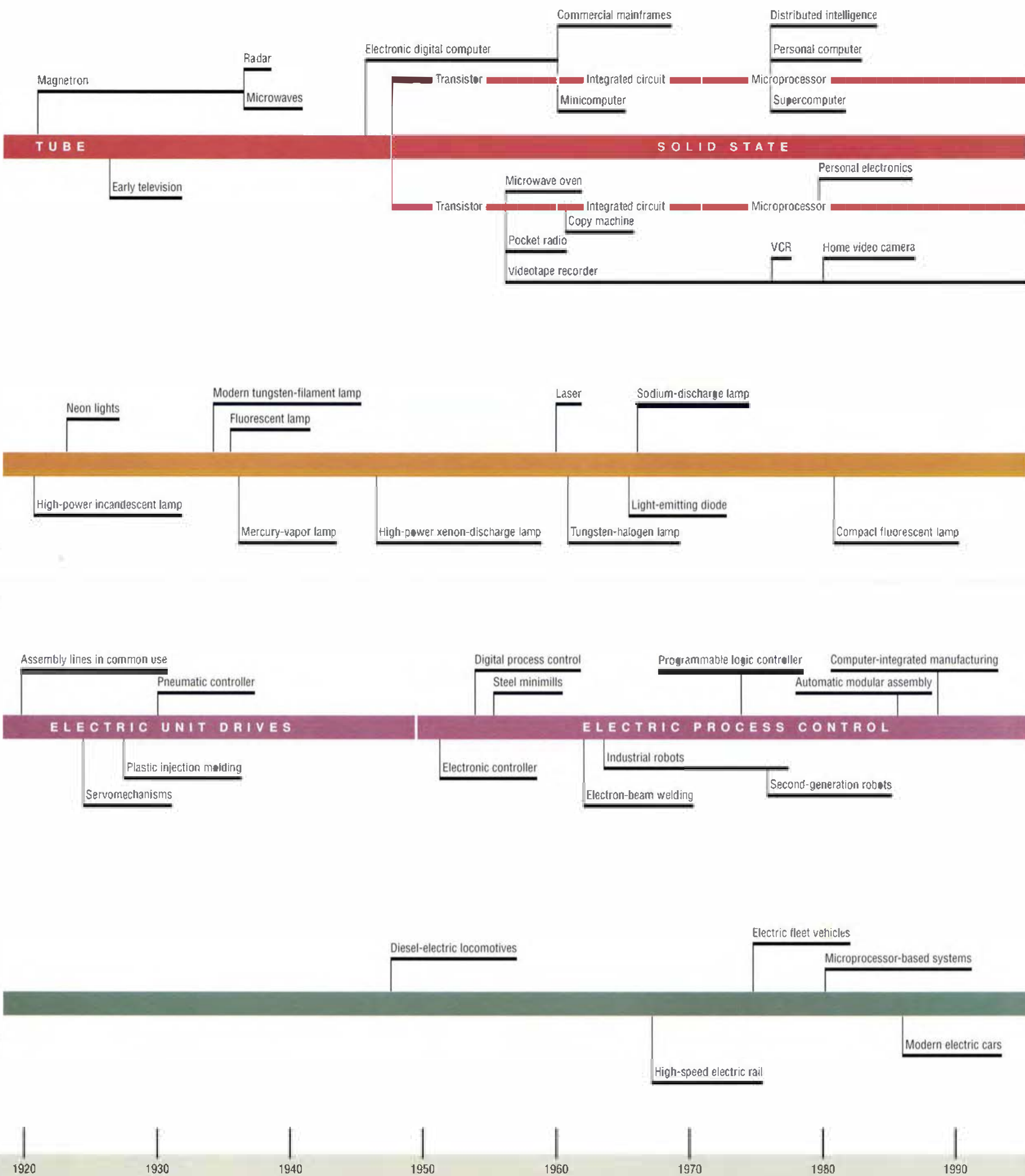
One reason is the richness of the intangible value. Edison is important to us not because he invented the electric light—a product—but because he invented the concept of electrification. The first electricity supply system was, in a sense, only an engineering detail required to make lightbulbs salable. Within a decade, electricity itself was the product, spawning the birth and development of our industry. But even this was not the article of great value. It was the incredible *capability* of easily accessible electric power to improve our lives on so many fronts—in business, industry, and our homes—that transformed modern society. Virtually every endeavor in modern society is powered by electricity. This capability for enabling progress is still potent today, with electrification being generally seen as one of the key requirements for the economic and social development of Third World countries.

Why do ideas and other intangibles have such an impact? Paul Romer of the University of California, Berkeley, suggests one reason as he draws a distinction between the "rival" and "nonrival" goods generated by research. Tangible items, he points out, tend to be rival goods, which individuals compete for and diminish through use—for example, food, a new car, a day's labor. Ideas, knowledge, physical laws, and so on are nonrival goods that can be used by one individual without diminishing their use

THE EDISON LEGACY
Over the past century, the benefits and beneficiaries of Thomas Edison's research have grown exponentially, with innovation building on innovation. His development in 1879 of a practical incandescent lamp and an electricity delivery system not only changed lighting technology forever, it also revolutionized

industry and had a substantial influence on transportation. The curiosity known as the "Edison effect," discovered during his lamp research, was the basis for the vacuum tube, which opened the door to modern electronics, telecommunications, and the information age.





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Microprocessor
Personal electronics
Pocket radio
Videotape recorder
VCR
Home video camera
Neon lights
Modern tungsten-filament lamp
Fluorescent lamp
Laser
Sodium-discharge lamp
High-power incandescent lamp
Mercury-vapor lamp
High-power xenon-discharge lamp
Tungsten-halogen lamp
Light-emitting diode
Compact fluorescent lamp
Assembly lines in common use
Pneumatic controller
Digital process control
Steel minimills
Programmable logic controller
Computer-integrated manufacturing
Automatic modular assembly
ELECTRIC UNIT DRIVES
ELECTRIC PROCESS CONTROL
Plastic injection molding
Servomechanisms
Electronic controller
Industrial robots
Electron-beam welding
Second-generation robots
Diesel-electric locomotives
Electric fleet vehicles
Microprocessor-based systems
High-speed electric rail
Modern electric cars
1920
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by another. These tend to benefit society broadly and, through time, lower costs and improve life for everyone.

Efforts to measure the value of research have traditionally focused on the tangible attributes of rival goods. But according to Romer's research, outlined in a 1993 Brookings Institute paper ("Implementing a National Technology Strategy with Self-Organizing Industry Investment Boards"), "Economists are beginning to uncover a great deal of evidence suggesting the economic importance of nonrival goods. . . . First, the social rate of return to investment in the broad class of nonrival goods is quite high, on the order of 30–50% [per year]. This level of return confirms the claim that these are in some sense the most important kinds of investments that can be made. Second, the research demonstrates that the social rates of return are significantly higher than the private rates of return."

The broader aspects of R&D value are more salient than ever, not despite but because of change. In a deregulated environment, many of the issues that used to be listed in the public-good category now shift squarely to that of self-interest.

Industry and the future of R&D

Romer's first observation in the above quotation is a welcome benchmark for the value of research and innovation. But his second observation, comparing social and private rates of return, is the sticking point for the future of R&D: if the largest value of research is so broadly disseminated to society, who should be responsible for funding the work? Current political thinking—that industry ought to shoulder this responsibility alone and that research should be another endeavor left to market forces—might generally work for rival goods, but the market lacks crucial profit incentives when it comes to nonrival goods, those most important to society and ones typically beyond proprietary control. Nonrival goods are simply not sold in the marketplace. In light of this public-benefit aspect, many people believe that R&D is too important to be left entirely in the hands of narrow interests.

The utility industry is clearly wrestling with such issues as it moves toward deregulation. Can utilities afford to be concerned about a broad base of beneficiaries and intangible value when competition is such a threat? Are these considerations still relevant to our industry? Does R&D have a future in an industry that is being forced to change so rapidly? In my view, the broader aspects of R&D value are more salient than ever, not despite but *because of* change. It is tempting to define the benefits of R&D in a continuum from basic self-interest to broad public good, and in times of stress, it may seem prudent to restrict concern to the former. However, in a deregulated environment, many of the issues that used to be listed in the public-good category now shift squarely to that of self-interest.

The most immediately important shift in the continuum, of course, involves providing power to the public at the lowest possible cost. That has always been an important goal for utilities, and research and technology have consistently delivered cost reductions that could be passed through to the benefit of ratepayers. But while being able to offer low rates has in the past primarily been a matter of a utility's profit margins, regulatory concerns, or customer relations, under deregulation and competition it becomes a survival issue. Being the low-cost provider of power is the most certain way to ensure a healthy position in an open market. Even more important, low-cost power is a way to ensure that the market continues to exist and flourish and is not killed off by global competition. Thus the utility serves itself by serving its customers and their customers in turn.

Another of the traditional public-good areas for research, environmental protection, has really been a self-interest issue for utilities for more than two decades because of the growth of environmental regulation. That will continue: whereas provision of electric service will become increasingly deregulated, environmental compliance—for utilities as well as other industries—almost certainly will not. In addition to regulatory demands, and perhaps eventually eclipsing them in urgency, is the threat of litigation on environmental issues. Lawsuits over postulated health effects of electric and magnetic fields (EMF), for example, have already surfaced, with utilities named as defendants. Research in this area, much of it fortunately performed long before EMF became a hot-button issue, has been instrumental in keeping EMF from becoming a public interest whipping boy in the media and the courts. Sound scientific research on this and other environmental issues provides valuable insurance.

Competition will, by definition, move utilities closer to their customers, creating another shift in the self-interest continuum. As discussed earlier, keeping costs low, a proven result of an effective R&D program, will be one key to utilities' competing successfully. In fact, it provides precisely the same advantage to utility customers—particularly the large industrial customers that mean so much to a utility's future. But R&D can provide another benefit often overlooked. In addition to lowering power costs, it can move advanced technology into utility customers' businesses, boosting their productivity and sending a new wave of economic benefit out into the economy. To my mind, we need to go much further than reducing costs. We need to develop broader and more-valuable service options to help our customers change their businesses in fundamental ways through technical innovation. The potential for improving the competitive position of customers through technological means is very high. In fact, in the work that won him the 1987 Nobel Prize for economics, Robert Solow of the Massachusetts Institute of Technology demonstrated conclusively that technological progress is the overwhelming determinant of economic growth in business.

Specifically, utilities can go beyond giving advice on lighting and space-conditioning systems to promoting improvements in the technology that lies at the core of an industrial company's production processes. R&D is developing a wide variety of innovative applications for laser, plasma, electrolysis, microwave, and other electrically powered technologies that can fundamentally improve energy efficiency and productivity while often reducing environmental concerns. These are advances that can give a company a crucial advantage in the marketplace. Working with customers to take advantage of such electrotechnology applications, premium power quality options, innovative load management approaches, and even environmental cleanup technologies can mean a great deal to the future of the customer, the utility providing the service, and the general population of the area.

R&D and the future of utilities

As the examples given above suggest, technology and the R&D that fuels its development will be crucial to utilities in the near term because it is a powerful differentiator and multiplier of customer value in a competitive sphere. This point is not diminished by likely changes in industry structure—the breakdown of vertically integrated utilities into companies specializing in discrete portions of traditional services, such as generation, transmission, or distribution. In fact, technical capabilities become even more important to utilities that specialize, because greater, more-focused expertise is expected. And, of course, utilities that go in the other direction, expanding to offer energy services and technology internationally, face some of the toughest competitors in the world. Success in these endeavors demands a knowledge and technological resource base that is on the cutting edge.

As important as R&D may be for the near future, its benefits will be much greater over the long run, owing to the expanded dimensions of value, and will have to do with developments that we can only glimpse today. We have just as much difficulty peering ahead into the twenty-first century as Edison's contemporaries had looking into the twentieth. Still, the developments we *can* see are terrifically exciting and have startling congruence with the needs of the new utility industry that appears to be developing.

Open access to utility transmission facilities is no longer in question, for example. The tremendous increase in electron traffic that this development implies will demand switching and control technologies far more sophisticated than those currently in place. Power electronics devices, now being demonstrated on utility systems, will be critical to the superfast switching and substantially increased line loading needed to keep the grid operating—technically and businesswise—in the future. Even if we consider only the capability of this technology to avoid additional line construction, the payoff is enormous. If the demand for power doubles over the next 35 years as expected, power electronics could save $300 billion in construction costs and right-of-way procurement in this country alone. When the technology is fully transferred from the transmission to the distribution level, the total benefits to society worldwide may top a trillion dollars.

The so-called information superhighway is another development certain to affect the industry's future. This revolution in communications, information processing, and remote control will dramatically change the way businesses relate to their customers, making true real-time interactive services possible for the first time. The development of an electronic communications gateway to individual customer premises—now under way—will unleash a host of consumer information capabilities and a broad range of unbundled energy service options to help utilities compete effectively. And the connection itself opens opportunities for diversification into telecommunications markets, currently valued at some $200 billion per year and growing rapidly. The companies that position themselves on this highway to best manage the service choice interface with their customers will also be in the best position to control their own destinies.

Superconductivity, which remained little more than a scientific curiosity for more than 50 years, is poised to break through to broad practical application with the continuing refinement of high-temperature superconducting materials. The possibilities for substantially upgrading traditional power equipment with low-loss generators, storage units, cables, and wires have been clear for some time. But what makes the high-temperature superconductivity development so exciting is the uses that are more broadly embedded in our culture—applications in motors, computer chips, and consumer electronics, for example. Essentially everything that runs on electricity—the whole of Edison's electrification legacy—may in the future have superconducting elements. Beyond this are electrical applications, processes, and technical concepts that have not even been considered because they would be possible only with no-loss electronics. Like plastics and silicon, superconducting materials have the potential to transform society. I'm not saying all this will happen—we can't see over the horizon—but it has the right feel. How it plays out is largely in the hands of the R&D enterprise.

When we view the benefits of research comprehensively—including the full array of beneficiaries, over time—the true return on an investment in research is two to three orders of magnitude greater than the numbers traditionally show.

Investing in the future

Some people consider the horizon problem to be one of divining the future. I believe that, more than this, it is a test of our confidence in *shaping* the future. As business people and as individuals, we like to see where we're headed, especially in times of change and turmoil. But the inability to clearly see our specific destination should not deter us from moving in what we know to be the right direction. History has demonstrated again and again that technological innovation is a powerful force for progress; recent business cycles have shown that it is also essential for economic survival. The prosperity of our nation and its ability to compete internationally depend on sustained, superior productivity. Electricity, unparalleled as an enabling technology, has a unique capability to provide this productivity and rebuild the competitive foundation of America through a powerful arsenal of electricity-based innovations. Such revitalization is not automatic—it requires the best ideas we can gather and the commitment to ensure their development through strategic investment.

As conservators of this transformative power, we in the utility industry face great responsibilities and great challenges. We know that in the future the ground rules for doing business will be different. We know that many of us will have to rethink our core businesses and reposition ourselves in the marketplace. We know that these changes will require new investment. In this context, the case for investment in R&D is clear to me. It enables us to lower the cost and improve the quality of service. It opens opportunities to expand into new and developing markets. It lets us anticipate and prepare technologically for the future challenges of the industry as a whole. And in the broadest terms, it generates capabilities and benefits that are distributed widely across the fabric of our society.

I believe, and I hope I have demonstrated, that when we view the benefits of research comprehensively—including the full array of beneficiaries, over time—the true return on an investment in research is two to three orders of magnitude greater than the numbers traditionally show. I urge you to consider this as you form your investment plans for the future. R&D is not the only tool that utilities will need in the coming decades, but for those who see its full value and take advantage of its unique power, it is sure to be an outstanding performer in a utility's investment portfolio. ■

A Three-Dime

Attempts to document the value of EPRI's research results started in the early 1980s, following traditional lines: the dollar value of the first (or an early) application of an EPRI-developed technology at a specific utility. These evaluations, based on methods established by the utility involved (to ensure objectivity), were published in documents initially called *First Use* and later known as *Innovators*. These documents were supplemented in the mid-1980s with the Benefit Assessment Program, in which interested utilities took an in-depth look at all the EPRI results they had applied and then calculated the return on their R&D investment.

The results were encouraging. The utilities that performed benefit assessments generally found a benefit-to-cost ratio of 3:1 or 4:1, with some ranging as high as 15:1. As for the *Innovators*, an evaluation of only the 550 documents produced in the five years between 1990 and the end of 1994 gave an aggregate value of about $17 billion, an impressive number. Even so, this total—based on single-utility use of 17% of the Institute's current products—represented only a thin slice of the value of EPRI's results. In essence, the numbers considered no breadth of beneficiaries—not even an extrapolation across the industry as a whole—and a very limited accounting of the time element. Virtually no intangible benefits were captured in this roll-up.

In an attempt to develop a more realistic accounting of the breadth dimension, EPRI did an expanded analysis of the *Innovators* data in early 1995 and found that when extrapolated to nationwide application, the value to electric utilities is approximately $383 billion in potential savings plus $30 billion in increased revenue. This total, while again representing only one-sixth of EPRI's research results, amounts to a latent return of nearly 7000% on the total utility investment in EPRI over its 23-year history. Even if the extrapolated benefits were devalued by a factor of 10, they would still have a value many times higher than their cost. And these numbers still do not reflect benefits to utility customers and society at large.

EPRI's value has indeed reached far beyond the industry itself. The Institute's work on energy efficiency and advanced end-use technologies, for example, has provided broad social benefit by reducing waste, improving productivity, and lowering energy bills. As society continues to

EPRI BENEFITS

Return Horizon	Beneficiary	Magnitude of Return
Short term (1 year)	An individual EPRI member	3:1 return on investment
	All EPRI members	$1–10 billion per year
Midterm (10 years)	Global power industry and its customers	$10–100 billion per year
Long term (20–40 years)	Society	$5–10 trillion cumulative total

nsional Look at EPRI's Value

rely on electricity-based technology for innovation and productivity, electricity's fraction of total energy is likely to grow from 39% today to 45% by 2010. The result will be to cut the overall growth in primary energy to roughly one-half the growth of the U.S. economy. In fuel savings alone, this would save roughly $10 billion a year, a total more than matched by the value of productivity improvements. A 1992 analysis of EPRI end-use products bears this estimate out. Again using only a fraction of EPRI's research output and very conservative assumptions (including only a 1% market penetration rate for most new products), the study determined the present value of EPRI's end-use work to be $36 billion.

The above example is just the beginning. EPRI has been *the* major player in two high-value areas discussed earlier—power electronics development and EMF research. In addition, the Institute has played key roles in the areas of clean coal technologies, nuclear safety, renewable energy, electric vehicles, and climate science, just to name a few that have broad benefit for the industry and beyond.

As for the intangible dimension of value, EPRI's ability to work effectively in such a wide spectrum of technologies and disciplines is one of a number of benefits that have distinguished EPRI as an exceptional provider of R&D services. Through coordination of thousands of topflight researchers from universities, manufacturers, private research companies, and government laboratories, EPRI has built a global network of diverse, highly specialized talent that develops new knowledge for utilities and brings fresh approaches to their problems. Over the years, this reservoir of expertise has helped the utility industry move its capabilities beyond the constraints of mechanical and electrical engineering to embrace advances offered by chemical, nuclear, and systems engineering, as well as environmental, information, and materials science. The ability to exploit the synergy among these disciplines has made a great difference in our progress toward becoming a truly high-tech industry.

Such broad capability permits pursuit of another intangible benefit: holistic problem solving. EPRI's integrated perspective on tough industry problems can be seen in everything from advanced power plant design and power systems control to asset and fuel management, but its expression has perhaps been most evident in the environmental areas. As part of its acidic deposition research in the early 1980s, EPRI built an entirely new interactive model of a lake's watershed, linking everything from tree canopy to soil, bedrock, and water chemistry. This model, which introduced a new standard of realism for environmental modeling, demonstrated the strong buffering effect of the watershed itself on acidified rainwater.

The upshot of this work was not just new insights into acidic deposition but a new integrated approach to studying environmental issues. Similar pioneering work has since been carried out on transport mechanisms for airborne gases and particles, the movement of chemicals through soil and groundwater, and—most recently—the potential effects and costs of global warming as a result of greenhouse gas emissions. Large-scale, holistic, cooperative research of this sort is essentially the only way to produce realistic, credible knowledge on complicated issues. With regulations being written by decision makers who often come from outside the scientific sphere, credible, well-documented scientific information is of enormous value to the industry.

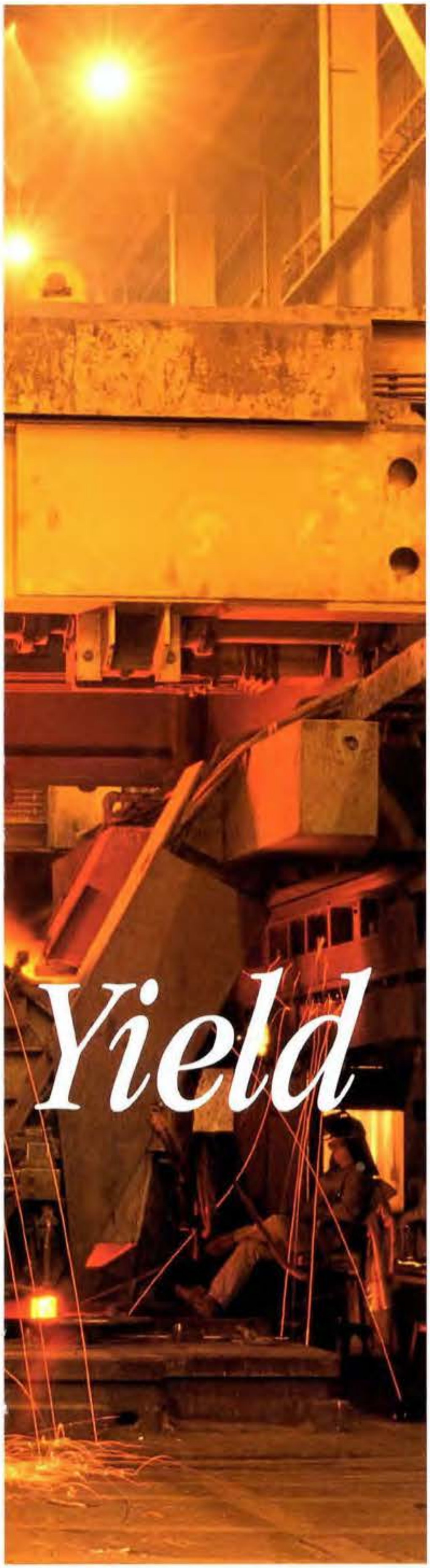
These are far from the only intangible benefits EPRI provides. For example, the Institute has shown a unique capability to translate and focus utility needs for vendors and commercial developers, helping those groups open up new applications, accelerate the development of technology, and provide a better base for cost-effective solutions and hardware. EPRI has provided continuity and a critical mass of expertise for the industry to pursue essential but expensive technology, often leveraging utility investment with resources and funding from outside the industry. And the Institute has been able to pursue multiple approaches to problems and opportunities in parallel, essentially providing alternative paths to the future for utilities; the real benefit of this approach is now becoming apparent as the industry pursues diverging strategies based on EPRI developments. □

FRAMEWORK

Basis of Return	Examples
Member Benefit Assessment calculations and *Innovators* series	Return of 3.6:1 for West Texas Utilities
Aggregated *Innovators* benefits	$9 billion per 1993 *Innovators*
Extrapolated benefits from work on: • Energy and economic efficiencies • Environment, health, and safety • Resource utilization • Fuel markets/prices	Worldwide IGCC use Clean coal technology Nuclear safety worldwide
Clusters of EPRI technical work, each with the potential to return more than $1 trillion in benefits to society within 40 years	Foundation of FACTS technology Leadership in environmental science Advanced electrotechnologies

Industrial Partnerships

Ron May



Yield EPIC Results

BY TAYLOR MOORE

THE STORY IN BRIEF With a new era of competition approaching in the electricity supply industry, utilities are getting closer than ever to their industrial customers, in many cases making direct alliances as partners to help customers become more efficient, productive, and competitive. The EPRI Partnership for Industrial Competitiveness—EPIC—program aims to help industrial customers address critical priorities in environmental impact, efficiency, and productivity with the ultimate goals of long-term profitability and job retention. By offering in-plant consultant evaluations of systems and processes, EPIC helps industrial customers develop strategic insights into their operations and leverage technology and productivity solutions for competitive business advantage.

Paying close attention to customers has always made good business sense, but the new era of competition among suppliers of electricity has raised the stakes considerably for utilities. Industrial customers are of particular importance, not only because they represent large blocks of electrical load but also because they are expected to be the first customers under deregulation to be able to choose their own energy suppliers. As a result, utilities are beginning to forge alliances with key industrial customers to help ensure the long-term survival of those customers as profitable businesses in an increasingly global marketplace.

The new alliances are a significant step beyond utility energy efficiency and demand-side management (DSM) programs, such as those that encourage customer adoption of energy-efficient technologies like new motors, lighting, and adjustable-speed drives by offering financial incentives that cover some of the incremental cost. Over the past 15 years, utilities have put in place a number of such programs focused on broad-based technology applications. These efforts, which have tended to be prescriptive, have met with varying degrees of success, and their results have often been difficult to quantify.

In the last three years, however, nearly two dozen utilities have begun to invest in their customers' competitiveness through participation in the EPRI Partnership for Industrial Competitiveness (EPIC) program. "EPIC seeks to blend the industrial customer's key priorities of safety, environmental impact, and productivity with the utility's customer objectives in an approach designed to maximize customer and societal benefits—such as profitability and job retention," explains William M. Smith of the Industrial & Agricultural Technologies & Services Business Unit in EPRI's Customer Systems Group.

"Over 90% of industrial customers have less than 5% of their operating budgets tied up in energy costs, with much bigger fractions of their budgets going for labor and materials. So they are focused on quality and productivity, because they are in business to make a product and a profit, and they're focused on the cost of compliance with environmental regulations. Productivity and environmental concerns are two major drivers of competitiveness for most of them," adds Smith. "EPIC provides a bridge, or common ground, between what utilities want to accomplish—to retain their industrial customers and the revenues from their electricity use—and what the customers want, which is to improve productivity and reduce the cost of environmental compliance."

EPIC Utility Participants
Centerior Energy
Central Hudson Gas & Electric
Cincinnati Gas & Electric (1992–1994)
Commonwealth Edison
Duke Power
East Kentucky Power Cooperative
Florida Power & Light (1992)
Illinois Power
Niagara Mohawk Power (1992–1994)
Northern States Power
PECO Energy
Pennsylvania Electric
Pennsylvania Power & Light
Salt River Project
San Diego Gas & Electric
Seattle City Light
South Carolina Electric & Gas
Southern California Edison
Tennessee Valley Authority
Union Electric
Wisconsin Electric Power

Smith says that under the new competitive paradigm for suppliers of electricity to industrial customers, "it is imperative that utilities understand what their customers do; how their customers' processes operate; what specific environmental, efficiency, and productivity issues they face; and what is being done about those issues." EPIC provides a structured and systematic approach to gaining such fundamental understanding and to leveraging this insight into customized strategic and tactical solutions that can make a bottom-line difference in a customer's competitiveness.

Recipe for success

Through EPIC, member utilities and EPRI are focusing on helping customers in selected industries identify strategic opportunities to enhance productivity, improve efficiency, and reduce environmental impacts. To date, EPIC participants have worked with firms representing over a dozen key industries. These include plastics and metals fabrication, pulp and paper, ore processing, metal foundries, forging and heat treating, textile manufacturing, printing, and computer chip and circuit board manufacturing. Industries currently targeted for development are baking, food canning and freezing, meat products, and soft drinks.

Basically, EPIC helps utilities identify key improvement opportunities for industrial customers that may be in danger of becoming uncompetitive because of poor productivity or rising costs of business and then provides expert consultation about those opportunities. Utility investors in EPIC receive two key resources relating to the selected industries—industry manuals and action guides—in addition to on-site plant surveys of selected customers by EPRI-sponsored teams of qualified industrial consultants. The industry manuals provide broad coverage of an industry, with information on various sectors linked by a focus on unit operations. The manuals can serve as useful reference tools with applicability across several processes and products within an industry. The action guides describe procedures for developing recommendations to improve industrial competitiveness on the basis of data collected during the plant surveys.

EPIC draws on EPRI's industrial centers and offices, whose staffs are recognized experts. Team members also come from Chem Systems and the Arlex Group, two consulting firms serving as project contractors. Industry experts are often retained directly by large and medium-size industrial firms, but EPRI member utilities, through EPIC, are making such expertise available to small and medium-size companies with typical electricity demands of 3–5 MW.

For an industrial plant survey, which usually involves two days of on-site inspection and discussion, an EPIC team is joined by plant personnel and utility marketing representatives. The survey team considers a variety of factors in assessing and prioritizing recommendations for enhancing competitiveness. Among these factors are plant equipment, product quality (including yield and rework rate), manufacturing processes, waste minimization and treatment, materials recycling and recovery, and energy efficiency considerations (including electrotechnology process alternatives, DSM options, and energy source options). Two review-feedback loops during the preparation of the plant survey report for the customer are aimed at helping build customer receptivity to implementing the identified improvement strategies. The plant survey and reporting procedures have been considerably refined on the basis of utility and customer feedback during the initial EPIC efforts.

EPIC experts who are intimately familiar with particular industry sectors can bridge a credibility gap that may result from the difference in business perspectives of utilities and many industrial customers, notes Kenneth Stern of Chem Systems. As an example of that difference, Stern notes that utilities have often tended to think in terms of energy and demand reductions, while industrial firms think in terms of cost reduction, which can sometimes entail increased energy consumption.

"From the perspective of the industrial customer, the utility often has very little, if any, knowledge of its process, plant, needs, or constraints—nor should the utility, to the customer's way of thinking, since these are not the utility's business," explains Stern. "As a result, virtually any initiative that goes beyond offering more-efficient lights and motors will be viewed with skepticism by industrial firms, unless the utility can demonstrate its credentials for participating in a more substantive dialogue. EPIC provides a level of credibility that utilities often find difficult to achieve with their industrial customers directly. Consequently, EPIC has earned broad support in both the utility and industrial communities."

John Svoboda of EPRI's Foundry Office is EPIC's expert for customers in the foundry, forging, and metal heat-treating industries. He has conducted over 14 on-site plant surveys so far and is averaging about 1 a month. Svoboda notes that patience and perseverance are essential in EPIC utility-customer partnerships because the incubation period between the customer's receipt of a final EPIC plant survey report and the actual implementation of recommended improvements can be lengthy.

In foundries, for instance, a recommendation to upgrade to more-efficient melting equipment to improve product quality or productivity could entail a capital expense of several hundred thousand dollars. "Most foundries are small operations and don't have a lot of capital in their operating budgets," says Svoboda. "So it can take a while to make a decision to spend that kind of money. But it does happen. We have visited two foundries that later decided, in part as a result of the EPIC survey results, to go ahead with the purchase and installation of new electric scrap melters." Seattle City Light and Duke Power Company still count those foundries as customers today.

"The electric utilities that have banded together with EPRI have found that the EPIC recipe can, indeed, provide the results desired," says William Smith. "EPIC's success rests on its ability to uncover win-win opportunities that represent common ground between the divergent sets of priorities held by industrial firms and utilities. Building on this common ground is the way to achieve EPIC's bottom line: getting industrial customers to take action on the opportunities identified to achieve greater competitive advantage."

EPRI Partnership for Industrial Competitiveness
AREAS OF FOCUS

Environment	Efficiency	Productivity
• Waste minimization • Waste treatment • Recycling • Recovery	• Electrotechnology alternatives • Demand-side management • Energy source options	• Quality: yield/rework • Operations: processes • Equipment

Smith points out that EPIC approaches energy efficiency issues from an overall production efficiency perspective and is neutral as to energy source. "The goal of the EPIC program is to identify whatever makes the most sense for the industrial customer. Thus the EPIC team could equally as easily recommend a new use of electricity (such as an electrotechnology), a simple work-flow rearrangement, or a natural-gas-fired heating technology, depending on which would help the customer become more competitive."

Since the recommendations that emerge from EPIC plant surveys are prioritized by the customers themselves according to the potential for the greatest improvement at the industrial plant level, EPIC offers a new paradigm for improving customer competitiveness—a top-down, holistic, and strate-

EPIC SURVEY EXAMPLE: SUMMARY OF OPPORTUNITIES This abbreviated summary of efficiency, productivity, and environmental improvement opportunities identified in an EPIC team survey of a foundry customer illustrates the range of possibilities considered and the magnitude of potential gains. The list was prioritized in consultation with the customer, which may choose to implement only the highest strategic priorities or those with the greatest anticipated benefit.

Recommendation	Impact Areas	Estimated Investment	Estimated Payback	Anticipated Benefits
Scrap reduction program	Efficiency, productivity	$20,000	8 months	Improved quality
Computerized rigging	Productivity	$100,000	13 months	Improved yield and quality
Demand control	Efficiency	$10,000	~4 months	Reduced power cost
Sand reclamation	Environment	$250,000	Not applicable	Reduced waste
Improved refractory practice	Efficiency, productivity	Up to $10,000	Not applicable	$25,000 per year in savings
New gas regulator	Efficiency	~$5000	A few months	Improved operations
ASD on dust collector	Efficiency, environment	~$20,000	2 years	Reduced power cost
Interlock rotoblast	Efficiency	~$2000	1 year	Reduced power cost
Upgraded ladle preheat	Productivity	$10,000–$20,000	2 years	Reduced power and refractory costs

gic examination of plant activities, rather than isolated and sporadic evaluations involving individual technology improvements. Notes Smith, "While the latter approach may result in a stand-alone success, the improvement may actually rank sixth or seventh on a customer-prioritized list. The industrial customer may risk diverting attention and resources from opportunities of higher priority for overall plant success and longer-term profitability. Short-term gains have little value if the customer ultimately goes out of business because it is uncompetitive."

Nothing succeeds like success

Of the more than 66 industrial customers visited by EPIC team and utility service representatives as of the middle of last September, 58 have received plant survey reports as of this writing. Smith estimates that so far about 15 of these customers have implemented one or more of the survey recommendations—reflecting the incubation period described by Svoboda. Yet every implementation represents a success story to the extent that it enhances the customer's competitiveness. And the list of EPIC successes is growing.

The success stories can be relatively simple. In response to an EPIC survey recommendation, a metals fabricator in the Northeast enhanced its productivity by changing from staged batch processing to continuous processing to eliminate piles of work in progress. The change decreased both the use of floor space and the production cycle time. The EPIC survey also showed the customer how to enhance its competitiveness through the use of activity-based cost accounting and concurrent engineering to integrate product design, manufacturing, and marketing and thus reduce product development time. The customer has, in addition, proposed to its parent company the purchase of an EPIC-recommended automated infrared system for drying powdered coatings and paints.

As a result of another EPIC plant survey, a northeastern plastics fabricator and customer of PECO Energy Company (formerly Philadelphia Electric Company) discovered that substituting infrared lamps for incandescent lamps in a heating process for plastic bottles will save 50–70% on costs—or about $50,000 a year. The savings on electricity will repay the cost of such a substitution in about six months (only the lamps, not the fixtures, will need to be replaced).

The PECO Energy customer is also moving ahead on two other EPIC recommendations. Techniques for quick die changes in blow-molding machines will cut inventory buildup during long production runs by as much as half, freeing up floor space and labor. Insulating the electric resistance bands used for heating raw plastic will lower by 20% the energy use associated with six heating barrels at the plant.

A copper processor in the Southwest is saving $340,000 a year by using finer screens for crusher discharge, a recommendation from its EPIC evaluation in partnership with the Salt River Project. The savings will pay back the cost of that measure in one year. Meanwhile, the processor is considering two other recommendations. The first, to shut down one of two underloaded mills and consolidate ore feed in one mill, would reduce electricity demand by 400 kW and save 3.3 million kWh a year (worth $160,000 a year); the payback period would be less than a year. A second EPIC recommendation, to substitute titanium anodes for the lead anodes used to collect copper from solution, could save another $770,000 annually, with payback in two years.

Central Hudson Gas & Electric Corporation in New York has used the EPIC plant survey program as a key part of its Energy Solutions program for industrial customers since EPIC's inception. The utility has been conducting plant surveys since 1993; by the end of 1995, it had completed work on eight. According to Matt Rush, manager of the Energy Solutions program, "The EPIC surveys have been a great benefit to Central Hudson, resulting in a higher level of customer satisfaction with us as the energy provider and in significant incremental increases in net revenues, decreased unit costs for manufacturing customers, and reduced customer overhead costs."

Adds Rush, "We receive good value from our investment in the EPIC program. The program's ability to provide recognized experts in a particular industry goes far beyond what we can offer in-house. In some cases, we see a revenue enhancement that offsets the cost of participation in EPIC. We also see DSM benefits and load reductions, and, although it is tough to quantify, the ultimate value of customer retention is tremendous. EPIC is helping our utility position itself in a competitive marketplace."

Rush relates three EPIC success stories. A plant survey for a plastics injection-molding customer that manufactures commercial lighting fixtures recommended improvements in process control, the use of quick mold changes, and various waste minimization measures. In response, the customer implemented a plan for plant reconfiguration and equipment modifications that will lower unit costs by reducing throughput time. The process improvements will also reduce the generation of scrap waste.

The decision by a manufacturer of architectural lighting products to install an infrared paint-curing oven in its assembly line as a result of an EPIC plant survey led to increased revenues for Central Hudson and to reduced unit costs for the customer. And the customer's adoption of activity-based cost accounting and concurrent engi-

Greg Loflin

AN EPIC SUCCESS FOR DUKE POWER
IEM Plastics, a manufacturer in Duke Power Company's service area, is one of the largest suppliers of plastic containers and the only one that can make them from 100% postconsumer waste. Duke Power worked with the customer through an EPIC plant survey to determine how productivity could be improved and costs reduced. IEM has begun implementing changes suggested as a result of the survey that could save it over half a million dollars in the next decade. In addition, Duke now delivers its waste plastic to IEM as source material and has introduced several new suppliers to the company. And the utility is also helping IEM with a power expansion that will increase the plant's recycling capability.

Ron May

FOUNDRIES

At some foundries, the installation of new electric scrap melters has reduced operating costs and the need for waste disposal. Other low-cost measures like improved ladle reheat and pouring practices can yield gains in efficiency and productivity with very short payback periods. Higher-cost improvements like induction melting can produce major savings in energy consumption, while electrotechnology-based sand reclamation systems promise to substantially lower waste disposal costs.

neering will have an even greater effect on its manufacturing productivity and competitiveness.

Another Central Hudson customer, a small foundry operator specializing in a variety of small and medium-size products, lacked the capital for long-term investments. The EPIC team worked with the customer to develop a list of affordable opportunities that could be readily implemented for short-term payback. The most significant improvement resulted from a recommendation to increase the capacity of the plant's compressed-air system to ensure that sufficient quantities of air were available at the required pressure. This improved the usefulness of certain tools and, in turn, reduced product throughput times, with payback in one year.

South Carolina Electric & Gas Company counts two success stories so far as a result of the five EPIC plant surveys completed in

TEXTILE MANUFACTURING

Capacity control for air compressors can reduce energy consumption and pay back the required investment in less than two years. Payback in less than one year may be possible for membrane separation systems for finishing wastes. Heat recovery systems for waste streams from bleaching and dyeing can lower disposal costs and improve efficiency. Ozonation and ultraviolet and electrolytic treatments offer alternatives to biotreatment in certain source-reduction measures.

METALS FABRICATION

Changing from staged batch processing to continuous processing eliminates both inventory and work in progress, reducing the need for floor space and cutting cycle time. Quick-change tooling and automated fabrication tooling can involve significant investment but produce multiple benefits in productivity and efficiency. Automated infrared paint-drying systems reduce environmental emissions and energy costs while improving product quality.

Paul Kennedy/Liaison

its service area as of mid-September 1995. Lewis Wessinger, industrial accounts manager, says that one of the earliest EPIC surveys for the utility involved a foundry customer that used the results in deciding to replace an aging induction melting furnace with a more efficient electric furnace and a new, smaller induction furnace. "We feel that, as a result of this action and because of the relationship we developed in working with this customer, we have gone a long way toward helping the customer be more profitable. If a day of decision came, I think we would stand a good chance of retaining this customer because of what we have done for them through EPIC."

The second success story involved one of the many textile companies in South Carolina Electric & Gas's service territory, a gray-goods manufacturer. This success could be multiplied many times over if the various measures identified in the survey can be applied by some of the utility's other textile manufacturing customers. "We think EPIC is a good program, and we have already benefited from it," says Wessinger. "Utilities that aren't taking advantage of it are missing the boat because there are good opportunities out there for improving business relationships with industrial customers."

They treat us like we're number one

One of the highest-value EPIC success stories to date is an effort between Duke Power Company and IEM Plastics, one of the nation's largest suppliers of plastic containers and the only manufacturer capable of making containers from 100% post-consumer waste. In addition to its ongoing goals of improving productivity and reducing costs, IEM had a specific need for more source material for its products. And Duke Power, as a part of efforts to work with targeted growth industries in its territory, was seeking a way to identify opportunities for IEM.

Through an EPIC plant survey, Duke helped IEM determine how productivity could be improved and costs reduced. EPIC consultants from the Arlex Group joined Duke customer service representatives for two days at IEM's Reidsville, North Carolina, facility, observing procedures and interviewing employees. The consultants' recommendations included implementing a total quality management program to improve cycle times and lower product costs, a total predictive maintenance program to address IEM's high maintenance costs, and an oil-recycling program to cut oil purchase and disposal costs.

So far, IEM has begun implementing the predictive maintenance program, made some changes in its plant layout, and reduced inventory by changing some of its marketing methods. During the EPIC survey, Duke noted that IEM was having trouble obtaining sufficient source material; it arranged to have its waste plastic delivered to IEM—up to 700,000 pounds per year—and introduced several new source material suppliers to IEM. Duke is also helping the plastics company with a 1-MW power expansion that will increase the plant's recycling capability to 80 million pounds per year.

IEM estimates that implementation of all the EPIC plant survey recommendations (at a cost of about $65,000) could save the company $568,000 (present value) over the next 10 years in reduced downtime, decreased labor costs, improved plant productivity, and lower product costs. IEM also benefits from the new sources of recycled material and from Duke's assistance in planning its power expansion. Duke, in turn, will bene-

Charlie Westerman/Liaison

PLASTICS FABRICATION

Savings of 50% to 70% on process heating costs can be achieved by substituting infrared lamps for incandescent lamps. New techniques for quick die changes in blow-molding machines can cut inventory buildup during long production runs. Improvements to materials-handling, vacuum, and compressed-air systems can pay back their cost in less than six months in reduced energy and maintenance costs.

fit from the increased revenue when the customer's expansion is completed.

"We know we're not Duke Power's biggest customer," says C. H. Lee of IEM, "but they treat us like we're number one." Kathleen Mullen, an energy analysis product manager with Duke, says, "We want our customers to be more competitive so that electricity keeps flowing into their plants."

Adds Mullen, "Because our markets and the competition are changing, utility sales representatives will need to change their relationships with customers. When individuals or organizations change their style or approach to others, they will be taking some risks until they acquire experience. Working with EPRI's consultants under the EPIC program provides us with fail-safe opportunities for our representatives to practice their business development skills." ■

Background information for this article was provided by William Smith of the Customer Systems Group's Industrial & Agricultural Technologies & Services Business Unit.

MINERALS PROCESSING

Copper and other ore processors can reap substantial savings in some cases by using finer screens for crusher discharge. Consolidating underloaded mills and replacing lead anodes with titanium anodes are among other high-priority opportunities with rapid payback in efficiency and productivity. The installation of adjustable-speed drives on certain pumps can have a major impact on operating efficiency.


ARMOR


BLANCO


O'CONNOR


CLARK


YEAGER


SMITH

Fossil Assets Management: Making Decisions on Older Plants (page 6) was written by science writer John Douglas with the assistance of members of two EPRI business units, Fossil Power Plants and Utility Resource Planning & Management.

Anthony Armor, director of the Fossil Power Plants Business Unit, came to EPRI in 1979 after 11 years at General Electric, where he held positions in the Large Steam Turbine-Generator and Energy Systems Divisions. Before that, he was a professor of engineering and mathematics at London Polytechnic (now the University of Westminster). Armor received a BS in mathematics and an MS in mining engineering from the University of Nottingham.

Michele Blanco, team manager for fossil plant operations in the Fossil Power Plants Business Unit, is responsible for research targets involving plant maintenance cost reduction, plant operations improvement and training, and fossil plant asset management. Before joining EPRI in 1989, Blanco spent seven years at Pacific Gas and Electric, working both as a power production engineer and as a design engineer for plant retrofit piping. She holds a BS in mechanical engineering from Marquette University and an MBA from the University of San Francisco.

Dave O'Connor is manager of asset management tools in the Fossil Power Plants Business Unit and also manages fuels work within the unit. Before joining EPRI in 1986, he worked for six years at Bechtel Group as a research engineer, providing analysis and testing services for coal-based energy ventures. O'Connor has a BS in mining engineering from the South Dakota School of Mines and Technology.

Charles Clark is team manager for the Utility Resource Planning & Management Business Unit. Before joining the Institute in 1991, he was a vice president at Decision Focus Incorporated and was earlier employed by ARCO, Northrop Corporation, Rockwell International, and SRI International. He holds a BS from the University of California at Los Angeles, an MBA in production management from the University of Pennsylvania's Wharton School of Business, and an MS in operations research from Stanford University. ■

R&D and the Dimensions of Value (page 16) was authored by **Kurt Yeager,** the Institute's executive vice president and chief operating officer. Prior to assuming his current position, Yeager served as senior vice president for strategic development and before that as senior vice president of technical operations, with responsibility for the integrated management of all EPRI technical programs. Before coming to EPRI in 1974, he was the director of energy R&D planning for the EPA Office of Research and still earlier was associate head of the Environmental Systems Department at MITRE Corporation. Yeager received a BS in chemistry from Kenyon College and did graduate work in chemistry and physics at Ohio State University and at the University of California at Davis, where he earned an MS. ■

Industrial Partnerships Yield EPIC Results (page 26) was written by Taylor Moore, *Journal* senior feature writer, with assistance from **William Smith,** executive project manager in the Industrial & Agricultural Technologies & Services Business Unit. Smith joined EPRI in 1985 as manager of demand-side planning and information after eight years with Pacific Gas and Electric, where he helped shape PG&E's demand-side management efforts. Smith received a BS in physics and MS and PhD degrees in astrophysics from the State University of New York at Stony Brook. ■

Hydropower

Consortium Spurs Development of New Diagnostic Tools

The smooth and cost-effective operation of hydro plants today is heavily dependent on operations and maintenance personnel who analyze vast quantities of detailed data from a variety of sensors monitoring such parameters as oil, temperature, and vibration. With the electric utility industry moving into a competitive environment, which has resulted in staff downsizing, some observers are concerned that if these personnel leave their companies, much of the knowledge and analytical skill they have attained will be lost.

A new consortium is working to prevent such a problem by funding the development of diagnostic tools that will help hydroelectric personnel translate the voluminous data gathered by hydro plant sensors into useful information. The Bonneville Power Administration, British Columbia Hydro, EPRI, Idaho Power Company, Manitoba Hydro, and the Tennessee Valley Authority have joined together in a four-year, $7 million program to enhance diagnostic capabilities. "In an era of cost cutting at utilities, you risk the chance of losing a lot of these minds," notes Jim Birk, manager of EPRI's Renewables & Hydro Business Unit. "In order to capture the intelligence they have, you're going to need an intelligent system."

The consortium, formed in late 1994, issued a request for proposals last August for the development of the diagnostic tools. According to Birk, the group seeks the development of three modules (focusing on bearings, generators, and turbines) that will receive and analyze data from hydro plant sensors, as well as a master module that will provide cross-module correlation of data and diagnostics. The system is expected to operate on commercial hardware platforms and to use standard communications protocols.

As well as making hydro plants less dependent on specific personnel, these advanced diagnostic tools will offer other benefits. The additional information they provide will enable utilities to run the plants at higher capacity when necessary and to better predict needed plant overhauls—benefits that will reduce costs and increase electric energy output.

Even though more than one contractor is expected to be involved in the development of the diagnostic tools, the modules will have a common graphical user interface, says Birk. The consortium aims to award at least one of the contracts early this year. The group is still open to new members, who would participate in specifying the technology, get early access to the products, and receive royalties on the commercialized products.

■ *For more information, contact Jim Birk, (415) 855-2562.*

Indoor Air Quality

EPRI Aims to Improve HVAC for Schools

Ensuring adequate ventilation in school buildings can be challenging, since these facilities are typically more densely occupied than other buildings, such as offices. In fact, while the occupancy of an office building might average one person for every 150 square feet, it is not unusual for a school to average 10 times that occupant density, says Mukesh Khattar, EPRI's manager for space conditioning and refrigeration.

Adding to the challenge of providing adequate ventilation in school facilities, communities across the country are beginning to adopt more-stringent ventilation codes that at least triple the amount of ventilation air required in a building. The more-demanding requirements, which are being implemented at local, regional, and state levels, are based on a standard for indoor air quality that was established by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) in 1989. The standard applies to all new commercial building types, including retail stores, supermarkets, and office buildings.

As Khattar points out, the standard not only will drive up customers' electric bills but will also result in deteriorating load factors for utilities. In response, EPRI is organizing an electric utility effort to develop and demonstrate energy-efficient electrotechnologies for effectively meeting the new standard. Educational facilities are just one customer segment that will benefit from this effort.

Already, EPRI has developed strategies and conceptual designs that are being incorporated by manufacturers and major end users. In one project, EPRI is extending a commercialization agreement with the manufacturer Climate Master to apply to a school environment the concept of an integrated air quality system developed for a Wal-Mart supercenter in Oklahoma.

This project is the latest in EPRI's series of school-related heating, ventilating, and air conditioning (HVAC) efforts. Also under way is a project with Hawaiian Electric Company in which a cool storage system will be installed at the Iolani School in Honolulu. The system, which will be monitored for one year, is expected to save on cooling costs and to achieve a lower humidity level despite a high ventilation rate. In another effort, a ground-coupled heat pump system in operation at New Jersey's Stockton State College since late 1993 is being monitored. A variant of water-loop heat pump technology, the system uses heat from the ground and is inherently very high in efficiency. In the past two years of operation, the unit has not required any backup gas heating.

"What we're trying to do," says Khattar, "is to take the best of all these educational facilities projects and develop an integrated system for school buildings that will meet the new ASHRAE standard." Data resulting from EPRI's school-related HVAC projects will be combined with information on water heating, lighting, food service, and other technologies and published in a guidebook specifically designed for utility marketing personnel, says Karl Johnson of EPRI, who is managing the book's production. The guidebook will serve as a reference that the marketing specialists can use when calling on educational facilities.

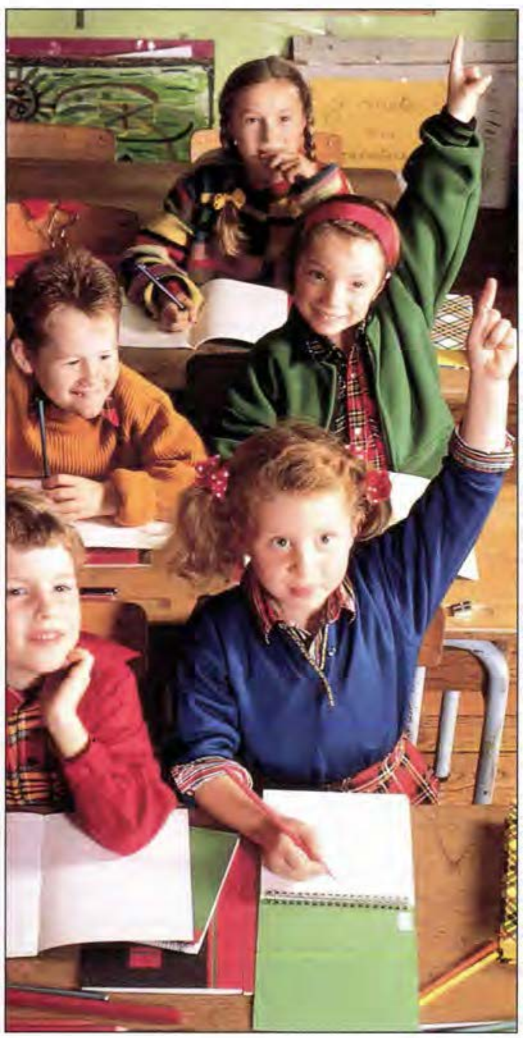
■ *For more information, contact Mukesh Khattar, (415) 855-2699.*

Drinking Water

Researchers Explore New Methods for Arsenic Removal

EPRI researchers have teamed up with experts at the Water Department of Fort Worth, Texas, to explore the feasibility of using an electrotechnology—ozonation—to enhance the removal of arsenic from drinking water.

A carcinogen that occurs naturally in some soils and minerals, particularly in the Southwest, arsenic can also be introduced by unnatural sources, like industrial discharge. Currently, water departments rely on conventional coagulation to remove arsenic from drinking water. But the Environmental Protection Agency has indicated that it is considering lowering the limit on arsenic content from the current standard of 50 micrograms per liter to as low as 2 micrograms per liter. Water quality experts say that current treatment technologies are not effective at removing arsenic at such low levels.



In the coagulation process, ferric sulfate, ferric chloride, or aluminum hydroxide is typically used to draw out contaminants. Through EPRI's project with the Fort Worth Water Department, researchers will try increasing the amounts of these substances to enhance coagulation. They will also test the use of ozonation in addition to the coagulation process to determine the effect of the combined treatment on coagulation and on arsenic removal itself.

In the ozonation process, ozone is produced by an electric corona discharge through air or oxygen. The ozone is then bubbled through water in order to inactivate various microbiological contaminants and destroy organic materials and herbicide residues. Commonly employed to disinfect drinking water in Europe, ozonation has just started to catch on in the United States.

Bench-scale tests of the new arsenic removal processes got under way last summer. Pilot-scale testing will provide a reality check for the bench-scale results and help determine the electric power requirements of ozonation equipment. The pilot-scale tests are expected to be completed by mid-1996. The city of Fort Worth will then determine whether to proceed with a full-scale demonstration of a chosen method for arsenic removal.

Although the EPA has not indicated precisely when it will adopt its new regulations on arsenic content, the agency has indicated that the more-stringent regulations are imminent.

■ *For more information, contact Keith Carns, (314) 935-8598.*

Members Sought to Host Demonstrations of Distributed Mobile Gas Turbines

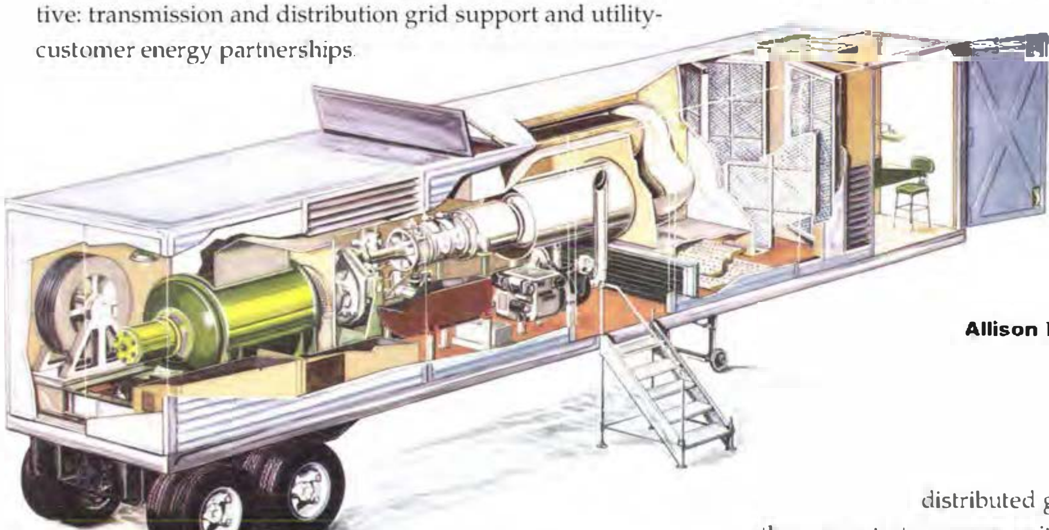
EPRI is seeking one or more member utilities to participate in collaborative R&D projects to demonstrate the use of 3- to 5-MW mobile gas turbines in high-value distributed generation applications. The projects, each involving the installation, lease, operation, and maintenance of a small mobile gas turbine as a distributed generation resource at a utility or customer site, will develop critical information for the participating utilities on the use of currently available small gas turbine technology to improve their competitive advantage.

Stand-alone or integrated use of small, modular, dispersed generation technologies like gas turbines can potentially benefit the overall reliability of the utility system, the reliability of service to specific customers, or both. (Fuel cells and internal combustion generator sets are other examples of gas-fueled distributed generation options.) Utility case studies examining the potential for distributed gas-fired generation have generally identified two applications as the most attractive: transmission and distribution grid support and utility-customer energy partnerships.

T&D grid support involves the siting of modular generation units at substations or near primary feeders to enhance the use of existing T&D assets, defer T&D capital expense, and improve service reliability. Typical three-year deferral values can be $474–$790/kW for a $3 million to $5 million T&D investment in areas experiencing 1 MW of incremental load growth per year.

Utility-customer energy partnership programs are designed primarily to retain customers and to offer value-added customer services. On-site modular generation can be used to enhance service reliability, provide for combined heat and power services, and improve T&D asset utilization in certain situations.

Although the benefits of modular generation have been theoretically estimated, the EPRI-utility R&D projects will address the need for validated information on the performance, operation and maintenance, emissions, interconnection, and dispatch and control of small mobile gas turbines and will help establish a set of best practices for their use as distributed generation resources. A one- to three-year test program, with quarterly reports and analysis, is envisioned for each participant.



Allison Engine Company's mobile unit

■ *For more information, contact Dan Rastler, (415) 855-2521.*

PECO Energy Uses Streamlined RCM to Reduce Preventive Maintenance Costs

Like many other electric utilities that operate nuclear power plants, PECO Energy has used reliability-centered maintenance (RCM) techniques since the early 1990s to optimize programs for preventive maintenance, which account for a large portion of plant operating and maintenance costs. In work with EPRI over the past several years, PECO Energy has developed and demonstrated a streamlined RCM process that will save an estimated $61 million at the company's twin-unit Limerick and Peach Bottom stations by eliminating many maintenance tasks or reducing their fre-

PECO Energy's Limerick station

quency. The streamlined RCM process also reduces by a factor of 4 the time required to perform an average RCM system analysis, yielding additional estimated cost savings of $3.8 million.

In an early phase of PECO Energy's RCM project with EPRI, 12 systems at each of the four units were analyzed by using a standard RCM approach. But the utility sought a more cost-effective approach for analyzing the remaining 58 systems over the following two and a half years. The PECO Energy–EPRI project team identified various potential improvements and combined them with elements of successful RCM programs in use in the industry. The techniques were validated on several plant systems and then implemented for the remainder of the RCM project. The goal was to demonstrate that a streamlined system analysis could be performed in less than two person-months per system without sacrificing quality. The streamlined techniques have been used to analyze 35 systems, with an average analysis period of five person-weeks.

"I believe that streamlined RCM analysis has been extremely cost-effective in enabling PECO Energy to optimize the utilization of our limited maintenance resources," says David Helwig, the utility's vice president for power delivery. Adds Steve Hess, who was an RCM manager for PECO Energy during the project, "The development of streamlined RCM analysis techniques has greatly enhanced our ability to perform system analyses and reduce analysis costs while maintaining high-quality results."

■ *For more information, contact John Gisclon, (415) 855-2571.*

Duct Retrofits Cut Leakage and Boost Heating-System Efficiency

EPRI-sponsored retrofits to six homes in the Pacific Northwest have demonstrated that significant energy savings can result when leaky residential ductwork is sealed. A recent technical report (TR-104426) describes field testing at the homes and documents the potential improvements in energy use, indoor air quality, and comfort that can be gained from aggressive duct sealing.

As engineers have recognized for years, residential forced-air thermal distribution systems with a major part of the ductwork outside the conditioned space incur significant thermal losses in duct air leakage. To assess the effect of duct-sealing retrofits on heating-system efficiency, six homes known to have significant duct leakage to the outside were selected for the project. Initial tests for duct leakage and heating-system efficiency were conducted on all the homes before aggressive retrofits using mastic and fiberglass tape were performed. The homes were then measured again for duct leakage and heating-system efficiency to determine the effectiveness of the duct sealing.

In the six homes studied in the test, the duct retrofits substantially improved heating-system efficiency: average efficiency rose from 69% to 83%. Duct leakage to the outside was reduced by an average of more than 70%.

Homes with the majority of ductwork in unconditioned spaces and with fairly high energy use have been found to be the best candidates for duct retrofits. In addition to reviewing the use of mastic and fiberglass tape for duct sealing, EPRI is also investigating the use of an aerosol spray.

■ *For more information, contact John Kesselring, (415) 855-2902.*

Applied Science and Technology

Clean and Superclean Steels for Turbines

by Vis Viswanathan, Strategic R&D Business Unit

The mechanical properties of steels currently used in steam turbine rotors and disks necessitate stringent controls on start/stop cycles, limit operating temperatures and generating efficiency, and shorten component lifetimes. Perhaps the most important performance- and life-limiting property of turbine steels is fracture toughness. Unfortunately, most techniques for improving toughness, like heat treatment or the modification of alloy content, have a deleterious effect on creep strength, another important mechanical property.

The relationship between impurity levels and toughness is the key to an alternative means of improving turbine steels. The adverse effects of impurities—phosphorus (P), antimony (Sb), tin (Sn), arsenic (As), sulfur (S), oxygen (O), and the deoxidants aluminum (Al) and silicon (Si)—on the mechanical properties of steels have been known for many decades. P, Sb, Sn, and As, acting synergistically with Si and manganese (Mn), cause temper embrittlement and lead to reduced fracture toughness and increased ductile-to-brittle fracture appearance transition temperature (FATT). The presence of sulfide inclusions and of nonmetallic oxide inclusions containing Al and Si can reduce creep ductility at high temperatures and fracture toughness at lower temperatures.

Since the mid-1970s, EPRI has sponsored and catalyzed research to improve rotor steels by reducing impurity levels during the manufacturing process.

Research objectives

Initial EPRI efforts focused on characterizing and quantifying the benefits of cleaner steels—steels having reduced impurity levels. A series of projects was conducted to demonstrate both the advantages of removing steel impurities and the technological and commercial viability of producing full-scale components with extremely low impurity levels.

On the basis of EPRI results, manufacturers have developed advanced techniques for removing impurities and deoxidants during steelmaking operations. The major advance involves secondary steel refining via ladle furnaces, in conjunction with vacuum degassing in the ladle and during casting (Figure 1). Clean steels with impurity and deoxidant levels as low as 20 ppm can be produced with this process. At these levels, Mn is no longer necessary to fix S in order to avoid sulfide inclusions; thus it is possible to produce superclean materials—reduced-impurity steels with as little as 0.02% Mn.

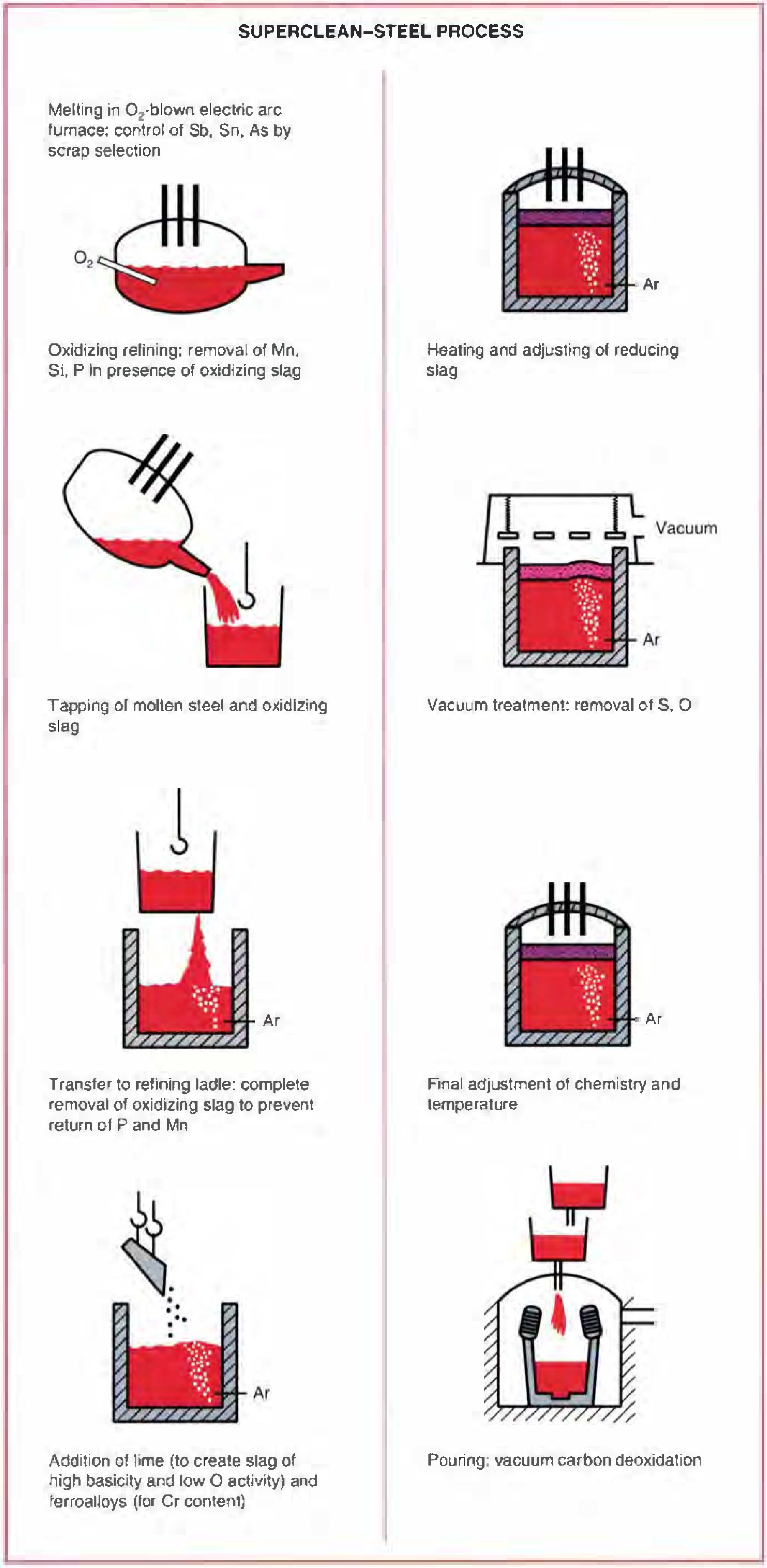
Subsequent EPRI research has focused on applying clean-steel technology to generation and has addressed the different performance requirements of various power plant steam turbine rotors: high-, intermediate-, and low-pressure (HP, IP, and LP, respectively) rotors and HP/LP single-shaft rotors. For all rotor types, the use of this technology has been demonstrated to significantly improve fracture toughness, FATT, immunity to temper embrittlement, and resistance to pitting corrosion while maintaining or enhancing creep strength and ductility. In the case of superclean LP rotor steels, improved stress corrosion cracking (SCC) resistance has also been demonstrated. On the basis of the results of these projects and other work, EPRI has prepared for utility use a superclean-steel guide (GS-6612) that summarizes a large body of available literature and provides a sample compositional specification.

HP and IP rotors

HP and IP rotors typically operate at a maximum temperature of 540–565°C, which occurs at the steam inlet end; the temperature at the steam exit end is about 345°C. For temperatures up to 540°C, a chro-

ABSTRACT *Impurity levels strongly influence the fracture toughness of steam turbine materials and thus their performance and reliability. Since the mid-1970s, EPRI has been sponsoring R&D to manufacture and evaluate clean and superclean steels—steels with reduced impurity levels—for turbine rotor applications. This work is beginning to come to fruition: improved fracture toughness characteristics have been conclusively demonstrated; and in Japan, Europe, and the United States, components constructed of steels manufactured to EPRI guidelines have been installed to increase steam turbine reliability, cycling ability, and efficiency while lowering operating and maintenance costs. Current R&D activities focus on increasing the use of emerging clean and superclean materials for steam turbine rotors and on establishing the suitability of these materials for new applications, such as combustion turbine disks.*

Figure 1 Impurity removal occurs throughout a typical superclean-steel manufacturing process, from scrap selection to casting. Carefully selected scrap is melted and refined under oxidizing conditions in an electric arc furnace. Further refining occurs in a ladle furnace under reducing and vacuum conditions; argon is bubbled through the melt to stir it and to maintain an inert environment. Finally, a vacuum technique removes impurities when the steel is poured into molds.



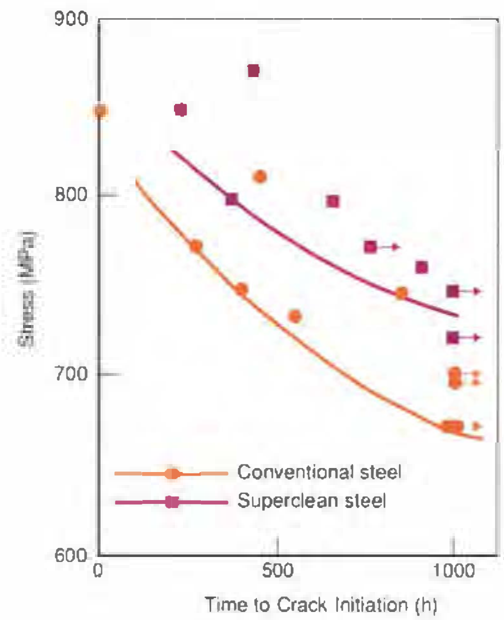
mium-molybdenum-vanadium steel (1Cr-1Mo-0.25V) is generally used, while variations of 12% Cr martensitic steel are employed for temperatures up to 565°C.

The first EPRI project dealing with clean steels (RP1343) was begun in the wake of the catastrophic failure of the Tennessee Valley Authority's Gallatin unit 2 HP/IP rotor in 1974, a failure blamed in part on the presence of sulfide inclusions at the bore. Three advanced steelmaking technologies—vacuum carbon deoxidation, electroslag remelting, and low-sulfur vacuum silicon deoxidation—were used to produce full-size (30-ton) 1Cr-1Mo-0.25V rotor forgings, which were then installed at three 520-MW U.S. power plants. Compared with conventional forgings, these clean steels exhibited improved fracture toughness, creep-rupture strength, and rupture ductility.

Recently, clean-steel HP/IP rotors made by vacuum carbon deoxidation have been used with good success in several fossil plants. The production of superclean 1Cr-1Mo-0.25V rotor steel, however, appears to be impractical (RP2060): lowering the Mn content to superclean levels reduces hardenability. Alloy modifications made to restore hardenability have led to the development of a superclean steel incorporating nickel (2.5Ni-Cr-Mo-V) that may be applicable to HP/LP single-shaft rotors.

Toward the goal of improving the fracture toughness of 12% Cr HP and IP rotor steels at and above 565°C, EPRI has published a report (CS-5277) that summarizes available information on what appear to be clean-steel compositions. Superclean versions of 12% Cr steel have not been studied for steam turbine applications. However, according to two recent non-EPRI evaluations of superclean 12% Cr steel for combustion turbine disk applications, superclean materials show excellent fracture toughness as well as immunity to embrit-

Figure 2 Stress versus crack initiation time for conventional and superclean 3.5Ni-Cr-Mo-V steels in a 30% sodium hydroxide solution at 100°C. These results illustrate the greater stress resistance of superclean steels, which translates into increased component lifetime under baseload and cycling conditions. (A data point with an arrow indicates that no cracking had occurred as of that time.)



tlement, a problem that plagues conventional 12% Cr steels.

LP rotors

LP rotors are typically made of 3.5Ni-Cr-Mo-V steel, which since the early 1960s has been produced with low FATTs and adequate toughness. However, the possibility of in-service temper embrittlement has limited the maximum operating temperature of rotors of this material to about 370°C. EPRI research has focused on eliminating temper embrittlement in order to increase operating temperatures and thus LP turbine efficiency.

In 1987, 100–200-kg ingots of superclean 3.5Ni-Cr-Mo-V steel were made, forged, and evaluated in laboratory tests (RP2060). Results showed that, compared with conventional Ni-Cr-Mo-V rotor steel, the superclean composition offered superior ductility, toughness, and high-temperature creep strength.

In response to these findings, EPRI cosponsored the production of three trial LP rotors using superclean 3.5Ni-Cr-Mo-V steel in 1991 (RP1403-15). Sections of these rotors were distributed worldwide, under EPRI sponsorship, for demonstration purposes. Subsequent analyses verified the earlier results for laboratory heats, with superclean material exhibiting lower FATTs, higher fracture toughness, immunity to temper embrittlement, increased creep strength, and greater resistance to SCC initiation (Figure 2). These properties translate into longer component lifetimes under steady and cycling conditions, as well as higher allowable steam temperatures.

The potential of superclean 3.5Ni-Cr-Mo-V steel is now widely recognized for LP rotors, for LP disks in both fossil and nuclear units, and for HP/LP single-shaft rotors at maximum steam temperatures of 500°C. One Japanese steelmaker alone reports having produced and shipped 28 superclean rotors. These have been installed both for increasing operating temperatures to improve efficiency and for improving resistance to stress corrosion at lower temperatures. At one 700-MW unit, for example, an LP rotor of superclean 3.5Ni-Cr-Mo-V steel allows LP inlet temperature to be maintained about 30°C higher than at plants with conventional LP rotors; the result is an improvement in thermal efficiency of about 0.1%, with no changes in turbine operation or inspection interval.

In this country, two recent LP rotor retrofits for Duke Power's River Bend station were manufactured of superclean 3.5Ni-Cr-Mo-V steel; at both 133-MW units, performance has met expectations. And in Europe, superclean 3.5Ni-Cr-Mo-V compositions have found extensive use in combustion turbine disk and other applications.

HP/LP single-shaft rotors

The most critical performance criteria for an HP/LP single-shaft rotor are high creep strength at one end and high toughness at the other. In the past six years, EPRI has sponsored two major clean-steel development efforts for these rotors. Results are encouraging, but further work will be necessary to demonstrate conclusively the advantages of clean steels in this application.

In the initial EPRI work (RP1403-21), researchers in 1989 optimized a clean version of a 2Cr-Mo-Ni-W-V steel by evaluating laboratory heats; they produced a trial HP/LP rotor using this composition and assessed its material properties. (A superclean version was not attempted because of hardenability concerns.) Preliminary results indicate that the optimized steel will most likely meet expectations regarding its mechanical properties.

In the second project (RP1403-55), conducted in 1994, a trial HP/LP rotor shaft of superclean 2.5Ni-Cr-Mo-V steel was produced as a follow-on to laboratory work. Tests conducted on the rotor revealed that the creep-rupture strength of the HP section was equivalent to that of conventional Cr-Mo-V rotor steel and that, in general, other characteristics (e.g., fatigue properties and fracture toughness) were equal or superior to those of the standard material.

Current R&D

Since 1986, EPRI has sponsored workshops to evaluate the technical and commercial status of clean and superclean steels. The most recent, held in London in March 1995, was attended by 80 delegates from 10 countries. Nearly 25 papers on application and manufacturing experience were presented. Proceedings will be published by the Institute of Materials (United Kingdom) in early 1996 and will be available to EPRI members. The next workshop, to be held in 1997, will focus on the performance potential of 9–12% Cr steels for utility applications.

EPRI work to advance steelmaking technology and demonstrate the benefits of clean and superclean steels has catalyzed an industry move toward the use of improved steels. Superclean Ni-Cr-Mo-V steels have found widespread acceptance for LP rotor applications in Japan and for gas turbine disks in Europe, and U.S. steelmakers are beginning to install facilities for the manufacture of clean and superclean steels. Although clean and superclean components have a higher initial cost, their benefits—increased fracture toughness, FATT, and creep strength; immunity to temper embrittlement; and improved resistance to SCC initiation—can be expected to result in significant cost savings and performance improvements over the life of a component.

New Contracts

Project	Funding / Duration	Contractor / EPRI Project Manager
Customer Systems		
R-407C Chiller Development and Demonstration (WO3412-21)	$120,500 15 months	ASW Engineering Management Consultants / *W. Krill*
Development of Heat Pumps With High-Ventilation-Air Fractions (WO3526-14)	$150,000 28 months	Climate Master / *M. Khattar*
National Equipment Sales Tracking Project (WO3539-2)	$70,100 9 months	Hagler Bailly Consulting / *R. Gillman*
Ozonation of Cooling-Tower Water (WO3761-3)	$50,000 20 months	TU Electric / *M. Jones*
Long-Term Performance of Compact Fluorescent Lamps (WO3781-1)	$194,300 24 months	Rensselaer Polytechnic Institute / *J. Kesselring*
EPRI Partnership for Industrial Competitiveness: Plant Surveys for Metals and Plastics (WO3829-21)	$300,000 12 months	Arlen Group / *W. Smith*
Field Testing of Aerosol-Based Duct Technology (WO3841-4)	$105,000 8 months	California Institute for Energy Efficiency / *S. Kondepudi*
Ground-Coupled Heat Pumps: Soil Thermal Conductivity (WO3848-4)	$202,400 18 months	Ewbank and Associates / *M. Khattar*
Electrotechnology for Environmentally Compatible Surface Coatings: Electric Infrared Preheating of Aluminum Wheels (WO3899-3)	$105,000 6 months	Taratec Corp. / *E. Eckhart*
Agriculture Electrotechnology Development: Dairy Farm Energy Efficiency Demonstration (WO4807-1)	$319,900 41 months	Hawaiian Electric Co. / *A. Amarnath*
Design Drawings and Specifications for a 30-Pound Microwave Clothes Dryer (WO4822-1)	$111,600 6 months	Thermo Energy Corp. / *J. Kesselring*
Electrotechnologies for Small Businesses (WO4824-1)	$282,500 13 months	Resource Dynamics Corp. / *W. Krill*
Nonthermal Processing of Food (WO4827-3)	$160,000 36 months	Washington State University / *A. Amarnath*
Development and Demonstration of an Off-Peak Heat Pump System (WO4836-1)	$110,000 24 months	Thermo Energy Corp. / *J. Kesselring*
A Primer for Costing and Profitability Analysis (WO4837-3)	$90,500 6 months	Energy and Environmental Economics / *P. Sioshansi*
Electric Vehicle Infrastructure Requirements Analysis (WO4838-2)	$284,700 24 months	PowerGen / *G. Purcell*
Technical Services in Wireless Communications (WO4840-1)	$190,200 4 months	Plexus Research / *R. Skelton*
Field Evaluation of Engine-Driven Heat Pumps (WO4843-1)	$201,000 30 months	AIL Research / *T. Statt*
Applied Quality Function Deployment for Key Accounts (WO4845-4)	$74,700 5 months	Putnam, Hayes & Bartlett / *T. Henneberger*
Best Practices in Competitive and Deregulated Industries (WO4853-1)	$69,500 4 months	Macro International / *T. Henneberger*
Strategic Costing, Pricing, and Profitability (WO4853-2)	$108,600 5 months	Putnam, Hayes & Bartlett / *T. Henneberger*
SAE-JEVA Conductive Coupler Contact Testing (WO4857-2)	$52,300 17 months	Underwriters Laboratories / *L. Sandell*
Development of Home Connection Device Prototypes for Electric Vehicles (WO4860-2)	$224,600 5 months	SCI Systems / *G. Purcell*
On-Site Source Reduction in a Chemical Plant by Catalytic Extraction (WO4877-1)	$641,000 13 months	Molten Metal Technology / *A. Amarnath*
Industrial Compressed-Air System Energy Management Controls (WO4879-1)	$599,000 33 months	Honeywell / *L. Carmichael*
Electric Chiller Guide (WO4880-4)	$71,000 6 months	Energy International / *W. Krill*
Review of Communications-Related Customer Service Options (WO4885-1)	$73,300 6 months	Levy Associates / *P. Meagher*
Electric Vehicle Development (WO4889-1)	$300,000 13 months	Renaissance Cars / *J. Guy*
Commercial Data Leveraging (WO4899-1)	$164,500 4 months	RLW Analytics / *R. Gillman*

Project	Funding / Duration	Contractor / EPRI Project Manager
Environment		
Characterizing Urban Organic Aerosols in Nashville, Tennessee (WO1630-29)	$129,800 21 months	Stanford University / *M. Allan*
Reliability of Reported Household Appliance Use (WO2964-31)	$223,200 12 months	Enertech Consultants / *L. Kheifets*
Role and Distribution of Mercury in Global Ecosystems (WO3297-4)	$50,000 15 months	Scope / *D. Porcella*
Florida Aquatic Ecosystem Mercury Cycling and Modeling Project: Modeling Component (WO3297-5)	$298,100 31 months	Tetra Tech / *D. Porcella*
Southeastern Aerosol and Visibility Study (SEAVS): Relationship Between Optics and Composition (WO4105-1)	$250,000 36 months	University of Minnesota / *P. Saxena*
Manhole Residual Management Study (WO4183-1)	$56,800 9 months	CH2M Hill / *I. Murarka*
Childhood Leukemia: Role of Magnetic Field Exposure in Tumor Relapse and in Survival (WO4305-3)	$1,723,900 56 months	Western Consortium for Public Health / *L. Kheifets*
Analysis of Volatiles in Air Samples Collected as Part of the Southern Oxidants Study (WO9031-5)	$70,000 9 months	University of Miami / *A. Hansen*
Florida Aquatic Ecosystem Mercury Cycling and Modeling Project (WO9050-4)	$796,200 27 months	KBN Engineering & Applied Sciences / *D. Porcella*
Design and Construction of a Pilot Curbside Water Treatment System for Manholes (WO9078-3)	$135,200 8 months	Flippo Construction Co. / *I. Murarka*
North American Research Strategy for Tropospheric Ozone (NARSTO)-Northeast: Technical Coordination (WO9108-1)	$775,200 40 months	Sonoma Technology / *P. Mueller*
NARSTO-Northeast: Surface Air Quality and Meteorology Sites (WO9108-4)	$820,700 37 months	Environmental Science & Engineering / *P. Mueller*
NARSTO-Northeast: Rawinsonde Measurements (WO9108-6)	$385,200 12 months	Technical & Business Systems / *P. Mueller*
NARSTO-Northeast: Hydrocarbon Sampling and Analysis (WO9108-9)	$510,200 24 months	Biospherics Research Corp. / *P. Mueller*
NARSTO-Northeast: Shenandoah Measurements and Data Analysis (WO9108-10)	$100,000 14 months	University of Maryland / *P. Mueller*
NARSTO-Northeast: Coordination Among Northeastern States (WO9108-11)	$151,000 12 months	Nescaum Air Quality Foundation / *P. Mueller*

Project	Funding/ Duration	Contractor/EPRI Project Manager
NARSTO-Northeast: Project Coordination (WO9108-12)	$124,600 20 months	ENSR Consulting and Engineering/P. Mueller
NARSTO-Northeast: Audits for Hydrocarbon and Carbonyl Measurements (WO9108-14)	$55,900 13 months	Desert Research Institute/P. Mueller
NARSTO-Northeast: Audits for Upper Air Meteorological Measurements (WO9108-15)	$105,500 13 months	Aerovironment/P. Mueller
NARSTO-Northeast: Audits for Air Quality and Surface Meteorological Measurements (WO9108-16)	$130,200 13 months	Enviroplan/P. Mueller
Response of Chaparral to Elevated CO_2 Levels (WO9110-1)	$65,000 5 months	San Diego State University Foundation/ L. Pitelka
Response of Fish Populations to Altered Flows (WO[illegible]111-1)	$68,400 10 months	Entrix/J. Mattice
Subsurface Fate and Transport of Cyanide at Manufactured Gas Plant Sites (WO9115-2)	$184,000 30 months	Remediation Technologies/I. Murarka
Systemwide Trace Substance Risk Assessment: Case Study 1 (WO9120-1)	$85,000 7 months	Decision Focus/L. Levin
Shoreline Dispersion Modeling and Evaluation: Measurements and Modeling of Coastal Influences on Air Quality (WO9122-1)	$254,200 18 months	Rutgers University/ C. Hakkarinen
Studies of Former Manufactured Gas Plant Sites (WO9129-1)	$76,100 5 months	Meta Environmental/ I. Murarka
Air-Sparging Research (WO9131-1)	$20[illegible],800 4 months	Pinnacle Geo Sciences/ I. Murarka

Generation

Project	Funding/ Duration	Contractor/EPRI Project Manager
Development of Heat Rate Degradation Advisor (WO1681-12)	$354,900 41 months	Sundram Information Systems/J. Tsou
Cycle Chemistry Advisors for Power Plants (WO2712-17)	$142,500 12 months	Jonas/B. Dooley
Radially Stratified Ultralow-NO_x Burner (WO2869-18)	$370,000 4 months	Empire State Electric Energy Research Corp./ A. Facchiano
High-Pressure/Intermediate-Pressure Steam Turbine Leakage Flow (WO3849-4)	$513,400 1[illegible] months	Enotech Engineering/ T. McCloskey
Repowering Studies and Repowering Technology Evaluation (WO3935-3)	$85,000 6 months	Sargent & Lundy/ S. Pace
Use of Acoustic Flow Turbulence Noise to Monitor Coal Flow (WO3938-1)	$264,300 18 months	Science Applications International Corp./ J. Weiss
Use of Microwave System to Monitor Pulverized-Coal and Primary Air Mass Flow (WO3938-3)	$55,800 1[illegible] months	Airflow Sciences Corp./ J. Weiss
Durability Surveillance of ABB GT24 Advanced Gas Turbine (WO3945-1)	$1,202,000 48 months	Fluor Daniel/W. Piulle
Gas Cofiring Evaluation (WO3[illegible]58-1)	$130,000 10 months	Southern Company Services/A. Mehta
Enhanced Monitoring Protocols for Particulates (WO3976-2)	$59,900 12 months	RMB Consulting and Research/C. Dene
Development of REMLIF-6 Life Management System for GE MS6001 Combustion Turbines (WO3981-1)	$2[illegible]9,300 34 months	Southwest Research Institute/G. Quentin
Application of REMLIF-6 Life Management System (WO3[illegible]81-2)	$380,000 34 months	KEMA/G. Quentin
Durability Surveillance of Siemens V94.2 Gas Turbine (WO4022-2)	$103,[illegible]00 28 months	Fluor Daniel/W. Piulle
Effects of Clonal Deployment Patterns on Productivity and Pests in Willow Biomass-Bioenergy Plantings (WO4062-4)	$92,800 37 months	SUNY Research Foundation/J. Turnbull
Control of Fine Particulates and Air Toxics (WO4091-1)	$99,800 22 months	Southern Company Services/R. Chang
Illinois Basin Coal Quality Assessment and Mapping (WO4152-1)	$123,000 26 months	Indiana University/ B. Toole-O'Neil
Demonstration of DYNAMICS for Economic Analysis of Cycling Modifications (WO4181-1)	$1,475,200 90 months	Decision Focus/ D. O'Connor
Distributed Generation Workstation (WO[illegible]194-1)	$75,000 4 months	Sargent & Lundy/ D. Herman
Flue Gas Conditioning Full-Scale Field Trial (WO4206-1)	$430,000 14 months	ADA Technologies/ R. Chang
Pilot Applications of Environmental Performance Measurement (WO9030-2)	$87,500 6 months	Decision Focus/ M. McLearn
Demonstration of Center-Dewatering Elements (WO9047-3)	$219,100 9 months	Wisconsin Electric Power Co./D. Golden

Nuclear Power

Project	Funding/ Duration	Contractor/EPRI Project Manager
Risk-Based In-Service Inspection Implementation Guideline Development (WO3230-7)	$128,900 11 months	Yankee Atomic Electric Co./S. Gosselin
Development and Demonstration of Rack-Saver Neutron Absorber (WO3290-13)	$55,000 10 months	Siemens Power Corp./ R. Yang
Thermal Evaluation of the Multipurpose Canister–Repository Interface (WO3290-14)	$68,600 11 months	VECTRA Technologies/ J. Kessler
On-Line Maintenance (WO3343-21)	$160,000 8 months	OES/F. Rahn
Realistic Method for PWR Large-Break Loss-of-Coolant Accident Licensing Analysis (WO3394-3)	$[illegible]0,000 18 months	Yankee Atomic Electric Co./M. Merilo
Electrochemical Methods for Mitigating Intergranular Stress Corrosion Cracking in BWR Pressure Vessel Internals (WO3468-11)	$99,500 24 months	Structural Integrity Associates/L. Nelson
Laser Cladding of Venturi Surfaces to Prevent Fouling (WO3500-33)	$124,900 15 months	J. A. Jones Applied Research Co./H. Ocken
Method for Monitoring Assembly of High-Pressure Bolted Connections (WO3660-3)	$136,400 9 months	Warren Engineering/ N. Hirota
Life-Cycle Management Implementation Demonstration: Condition Monitoring Program for 4-kV EQ Motors (WO3698-6)	$99,800 9 months	Kiran Consultants/ J. Carey
Demonstration of Filter Demineralizer Performance Improvement Program (WO3801-17)	$90,100 11 months	CenTec-21/ C. Hornibrook
Diesel Engine Analysis Guidelines (WO3814-20)	$90,000 16 months	MPR Associates/ J. Sharkey
Technology Transfer for Major Component Reliability (WO3887-2)	$100,000 10 months	J. A. Jones Applied Research Co./J. Gilman
Identification of Available Irradiated Materials for Future Testing for Irradiation-Assisted Stress Corrosion Cracking (WO4068-18)	$249,500 15 months	Modeling & Computing Services/L. Nelson
Optimization of Reactor Pressure Vessel Pressure-Temperature Limits (WO4221-1)	$83,900 17 months	Sartrex Corp./ S. Gosselin
Development of Methods for Evaluating Plant Stratification Monitoring Results (WO4240-1)	$239,100 1[illegible] months	Structural Integrity Associates/S. Gosselin
Development of Corrosion Models (WO4528-3)	$71,200 5 months	AECL Technologies/ R. Mahini
Incorporation of THERMAC in CHECWORKS (WO4528-4)	$135,700 12 months	S. Levy/R. Mahini
BWR Internals Information Gathering (WOB110-3)	$117,700 5 months	Dominion Engineering/ K. Ramp
IAM System PlantView, Release 1.0 (WOB110-4)	$86,400 5 months	Dev Team One/K. Ramp
Support of BWR Vessel and Internals Program Beltline Team (WOB302-1)	$156,000 10 months	Structural Integrity Associates/R. Carter
Oxide Film Characterization Database (WOB401-5)	$80,000 18 months	General Electric Co./ H. Ocken
Ammonia Injection and Transport in a BWR Operating Under Hydrogen Water Chemistry Conditions (WOB401-10)	$50,000 3 months	General Electric Co./ L. Nelson
Fabrication of Circumferential Stress Corrosion Cracks in Alloy 600 Steam Generator Tubing (WOS530-14)	$199,900 9 months	Westinghouse Electric Corp./M. Behravesh

Project	Funding/ Duration	Contractor/EPRI Project Manager
Nondestructive Evaluation Support for Welded Tube Repair (WOS530-15)	$105,700 9 months	J. A. Jones Applied Research Co./ *M. Behravesh*
Tube Integrity Methodology for Circumferential Cracking (WOS550-19)	$961,000 12 months	Westinghouse Electric Corp./*D. Steininger*
Tube Integrity Methodology for Circumferential Cracking (WOS550-20)	$181,100 12 months	Packer Engineering/ *D. Steininger*
Mechanism of Hydrogen Pickup in Zirconium-Base Alloys (WOX103-2)	$375,800 26 months	Commissariat à l'Energie Atomique/*S. Yagnik*
Dynamic Safety System (WOX103-25)	$493,200 28 months	AEA Technology/ *S. Yagnik*
Power Delivery		
Advanced Marginal Costing in Transmission Networks (WO3581-5)	$226,100 5 months	Christensen Associates/ *C. Clark*
Assessment and Inspection Methods Phase 3 (WO3621-4)	$88,900 3 months	J. A. Jones Power Delivery/*P. Lyons*
TLWorkstation Framework Module Conversion (WO3928-8)	$226,100 6 months	J. A. Jones Power Delivery/*A. Hirany*
Five-Wire Distribution System (WO3968-1)	$555,000 32 months	New York State Electric & Gas Corp./*H. Ng*
UCA 2.0 Development Support (WO3977-2)	$96,400 10 months	Tamarack Consulting/ *W. Blair*
Severe Storm and Lightning Research (WO3978-1)	$263,000 24 months	Geomet Data Services/ *R. Bernstein*
Conductor Drag Coefficient Database (WO4016-1)	$234,100 24 months	J. A. Jones Power Delivery/*P. Lyons*
Development of a Ground-Penetrating Radar System (WO4029-1)	$449,900 8 months	Lockheed Missiles & Space Co./*R. Bernstein*
Lightning Protection Design Workstation Version 3.0 Development (WO4098-1)	$80,900 5 months	Distributed Energy Systems Group/ *R. Bernstein*
Development of a Gas Monitor for Underground Electric Utility Vaults (WO4142-2)	$187,800 9 months	Carnegie Mellon Research Institute/ *R. Bernstein*
Satellite Communications for Remote Substation Monitoring and Control and Voice Applications (WO4172-1)	$1,177,000 13 months	Southern California Edison Co./ *D. Richardson*
Electrical Systems Software Integration (WO4174-1)	$143,500 12 months	BSG Consulting/ *P. Hirsch*
Transmission Line Surge Arresters (WO4207-1)	$157,000 17 months	J. A. Jones Power Delivery/*A. Hirany*
Unified Power Flow Controller, Initial Tasks (WO7006-2)	$708,000 10 months	Westinghouse Electric Corp./*A. Edris*
Sulfur Hexafluoride Database (WO7007-1)	$291,400 26 months	AAI Research and Development/*B. Damsky*
Distribution Static Compensation Demonstration (WO7023-1)	$390,600 9 months	Westinghouse Electric Corp./*A. Sundaram*
UCA Integration, Protection, Controls, and Data Acquisition (WO7085-1)	$52,000 6 months	Duke Power Co./ *J. Melcher*
Solid-State Transfer Switch (WO7102-1)	$588,000 24 months	Silicon Power Networks Partnership/ *D. Richardson*
Retail Service Design and C-VALU Beta Test (WO7802-13)	$64,000 7 months	Christensen Associates/ *C. Smyser*
Strategic R&D		
Rough-Fuzzy Controllers for Complex Systems (WO8015-8)	$196,600 23 months	San Jose State University Foundation/ *M. Wildberger*
Value of Improved Short-Term Load Forecasts (WO8015-9)	$131,000 23 months	Case Western Reserve University/*D. Sobajic*
Environmental Biodetoxification Mechanisms (WO8021-9)	$150,000 39 months	University of Massachusetts/*R. Goldstein*
Sensors for On-Line Measurement of Flame Radicals and Gas Temperature (WO8031-5)	$144,000 7 months	Foster-Miller/ *R. Frischmuth*
Advanced Experimental and Computational Tools for Unburned-Carbon Prediction (WO8032-4)	$255,000 34 months	Brown University/ *A. Mehta*
Reversibility of Combustion Processes (WO8032-6)	$179,500 29 months	Dartmouth College/ *J. Maulbetsch*
Vibration Suppression in Intelligent Structures (WO8033-2)	$296,100 41 months	Pennsylvania State University/*T. McCloskey*
Thin-Film Electrolytes for Solid-Oxide Fuel Cells (WO8062-11)	$50,000 13 months	Lawrence Berkeley National Laboratory/ *W. Bakker*
Solid-Electrolyte Proton Conductors (WO8062-12)	$187,500 60 months	University of Washington/*R. Goldstein*
Visible-Light-Emitting Diodes Fabricated From Soluble Semiconducting Polymers (WO8067-1)	$64,300 12 months	University of California, Santa Barbara/*P. Grant*
Technical Issues, Methods, and Tools in Emerging Energy Market Structures (WO8501-1)	$298,700 7 months	Putnam, Hayes & Bartlett/*A. Vojdani*
Increased Efficacy of Incandescent Lamp Filaments With High-Temperature Coatings (WO8503-1)	$100,000 5 months	New York State Energy Research/*K. Johnson*
Preparation and Evaluation of Activated-Carbon Functional Groups for Mercury Removal (WO8505-4)	$180,000 22 months	University of Illinois, Urbana/*R. Chang*
AC Loss Measurements on High-Temperature-Superconductor Cable (WO8506-2)	$150,000 12 months	Los Alamos Scientific Laboratory/*P. Grant*
Development of Light-Controlled Silicon Switches for Electric Utility Applications (WO8510-1)	$99,900 4 months	Energy Compression Research Corp./ *J. Melcher*
Development of Advanced MOS-Controlled Thyristor Devices (WO8510-2)	$68,800 6 months	Harris Corp./*B. Damsky*
Power Electronic Building Blocks (WO8510-3)	$4,000,000 48 months	Harris Corp./*B. Damsky*
High-Voltage, High-Power Diamond Switches (WO8510-4)	$100,400 9 months	Alameda Applied Sciences Corp./ *D. Richardson*
Novel New Chemicals and Mixtures as R-22 Alternatives (WO8511-2)	$200,000 29 months	Clemson University/ *W. Krill*
Untapped Potential of CO_2 for Vapor Compression HVAC Systems (WO8511-3)	$63,200 6 months	DRF R&D/*S. Kondepudi*
Kinetic Modeling of Advanced-Cycle-Turbine Pollutant Formation (WO8512-1)	$50,000 9 months	Energy and Environmental Research Corp./*A. Cohn*
Improved Performance and Stability for Silicon-Based Materials and Devices: Fabrication, Measurement, and Computer Modeling Activities (WO8513-2)	$200,000 9 months	Pennsylvania State University/*T. Peterson*
Application of Differential Sensitivity Analysis Theory (WO9000-33)	$50,000 6 months	Computer Simulation and Analysis/*L. Agee*
Testing-Based Application-Specific Integrated Circuit Design (WO9000-34)	$50,000 4 months	ECR Laboratory/*J. Naser*
Application of Nonlinear Dynamics to Utility-Related Materials Problems (WO9000-35)	$307,400 16 months	Ohio State University Research Fund/ *J. Stringer*
Mathematical Modeling of the Dynamics of Magnetic-Field-Influenced Free-Radical Lipid Transformations (WO9000-36)	$50,000 4 months	University of Illinois, Urbana/*M. Wildberger*
Processing of Metal-Clad, Powder-Filled Composite Wires and Ribbons by the Continuous-Tube-Forming-Filling Method (WO9001-6)	$110,300 16 months	Ohio State University Research Fund/ *J. Stringer*
Application of Chaotic Time Series Analysis to Low-NO_x Burner Technology (WO9002-17)	$100,000 7 months	Babcock & Wilcox Co./ *J. Stallings*
Multilayer Thermal Barrier Coatings for Gas Turbine Engines (WO9002-18)	$675,000 36 months	Battelle Pacific Northwest Laboratories/*W. Bakker*
Burner Rig Tests to Assess Waterwall Corrosion (WO9002-19)	$194,800 20 months	University of Leeds Innovations/*A. Mehta*
Advanced Coating Developments for Gas Turbine Components (WO9005-3)	$163,900 10 months	Southwest Research Institute/*V. Viswanathan*
Quantitative Assessment of Trace Element Forms and Concentrations (WO9998-1)	$390,000 18 months	University of Kentucky Research Foundation/ *A. Mehta*

New Technical Reports

Requests for copies of reports should be directed to the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, California 94523; (510) 934-4212. EPRI members that fund the business unit issuing a report can receive the report free of charge (or, in the case of bulk orders, for a nominal price). Domestic organizations not eligible for EPRI membership pay the listed price. Others should contact the Distribution Center for further information.

CUSTOMER SYSTEMS

Measured Efficiency Improvements From Duct Retrofits on Six Electrically Heated Homes
TR-104426 Final Report (RP3512-12); $200
Contractor: Ecotope, Inc.
Business Unit: Residential & Small Commercial
EPRI Project Manager: J. Kesselring

CLASSIFY Profiles, Vol. 2: Commercial and Industrial Customer Needs and Energy Decision Making
TR-104567-V2 Final Report (RP4001-3); $200
Contractor: National Analysts, Inc.
Business Unit: Retail Market Tools & Services
EPRI Project Manager: T. Henneberger

CLASSIFY Profiles, Vol. 3: Trade Ally Needs and Influences on Utility Customer Decisions
TR-104567-V3 Final Report (RP4001-3); $200
Contractor: National Analysts, Inc.
Business Unit: Retail Market Tools & Services
EPRI Project Manager: T. Henneberger

Performance Evaluation of the Hydronic Heat Pump System, Vol. 2: Cooling Season
TR-104891-V2 Final Report (RP2892-27); $200
Contractor: GEOMET Technologies, Inc.
Business Unit: Residential & Small Commercial
EPRI Project Manager: J. Kesselring

Building a New Understanding of Customer Loyalty and Satisfaction
TR-105150 Interim Report (RP4001-3); $200
Contractor: National Analysts, Inc.
Business Unit: Retail Market Tools & Services
EPRI Project Managers: T. Henneberger, R. Gillman

Winning Retail Strategies: Beyond Innovative Rate Design
TR-105226 Final Report (RP2343-14); $200
Contractor: Barakat & Chamberlin, Inc.
Business Unit: Retail Market Tools & Services
EPRI Project Manager: P. Sioshansi

The Challenges of Electrotechnology Research, Development, and Deployment
TR-105267 Final Report (RP3557); $200
Business Units: Power Quality & Information Technology; Residential & Small Commercial
EPRI Project Managers: C. Gellings, M. Blatt

ESPRE Compact User's Guide: Residential Energy Analysis on a Palmtop Computer
TR-105282 Final Report (RP3512-23); $200
Contractor: Analysis and Control of Energy Systems, Inc.
Business Unit: Residential & Small Commercial
EPRI Project Manager: J. Kesselring

Developing Customer Service Opportunities: A Case Study Employing Advanced Metering, Communication, and Information Technologies
TR-105381 Final Report (RP3084-17); $200
Contractor: Levy Associates
Business Unit: Retail Market Tools & Services
EPRI Project Managers: P. Meagher, J. Bloom

ENVIRONMENT

Exposure to Residential Electric and Magnetic Fields and Risk of Childhood Leukemia
TR-104528 Final Report (RP2964-1); $200
Contractor: University of Southern California
Business Unit: Environmental & Health Sciences
EPRI Project Manager: L. Kheifets

Management Practices for Used Treated Wood
TR-104966 Final Report (RP2879-2); $200
Contractor: Tetra Tech, Inc.
Business Unit: Environmental & Health Sciences
EPRI Project Manager: I. Murarka

Interim Report on the Fate of Wood Preservatives in Soils Adjacent to In-Service Utility Poles in the United States
TR-104968 Interim Report (RP2879-9, -12, -35); $200
Contractors: META Environmental, Inc.; Atlantic Environmental Services, Inc.; Utah State University; Science and Technology Management, Inc.
Business Unit: Environmental & Health Sciences
EPRI Project Managers: I. Murarka, A. Quinn

Geochemical Investigation of Pyrite Codisposal With Sluiced Fly Ash and Implications for Selecting Remedial Actions
TR-105065 Final Report (RP2485-8, RP2879-2 -12); $200
Contractors: Battelle Pacific Northwest Laboratories; Tetra Tech, Inc.
Business Unit: Environmental & Health Sciences
EPRI Project Manager: I. Murarka

Acid Deposition and Air Quality Related Values in North Central Colorado Wilderness Areas
TR-105192 Final Report (RP2377-4); $200
Contractor: University of California, Riverside, Center for Environmental Research and Technology
Business Unit: Environmental & Health Sciences
EPRI Project Manager: R. Brocksen

Land Application Uses for Dry Flue Gas Desulfurization By-Products
TR-105264 Final Report (RP2796-2); $200
Contractors: Ohio State University, Ohio Agricultural Research and Development Center; United States Geological Survey
Business Unit: Environmental & Health Sciences
EPRI Project Manager: I. Murarka

Microscale Solvent Extraction Methods for the Analysis of Solids and Liquids, Vols. 1 and 2
TR-105317-V1, TR-105317-V2 Final Report (RP2879-12); $500 for set
Contractor: META Environmental, Inc.
Business Unit: Environmental & Health Sciences
EPRI Project Managers: I. Murarka, A. Quinn

GENERATION

Guidelines for Flue Gas Flow Rate Monitoring
TR-104527 Final Report (RP1961-13); $10,000
Contractors: Fossil Energy Research Corp.; Airflow Sciences Corp.; RMB Consulting & Research
Business Unit: Environmental Control
EPRI Project Managers: E. Petrill, C. Dene

Kingston Controls Upgrade Retrofit Study: Application of EPRI Products and Controls Guidelines
TR-104538 Final Report (RP2710-27); $10,000
Contractor: Gilbert Commonwealth, Inc.
Business Unit: Fossil Power Plants
EPRI Project Manager: J. Weiss

FGD By-Product Disposal Manual, Fourth Edition
TR-104731 (RP2807-1); $10,000
Contractor: Baker Environmental (under subcontract to ICF Technology, Inc.)
Business Unit: Environmental Control
EPRI Project Manager: D. Golden

Options for Handling Noncombustion Waste, Third Edition
TR-105152 Final Report (RP3006-2); $10,000
Contractors: Mittelhauser Corp.; Roy F. Weston, Inc.; Precor Corp.
Business Unit: Environmental Control
EPRI Project Managers: M. McLearn, P. Radcliffe

Review of River-Bed Sediment Problems at Intakes
TR-105201 Final Report (RP3456); $10,000
Contractor: University of Iowa
Business Unit: Fossil Power Plants
EPRI Project Manager: J. Tsou

Guidelines for Conversion From Coal and Oil to Gas Firing
TR-105230 (RP2819-23); $10,000
Contractor: Stone & Webster Engineering Corp.
Business Unit: Fossil Power Plants
EPRI Project Manager: E. Petrill

Proceedings: 1994 EPRI Fossil Plant Cycling Conference
TR-105382 Proceedings (RP1184); $1000
Business Unit: Fossil Power Plants
EPRI Project Managers: D. O'Connor, D. Broske

Hydraulic Turbine–Driven Boiler Circulation Pump: Field Testing at Southern Power Plant, St. Petersburg, Russia
TR-105532 Final Report (RP1403-25); $10,000
Contractor: Joseph Technology Corp., Inc.
Business Unit: Fossil Power Plants
EPRI Project Manager: W. Piulle

NUCLEAR POWER

Steam Generator Reference Book, Revision 1, Vol. 1
TR-103824-V1R1 (RP2858, RP4004); $1000
Business Unit: Nuclear Power
EPRI Project Manager: P. Paine

Documentation of Probabilistic Fracture Mechanics Codes Used for Reactor Pressure Vessels Subjected to Pressurized Thermal Shock Loading, Parts 1 and 2
TR-105001 Final Report (RP2975-5); $200
Contractor: Westinghouse Electric Corp.
Business Unit: Nuclear Power
EPRI Project Manager: R. Carter

Experience With Inhibitor Injection to Combat IGSCC in PWR Steam Generators
TR-105003 Topical Report (RPS401-1, RPS416-10, RPS510-2); $1000
Contractor: NWT Corp.
Business Unit: Nuclear Power
EPRI Project Manager: P. Paine

Proceedings: Joint DOE/EPRI International Conference on Cost-Effective Instrumentation and Control Technology Upgrades for Nuclear Power Plants
TR-105148 Proceedings (RP3373); $200
Business Unit: Nuclear Power
EPRI Project Manager: D. Wilkinson

PSA Applications Guide
TR-105396 Final Report (RP3200-12); $200
Business Unit: Nuclear Power
EPRI Project Managers: J. Sursock, J. Haugh

POWER DELIVERY

Development of an Oil Deterioration Test Method to Monitor the Condition of High-Pressure Fluid-Filled Paper Cable
EL-7488-L Final Report (RP7895-1); license required
Contractor: Detroit Edison Co.
Business Unit: Transmission
EPRI Project Managers: T. Rodenbaugh, D. Von Dollen

Development of Advanced Composite Materials for Utility Application, Phase 1
TR-104830 Final Report (RP3229-1); $5000
Contractor: Foster-Miller, Inc.
Business Unit: Distribution
EPRI Project Managers: T. Kendrew, B. Bernstein

Robust Interior Point Optimal Power Flow
TR-105081 Final Report (RP3788-1); license required
Contractor: Howard University
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: R. Adapa

Linemen's Protective Equipment
TR-105184 Final Report (RP2239-2); license required
Contractor: Battelle Columbus Laboratories
Business Unit: Distribution
EPRI Project Managers: T. Kendrew, B. Bernstein

DRUMS Leak Detection for HPFF Pipe-Type Cable Systems
TR-105250 Final Report (RP7900-1); $5000
Contractor: Underground Systems, Inc.
Business Unit: Transmission
EPRI Project Managers: T. Rodenbaugh, F. Garcia

Flexible AC Transmission System (FACTS): System Studies to Assess FACTS Device Requirements on the Entergy System
TR-105260 Final Report (RP3789-2); $5000
Contractors: Entergy Services, Inc.; General Electric Co.
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: R. Adapa

Basic Breakdown Study of HPFF and Extruded-Dielectric Cables
TR-105301 Final Report (RP7879-1); $5000
Contractor: Underground Systems, Inc.
Business Unit: Transmission
EPRI Project Manager: T. Rodenbaugh

STRATEGIC R&D

Fluid-Elastic Excitation in Heat Exchanger Tube Bundles
TR-103507 Final Report (RP8006-12); $200
Contractor: Oklahoma State University
Business Unit: Strategic R&D
EPRI Project Manager: D. Steininger

Proof of Principle of the Solid-State Transformer: AC/AC Switchmode Regulator
TR-105067 Final Report (RP8001-13); $5000
Contractor: San Jose State University, Power Electronics/Control Laboratory
Business Unit: Strategic R&D
EPRI Project Manager: R. Richardson

High-Efficiency Flame Retardants for Polyolefins
TR-105254 Final Report (RP8007-18); $5000
Contractor: Polytechnic University
Business Unit: Strategic R&D
EPRI Project Manager: B. Bernstein

New Computer Software

Orders for EPRI-developed software should be directed to the Electric Power Software Center, 13601 Preston Road, Suite 800W, Dallas, Texas 75240; (800) 763-3772. EPRI members can receive, free of charge, software developed by the business units to which they subscribe. Others should contact EPRI's Licensing Office at (415) 855-2974.

ABC: Advisor on Blade Coatings
Version 2.0 (PC-DOS)
Contractor: Southwest Research Institute
Business Unit: Fossil Power Plants
EPRI Project Manager: George Quentin

Desk Book™: Residential End-Use Technologies
Version 1.0 (PC-DOS/Windows)
Contractor: Energy International, Inc.
Business Unit: Residential & Small Commercial
EPRI Project Manager: John Kesselring

EGEAS: Electric Generation Expansion Analysis System
Version 7.31 (PC-DOS/Windows)
Contractor: Stone & Webster
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: Ram Adapa

ESP: Expert System for Power System Planning and Engineering
Version 1.0 (DEC-ALPHA)
Contractor: ABB Systems Control
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: Ram Adapa

ESPRE Compact: Residential Energy Analysis on a Palmtop Computer
Version 1.0 (PC-DOS)
Contractor: Analysis and Control of Energy Systems, Inc.
Business Unit: Residential & Small Commercial
EPRI Project Manager: John Kesselring

GasPlan: Gas Procurement and Operations Planning Tool
Version 1.5 (PC-DOS)
Contractor: Applied Decision Analysis
Business Unit: Utility Resource Planning & Management
EPRI Project Manager: Richard Goldberg

LPDW™: Lightning Protection Design Workstation
Version 2.0 (PC-DOS)
Contractor: Power Technologies, Inc.
Business Unit: Distribution
EPRI Project Manager: Ralph Bernstein

PMOS™: Plant Modification Operating Savings
Version 2.0 (PC-DOS/Windows)
Contractor: Decision Focus Inc.
Business Unit: Fossil Power Plants
EPRI Project Manager: Dave O'Connor

RIVRISK
Version 2.0 (PC-DOS/Windows)
Contractor: Tetra Tech, Inc.
Business Unit: Environmental & Health Sciences
EPRI Project Manager: Robert Goldstein

SURIS: Demand-Side Survey Information System
Version 5.0 (PC-DOS)
Contractor: Plexus Research
Business Unit: Retail Market Tools & Services
EPRI Project Manager: Paul Meagher

TLWorkstation™: Transmission Line Workstation
Version 2.4M (PC-DOS)
Contractor: BSG Alliance/IT, Inc.
Business Unit: Transmission
EPRI Project Manager: Anwar Hirany

EPRI Events

MARCH

7–8
EPRI Partnership for Industrial Competitiveness
Chattanooga, Tennessee
Contact: Bill Smith, (415) 855-2415

11–15
Steam Turbine Blade Life Evaluation
Rochester, New York
Contact: Jeannie Blanchard, (716) 424-2010

12–14
Disaster Preparedness
New York, New York
Contact: Susan Bisetti, (415) 855-7919

18–19
Cascading-Failure Risk Assessment Workshop
Haslet, Texas
Contact: Jon Ferguson, (817) 439-5900

19–20
Managing for Biodiversity: Emerging Ideas for the Electric Utility Industry
Williamsburg, Virginia
Contact: Christine Lillie, (415) 855-2010

19–21
Seminar: Comanagement of Utility Wastes
Williamsburg, Virginia
Contact: Ishwar Murarka, (415) 855-2150

20–22
Power Plant Automation Technologies
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (610) 595-5922

27–29
Innovative Approaches to Electricity Pricing: Managing the Transition to Market-Based Pricing
San Diego, California
Contact: Lori Adams, (415) 855-8763

APRIL

8–11
1996 International Fossil Simulation and Training Meeting
New Orleans, Louisiana
Contact: Ron Griebenow, (816) 235-5622

9–11
The Future of Power Delivery
Washington, D.C.
Contact: Christine Lillie, (415) 855-2010

9–11
1996 Electric Food Service Symposium
Nashville, Tennessee
Contact: Susan Bisetti, (415) 855-7919

10–12
Pollution Prevention Seminar
Denver, Colorado
Contact: Michele Samoulides, (415) 855-2127

16–18
Mixed-Waste Training Course
Boston, Massachusetts
Contact: Denise Wesalainen, (415) 855-2259

17–18
Decision Analysis for Environmental Risk Management
Washington, D.C.
Contact: Robert Goldstein, (415) 855-2593

MAY

8–10
CEM (Continuous Emissions Monitoring) Users Group Meeting
Kansas City, Missouri
Contact: Lori Adams, (415) 855-8763

22–24
1996 Heat Rate Improvement Conference
Dallas, Texas
Contact: Susan Bisetti, (415) 855-7919

JUNE

3–4
Motor Rewind Course
Atlanta, Georgia
Contact: Denise Wesalainen, (415) 855-2259

4–5
Repowering Workshop
Washington, D.C.
Contact: Christine Lillie, (415) 855-2010

4–6
EPRI Reactor Pressure Vessel Inspection Conference
Squaw Valley, California
Contact: Susan Otto, (704) 547-6072

10–13
Balance-of-Plant Heat Exchanger Workshop
Jackson Hole, Wyoming
Contact: Kenji Krzywosz, (704) 547-6096

11–13
Interaction of Non-Iron-Based Materials With Water and Steam
Piacenza, Italy
Contact: Michele Samoulides, (415) 855-2127

17–19
6th International ISA POWID/EPRI Controls and Instrumentation Conference
Baltimore, Maryland
Contact: Lori Adams, (415) 855-8763

25–27
Service Water Systems Reliability Improvement Seminar
Daytona Beach, California
Contact: Susan Otto, (704) 547-6072

JULY

22–24
1996 International Low-Level-Waste Conference
New Orleans, Louisiana
Contact: Michele Samoulides, (415) 855-2127

24–26
ASME/EPRI Radwaste Workshop
New Orleans, Louisiana
Contact: Michele Samoulides, (415) 855-2127

29–August 1
Fossil Plant Maintenance Conference
Baltimore, Maryland
Contact: Lori Adams, (415) 855-8763

AUGUST

4–8
4th International Conference on Mercury as a Global Pollutant
Hamburg, Germany
Contact: Don Porcella, (415) 855-2723

5–7
Turbine Generator Operation
Redondo Beach, California
Contact: Denise Wesalainen, (415) 855-2259

7–9
International Conference on Sustainable Thermal Energy Storage
Chicago, Illinois
Contact: Beverly Speer, (608) 262-8220

26–30
Condenser Technology Seminar and Conference
Boston, Massachusetts
Contact: Lori Adams, (415) 855-8763

OCTOBER

3–4
Decision Analysis for Environmental Risk Management
Palo Alto, California
Contact: Robert Goldstein, (415) 855-2593

7–10
Hydrogenerator Maintenance
Seattle, Washington
Contact: Denise Wesalainen, (415) 855-2259

NOVEMBER

13–15
Solid-Particle Erosion
Nashville, Tennessee
Contact: Michele Samoulides, (415) 855-2127

FEBRUARY 1997

22–26
Environmental Concerns in Right-of-Way Management
New Orleans, Louisiana
Contact: Myra Fraser, (415) 855-2507

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